

Chapter 15

Generative Spacetime

Spatiotemporal Architecture and Chapter Scope

Chapter 15 develops generative spacetime as the fourth substantive layer of Part V. Chapter 12 established the relational architecture of economic systems, Chapter 13 examined allocation as a relational intervention within that architecture, and Chapter 14 developed the generation, propagation, transmission, transfer, conversion, recirculation, accumulation, dissipation, extraction, measurement, and historical transformation of value. The present chapter asks how economically relevant events, processes, relations, capacities, constraints, institutions, interventions, and value processes are situated across time, space, historical sequence, relational distance, and changing fields of possibility. Its role is to supply the spatiotemporal grammar required when a contemporaneous state description leaves consequential order, delay, accessibility, historical inheritance, or future branching analytically unresolved.

The term *generative spacetime* names an analytical architecture that can be realized through several representational forms. Time can concern event order, duration, pace, rhythm, latency, recurrence, horizon, synchronization, and inherited sequence. Space can concern territory and physical distance together with infrastructural, institutional, social, epistemic, economic, and technological organization. Accessibility concerns which positions, resources, institutions, information, and future pathways can be reached under specified conditions. Historical structure concerns how earlier events and relations alter later constraints, capacities, transition possibilities, and evidential conditions. These dimensions can be represented qualitatively, historically, geographically, through networks, through dynamical models, or through more formal constructions when the inquiry warrants them. Ontological suspension remains in force: the chapter uses spacetime, topology, trajectory, partial order, field, and related language as disciplined analytical representations whose adequacy depends on the economic mapping being made.

The chapter has four principal objectives. First, it develops a bounded event-trajectory architecture for historically extended economic processes. Events provide analytically defensible points of change, activation, interruption, recognition, commitment, or transformation; processes connect such events across longer horizons; trajectories reconstruct the histories of states, resources, values, relations, capabilities, and institutions. Several trajectories can coexist and diverge within the

same economic history. Where a single ordered path suppresses materially relevant concurrency, branching, or incomplete temporal comparability, the chapter permits partially ordered trajectory complexes and spin-foam-inspired generative histories as higher-resolution representations. Their function is structural: they organize events, relations, and alternative histories while leaving the empirical and ontological interpretation to the inquiry in which they are used.

Second, the chapter differentiates the spatiotemporal conditions through which economic possibility becomes unevenly organized. Heterogeneous presents capture interacting positions with different horizons, deadlines, update frequencies, waiting times, and inherited commitments. Relational distance extends analysis beyond geography to institutional, social, epistemic, economic, and technological separation. Causal and generative accessibility concern reachability through pathways that can be directional, mediated, delayed, historically produced, or blocked. Sequence, timing, duration, rhythm, synchronization, asynchrony, critical junctures, and irreversibility then clarify why the ordering of otherwise similar events can matter. Path dependence, delayed and latent generation, spatial propagation, and historical branching show how earlier contingencies and infrastructural arrangements can persist in later opportunity structures.

Third, the chapter examines transformation of the spatiotemporal architecture itself. Economic change can alter topology, constraints, capacities, institutions, boundaries, degrees of freedom, generative rules, and the support or weighting of admissible futures. These transformations can unfold across individual, organizational, institutional, generational, local, transnational, and historical scales whose temporalities and spatial organizations do not automatically coincide. The chapter consequently treats scale as a constitutive part of the representation whose relevance depends on the processes under inquiry. It then reconnects generative spacetime to the value architecture of Chapter 14 by tracing generation, propagation, transmission, transfer, conversion, recirculation, accumulation, dissipation, extraction, and long-horizon return through differentiated pathways. Intervention is analyzed in the same framework through intervention point, timing, scale, reach, delay, feedback, reversibility, historical consequence, epistemic events, and changes in admissible histories.

Fourth, the chapter incorporates epistemic revision and asymmetries relevant to power while preserving their provisional analytical status. Historical re-epistemization distinguishes revision in a warranted reconstruction of an earlier trajectory from a claim that the underlying past process itself changed merely because later evidence, categories, models, evaluative standpoints, or reconstructive methods changed. This distinction permits later inquiry to revise warranted descriptions and judgments while preserving the provenance of what was available to earlier actors and analysts. The closing section then identifies generative-spacetime asymmetries in temporal position, reach, delay capacity, exit capacity, and influence over future options. These asymmetries provide conditions that can become relevant to power, justice, and governance when they interact with dependence, control, constraint, institutionalization, justification, and historical persistence. Chapter 16 develops those relations explicitly.

The analytical stance throughout is proportional and methodologically plural. A cross-sectional description, chronological sequence, geographic map, institutional ac-

count, or conventional dynamical model can remain fully adequate when omitted dimensions do not materially affect the question. Greater spatiotemporal resolution becomes warranted when order, delay, relational distance, accessibility, partial temporal order, path dependence, historical branching, changing generative rules, or unequal future possibility would alter explanation, attribution, evaluation, or intervention. Historical reconstruction, qualitative interpretation, process tracing, spatial analysis, network representation, formal modeling, and computational simulation can therefore occupy different roles within the same research programme. The chapter seeks sufficient structure for each inquiry and avoids unnecessary formalization.

The internal organization follows a progressive increase in spatiotemporal resolution. Section 15.1 establishes the chapter's spatiotemporal foundations, and Section 15.2 develops its event-process grammar. Section 15.3 introduces trajectories, coupled trajectories, partially ordered trajectory complexes, and higher-resolution generative histories. Sections 15.4–15.7 differentiate heterogeneous presents, relational distance, causal and generative accessibility, and temporal order. Sections 15.8–15.10 examine path dependence, delayed and latent generation, and spatial propagation. Section 15.11 treats structural transformation, followed by the multiscale architecture of Section 15.12. Sections 15.13 and 15.14 situate value processes and intervention within generative spacetime. Section 15.15 develops historical re-epistemization and preservation of trace. Section 15.16 closes the chapter by identifying the spatiotemporal asymmetries that form an interface with the following chapter's treatment of power, justice, and governance.

The chapter's structural contribution is therefore a language for economic histories in which the organization of possibility can itself change. Earlier relations can reshape later reachability; delays can activate or suppress effects; institutions can alter distances and pathways; interventions can reweight represented or decision support among possible histories and can sometimes transform practical accessibility; later evidence can transform what can responsibly be known about earlier processes; and positions within the same configuration can inherit unequal capacities to wait, move, exit, revise, or preserve alternatives. Generative spacetime places these phenomena within one bounded analytical architecture while retaining simpler representations wherever they remain sufficient. Part V thereby closes with a temporal, spatial, relational, and historical account of economic generation that prepares the book's subsequent analysis of power, knowledge, and artificial intelligence.

15.1 Spatiotemporal Structure in GRE

This section establishes the basic spatiotemporal coordinates required by Chapter 15. Its role is to specify why some economic questions in GRE require more than a description of contemporaneous states, while preserving simpler representations where they remain adequate. The objective is to define a bounded analytical language for dynamic economic configurations, time, space, historical depth, relational distance, causal accessibility, and the disciplined use of physical analogy. The discussion proceeds from the economic configuration as a changing relational object to the temporal and spatial distinctions through which its transformations can be reconstructed, and closes by stating the limits of importing physical concepts into

economic analysis. The method is synthetic and methodological: established process-sensitive social science, relational geography, complexity economics, and selected physical formalisms are used as analytical precedents without being combined into a single ontology (Abbott 2001; Massey 1994; Arthur 1999; Rovelli 2004).

A static description can be exactly the right tool for a static question. A balance sheet, ownership map, price vector, capability profile, organizational chart, or institutional status at a specified date may answer a clearly bounded inquiry. The analytical difficulty arises when two similar present states have different implications because they were produced through different sequences, carry different inherited obligations, occupy different relational positions, or permit different future continuations. In such cases, present-state similarity does not establish historical or generative equivalence. GRE therefore treats spatiotemporal structure as an additional analytical layer whose use depends on whether order, duration, distance, accessibility, historical inheritance, or changing possibility materially affects the claim.

The term *spatiotemporal* is intentionally broader here than clock time plus geographic coordinates. Time can concern event order, duration, pace, latency, recurrence, horizon, and historically inherited sequence. Space can concern territory and physical distance, while also including infrastructures, jurisdictions, organizational locations, network positions, and relationally constituted places. Distance can consequently be geographic, institutional, social, epistemic, economic, or technological. Accessibility can be asymmetric: one position may be able to affect, reach, enter, or use another while the reverse pathway remains blocked. These dimensions can overlap without being interchangeable.

Definition 15.1 (Spatiotemporal economic configuration). Within GRE, a *spatiotemporal economic configuration* is a bounded analytical representation of economically relevant subjects, entities, relations, institutions, resources, capacities, constraints, events, and possible continuations together with those temporal, spatial, relational, and accessibility distinctions that materially affect the inquiry. The representation may be qualitative, historical, spatial, network-based, dynamical, formal, or computational. It does not imply that economic reality possesses a literal physical spacetime geometry.

Definition 15.1 places a boundary around the chapter's use of spacetime language. It does not require every empirical study to reconstruct a complete history or multidimensional geometry. It requires only that materially consequential temporal, spatial, relational, historical, and accessibility distinctions remain visible when their omission would change the explanation, attribution, evaluation, or intervention being considered.

Table 15.1 summarizes the seven dimensions developed in this section.

15.1.1 Dynamic Economic Configurations

A dynamic economic configuration is an economic arrangement whose analytically relevant relations, capacities, constraints, institutions, resources, expectations, or boundaries can change through time. This formulation adds dynamics to the relational architecture developed earlier in the book without assuming that every element changes continuously or at the same rate. Some components may be highly

Table 15.1: Foundational dimensions of spatiotemporal structure in GRE

Dimension	Analytical focus	Primary diagnostic question
Dynamic configuration	Changing relational and institutional organization	Which economically relevant states, relations, capacities, constraints, and continuations change through the process?
Time	Order, duration, pace, latency, recurrence, and horizon	Which temporal distinctions alter explanation or practical consequence?
Space	Location, territory, infrastructure, jurisdiction, and relationally constituted place	Through which spatial arrangements are economic possibilities enabled, separated, concentrated, or connected?
Historical depth	Inherited layers of prior events and transformations	Which earlier conditions remain active in the present configuration, and through what mechanisms?
Relational distance	Process-specific separation among positions	Which forms of proximity or separation matter for interaction, conversion, coordination, or exclusion?
Causal accessibility	Directional reachability through plausible pathways	Which positions or events can materially affect or enable others, through which mediating conditions?
Physical analogy	Bounded transfer of structural ideas from physics	Which formal feature is being borrowed, which assumptions are retained, and where does the analogy cease to be warranted?

persistent while others vary rapidly. A legal regime can remain stable while prices change daily; infrastructure can persist for decades while organizational membership changes within months; a platform standard can remain technically stable while the relations of dependence organized around it intensify.

The distinction between *state* and *configuration* is useful here. A state records selected properties at one analytical moment. A configuration additionally emphasizes how those properties are related. Two economies can display similar aggregate employment, output, or investment while differing substantially in ownership, dependency, technological complementarity, institutional access, ecological burden, or organizational structure. Once change is considered, the difference becomes larger: similar measured states can support different transition possibilities because the relations joining their components differ.

Complexity economics provides one precedent for treating economic structure as recursively altered by the actions of heterogeneous participants. Arthur's formulation emphasizes agents adapting to aggregate patterns that they jointly help to create, so the environment of action is itself historically modified by prior action (Arthur 1999). GRE uses this precedent selectively. A dynamic configuration need not be a complex adaptive system in a technical sense, and adaptation is only one possible mechanism. Legal amendment, technological innovation, ecological disturbance, conflict, demographic change, institutional learning, infrastructural investment, and deliberate policy can also transform the configuration.

The relevant dynamics can be represented at different resolutions. For a short op-

erational question, the configuration may include a small set of states and transition conditions. For an institutional history, the analyst may need events, actors, rules, material infrastructures, and changing relations over several periods. For a generative question, the key object may be the alteration of later possibilities: which new capacities become reachable, which constraints appear, which relations stabilize, and which pathways disappear.

This last point distinguishes dynamic change from mere numerical movement. A variable can change while the underlying generative architecture remains similar. Conversely, a structural reorganization can occur before large aggregate indicators move. A new property rule, interoperability standard, organizational boundary, credentialing institution, or communication infrastructure can alter who may interact with whom and which actions become practical even when headline quantities remain temporarily stable. Chapter 15 will therefore distinguish state trajectories from relational, capability, institutional, and coupled trajectories rather than presuming that one scalar series can represent the relevant dynamics.

A dynamic configuration also contains uneven persistence. Some relations are reproduced through continual maintenance rather than passive survival. Others persist because exit is costly, alternatives are unavailable, or institutional rules reinforce them. Apparent stability can therefore have different mechanisms. This matters for intervention: changing a flow variable, changing a relation, and changing the rule by which later relations are generated can require different analytical and practical strategies.

The configuration concept remains bounded by the research question. GRE does not require an analyst to include every actor, relation, or environmental condition that could in principle matter. The task is to preserve those components and interactions whose omission would materially alter the claim. This proportionality principle will recur throughout the chapter as the representations become richer.

15.1.2 Time

Time in GRE is not restricted to a single clock coordinate. Clock time remains indispensable for many empirical questions: dates, durations, lags, rates, and synchronized observations often require ordinary chronological measurement. The additional claim is that chronological position alone may fail to preserve the temporal relations relevant to explanation. Abbott's methodological work emphasizes that events, order, turning points, and temporal assumptions can change the meaning of social-science observations (Abbott 2001). GRE adopts this process-sensitive orientation while keeping distinct the several temporal structures that later sections analyze more precisely.

At least six temporal distinctions can be relevant. *Order* concerns which event precedes or enables another. *Duration* concerns how long a state, relation, intervention, or exposure persists. *Pace* concerns the rate at which change occurs relative to other processes. *Latency* concerns the interval between contributing conditions and observable realization. *Recurrence* concerns repeated or cyclical processes. *Horizon* concerns the temporal range within which consequences, responsibilities, or future options are being evaluated.

These distinctions can diverge. Two interventions can begin on the same date yet have different durations and realization lags. Two institutions can be equally old in calendar years while differing in the number and significance of transformations through which they have passed. A technological change and a legal reform can occur close together chronologically while remaining poorly synchronized in practice because organizational routines, professional capabilities, or infrastructure adapt at different rates. The nominal present can therefore contain heterogeneous temporal positions, a problem developed later in the chapter.

Temporal representation also depends on resolution. A transaction may be treated as instantaneous in one model while another inquiry decomposes it into negotiation, authorization, settlement, delivery, use, and later consequence. Neither representation is automatically superior. Fine temporal resolution is useful when event order or delay changes the conclusion; coarse resolution is appropriate when those distinctions are immaterial. Precision in timestamps should therefore be distinguished from substantive temporal resolution.

Time can also be endogenous to economic organization. Institutions create deadlines, waiting periods, vesting schedules, depreciation conventions, fiscal years, planning horizons, contract durations, and procedural sequences. Technologies alter communication speed, production cycles, settlement times, and response expectations. Economic actors can sometimes buy speed, defer obligations, impose waiting on others, or preserve the option to delay. Temporal position can therefore become a distributive and power-relevant feature rather than a neutral background coordinate.

The chapter will later develop sequence, path dependence, delayed generation, intervention timing, and unequal temporal position in greater detail. At this foundational stage, the important point is narrower: an adequate temporal representation should preserve those forms of order, duration, pace, latency, recurrence, and horizon that materially shape the process under study.

15.1.3 Space

Space enters economic analysis through more than location on a map. Geographic distance, transport cost, land, proximity, territorial jurisdiction, ecological conditions, and infrastructure remain important, and spatial dependence can often be studied empirically through geographic coordinates and neighborhood structures. Tobler's influential formulation concerning spatial proximity helped motivate a broad family of spatial approaches, while its use is best treated as an empirical regularity rather than a universal rule (Tobler 1970). GRE retains geographic space while placing it within a broader relational account.

Massey's relational conception of space and place provides an important precedent: places can be understood through intersecting social relations and historical processes rather than as self-contained containers (Massey 1994). An economic locality can therefore be constituted partly through relations extending beyond it: supply chains, migration, finance, legal authority, media, digital platforms, ecological flows, transport networks, and organizational hierarchies. A spatial boundary can remain administratively important without containing the full set of relations through which the locality is generated or sustained.

This relational view does not dissolve geography. Physical distance can remain decisive where transport, mobility, bodily presence, ecological exposure, land use, or material infrastructure matters. The analytical task is to identify the spatial mechanism rather than to assume either that geography determines relation or that relational connectivity renders geography irrelevant. A remote digital collaborator can be technically close and geographically distant; a nearby resident can be institutionally excluded from a facility located across the street.

Spatial organization can also structure conversion conditions. Access to a school, clinic, market, research facility, public office, data center, port, or workplace depends not only on its existence but on transportation, opening hours, jurisdiction, cost, eligibility, language, digital connectivity, and physical usability. Space therefore interacts with capability, institutional status, and relational position. An allocation of infrastructure to one site can change the effective economic distance among many other positions.

Different spatial representations serve different questions. Euclidean distance may be useful for transport or land-use problems. Travel time can better represent mobility. Network distance can represent infrastructure or communication pathways. Jurisdictional boundaries can matter for legal and fiscal processes. Ecological watersheds or climatic zones can define another relevant spatial unit. Organizational or platform architectures can create functional spaces with little correspondence to geographic distance. GRE therefore treats spatial representation as process-specific.

The later sections on relational distance and spatial propagation will differentiate these structures more fully. The foundational claim is that economic space is both materially situated and relationally organized. Appropriate analysis preserves geography where it matters while also representing infrastructures, boundaries, and long-distance relations that reshape the practical meaning of location.

15.1.4 Historical Depth

Historical depth concerns the extent to which a present economic configuration contains active consequences of earlier events, decisions, institutions, investments, classifications, ecological changes, and relational histories. It is not simply the chronological age of a system. A recently created organization can inherit deep legal, technological, linguistic, and institutional structures; an old organization can undergo a transformation that makes some earlier layers practically irrelevant to a particular question.

The concept is useful because present conditions often embody accumulated history without displaying that history directly. Infrastructure carries earlier design choices. Credentials embody prior educational and institutional judgments. Property relations embody legal histories. Organizational routines preserve learned practices. Technologies incorporate standards and complementarities established by earlier coordination. Ecological conditions can embody long sequences of extraction, restoration, pollution, or land use. A static observation sees the current configuration; historical-depth analysis asks which prior layers remain causally or generatively active within it.

Historical depth should be reconstructed through mechanisms rather than as-

sumed from chronology. An earlier event matters to a current outcome only through some persistence, transmission, transformation, constraint, memory, material residue, institutional rule, expectation, or other pathway. Path-dependence research provides well-known cases in which early sequence becomes consequential under specified reinforcing mechanisms, but historical dependence is analytically broader than self-reinforcing lock-in (David 1985; Pierson 2000). Earlier conditions can matter through depletion, accumulated capability, legal precedent, ecological inheritance, organizational memory, demographic structure, or unresolved liability even without increasing returns.

Historical layers can also be heterogeneous in visibility. Some are recorded in contracts, archives, technical standards, or physical infrastructure. Others survive through tacit skill, informal norms, trust, stigma, organizational memory, or patterns of expectation. The absence of an explicit record therefore does not establish absence of historical depth, although empirical claims about such depth still require evidence appropriate to the case.

The concept also protects against retrospective flattening. Present categories should not automatically be projected backward as if actors in earlier periods possessed the same classifications, information, or option sets. A current institution can be reconstructed through earlier decisions without assuming that its current form was foreseen. Historical depth therefore includes contingency and re-epistemization: later observers can discover mechanisms or consequences that were unavailable to earlier participants, while the evidential difference between contemporary knowledge and later reconstruction remains explicit.

Chapter 15 will later analyze path dependence, latent generation, historical branching, and re-epistemization in greater detail. Here historical depth serves as a foundational diagnostic: when present meaning depends materially on inherited layers, the economic configuration should be represented with enough history to preserve those layers and their mechanisms.

15.1.5 Relational Distance

Relational distance names process-specific separation among economic positions that cannot be read directly from geographic distance alone. Two actors can be physically close yet separated by institutional hierarchy, language, professional specialization, technology, legal status, information, trust, wealth, or incompatible standards. Conversely, distant actors can be tightly connected through finance, supply chains, platforms, scientific collaboration, kinship, or shared institutions.

Distance should therefore be indexed to the relation or operation under study. The relevant question is not whether two positions are *close in general*, but whether they are close enough for a specified interaction, transfer, conversion, coordination, observation, or intervention to occur under the relevant conditions. A firm can be financially close to a distant investor while epistemically distant from its own front-line workers. A resident can be geographically close to a public agency while institutionally distant because procedures, documentation, language, or legal status make access difficult.

Relational distance can have several components. Institutional distance can con-

cern the number or difficulty of procedural interfaces separating positions. Epistemic distance can concern differences in language, concepts, expertise, evidence, or credibility. Technological distance can concern interoperability and standards. Economic distance can concern affordability, bargaining position, or conversion capacity. Social distance can concern status, identity, trust, or recognized membership. These dimensions can reinforce or offset one another.

GRE does not assume that every form of distance can be placed on one metric. For some problems, a shortest-path or travel-time measure is appropriate. Others require categorical distinctions, ordinal levels, qualitative process tracing, or several dimensions recorded separately. A multidimensional distance profile can be more faithful than a scalar index when different forms of separation matter through different mechanisms.

Distance is also transformable. Translation, infrastructure, institutions, standards, mobility, education, trust-building, technological interfaces, subsidies, or legal reform can reduce some distances. Conflict, exclusion, monopolization, new compliance burdens, border closure, or technological incompatibility can increase them. The economic significance of a relation can therefore change even when the physical positions remain fixed.

The dedicated section on relational distance will develop these dimensions and transformations more systematically. The present subsection establishes the foundational point that distance in GRE is relational, process-specific, and representationally plural.

15.1.6 Causal Accessibility

Causal accessibility concerns whether an economically relevant effect, event, position, or later configuration can be reached through a plausible pathway from another position or event under specified conditions. The concept adds directionality to relational analysis. Connection alone does not imply access, and access in one direction does not imply reciprocal access.

The term *causal* should be used cautiously. Accessibility is not itself proof of causation. It identifies a structured possibility of influence, enabling, transmission, conversion, propagation, or intervention that a causal argument may need to establish more fully. A funding agency can be institutionally connected to a research group without every change in the group being attributable to the agency. A transport network can make a market reachable without guaranteeing that trade will occur. A legal entitlement can establish a pathway to a service while practical barriers continue to block realization.

Accessibility can therefore be decomposed into pathway and condition. A pathway identifies the sequence or network of relations through which an effect could travel. Conditions determine whether the pathway is practically usable: capacity, authorization, timing, compatibility, information, trust, resources, infrastructure, and absence of blocking constraints can all matter. An existing path can be dormant until a threshold or enabling condition is met.

Accessibility is often asymmetric. A regulator may be able to impose requirements

on a small firm while the firm has little capacity to alter the regulator's rules. A digital platform may reach users instantly while users have limited routes to influence the platform's architecture. Capital can move across borders more readily than some workers can. Information can flow from a household to an institution through mandatory reporting while institutional knowledge remains difficult for the household to access. These asymmetries later become important for power and governance.

Accessibility also differs from probability. A low-probability event can remain reachable; a high-probability event can be unreachable from a particular intervention point. Similarly, accessibility differs from desirability: a pathway can be causally open while normatively objectionable, dangerous, or institutionally prohibited. Keeping these dimensions separate prevents reachability from becoming a disguised evaluative conclusion.

Formal representations of accessibility can use directed graphs, event structures, partial orders, transition systems, causal models, or other tools when their assumptions fit the question. Qualitative process tracing can represent the same underlying problem through historically reconstructed mechanisms. Chapter 15 will later distinguish causal and generative accessibility more carefully, including blocked pathways, mediation, delay, historical accessibility, and unequal reach.

At this stage, causal accessibility serves as a foundational bridge between spatiotemporal configuration and possible continuation. It directs attention to which later events or positions are reachable from the present configuration and which mediating conditions make that reachability practical.

15.1.7 Interpretive Scope of Physical Analogy

The language of spacetime, events, causal accessibility, geometry, fields, trajectories, and partial order has important physical lineages. GRE uses some of these concepts because they offer precise ways to think about order, locality, reachability, changing backgrounds, and historically structured possibility. Their physical origin does not establish that economic systems instantiate the same ontology or equations.

General relativity provides a particularly useful methodological precedent because spacetime geometry participates in the physical dynamics rather than functioning only as a fixed external stage; background-independent approaches in gravitational theory develop this idea further (Rovelli 2004). The relevance to GRE is structural and limited. Economic inquiry also encounters cases in which the environment conditioning action—institutions, infrastructures, relations, rules, classifications, technologies, and boundaries—can itself be transformed by the processes occurring within it. This resemblance motivates questions about variable backgrounds. It does not imply that an economy possesses a Lorentzian metric, obeys Einstein's field equations, or shares the conservation, invariance, and causal properties of relativistic physics.

The same restraint applies to geometric and network language. Terms such as distance, neighborhood, topology, trajectory, field, curvature, or boundary can each be useful if the corresponding economic relation is defined. A network distance may represent the number of intermediaries in a supply chain. A topological change may represent creation or removal of a connection or institutional pathway. A boundary

can represent jurisdiction, membership, technical compatibility, or organizational authority. These uses are analytical translations whose validity depends on the mapping between formal structure and empirical meaning.

Physical analogy is most useful when it performs a specified analytical task. A disciplined transfer should identify at least five elements: the target economic problem; the structural feature borrowed from the source formalism; the mapping between source and target objects; assumptions that are retained or altered; and the conditions under which the analogy would cease to be informative. This procedure makes visible what is gained through formalization and what remains outside it.

Several limits follow. Economic events are interpreted and institutionally classified; their boundaries can be contested. Economic agents can form expectations about representations and react to them. Normative judgments are part of many economic questions and have no direct physical analogue. Legal, political, cultural, ecological, and epistemic relations can change the meaning of formally similar structures. Measurements can be performative. Historical evidence is often incomplete. These features require methods that physical analogy alone cannot supply.

The ontological suspension adopted throughout GRE therefore remains decisive. A useful formal representation can establish conditional relations inside a model without proving that the represented economic world literally has the model's ontology. Conversely, the absence of a literal physical identity does not make mathematical or physical formalisms useless. The question is whether the translated structure clarifies a genuine economic problem, remains empirically interpretable, and exposes rather than conceals its assumptions.

Proposition 15.2 states the section's resulting scope condition.

Proposition 15.2 (Spatiotemporal representation adequacy). *Within GRE, a spatiotemporal representation is adequate to the extent that it preserves the temporal order, duration, spatial organization, historical depth, relational distance, and accessibility distinctions materially required by the inquiry, while making explicit the assumptions and interpretive limits of any imported formal analogy. Richer space-time structure is warranted when those distinctions alter explanation, attribution, evaluation, or intervention. A simpler state-based, chronological, geographic, or lower-dimensional representation remains adequate when omitted distinctions do not materially change the claim.*

Proposition 15.2 establishes the chapter's proportionality rule. Generative space-time is not a demand that every economic analysis become geometric or event-theoretic. It is a framework for recognizing when state descriptions omit consequential order, distance, reachability, historical inheritance, or transformation of later possibilities. The following sections progressively increase the resolution of this framework by differentiating events and processes, reconstructing trajectories, examining heterogeneous presents, and developing the chapter's accounts of distance, accessibility, sequence, path dependence, delay, propagation, structural transformation, and multiscale organization.

15.2 Events and Processes

This section establishes the event–process grammar through which the spatiotemporal configurations introduced in Section 15.1 can be reconstructed. Its role is to distinguish bounded economic, relational, institutional, and generative events from the longer processes in which such events participate, while preserving uncertainty about where an event begins and ends. The objective is methodological rather than metaphysical: GRE requires units that are sufficiently stable for historical reconstruction, causal inquiry, comparison, and intervention analysis without treating those units as pre-given atoms of economic reality. The discussion therefore moves from event types to processes, then to event–process relations and criteria for event boundaries. It draws selectively on event-sensitive historical sociology, process philosophy, and mechanism-oriented inquiry as precedents for treating order and becoming as analytically consequential while retaining GRE’s ontological suspension (Abbott 2001; Whitehead 1929; Dewey 1925; Beach and Pedersen 2019). Table 15.2 summarizes the event and process distinctions developed in the section.

An event is useful in GRE when something economically relevant can be bounded as having occurred: a contract is signed, a payment clears, a relation of access begins, a rule becomes operative, a strike interrupts production, a platform changes an interface, a laboratory result alters an investment decision, or an organization acquires a new legal status. Such events can often be dated, located, attributed to participants, and linked to prior and later conditions. Yet their analytical boundaries are rarely identical to the full histories that make them possible. A merger announcement, for example, may be one event; negotiation, regulatory review, organizational integration, and later restructuring belong to a wider process. The event is therefore neither an arbitrary label nor a self-sufficient explanation.

This distinction matters because GRE is concerned with generation. A bounded occurrence can change later relations, capacities, constraints, institutions, or option structures, but the change may depend on processes that precede and outlast the occurrence. Conversely, a process that appears gradual can contain event-like discontinuities at which authorization, recognition, access, commitment, or practical possibility changes. Event and process are therefore complementary analytical resolutions rather than competing descriptions.

Definition 15.3 (Analytical event). Within GRE, an *analytical event* is a bounded occurrence or transition treated as economically relevant because, within a stated scale and evidential frame, it marks a materially consequential change, activation, interruption, recognition, commitment, or transformation in a spatiotemporal economic configuration. Its boundary is an analytical and evidential achievement rather than an assumption of ontological indivisibility.

Definition 15.3 places two requirements on event analysis. First, the event must be consequential relative to a specified inquiry. Second, the analyst must be able to state why the chosen boundary is defensible. A transaction may be a sufficient event for a payment-system study, while an inquiry into financial exclusion may require the prior identification procedure, institutional eligibility rule, failed attempts, and later access consequences to remain visible. Event resolution is therefore purpose-indexed.

Table 15.2: Event and process distinctions in GRE

Analytical object	Primary focus	Boundary question
Economic event	Bounded economically consequential occurrence or transition	Which change is sufficiently discrete to be treated as one analytical occurrence?
Relational event	Change in an economically consequential relation	Which relation changed, for whom, and with what effective incidence?
Institutional event	Change in operative rules, standing, authorization, or recognized categories	When did an institutional change become practically operative rather than merely announced?
Generative event	Occurrence that materially changes later reachable capacities, relations, constraints, or possibilities	Which later pathways became enabled, disabled, reweighted, or newly reachable?
Process	Temporally extended patterned transformation or reproduction	Which linked changes constitute one continuing process at the chosen scale?
Event–process relation	Participation of bounded events in longer histories	Does the event initiate, mediate, interrupt, redirect, stabilize, reveal, or terminate a process?
Event boundary	Evidentially justified delimitation of an occurrence	Which temporal, relational, institutional, spatial, and evidential criteria justify inclusion or exclusion?

15.2.1 Economic Events

An economic event is a bounded occurrence that changes an economically relevant state, relation, commitment, resource position, capability, constraint, expectation, or institutional standing. The category is intentionally broad enough to include market transactions and production events while also covering occurrences that conventional transaction-centered analysis can underrepresent. A contract signature, default, hiring decision, bankruptcy filing, price revision, resource delivery, strike, patent grant, procurement award, data release, migration decision, or opening of a public facility can each function as an economic event when the occurrence materially affects the inquiry.

Eventhood is consequently not determined by whether money changes hands. Some economically consequential events are legal, epistemic, organizational, technological, ecological, or relational. A court judgment can change liability and bargaining positions without an immediate transfer. Publication of a verified scientific finding can alter investment and regulation before any new physical asset exists. A transport disruption can change effective access even when ownership and nominal resource stocks remain unchanged. GRE therefore indexes economic events to consequence within an economic configuration rather than to one privileged transactional form.

The same occurrence can also be represented at several resolutions. Consider a loan. At one resolution, contract execution is the event. At another, origination consists of application, assessment, approval, documentation, disbursement, and later activation of repayment obligations. A study of credit volume may need the first representation; a study of exclusion, information asymmetry, or default may require

the second. Neither resolution is intrinsically more accurate. Adequacy depends on whether the chosen event unit preserves the distinctions required by the claim.

Economic events also differ in temporal extension. Some are effectively punctuated for the purpose of analysis, such as a recorded payment at a timestamp. Others have a bounded duration, such as an auction, labor action, production shutdown, negotiation round, or emergency intervention. Event analysis therefore should not equate an event with a mathematical instant. The relevant requirement is boundedness relative to the process and scale being studied.

A further distinction concerns announced and enacted events. A policy can be announced on one date, legally adopted on another, administratively implemented later, and become practically usable still later. Treating these moments as one event can erase mechanisms of delay, noncompliance, implementation failure, or unequal access. GRE therefore encourages analysts to distinguish symbolic, formal, enacted, and realized event moments when those differences materially affect subsequent trajectories.

This distinction is especially important for historically consequential commitments. A budget authorization, infrastructure decision, long-term contract, standard adoption, or institutional merger can alter expectations before full implementation. Expectations, complementary investments, and anticipatory behavior can themselves generate economic effects. The event may thus participate in changing the configuration before its most visible material consequence appears.

15.2.2 Relational Events

A relational event is a bounded occurrence in which an economically consequential relation is formed, activated, modified, suspended, terminated, or newly recognized. Examples include entering employment, joining a supply network, obtaining access to a platform, forming a research partnership, ending a care arrangement, acquiring representation within a governance body, or losing access to an intermediary whose position had become necessary for participation.

The relevant object is the relation rather than the isolated states of its participants. If firm A and supplier B sign an agreement, the event can be recorded as a contract execution. A relational representation additionally asks what relation becomes operative: exclusivity, dependency, information sharing, priority access, maintenance responsibility, bargaining commitment, interoperability, or another economically relevant connection. The relation can change later even if the parties remain the same.

Relational events can be asymmetric. An organization may recognize a person as an authorized user while the person has little influence over the terms of access. A platform can change an interface that alters thousands of participant relations simultaneously. A government can recognize a credential issued elsewhere, changing the practical relation between an individual and an occupational field. Event analysis should therefore record directionality, standing, rights, obligations, replaceability, and exit where they materially affect incidence.

A relational event need not create a wholly new tie. Activation can be sufficient. A dormant contractual right may become economically consequential when a con-

tingency occurs. An acquaintance can become a financing relation when a loan is made. An existing institutional membership can acquire new authority after a rule change. The event lies in the change of relational function or effective incidence, not necessarily in first contact.

Relational dissolution likewise requires care. Formal termination and practical disappearance can diverge. A contract may end while technological dependence, debt, reputation, data retention, shared infrastructure, or accumulated knowledge continues to bind the parties. Conversely, a nominal relation may persist while the practices that gave it economic significance have ceased. Event boundaries should therefore avoid equating formal labels with the full relational condition.

This relational view also prevents attribution from becoming person-centered by default. When an economically relevant outcome follows a relational event, the analyst can ask which part of the effect belongs to the newly organized relation, which part to the capacities of participating positions, and which part to wider institutions or infrastructures. The event becomes a locus for inquiry rather than an automatic unit of causal ownership.

15.2.3 Institutional Events

Institutional events concern bounded changes in rules, categories, authorization, recognized standing, procedures, governance arrangements, enforcement, or durable expectations that structure economic action. Legislation, court decisions, regulatory approvals, certification decisions, organizational rule changes, treaty entry into force, changes in accounting standards, and formal creation or dissolution of institutions can all function as institutional events.

Institutional events require a distinction between formal occurrence and operative consequence. A law can be enacted without being implemented uniformly. A rule can enter into force while administrative capacity remains insufficient. A new entitlement can exist formally while eligible subjects lack information, documentation, physical access, or practical means of claiming it. Conversely, anticipatory behavior can begin before formal adoption when a change is sufficiently credible. The event therefore has several possible temporal markers: proposal, authorization, legal effect, administrative implementation, practical uptake, and stabilization.

Institutional event analysis also requires attention to category change. When an institution changes who counts as a beneficiary, worker, resident, creditor, recognized qualification holder, protected subject, taxable entity, or eligible organization, it can transform economic positions through classification itself. Such an event can alter access and obligation even without changing the material resource endowment at the same moment. The classification can also produce new data, expectations, compliance practices, and organizational responses.

Events involving institutions are often nested. A national rule change can trigger regional administrative changes, organizational compliance events, platform redesign, contractual revisions, and household adaptations. Treating the initial rule as the sole event can obscure the sequence through which formal authority becomes realized. Conversely, treating every local implementation detail as an independent event can fragment the process beyond analytic usefulness. The appropriate event

architecture should therefore preserve the levels at which distinct mechanisms operate.

Institutional events can also stabilize prior informal arrangements. Recognition may formalize practices that already existed. The analytical question then concerns what changes because of institutionalization: enforceability, legitimacy, eligibility, visibility, funding, accountability, durability, or transferability. A formal event can be consequential even when behavior appears superficially continuous because the space of later possibilities has changed.

Historical sociology has long emphasized that timing and sequence can matter for institutional development (Abbott 2001). GRE retains this insight while avoiding the assumption that every formal institutional change is a decisive historical turning point. The strength of the event claim depends on evidence that the institutional occurrence materially reorganized later constraints, capacities, relations, or reachable paths.

15.2.4 Generative Events

A generative event is an analytical event whose significance lies partly in its effect on what can happen later. It can create or strengthen a capability, relation, institution, infrastructure, constraint, option, or rule of transformation that materially changes later reachable trajectories. This definition is descriptive before normative evaluation. A generative event can expand desirable capacities, reproduce exclusion, intensify dependency, or generate harmful constraints.

A distinction is needed between an event that produces an immediate outcome and an event that modifies later generative conditions. A cash transfer may improve present consumption without materially altering later productive capacity. A training programme may create a capability that becomes useful only when a later employment opportunity appears. Adoption of a technical standard may initially change little observable output while restructuring future compatibility and investment decisions. Creation of a data repository can alter later research possibility long after the collection event. Generative significance therefore can be delayed or latent.

Generative events can also concern rules rather than outputs. A constitutional amendment, governance reform, platform protocol change, institutional redesign, or new scientific method may alter how later events are generated, selected, interpreted, or constrained. These rule-level events can have wider effects than their immediate material footprint suggests. Their importance, however, should be established rather than presumed. A formal rule that is ignored or inaccessible may have weak realized generativity.

The event concept is useful here because it permits analysts to mark candidate transformation points without claiming that the transformation occurred instantaneously. A generative event can initiate a process whose realized consequences emerge later through learning, diffusion, institutionalization, complementary investment, or ecological response. Event and process therefore remain coupled: the event can be analytically bounded while the generative mechanism continues.

Generative events can also be negative. A sudden loss of legal status, infrastructure

destruction, institutional closure, exclusion from a platform, or irreversible ecological damage can narrow later possibility. The relevant criterion is not whether the event appears innovative or productive but whether it materially changes the later generative configuration. This continuity with the book's analysis of negative generativity protects the term from becoming an automatic synonym for improvement.

A strong generative-event claim should identify at least the event boundary, affected positions, altered generative condition, plausible pathway to later effects, relevant time horizon, and material alternatives. This evidential discipline becomes especially important when later success or failure is retrospectively attributed to a dramatic moment. The event may have mattered, but later trajectories can also depend on conditions not contained in that event.

15.2.5 Processes

Processes are temporally extended patterns of transformation, reproduction, maintenance, learning, coordination, accumulation, depletion, institutionalization, or other change through which an economic configuration develops. A process can include many events, stretches of apparent continuity, recurring practices, feedback loops, and periods during which no discrete turning point is empirically identifiable. Process language is therefore appropriate when the phenomenon of interest is constituted through continuation and relation among changes rather than through one bounded occurrence.

Within GRE, processes need not imply smoothness. A process can contain discontinuities. Industrial restructuring can involve layoffs, mergers, plant openings, closures, regulatory changes, and technological adoption. Institutional learning can proceed through repeated monitoring, occasional crises, rule revision, and long periods of routinization. Ecological depletion can accumulate gradually and then cross a threshold. The process is the organized history through which these heterogeneous changes become analytically connected.

Processes can also reproduce rather than transform. Wage payment, maintenance, care, data updating, routine governance, and infrastructure repair may sustain a configuration that appears stable at an aggregate level. Stability can therefore be processual. It may require recurrent expenditure of resources, attention, coordination, legitimacy, and repair. When these maintenance processes fail, the apparent state can deteriorate rapidly. GRE consequently treats reproduction as analytically active rather than as the absence of change.

Process analysis is also scale-sensitive. What appears as one process at an organizational scale can consist of many processes at the level of departments, households, technologies, or jurisdictions. A national labor-market transition can contain sector-specific hiring processes, migration processes, educational transitions, legal changes, and firm-level reorganizations. Multiscale representation becomes necessary when these processes interact in ways that alter the claim.

Mechanism-oriented inquiry provides one methodological precedent for reconstructing processes by linking observations to hypothesized causal mechanisms rather than relying only on correlations between initial and final states (Beach and Pedersen 2019). GRE uses this precedent cautiously. A process can be described

before its causal mechanism is fully established, and several mechanisms can contribute to the same observed sequence. Process representation should therefore preserve the distinction between observed order, interpreted mechanism, and stronger causal attribution.

Process boundaries are no less constructed than event boundaries. An analyst may describe a housing crisis process beginning with deregulation, a credit expansion, an asset-price shift, or a later default wave depending on the question. The appropriate response is not to eliminate boundary judgment but to state the boundary, justify it, and test whether plausible alternatives materially change the conclusion.

15.2.6 Event–Process Relations

Events and processes are analytically linked through several recurrent relations. An event can initiate a process, accelerate or slow it, redirect it, stabilize it, reveal a latent process, interrupt it, terminate it, or transform the rule by which it continues. A process can, in turn, generate conditions under which an event becomes possible, likely, recognizable, or consequential. The relationship is therefore reciprocal without implying symmetry.

Consider institutional reform. A legislative enactment can initiate implementation, but the enactment itself may be the result of a longer process of mobilization, negotiation, evidence production, crisis, or coalition formation. Implementation can then generate further events such as organizational restructuring or legal challenge. Selecting the enactment as an event does not deny its antecedent process or downstream consequences. It identifies one bounded transition that is useful for a specified analytical purpose.

Some events are better understood as crystallizations of processes already underway. A financial failure can reveal accumulated leverage and liquidity fragility. A strike can make visible a longer deterioration in labor relations. A court judgment can formalize a shift in interpretation built through earlier cases. An innovation launch can condense years of research, investment, organizational learning, and infrastructure development. Retrospective analysis should therefore avoid assigning the whole process to the visible event merely because it is easily dated.

Other events transform the process itself. Adoption of a new standard can alter interoperability; a constitutional rule can alter decision procedures; an infrastructure opening can alter geographic accessibility; an AI system can change the marginal cost or speed of producing certain forms of information. In such cases, the event does more than change one state. It modifies conditions governing later events. This is especially important for generative analysis because the event participates in changing the future event architecture.

The same process can also contain competing event interpretations. Participants may disagree about which moment constituted commitment, breach, recognition, exclusion, or success. Administrative records may date a change differently from affected subjects' lived experience. Digital logs may record activation while practical use begins later. Event–process analysis should preserve these differences when they materially affect causal or normative interpretation rather than forcing one timestamp to carry every meaning.

A useful event–process representation therefore records provenance. For important events, the analyst should be able to state what evidence supports the occurrence, which process it is placed within, what role the event is hypothesized to play, and which alternative placements remain plausible. This preserves revisability when later evidence changes the reconstruction.

15.2.7 Event Boundaries

Event boundaries determine what is counted as one occurrence, which conditions are treated as antecedent, which consequences are treated as downstream, and which actors or relations are considered part of the event. Boundary decisions therefore affect explanation, attribution, measurement, and evaluation. Event-sensitive social science has long emphasized that the way events and cases are temporally carved can carry substantive theoretical assumptions (Abbott 2001). GRE makes those assumptions explicit rather than attempting to eliminate them through a single universal event ontology.

At least five boundary dimensions can matter. A *temporal boundary* specifies when the event begins and ends. A *relational boundary* identifies which positions and relations participate in the event. An *institutional boundary* identifies which rules, jurisdictions, or organizational procedures define its operative scope. A *spatial boundary* identifies relevant physical or territorial extent. An *evidential boundary* identifies which observations justify treating the event as having occurred. These dimensions can coincide, but they need not.

Different empirical sources can imply different event boundaries. A contract database records signature; a payment system records settlement; interviews record when participants considered themselves committed; organizational documents record implementation; downstream data may reveal when behavior actually changed. An adequate reconstruction can preserve several event moments rather than choosing one as universally authoritative. The relevant question is which moment matters for the claim being made.

Boundary choice should also be stable enough for comparison. If one case defines an institutional reform at legal enactment while another defines it at effective implementation, the comparison can become misleading unless the difference is intentional and justified. Event definitions should therefore be operationally explicit when events are compared, counted, modeled, or used as units in a formal representation.

At the same time, event boundaries should remain revisable. New archival evidence, participant testimony, measurement, or causal analysis can show that an earlier boundary was too narrow, too broad, or placed at the wrong stage. Revisability is compatible with rigor when the earlier boundary and the reason for changing it remain documented. This is one reason to preserve provenance rather than overwrite successive historical reconstructions.

Process philosophy offers a broad intellectual precedent for treating reality through becoming and event-like occurrences rather than static substances alone (Whitehead 1929; Dewey 1925). GRE does not adopt that metaphysics as a premise. Event language is used because it can improve economic reconstruction when sequence, activation, transformation, and historical consequence matter. The frame-

work remains open to entity-centered, state-centered, continuous-time, narrative, institutional, network, or other representations where those are more adequate.

Proposition 15.4 (Boundary adequacy for event–process analysis). *Within GRE, an event boundary is analytically adequate when it is explicit enough to identify the relevant occurrence, evidence, participating positions, and scale, and when alternative plausible boundaries would not materially alter the claim without being acknowledged. Adequacy does not require the boundary to be ontologically unique. Where competing boundaries materially change explanation, attribution, or evaluation, that boundary dependence should remain part of the result.*

Proposition 15.4 provides the scope condition for later sections. The trajectory analysis that follows can represent events as nodes or ordered elements only after their boundaries are sufficiently specified for the research purpose. Later partial-order and trajectory-complex formalisms therefore inherit, rather than eliminate, the evidential and interpretive responsibilities established here.

15.3 Trajectories

This section develops trajectories as the principal representation of historically extended economic change within generative spacetime. Its role is to connect the event–process distinctions established in Section 15.2 with later analyses of heterogeneous presents, accessibility, sequence, path dependence, delay, spatial propagation, and structural transformation. The objective is to distinguish several trajectory objects that can coexist within one economic history, to clarify how they couple and diverge, and to specify when a one-dimensional path should be replaced by a partially ordered trajectory complex. The discussion proceeds through state, resource, value, relational, capability, institutional, and coupled trajectories; trajectory divergence; partially ordered trajectory complexes; spin-foam-inspired generative histories; and history weights and transition potentials. The method is reconstructive and formal where useful. It preserves evidential provenance, scale dependence, and ontological restraint rather than treating a trajectory as a literal line followed by an economic system.

Trajectory language is useful because economic histories rarely consist of one variable changing against an otherwise fixed background. A household can experience rising income while losing access to care. A firm can accumulate financial resources while its supplier relations become more concentrated. A public institution can acquire formal authority while implementation capability erodes. A community can gain infrastructure while losing ecological options. The relevant historical object can therefore be a bundle of partially coupled trajectories whose directions, rates, and turning points differ.

A trajectory should also be distinguished from a forecast. A reconstructed trajectory describes or interprets an observed or evidentially supported history over a specified horizon. A prospective trajectory represents a possible continuation under stated assumptions. A policy scenario, simulation path, or model-generated history can be useful without being a claim that the represented path will occur. GRE therefore treats past reconstruction, present diagnosis, and prospective history as related

Table 15.3: Trajectory forms in generative-spacetime analysis

Trajectory form	Primary object of change	Typical analytical question
State	Represented condition of a subject, entity, relation, or configuration	Which materially relevant states were occupied, revisited, or bypassed?
Resource	Availability, control, quality, access, or composition of resources	How did resources accumulate, move, degrade, become accessible, or cease to be usable?
Value	Value forms, realization, conversion, propagation, or return	How did value-bearing significance change form, incidence, or practical realization?
Relational	Economic relations and their structure, quality, or directionality	Which relations formed, persisted, weakened, concentrated, or transformed?
Capability	Effective capacities for action, conversion, participation, maintenance, or generation	How did practical ability expand, erode, combine, or become dependent on complementary conditions?
Institutional	Rules, categories, authority, procedures, infrastructures, and operative practice	How did formal and practical institutional conditions co-evolve?
Coupled	Interdependent trajectories of different types or scales	Where did one trajectory enable, constrain, redirect, or lag behind another?

but epistemically distinct uses of trajectory representation.

Definition 15.5 (Economic trajectory). An *economic trajectory* is a scale- and representation-indexed account of historically extended change in a specified economic object or configuration, preserving the states, events, relations, transitions, evidential provenance, and uncertainty materially relevant to the inquiry.

Definition 15.5 deliberately leaves the representational space open. A trajectory can be expressed through a time series, event sequence, qualitative process history, institutional phase structure, network evolution, partially ordered event complex, scenario tree, or other form adequate to the question. The analytical burden lies in specifying what is changing, how change is observed or inferred, and which distinctions would be lost under a simpler representation.

Table 15.3 summarizes the trajectory forms developed in this section. The rows should be read as analytical perspectives rather than mutually exclusive classes. One empirical history can support several trajectory descriptions at once, and their interaction can itself become the principal object of explanation.

15.3.1 State Trajectories

A state trajectory records how a specified analytical object occupies changing represented conditions across a historical horizon. It provides the most general trajectory form because nearly any economic object can be described through a sequence or partial ordering of states. The analytical usefulness of a state trajectory depends less on the existence of a state variable than on whether the chosen state representation

preserves differences that matter to the generative question.

States can be quantitative, categorical, relational, institutional, qualitative, or mixed. Household liquidity, legal status, organizational form, network position, access to infrastructure, ecological condition, market structure, or a multidimensional capability profile can each define a state representation. A transition between states can correspond to continuous change, threshold crossing, reclassification, institutional reform, relational reorganization, or an event that changes which dimensions are relevant. State trajectories therefore need not presuppose a fixed Euclidean state space.

A before–after comparison is a limiting case of trajectory analysis. It can be sufficient when the intermediate path has no material bearing on explanation or evaluation. It becomes insufficient when the route itself changes later possibilities. Two organizations can begin and end with similar formal structures while differing in accumulated knowledge, trust, debt, institutional memory, supplier dependence, or employee capability because the intermediate histories differed. A trajectory representation preserves the historical residue that an endpoint comparison can erase.

State recurrence requires similar caution. A configuration that appears to return to an earlier measured state can carry a different historical composition. A household whose income recovers after unemployment may retain debt and depleted savings. A firm returning to its previous output level may now depend on a different technology or platform. An institution restoring an earlier rule can operate under changed legitimacy or administrative capacity. Recurrence in observed state variables therefore does not establish recurrence of the wider generative configuration.

State trajectories should consequently record the scope of state equivalence. When two positions are treated as the same state, the equivalence criterion should correspond to the inquiry. A narrow classification can be entirely legitimate for a narrow question. It becomes misleading only when unrepresented historical differences materially alter the conclusion.

15.3.2 Resource Trajectories

Resource trajectories follow the changing availability, control, quality, accessibility, composition, and usability of economically relevant resources. Their role is to move beyond a static inventory toward the historical processes through which resources are accumulated, transmitted, maintained, depleted, reclassified, or rendered unusable. The object can include material resources, financial resources, infrastructure, land, energy, data, time, ecological conditions, technical capacity, or other resources specified by the research problem.

A resource trajectory should distinguish quantity from effective availability. A resource can remain physically present while becoming inaccessible because of price, law, location, institutional exclusion, technical incompatibility, or loss of complementary capability. Conversely, a resource stock can decline while effective access expands through infrastructure, coordination, or technological change. Resource trajectory analysis therefore benefits from recording control, access, quality, and conversion conditions alongside nominal quantity when those dimensions matter.

Resource identity can also change historically. Land can shift among subsistence, industrial, conservation, speculative, or infrastructural functions. Data generated as an operational by-product can become an economically valuable input after advances in storage, computation, or machine learning. Waste streams can become inputs when technologies and institutions of recovery change. Such changes are not merely movements of a fixed resource through time; they can involve transformations in what counts as a resource and for whom.

Maintenance belongs inside the trajectory rather than outside it. Infrastructure, soil fertility, software, organizational records, equipment, and human capabilities can deteriorate if maintenance processes fail. A resource trajectory that records only acquisition can therefore overstate later availability. The relevant history can include maintenance burdens, replenishment, repair, depreciation, depletion, and the institutional arrangements through which continued usability is sustained.

Resource trajectories also interact with distribution. Aggregate resource growth can coexist with reduced access for particular subjects, regions, or institutions. A generative-spacetime account should therefore preserve incidence where concentration, exclusion, or dependency changes who can mobilize the resource and what later trajectories become reachable.

15.3.3 Value Trajectories

Value trajectories represent historically changing value-bearing conditions, value forms, realization pathways, conversions, propagation, recirculation, accumulation, dissipation, extraction, harm, and return. Their substantive architecture was developed in Chapter 14. Within generative spacetime, the task is narrower: to preserve the temporal and relational path through which value becomes realized, transformed, displaced, or re-enters later processes.

A value trajectory should not be mistaken for a time series of one universal value magnitude. Material, financial, capability, relational, epistemic, institutional, participatory, option, future, ecological, and other values can follow different trajectories and need not share a common metric. The same process can increase one value form while eroding another. The historical representation should therefore retain value-form identity and conversion provenance where aggregation would conceal the relevant transformation.

Timing also matters. Value can be generated at one moment, recognized later, converted later still, and recirculated after another delay. A research output can acquire epistemic significance before it gains institutional recognition. Infrastructure can create option value before utilization rises. Ecological depletion can remain weakly represented in current financial measures until thresholds or valuation practices change. Value trajectories therefore often contain delayed manifestation and changing observability.

The same value-bearing condition can also propagate unevenly. Knowledge can diffuse rapidly across one professional network while remaining inaccessible to another. Financial gains can concentrate at one interface while relational or ecological burdens propagate elsewhere. A trajectory should therefore preserve affected positions and pathways, not merely the history of an aggregate measure.

Historical re-epistemization further complicates reconstruction. Later evidence can revise what earlier stages of the trajectory are understood to have contained. The underlying historical condition and the later representation of that condition should remain distinguishable. A revised value trajectory can therefore document both a substantive history and the history of its successive reconstructions.

15.3.4 Relational Trajectories

Relational trajectories follow the formation, persistence, weakening, reorganization, directionality, and dissolution of economically consequential relations. Their role is to represent changes that cannot be located adequately within isolated subjects or entities. Supplier dependence, employment relations, credit relations, care arrangements, platform participation, interorganizational collaboration, governance relations, and institutional recognition can all evolve through trajectories whose structure matters to later possibilities.

A relational trajectory contains more than tie presence. The same formally continuous relation can change in intensity, reciprocity, authority, trust, maintenance burden, exclusivity, replaceability, information asymmetry, or practical exit. A firm can retain the same supplier while becoming more dependent on it after adopting proprietary standards. A household can remain connected to a service provider while its bargaining position deteriorates. An institutional partnership can persist formally while operational collaboration weakens. Binary network snapshots can miss these transformations.

Relation identity can also be historically contested. A recurring exchange can become an employment relation, a partnership can become hierarchical, or an informal practice can acquire legal recognition. The question of whether the relation has persisted or transformed depends partly on the analytical dimensions used to define identity. Trajectory reconstruction should state that criterion rather than treating relation identity as self-evident.

Relational trajectories are especially important for generation because current relations condition later resource access, information flow, trust, coordination, and option structure. Historical relations can persist as infrastructure even after the original event that formed them has receded. Conversely, rupture can alter many downstream trajectories simultaneously. A relational trajectory therefore provides one route through which historical depth becomes economically operative.

The representation should also preserve higher-order change. A bilateral relation can remain stable while the wider configuration around it changes, altering its practical significance. A supplier relation embedded in a diversified network differs from the same relation inside a concentrated chain. The relevant trajectory can consequently concern a relation within a changing relational field rather than the dyad alone.

15.3.5 Capability Trajectories

Capability trajectories represent historical change in effective abilities to act, convert resources, participate, maintain, adapt, learn, coordinate, refuse, exit, or generate

further possibilities. Their role is to distinguish the possession of resources from the practical capacity to mobilize them across time. Because capabilities depend on personal, relational, institutional, technical, and environmental conditions, their trajectories are often inherently coupled to other trajectories.

Capability formation can be cumulative. Learning, organizational routines, technical infrastructure, institutional knowledge, trust, and professional networks can make later action easier than earlier action. Yet capabilities can also erode through disuse, staff turnover, institutional damage, illness, exclusion, technological obsolescence, or loss of complementary resources. A trajectory should therefore permit formation, stabilization, substitution, and erosion rather than assume monotonic accumulation.

The same observed action can be compatible with different capability trajectories. A household can maintain consumption through growing debt rather than stronger income-generating capacity. An organization can sustain output through extraordinary staff effort while underlying maintenance capacity deteriorates. A government can deliver a programme through temporary external expertise without building internal administrative capability. Outcome trajectories therefore should not be substituted automatically for capability trajectories.

Latent capability also matters. A capability can exist without continuous exercise, provided the relevant conversion conditions remain available. Emergency capacity, scientific expertise, institutional memory, or legal authority can become visible only when activated. The trajectory may therefore include periods in which capability is maintained but weakly manifested. Evidence for those periods can require records of staffing, infrastructure, training, rights, procedures, or other enabling conditions rather than observed output alone.

Capability trajectories also alter future option spaces. An intervention that expands current output while reducing learning, maintenance, or exit capability can improve one trajectory while worsening another. Generative analysis should therefore preserve capability paths when they materially change the set of later reachable actions.

15.3.6 Institutional Trajectories

Institutional trajectories follow changes in rules, categories, authority, recognized positions, procedures, enforcement, infrastructure, legitimacy, and operative practice. Their role is to separate formal institutional change from practical institutional development. A law can change at one date while implementation, interpretation, administrative capacity, compliance, and public expectations evolve on different schedules.

Institutional trajectories are therefore frequently multidimensional. Formal rules, organizational routines, classifications, information systems, budgets, professional norms, judicial interpretation, and enforcement practices can reinforce or contradict one another. A trajectory represented only by the date of legal enactment can misstate when practical access or constraint actually changed. Conversely, informal institutional change can precede formal codification.

Institutional persistence can also conceal transformation. A rule can retain the

same text while its interpretation shifts. An eligibility category can remain formally stable while digital verification changes who can satisfy it. A regulatory agency can preserve its mandate while losing expertise or enforcement capacity. Institutional identity should therefore be reconstructed through the dimensions relevant to the claim rather than inferred from nominal continuity.

Institutions can carry historical memory. Precedents, records, installed infrastructure, professional routines, classifications, and past enforcement can condition later decisions even after personnel change. These residues can make an institutional trajectory path-dependent without requiring deliberate preservation of the earlier arrangement. Historical depth can therefore be embedded in procedures and infrastructures as well as explicit rules.

Institutional trajectories are also generative because institutions shape which relations, conversions, and actions become possible. A new legal status can open financial access; a changed standard can redirect technological investment; a new administrative category can make a population visible for allocation while excluding others. Institutional change therefore often couples directly to resource, capability, relational, and value trajectories.

15.3.7 Coupled Trajectories

Coupled trajectories represent histories in which change in one trajectory materially alters the transition conditions, accessibility, interpretation, or future development of another. Their role is to move beyond parallel description toward a structured account of interdependence while preserving the distinct objects being coupled. Coupling can be directional, reciprocal, delayed, conditional, asymmetric, or scale-dependent.

Resource and capability trajectories provide a simple example. Financial investment can support training and infrastructure, which expand capability; accumulated capability can later alter the productivity or convertibility of additional resources. Institutional and relational trajectories can similarly interact: formal recognition can stabilize a relation, while a changing relational coalition can alter institutional reform. Value and resource trajectories can couple when a newly recognized value form changes what counts as a resource or how resources are allocated.

Coupling should not be inferred from co-movement alone. Two trajectories can move together because of a common external condition, shared measurement artifact, or coincident timing. A coupled-trajectory claim requires a plausible relation through which one trajectory enters the generative conditions of the other, together with evidence appropriate to the strength of the attribution.

Temporal mismatch can weaken or reverse coupling. Capability investment may take years to mature while funding is allocated annually. Infrastructure can outlast institutional support. Ecological degradation can accumulate slowly relative to market signals. A coupled analysis can therefore reveal why interventions fail even when each component appears adequate in isolation: the trajectories may operate on incompatible timescales or activation schedules.

For compact representation, a coupled trajectory system can be written as a fam-

ily of typed trajectories together with explicitly interpreted couplings. Equation 15.1 states this as a structural record.

$$\Gamma = (\Gamma_{\text{state}}, \Gamma_{\text{res}}, \Gamma_{\text{val}}, \Gamma_{\text{rel}}, \Gamma_{\text{cap}}, \Gamma_{\text{inst}}; \Lambda), \quad (15.1)$$

where Γ_{state} , Γ_{res} , Γ_{val} , Γ_{rel} , Γ_{cap} , and Γ_{inst} denote selected state, resource, value, relational, capability, and institutional trajectories, while Λ records the couplings materially relevant to the inquiry. Equation 15.1 is not a claim that every application requires all six trajectory types or that they form a complete ontology. It is a book-keeping structure for cases in which several histories must remain distinct while their interdependence is analyzed.

Couplings can themselves change. A subsidy can initially affect capability only through resource provision and later operate through institutional learning. A platform can begin as an optional communication channel and later become infrastructure whose failure constrains several trajectories at once. A coupled model should therefore permit changes in Λ rather than treating interdependence as fixed background structure.

15.3.8 Trajectory Divergence

Trajectory divergence concerns the emergence of materially different histories from previously similar, shared, or partially shared configurations. Its role is to identify when and through which mechanisms paths become distinct without assuming that a single branching event fully explains the later difference. Divergence can arise through different events, different event order, unequal resources, distinct institutional responses, heterogeneous subject positions, stochastic perturbations, cumulative feedback, or changes in the generative rules themselves.

A divergence claim requires a reference relation. Two trajectories can diverge in income while converging institutionally, diverge in capability while remaining similar in resource stock, or diverge at one scale while converging at another. The analyst should therefore state the trajectory dimension, temporal horizon, and comparison criterion rather than treating divergence as self-evident.

Divergence can also be gradual. Small early differences can accumulate until they become institutionally or relationally consequential. Alternatively, trajectories can remain similar for a long period and separate after a threshold or reclassification. A visible turning point can be useful for reconstruction, but it should not automatically be treated as the sole causal origin of the later difference.

Convergence deserves equal attention. Divergent histories can later approach similar represented states through different mechanisms. Such convergence can be superficial when latent capacities, liabilities, institutions, or relations remain different. Conversely, distinct starting conditions can converge through common institutions, technologies, or coordinated intervention. Trajectory analysis should therefore preserve both path difference and endpoint similarity where they coexist.

Counterfactual comparison can sharpen divergence analysis when used modestly. The relevant question is often whether a plausible alternative event, sequence, or institutional response would have kept the trajectory within a different family of his-

tories. Such comparison should preserve uncertainty rather than assigning deterministic significance to a branch point merely because later outcomes differ.

15.3.9 Partially Ordered Trajectory Complexes

A single trajectory line becomes inadequate when economically relevant change includes concurrent events, unresolved order, distributed generation, branching, convergence, or higher-order process structure. The partially ordered generative trajectory complex introduced methodologically in Chapter 8 provides a more suitable carrier. Section 15.2 has already established the evidential responsibility associated with event boundaries; the present subsection gives that complex a substantive economic interpretation.

The basic complex can retain event vertices, local coupling or gluing edges, higher-order faces, a partial precedence relation, analytical typing, and evidential provenance. In the economic application, these elements can carry annotations for resources, value forms, capabilities, constraints, institutions, spatial scale, affected positions, and other domain-specific features. The complex therefore represents a history in which several economic objects can change jointly without being compressed into one homogeneous state vector.

Partial order is especially important. If two investments occur in different regions and the available evidence establishes only that both precede a later network expansion, the model need not invent an order between them. If two institutional reforms overlap in implementation, their relation can remain incomparable at the selected resolution while both participate in a later transition. The representation can subsequently be refined if stronger evidence becomes available.

Temporal order and structural coupling should remain separate. Precedence does not by itself establish a generative pathway, and local coupling does not require a total chronological sequence. A supplier shock can precede a policy response without directly generating it; both can be connected through a higher-order process. Conversely, contemporaneous organizational units can be tightly coupled even when no temporal precedence relation is meaningful between their local activities.

Faces provide one way to represent higher-order economic coherence. A face can record a persistent supply relation, an institutional process, a capability configuration, a market-making arrangement, or another analytical object whose existence depends on several local events and couplings. This is a representational convention rather than a claim that such objects possess literal geometric surfaces.

The trajectory complex also accommodates multiscale reconstruction. A subcomplex of many local events can be coarse-grained into one higher-level event or institutional phase. The coarse representation can be useful for macro-level analysis while preserving a documented map to the finer history when distributional or causal interpretation depends on it. This is important because a trajectory that appears smooth at one scale can contain conflict, exclusion, or abrupt transitions at another.

Proposition 15.6 (Trajectory-complex adequacy). *Within GRE, a partially ordered trajectory complex is analytically warranted when materially relevant concurrency, branching, higher-order composition, scale interaction, or unresolved temporal order*

would be distorted by representing the history as a single totally ordered trajectory. The added structure should preserve rather than obscure evidential provenance and the distinction between temporal precedence and generative coupling.

Proposition 15.6 is a proportionality rule. Many economic questions remain adequately represented by ordinary time series, sequences, or narrative histories. The complex is useful where the richer historical structure changes the claim, not because formal complexity is intrinsically preferable.

15.3.10 Spin-Foam-Inspired Generative Histories

Spin-foam-inspired generative histories provide a compositional representation of alternative typed trajectory complexes connecting boundary configurations. Their substantive role in GRE is to make visible that the same earlier and later observed configurations can be connected by several historically different interiors: different event orderings, relations, conversions, institutional sequences, or higher-order process structures. The useful borrowing is the architecture of labeled two-complex histories, not the physical ontology from which spin foams originate.

An earlier boundary can represent a documented economic configuration and a later boundary another configuration observed after a period of transformation. Between them, several admissible history complexes may remain compatible with evidence. One history can involve early institutional reform followed by capability formation; another can involve capability accumulation preceding formal recognition. Both can lead to a similar later state while carrying different implications for dependence, reversibility, future options, or generative return.

The representation is especially useful when history is incomplete. Instead of drawing a single interpolated path through missing periods, analysis can preserve a family of candidate interiors. Evidence can rule out some histories, strengthen others, or leave several partially ordered reconstructions viable. The resulting uncertainty is structural rather than merely numerical: uncertainty can concern which events occurred, how they were coupled, which higher-order processes existed, and which order relations are warranted.

Cell labels can carry economic information such as event type, institutional location, resource condition, value form, capability state, affected position, scale, or evidential status. A history can therefore be compared with another history through differences in composition as well as differences in endpoints. This is valuable when the research question concerns how later possibilities were generated rather than only whether a later state was reached.

The spin-foam analogy has strict limits. GRE does not infer quantum dynamics, Lorentzian geometry, complex amplitudes, physical conservation laws, or a fundamental discretization of social reality. Vertices, edges, faces, boundary configurations, and history weights are modeling devices whose empirical interpretation must be supplied by the economic inquiry. If a simpler event graph or process narrative preserves the relevant distinctions, the spin-foam-inspired representation adds little and should not be preferred for stylistic reasons.

The representation also does not imply that every alternative history is equally

real or equally supported. Some histories can be inconsistent with evidence or institutional constraints; others can be possible in a formal model yet implausible empirically. The family of admissible histories therefore needs explicit rules of admissibility and evidential provenance. Historical imagination becomes analytically useful only when it remains constrained by those rules.

15.3.11 History Weights and Transition Potentials

History weights and transition potentials provide two different ways to represent differentiated possibility within a family of trajectories. Their role is to avoid the false choice between a single deterministic history and an unstructured set of alternatives. The objective is to distinguish retrospective or global weighting of complete candidate histories from local or prospective representation of how current conditions support different admissible extensions.

A *history weight* assigns an explicitly interpreted score, plausibility, evidential support, probability contribution, or other model-specific quantity to a candidate history. The meaning of the weight must be stated. An evidential support score is not automatically a probability; a model plausibility weight is not automatically a welfare value; and a normative ranking is not automatically a causal likelihood. History weights should therefore preserve their epistemic or evaluative type rather than being combined merely because they are numerical.

A *transition potential* is an explicitly typed represented profile over possible local extensions from a current configuration under specified resources, capacities, constraints, institutions, relations, and background conditions. Depending on the model, its entries can represent practical feasibility or accessibility, evidential or model support, decision support, transition cost, strategic attractiveness, or another explicitly defined property. These types should remain distinguishable and should not be silently aggregated merely because each admits a numerical representation. The term *potential* is used structurally. It need not denote physical potential energy, and it need not be normalized as a probability distribution.

One minimal representation is to associate a typed transition-potential profile Φ_t with the admissible extensions η of a current configuration X_t . When a materially relevant epistemic event ε changes information, classification, expectation, or institutional interpretation, the represented profile can be updated through a model-specific map. This relation is stated in Equation 15.2.

$$\Phi_{t+} = \mathcal{U}_\varepsilon[\Phi_{t-}], \quad (15.2)$$

where $\mathcal{U}_\varepsilon$ denotes an explicitly interpreted update induced by the epistemic event. Equation 15.2 is a structural formalization. It does not require a linear operator, quantum measurement rule, or a unique numerical potential. Its analytical function is to express that an epistemic event can alter represented evidential or decision support for later trajectories even when material resources have not yet changed. A change in practical accessibility requires an additional world-internal pathway, for example through altered expectations, authorization, coordination, classification, or behavior; an analyst's learning alone does not alter the realized possibility structure.

This distinction is important for economic decision processes. Publication of new evidence can redirect investment; legal interpretation can alter the attractiveness of previously available transactions; a credit-rating change can alter financing conditions; recognition of ecological risk can reweight infrastructure plans. These events can modify future transition conditions through expectations, classification, rules, or coordination. Their effects can later become material through investment, allocation, regulation, or withdrawal.

History weights and transition potentials can interact without being identical. Local transition potentials can help generate a family of candidate histories, while a history weight can evaluate the resulting whole path under a model or evidence set. Conversely, evidence concerning a completed history can update parameters used to assess future transition potentials. The relation depends on the modeling architecture and should not be assumed to factorize locally.

Weights can also change because the generative rule changes. An institutional reform, technological innovation, ecological threshold, or structural intervention can alter which extensions are admissible at all. In such cases the model should distinguish *reweighting within an existing history family* from *transformation of the family of admissible histories*. The latter is a deeper change because the possibility structure itself has been modified.

Proposition 15.7 (Trajectory-weight interpretation). *A weighted trajectory representation in GRE is analytically adequate only when the meaning, type, domain, and evidential basis of its history weights or transition potentials are stated, and when changes in represented support, changes in practical accessibility, and transformation of the admissible history space are distinguished where they differ. Numerical weighting does not by itself establish probability, causal force, value, normative desirability, or physical dynamics.*

Proposition 15.7 completes the section's bridge from trajectory reconstruction to generative spacetime. State, resource, value, relational, capability, and institutional trajectories identify different historical objects; coupled trajectories show how those histories condition one another; divergence identifies separation among paths; partially ordered complexes preserve concurrency and higher-order structure; spin-foam-inspired histories organize alternative interiors; and history weights or transition potentials provide disciplined ways to represent differentiated possibility. The next sections can therefore examine heterogeneous temporal positions and relational distance without assuming that economic history unfolds along one shared clock or one universally ordered path.

15.4 Heterogeneous Presents

Economic processes frequently couple subjects and institutions whose operative temporal positions differ even when they act at the same clock time. A household facing an immediate liquidity constraint, a firm planning a five-year investment, a regulator working through statutory review, a technology platform updating weekly, and a pension system carrying obligations across generations can participate in one economic configuration while orienting action toward markedly different horizons, rhythms,

delays, and inherited commitments. This section develops the concept of *heterogeneous presents* to represent such coexistence without suggesting that actors inhabit different physical times. Its role in Chapter 15 is to make temporal position itself relationally and institutionally structured before later sections examine distance, accessibility, sequence, path dependence, and delayed generation. The analysis proceeds through unequal temporal positions, institutional, technological, generational, legal, and economic temporalities, their coexistence, and the forms of temporal misalignment that can arise among them. The method is interpretive and structural: different temporalities are treated as analytically distinguishable organizations of deadlines, expectations, memory, duration, recurrence, and future commitment, while ordinary chronological time remains available wherever it is sufficient.

The argument builds on process-sensitive approaches that treat temporal order and historical sequence as constitutive of social explanation rather than as neutral containers for otherwise timeless variables (Abbott 2001). It also draws on conceptual-historical attention to changing relations between experience and expectation (Koselleck 2004). GRE uses these resources narrowly. Heterogeneous presents are not proposed as a universal metaphysics of social time. They are a representation for economic situations in which differences in operative horizon, cadence, latency, or inherited obligation materially alter what actors can perceive, decide, coordinate, or sustain.

Definition 15.8 (Heterogeneous present). A *heterogeneous present* in GRE is a contemporaneous economic configuration in which materially interacting subjects, institutions, or processes occupy different operative temporal positions with respect to relevant horizons, deadlines, inherited commitments, update frequencies, waiting times, or anticipated futures. The term denotes heterogeneity of economically consequential temporal organization within a shared historical situation; it does not imply separate physical presents.

Definition 15.8 makes contemporaneity compatible with temporal heterogeneity. Two positions can be present in the same calendar year while one is constrained by obligations due tomorrow and another by infrastructures whose consequences unfold over decades. The analytical question is therefore not merely *when* actors are, but which temporal distinctions structure their present capacities, constraints, expectations, and relations.

Table 15.4 summarizes the main temporal dimensions used in this section. The categories can overlap. A legal deadline can become an economic deadline; technological update cycles can reshape institutional review periods; generational commitments can be mediated through financial contracts. The table is therefore a diagnostic map rather than a taxonomy of mutually exclusive times.

15.4.1 Unequal Temporal Positions

Unequal temporal positions arise when actors participating in a shared process have different capacities to wait, accelerate, defer, commit, revise, or absorb delay. The relevant inequality is therefore not reducible to clock time. It concerns the distribution of temporal flexibility and temporal exposure. A subject who must accept income immediately can occupy a different bargaining position from one able to wait for a

Table 15.4: Analytical dimensions of heterogeneous presents in GRE

Temporal dimension	Primary organizing feature	Illustrative economic significance
Unequal temporal position	Unequal urgency, waiting, commitment, or capacity to defer	Bargaining position, liquidity pressure, exposure to delay, unequal option preservation
Institutional time	Procedural cycles, budgeting, review, organizational memory	Eligibility, authorization, continuity, implementation lag
Technological time	Innovation, update, obsolescence, compatibility cycles	Investment horizon, skill depreciation, infrastructure mismatch
Generational time	Overlapping life courses and inherited obligations	Intergenerational transfer, ecological burden, institutional succession
Legal time	Deadlines, limitation periods, rule changes, adjudicative delay	Rights realization, uncertainty, compliance, enforceability
Economic time	Turnover, credit maturity, production, maintenance, demand cycles	Financing pressure, inventory, fixed capital, return horizon
Coexisting presents	Coupled but nonidentical temporal orientations	Coordination across actors whose relevant horizons differ
Temporal misalignment	Mismatch among temporal requirements or capacities	Delay costs, premature commitment, stranded capacity, coordination failure

better offer, even when both receive the same information at the same moment. A creditor can often structure repayment over a longer horizon than a debtor facing a near-term liquidity constraint. An institution with reserves can postpone a project decision; a small organization whose funding expires this month may have little comparable freedom.

Temporal position becomes economically important when waiting itself has costs or when delay changes feasible action. These costs can include foregone income, interest, health deterioration, option expiration, contractual penalties, reputational damage, technical obsolescence, or loss of access to a scarce opportunity. The ability to impose delay can therefore strengthen a bargaining position and, under additional relations of dependence or control, become power-relevant. Conversely, the inability to wait can narrow effective choice and contribute to acceptance of unfavorable terms even without overt coercion. This is one reason that nominally identical choice sets can correspond to different effective option structures.

Unequal temporal position can also concern the capacity to accelerate. Fast access to credit, legal advice, data, compute, logistics, or administrative decision can allow one actor to act while another remains in a queue. The difference can compound when early action secures scarce resources or establishes standards that later entrants must adopt. Temporal advantage can therefore propagate into institutional or relational advantage without being reducible to an initial wealth difference.

Waiting and acceleration should nevertheless be interpreted contextually. Rapid decision can expose actors to error, while slower procedures can protect due process,

quality, safety, or deliberation. A short horizon can sometimes be appropriate in emergencies, and long horizons can entrench commitments that later circumstances make undesirable. GRE therefore treats temporal position as a distribution of capacities and constraints whose effects depend on the process under study, not as a universal ranking in which faster or slower is always better.

The same actor can occupy different temporal positions across relations. A large firm may be able to wait in a procurement negotiation yet face severe urgency in a re-financing cycle. A government may possess a long fiscal horizon while confronting an immediate electoral or disaster-response deadline. Temporal position is accordingly relation-specific and process-specific. Analysis should identify which delay, duration, deadline, or horizon matters to the claim and whose ability to absorb or impose it is at issue.

15.4.2 Institutional Time

Institutional time concerns the temporal organization produced by rules, routines, budgeting cycles, review procedures, reporting periods, appointment terms, organizational memory, and recurring decision calendars. Institutions do more than act within time; they help construct economically consequential temporal structures by deciding when claims can be filed, when resources are released, how long approvals remain valid, when performance is reviewed, and which past records remain operative.

These temporal structures can stabilize expectations. Regular budget cycles, reporting schedules, and review periods allow actors to coordinate investment and staffing. Long-lived procedures can preserve institutional memory across personnel turnover. Predictable renewal rules can reduce uncertainty for organizations that depend on continued authorization or funding. Institutional time can therefore be an enabling condition for durable coordination.

The same structures can also generate delay or mismatch. A research project may require rapid access to equipment while the procurement cycle operates annually. A local emergency can arise between budget windows. A rapidly changing technical standard can outpace a regulatory review period. These cases do not show that institutional procedures are intrinsically too slow; they show that the temporal design of an institution can become consequential relative to the temporal requirements of the process it governs.

Institutional time has historical depth. Rules created under earlier conditions can continue organizing present action after the environment that motivated them has changed. Prior classifications, fiscal calendars, licensing periods, or organizational routines can therefore act as temporal inheritances. Process-sensitive institutional analysis is useful here because present decisions can be shaped by the sequence through which rules, expectations, and commitments accumulated (Abbott 2001).

Institutional temporalities also differ internally. Finance, legal review, human resources, technical operations, and political oversight within the same organization can follow different schedules. Coordination problems can therefore arise inside an institution before they arise between institutions. A useful analysis should resist speaking of an organization's single "time" when its internal processes are temporally

heterogeneous in ways that affect implementation.

15.4.3 Technological Time

Technological time concerns innovation cycles, deployment rhythms, update frequencies, maintenance intervals, compatibility windows, skill obsolescence, and the changing duration over which technical infrastructures remain usable. Its role in GRE is to identify how technical systems create temporal conditions for economic action and how these conditions interact with slower or differently organized institutions, capabilities, and investments.

Technologies can compress some durations. Communication, computation, logistics, and automated coordination can reduce the time required for transactions, analysis, production, or distribution. Yet such compression rarely occurs uniformly. Faster information flow can increase the value of rapid response while placing actors without compatible infrastructure at a disadvantage. Technical acceleration can therefore create temporal asymmetry even when the technology is widely available in principle.

Technological systems also generate maintenance time. Software requires updates; hardware deteriorates; data formats become incompatible; security practices must respond to changing threats; specialized skills need renewal. A system that appears to save time at the point of use may transfer temporal burdens into maintenance, training, migration, or dependency on update providers. Technological time should therefore include the life cycle of a technical arrangement rather than only its moment of adoption.

Obsolescence is especially important for fixed investments. Infrastructure, equipment, credentials, and organizational routines can be designed around a technical regime whose replacement cycle is shorter than their amortization or learning horizon. This can create stranded capabilities or repeated conversion costs. Conversely, a deliberately stable standard can preserve interoperability but slow the incorporation of beneficial innovations. Neither rapid turnover nor long technological durability is normatively self-validating.

Technological time can also reshape expectation. When actors anticipate frequent improvement, they may postpone adoption; when they fear imminent obsolescence, they may shorten investment horizons. Expectations about technological change thus feed back into present allocation. The relevant temporal object is not only the realized update cycle but also the anticipated future of the technology and the confidence attached to that expectation.

15.4.4 Generational Time

Generational time concerns the overlapping life courses, inherited conditions, succession processes, and long-horizon consequences through which economic activity connects people who enter and leave institutions at different historical moments. It is analytically relevant when the effects of present action extend beyond the planning horizon or lifetime of current decision makers, or when inherited infrastructures, liabilities, ecological conditions, capabilities, and institutions shape the possibilities of

later cohorts.

Generational position is not identical to age. Two people of the same age can inherit different institutional histories, wealth, environmental conditions, technologies, and educational infrastructures. Conversely, people of different ages can share a generational exposure to a war, technological transition, financial crisis, legal reform, or climatic event. The relevant unit therefore depends on the process being studied.

Intergenerational economic relations often combine transfer and constraint. Later generations can receive capital, knowledge, infrastructure, institutions, and ecological stewardship; they can also inherit debt, degraded environments, rigid infrastructures, exclusionary classifications, or technological lock-in. These inheritances are rarely singular. The same infrastructure can be an enabling resource and a maintenance burden. The same institution can preserve valuable memory while constraining reform. Generational analysis should therefore preserve the plurality of inherited value and harm rather than treating inheritance as a single net quantity.

Generational time also raises problems of representation because future affected positions cannot participate symmetrically in present bargaining. Institutions may attempt to represent future interests through fiduciary duties, constitutional constraints, sustainability rules, long-horizon planning, or precautionary practices. Such arrangements are themselves historically situated and contested. GRE can analyze their temporal architecture without assuming that one procedure uniquely represents future generations.

Conceptual history is relevant because expectations about the future and interpretations of the past are themselves historically variable (Koselleck 2004). Economic actors do not simply face an objective horizon of years; they act through culturally and institutionally organized expectations of progress, decline, risk, inheritance, and possibility. Generational time therefore combines material duration with historically situated horizons of expectation.

15.4.5 Legal Time

Legal time concerns deadlines, notice periods, limitation rules, contract duration, adjudicative delay, prospective and retrospective application, transitional arrangements, and the temporal conditions under which rights, duties, statuses, and remedies become operative. Its economic significance lies in the way legal temporalities shape access, enforceability, uncertainty, and the timing of action.

A right can exist formally while remaining economically weak if realization requires a procedure whose duration exceeds the affected subject's capacity to wait. A business may possess a legal claim yet fail before judgment. A worker may have a remedy whose value declines as evidence disappears or immediate income needs intensify. Legal time therefore mediates the conversion of formal entitlement into practical capability.

Prospective rules also change present behavior before their formal effective date. Announced tax changes, environmental standards, licensing reforms, or reporting requirements can alter investment, contracting, hiring, or technological choices in anticipation. Legal events consequently possess both formal dates and broader expect-

tation effects. The economically operative period can begin before legal effectiveness and persist after formal repeal through contracts, sunk investments, or institutional routines.

Transitional rules are especially important when legal regimes change. Immediate application can impose sharp adjustment costs; extended transition can preserve stability while delaying intended reform. The relevant analysis should identify who receives time to adapt, who bears uncertainty during transition, and whose existing investments are protected or impaired. Temporal design is therefore part of the distributional and generative incidence of legal change.

Legal time can also conflict with other temporalities. Technological practices may evolve faster than adjudication; ecological harm can accumulate faster than regulatory enforcement; institutional review can outlast market opportunities. Such mismatches do not establish that law should simply accelerate. Due process, evidential quality, participation, and predictability can justify duration. The analytical question is whether the legal temporal structure is adequate to the harms, rights, uncertainties, and coordination problems it is intended to govern.

15.4.6 Economic Time

Economic time concerns the recurrent and historically variable temporal organization of production, turnover, credit, investment, maintenance, consumption, employment, inventory, demand, and return. Its role in this section is to identify temporal structures internal to economic processes rather than treating the economy as operating on one homogeneous clock.

Different activities have different turnover periods. Working capital can circulate rapidly while infrastructure investment remains fixed for decades. Agricultural production can follow seasonal cycles, software services continuous update, and housing investment long construction and repayment horizons. Credit instruments can create maturity structures that do not coincide with the timing of productive return. Political-economic analysis has long emphasized how turnover, fixed capital, credit, and spatial investment shape accumulation and constraint (Harvey 1982). GRE retains this insight while broadening attention to relational, capability, institutional, ecological, and generative effects.

Economic time also includes maintenance and reproduction. Productive capacity depends on activities whose temporal rhythm can differ from the output cycle: equipment maintenance, care, training, soil restoration, software migration, institutional renewal, and knowledge preservation. If evaluation focuses only on short reporting periods, these slower requirements can appear as current costs rather than conditions of later generation. Conversely, invoking a long horizon can be used rhetorically to postpone accountability for present harms. Horizon choice should therefore be explicit and justified.

Financial time can amplify temporal asymmetry. Interest, refinancing, collateral calls, liquidity requirements, and maturity dates can force action before longer-term value is realized. An enterprise can be productive over a ten-year horizon while failing under a one-year financing structure. A household can possess valuable assets while facing an immediate cash shortfall. These cases illustrate why present

economic capacity depends partly on the alignment between value realization and obligation schedules.

Economic temporalities also shift historically. Technologies, logistics, financial institutions, labor arrangements, and regulation can accelerate some cycles while extending others. Faster settlement may coexist with longer supply chains; shorter product cycles with longer infrastructure dependence; instantaneous communication with lengthy credential acquisition. “Economic time” should therefore remain plural and process-specific rather than serving as a synonym for generalized acceleration.

15.4.7 Coexisting Presents

Coexisting presents describe the coupling of actors and processes whose operative temporalities differ within one historical configuration. The concept is useful when those differences materially affect coordination, interpretation, bargaining, or causation. It captures a common economic condition: a technologically rapid process, a legally slower process, a long-lived infrastructure, a short financing horizon, and a generational ecological consequence can be parts of the same present economy.

Coexistence does not require synchronization. A platform can update weekly while a regulator reviews annually; a municipality can plan infrastructure over decades while contractors manage monthly cash flow; a university can preserve institutional commitments across generations while students experience two- or four-year participation windows. These actors interact now, yet “now” carries different practical meanings because their commitments, deadlines, memories, and anticipated futures differ.

The concept also helps explain disagreement that might otherwise appear merely cognitive. Actors can interpret the same project differently because they evaluate it over different horizons. A short-horizon investor can emphasize near-term liquidity; a public institution can emphasize durability; a community can emphasize intergenerational continuity; an engineer can emphasize technological obsolescence. The disagreement can involve substantive values and interests, but part of its structure can be temporal. Making that structure explicit can clarify which conflicts arise from horizon choice and which persist after horizons are aligned.

Coexisting presents are also spatially and relationally organized. A supply chain links regions with different institutional calendars, labor cycles, regulatory timelines, and exposure to seasonal or ecological constraints. A transnational project can therefore contain multiple temporal regimes within one contractual network. Relational space, understood as constituted through intersecting social relations and histories, provides a useful complement to this temporal view (Massey 1994). The resulting configuration is simultaneously spatially connected and temporally heterogeneous.

Proposition 15.9 (Contemporaneity without temporal homogeneity). *Actors or processes can be contemporaneous in chronological time while occupying materially different operative temporal positions. When those differences affect feasible action, interpretation, bargaining, coordination, or downstream incidence, an analytically adequate representation should preserve the relevant temporal heterogeneity rather than compressing the configuration into a single shared present.*

Proposition 15.9 is a representation principle. It does not imply that every actor possesses a private time. The claim is narrower: shared chronological location does not guarantee shared economic horizon, deadline structure, waiting capacity, update cycle, or historical inheritance.

15.4.8 Temporal Misalignment

Temporal misalignment occurs when the operative temporal requirements or capacities of interacting processes are sufficiently mismatched to alter coordination, realization, risk, or later possibility. The concept names a relation among temporal structures rather than a general preference for synchronization. Some systems benefit from asynchronous operation, buffers, staged review, or deliberate delay. Misalignment becomes analytically significant when temporal difference produces a material consequence relative to the process being studied.

Examples include financing that matures before productive return can be realized; legal remedies that arrive after practical exit has disappeared; technical systems whose update cycle is shorter than institutional procurement; infrastructure whose service life exceeds the planning horizon of its funding authority; education whose capability effects emerge after evaluation periods close; and ecological damage whose latency exceeds ordinary accounting or electoral cycles. In each case, the issue is not merely that processes move at different speeds. The problem is that their temporal coupling changes what can be sustained, known, financed, governed, or repaired.

Misalignment can generate both premature action and delayed action. A short horizon can induce underinvestment in maintenance or future capacity. A long procedure can postpone necessary response. Yet apparent misalignment can also be protective: cooling-off periods can reduce impulsive decisions; independent review can slow politically pressured action; long-term contracts can protect investment against short-term volatility. Diagnosis therefore requires specifying the function of each temporal structure and the consequence of their interaction.

Temporal misalignment can also redistribute risk. The actor able to shift waiting time onto another party may preserve flexibility while the other bears liquidity cost, uncertainty, or deterioration. Contractual scheduling, queue design, payment terms, administrative delay, and information-release timing can therefore become distributive mechanisms. The incidence may be hidden when analysis records only final transfer values and omits the duration over which different actors had to finance, wait, maintain, or remain exposed.

A useful temporal-misalignment analysis should identify at least four elements: the interacting processes, their relevant temporal structures, the mechanism through which the mismatch matters, and the positions bearing the resulting benefits, costs, or option changes. Where these elements are absent, the language of misalignment risks becoming a vague label for dissatisfaction with timing.

Definition 15.10 (Temporal misalignment). *Temporal misalignment* is a relation between two or more interacting economic processes whose operative horizons, deadlines, rhythms, waiting capacities, update cycles, or realization periods differ in a way that materially changes coordination, conversion, risk, accessibility, maintenance, or later feasible trajectories. The definition is process-relative and does not presume

that full synchronization is desirable.

Temporal misalignment connects heterogeneous presents to the remainder of Chapter 15. Relational distance can include temporal frictions as well as spatial or institutional separation; accessibility can be delayed or blocked by timing; sequence and temporal order determine whether opportunities remain reachable; path dependence can amplify early mismatches; and delayed generation can conceal effects until after the decision horizon that produced them. The concept therefore prepares the chapter to analyze distance and accessibility without assuming that temporally co-present actors occupy equivalent positions within generative spacetime.

15.5 Relational Distance

Economic interaction is shaped by several kinds of distance whose effects cannot be inferred from geography alone. Two organizations can occupy adjacent buildings yet remain institutionally distant because their procedures, standards, legal mandates, or authorization structures do not interoperate. Researchers and policy makers can exchange documents instantly while remaining epistemically distant because they use different categories, evidential standards, or interpretive languages. Conversely, actors separated by continents can become operationally close through stable logistics, shared technical standards, interoperable platforms, contractual routines, translation, and durable social relations. This section develops *relational distance* as a process-specific representation of such separations. Its role in Chapter 15 is to distinguish the several dimensions through which positions become nearer or farther with respect to an economically relevant process before the next section examines whether pathways among those positions are actually causally or generatively accessible. The analysis proceeds through geographic, institutional, social, epistemic, economic, and technological distance and concludes with distance transformation. The method is structural and comparative: each distance is defined relative to a specified process, and no universal scalar metric is presumed.

Spatial dependence remains economically important. Tobler's well-known formulation that near things are often more related than distant things provides a useful methodological reminder that geographic separation can shape interaction, while offering neither a universal law nor a license to identify geographic proximity with relational similarity (Tobler 1970). Relational approaches to space likewise emphasize that spatial configurations are constituted through intersecting social relations and histories rather than exhausted by Euclidean location (Massey 1994). GRE builds on this narrower insight: distance is analytically useful when it identifies a mechanism through which separation alters coordination, access, interpretation, conversion, transmission, or the practical reach of action.

Definition 15.11 (Relational distance). *Relational distance* in GRE is the process-relative separation between economically relevant positions with respect to a specified dimension of interaction, such as geographic reach, institutional interoperability, social connection, epistemic intelligibility, economic access, or technological compatibility. A relational-distance claim should identify the dimension being represented and the mechanism through which greater or lesser separation matters. The

Table 15.5: Analytical dimensions of relational distance in GRE

Distance dimension	Primary separation	Illustrative economic consequence
Geographic	Physical location, travel, terrain, territorial separation	Transport cost, delay, embodied access, jurisdictional exposure, spatial concentration
Institutional	Rules, mandates, procedures, legal forms, standards	Eligibility friction, recognition failure, coordination burden, delayed authorization
Social	Weak, absent, segmented, or hierarchical social relations	Reduced trust, brokerage dependence, exclusion, unequal referral or support pathways
Epistemic	Categories, evidence, expertise, language, interpretive frames	Misunderstanding, translation cost, credibility gaps, weak learning or knowledge transfer
Economic	Unequal practical access to resources, markets, finance, entitlements, or exchange positions	High switching costs, liquidity barriers, constrained participation, unequal convertibility
Technological	Compatibility, standards, infrastructure, interfaces, technical capability	Interoperability failure, migration cost, platform dependence, uneven access to productive tools

term does not imply a universal metric or that different dimensions are mutually commensurable.

Definition 15.11 makes distance indexical rather than absolute. A supplier can be geographically remote and technologically close because shared standards make integration easy. A citizen can be geographically close to a public office while institutionally distant because procedures, eligibility rules, language, documentation requirements, or administrative discretion make effective access difficult. The relevant distance is therefore the one that materially affects the process under study.

Table 15.5 summarizes the principal dimensions used in this section. The dimensions can interact and should not be read as independent coordinates. Geographic remoteness can increase economic cost; technological incompatibility can produce institutional barriers; social relations can reduce epistemic distance through repeated translation and trust. The table therefore functions as a diagnostic map rather than a fixed metric space.

15.5.1 Geographic Distance

Geographic distance concerns physical separation among economically relevant positions and the material conditions through which that separation becomes consequential. Travel time, transport cost, terrain, jurisdictional borders, logistics infrastructure, energy use, bodily presence, and spatial concentration can all make location economically significant. Geographic distance remains indispensable where goods, persons, care, land, ecological processes, or infrastructure cannot be treated as frictionlessly mobile.

The economic significance of physical distance is mediated rather than fixed. A

hundred kilometres connected by high-capacity rail can be practically closer for some activities than ten kilometres separated by poor transport, administrative borders, congestion, or inaccessible terrain. Digital communication can sharply reduce the relevance of physical separation for document exchange while doing little to reduce distance for construction, caregiving, surgery, agriculture, ecological restoration, or embodied trust-building. Geographic distance should therefore be interpreted together with the infrastructure and process through which it operates.

Spatial dependence can also be endogenous. Economic activity frequently changes the geography through which later activity occurs. Ports, transit systems, housing, data centres, industrial clusters, migration, environmental degradation, and land regulation can alter the effective distance among positions. A region that was economically peripheral can become connected through infrastructure, while displacement or ecological loss can make previously nearby resources practically remote. Geographic distance is thus partly inherited from earlier economic and institutional decisions.

The empirical relevance of proximity also varies by process. Tobler's spatial observation is useful as a starting intuition, yet near positions need not be economically similar, connected, or mutually accessible (Tobler 1970). The proper question is whether physical separation changes the relevant mechanism: movement, exposure, information, coordination, transaction, ecological spillover, or some other process. Where it does not, geographic distance should not be retained merely because it is easy to measure.

15.5.2 Institutional Distance

Institutional distance concerns separation created by differences in rules, legal statuses, organizational mandates, administrative procedures, recognized categories, standards, and decision rights. Positions can be institutionally distant even when they are physically close and participate in the same nominal market. A firm and regulator, two agencies, a migrant and public service, or organizations operating under different accounting and legal regimes can face substantial coordination barriers because the institutional conditions governing their interaction differ.

Institutions structure incentives and uncertainty through formal and informal constraints (North 1990). From a relational-distance perspective, their significance also lies in the interfaces they create. A license, credential, legal personality, recognized data standard, procurement category, or jurisdictional status can make one position legible to another. Absence of recognition can lengthen the pathway between them even when substantive capacities are otherwise present.

Institutional distance can therefore be represented through questions of interoperability. Can one institution recognize another's documents, authority, accounting categories, rights, or evidence? Can a decision made in one jurisdiction be acted upon in another? Can resources move without repeated approval? Can affected subjects contest a decision across organizational boundaries? These questions concern practical relation-building among institutional positions rather than an abstract ranking of institutional similarity.

Distance can also be asymmetric. A central institution may be easy for a periph-

eral actor to observe while remaining difficult to influence; a large organization may impose documentation standards on small suppliers without facing equivalent adaptation costs. Institutional proximity should therefore not be inferred from one-way visibility or formal membership. The direction of recognition, authorization, and contestation matters.

Institutional distance sometimes protects valuable differentiation. Independent courts, scientific review, professional standards, regulatory separation, or organizational autonomy can intentionally maintain distance in order to prevent capture or preserve specialized judgment. Reducing institutional distance is therefore not automatically desirable. The evaluative question concerns which separations enable legitimate differentiation and which create avoidable exclusion, delay, or coordination failure.

15.5.3 Social Distance

Social distance concerns the relational separation among subjects or groups produced by weak connection, segregation, hierarchy, unequal recognition, limited trust, or restricted access to social networks. Economic action is embedded in ongoing social relations rather than occurring among wholly atomized actors (Granovetter 1985). These relations can alter information flow, reputation, referral, cooperation, enforcement, opportunity discovery, and the practical cost of forming new economic ties.

GRE uses social distance cautiously. The concept should not reduce social structure to a single measure of interpersonal closeness. Dense relations can support trust and mutual aid while also enabling exclusion, surveillance, conformity, or capture. Weak ties or brokerage can sometimes connect otherwise separated groups. The relevant question is which pattern of social connection affects the economic process being studied.

Social distance can be directional and position-dependent. A professional network may provide insiders with rapid access to information and opportunities while remaining opaque to newcomers. A community may trust an intermediary who can translate between institutional and local settings, making the intermediary socially close to both sides even when the two sides remain distant from each other. Brokerage can therefore reduce effective distance while also creating dependency on the broker.

Hierarchical relations complicate ordinary proximity language. A worker and manager can interact daily while remaining socially distant with respect to authority, disclosure, or reciprocal recognition. Repeated contact is therefore insufficient to establish low social distance. The relevant features may include trust, reciprocity, status, shared norms, mutual intelligibility, or the practical possibility of requesting assistance and contesting decisions.

Social distance also changes historically. Migration, education, conflict, shared work, organizational membership, digital platforms, public institutions, discrimination, and collective action can reorganize who is connected to whom and under what terms. These changes can alter economic opportunity even before material resource distributions visibly change, because they transform pathways through which infor-

mation, support, legitimacy, and collaboration become available.

15.5.4 Epistemic Distance

Epistemic distance concerns separation in knowledge, concepts, evidence, language, interpretive frameworks, expertise, and standards of credibility that materially affect whether positions can understand, evaluate, or use one another's claims. It is distinct from simple information scarcity. Two actors can possess extensive information about the same issue yet remain epistemically distant because they classify the problem differently, rely on different evidential standards, or lack a shared vocabulary through which claims can be translated.

Dispersed knowledge creates a classical coordination problem in economics (Hayek 1945). GRE adds that knowledge is not only dispersed in quantity; it can be differently organized, encoded, situated, and institutionally recognized. A technical expert, local resident, administrator, and legal practitioner may each possess relevant knowledge while being unable to convert it directly into the categories recognized by the others. Epistemic distance can therefore arise at the level of translation and institutional intelligibility as well as access to information.

The distance can also be asymmetric. An organization can understand a community well enough to classify or target it while the community lacks comparable knowledge of the organization's rules or predictive systems. A platform can infer user behavior while users cannot inspect the model that shapes their opportunities. Such cases involve differences in epistemic reach and observability, not merely different amounts of knowledge.

Translation can reduce epistemic distance, but translation is rarely lossless. Concepts can be compressed when converted into standardized indicators, administrative categories, model variables, or machine-readable labels. Conversely, common standards can enable large-scale coordination precisely because they sacrifice some local specificity. Epistemic proximity should therefore be evaluated relative to the task: enough shared structure for the intended judgment may be adequate even when complete conceptual equivalence is impossible.

Epistemic distance is especially consequential for innovation and learning. Collaboration requires some ability to exchange and interpret knowledge, while complete sameness of perspective can reduce the informational gains from collaboration. The objective is therefore not universal epistemic homogeneity. Productive configurations can combine differentiated knowledge with institutions, translators, boundary objects, or repeated relations that make cross-position learning possible.

15.5.5 Economic Distance

Economic distance concerns separation in practical access to resources, markets, finance, entitlements, productive capacities, exchange positions, and conversion opportunities. It is not reducible to income difference. Two households with similar nominal income can be economically distant from the same opportunity if one has collateral, legal status, transport, childcare, credit access, or institutional recognition while the other does not. Similarly, two firms with similar output can differ greatly

in access to finance, standards compliance, supplier networks, or bargaining alternatives.

Entitlement analysis illustrates why aggregate availability and practical command should be distinguished (Sen 1981). A resource can exist within a region while remaining economically distant from subjects who lack the legal, financial, institutional, or relational means to command it. Development understood through substantive freedoms likewise directs attention toward what persons are effectively able to do with available resources rather than toward nominal possession alone (Sen 1999). In GRE, economic distance therefore concerns the pathway from nominal availability to effective economic reach.

Several mechanisms can create such distance: price, liquidity constraints, collateral requirements, transaction costs, switching costs, information asymmetry, bargaining position, market segmentation, documentation, or dependence on complementary resources. These mechanisms need not move together. A service can be cheap but economically distant because access requires time, credentials, language, or technology; an expensive asset can be economically close to a well-capitalized organization with established financing channels.

Economic distance also has relational incidence. A dominant buyer can make a market economically close to itself while suppliers remain distant from alternative buyers because of specialized investments, standards, or long-term contracts. A platform can reduce search and transaction distance between participants while increasing their dependence on the platform's rules. Reduced economic distance along one pathway can therefore coexist with increased distance from alternatives.

For this reason, economic distance should be indexed to a target capability or transaction. Asking whether a person is “close to the market” is too vague. The relevant question might concern access to employment, housing, credit, health care, productive equipment, education, or an exit option. Each can have different effective distances and different mechanisms of transformation.

15.5.6 Technological Distance

Technological distance concerns separation in technical capability, infrastructure, standards, interfaces, architectures, compatibility, and practical ability to adopt or integrate a technology. Geographic proximity and common access to information do not ensure technological closeness. Organizations can operate in the same sector yet be separated by incompatible data formats, legacy systems, specialized equipment, security requirements, compute capacity, or missing technical skills.

Compatibility can sharply alter technological distance. Systems markets and network effects show how value can depend on compatibility, installed bases, and expectations about adoption (Katz and Shapiro 1994). From a GRE perspective, common standards or interfaces can make previously separated technological positions interoperable, while proprietary interfaces, switching costs, or rapid version changes can enlarge distance from alternative systems.

Technological distance has both capability and infrastructural components. A device can be physically present while remaining practically distant if users lack main-

tenance knowledge, electricity, connectivity, complementary software, repair access, or institutional permission. Conversely, cloud infrastructure and standardized interfaces can allow geographically distant organizations to use similar technical capacities. The effective distance therefore depends on a stack of enabling conditions rather than the location of a device alone.

Technological distance can also be strategically produced. Firms may design proprietary standards, ecosystems, certification requirements, or data formats that facilitate coordination within one system while making exit or cross-system migration costly. Such arrangements can generate valuable reliability and integration, yet they can also produce dependence and unequal control over conversion interfaces. Analysis should identify both effects rather than treating openness or closure as intrinsically desirable.

Differences in technological pace can interact with the heterogeneous presents developed in Section 15.4. Rapid technical change can increase distance for institutions whose procurement, legal review, training, or infrastructure replacement operates more slowly. Technological distance is therefore partly temporal: compatibility can decay as systems evolve, and the cost of catching up can depend on the sequence through which earlier investments accumulated.

15.5.7 Distance Transformation

Economic processes do not merely operate across pre-existing distances; they can transform the distances that condition later interaction. Infrastructure can reduce travel time, standardization can reduce institutional or technological distance, education and translation can reduce epistemic distance, repeated collaboration can reduce some forms of social distance, and public provision can reduce economic distance to essential capabilities. The same processes can create new separations elsewhere through exclusion, displacement, proprietary control, segmentation, or dependency.

Distance transformation should therefore be represented dimension by dimension. A digital platform can reduce geographic and search distance while increasing technological dependence and institutional distance from the rules governing participation. A new credential can reduce epistemic uncertainty for employers while increasing institutional distance for competent persons who lack recognized certification. A transport project can reduce travel distance to a regional centre while increasing ecological or economic distance for communities displaced by construction. There is no general rule that “reducing distance” constitutes improvement.

The transformation can also be asymmetric. One actor may become closer to another without reciprocal closeness. A firm can acquire detailed data about customers while customers remain distant from the firm’s decision process. A state can make citizens administratively legible while remaining difficult for them to contest. A buyer can integrate suppliers into a digital procurement system while retaining easy substitution among them, even as suppliers become more dependent on the buyer. Direction therefore belongs to the analysis whenever the mechanism is asymmetric.

Distance can also be redistributed across a network. Shortening a pathway between two positions can increase the centrality of an intermediary, bypass a previous broker, or isolate another region or institution. Infrastructure and standards can

reorganize topology rather than merely shorten pairwise paths. Network analysis is useful where such structural effects matter because connectivity, clustering, and intermediary positions can alter the functional meaning of distance (Newman 2003). The appropriate representation may consequently concern path structure or reachability rather than a single dyadic measure.

Proposition 15.12 (Multidimensional adequacy of relational distance). *A relational-distance representation is adequate to the extent that it identifies the distance dimension materially relevant to the economic process, the mechanism through which separation affects interaction or realization, the directionality and affected positions where these matter, and the possibility that intervention changes several distance dimensions differently. Greater proximity on one dimension does not establish proximity on another, and no common scalar metric is required unless the research design independently justifies one.*

Proposition 15.12 gives relational distance a scope discipline. A locally justified measure can still be quantitative: kilometres, travel time, network path length, switching cost, interoperability rate, translation error, or another operational measure may be appropriate to a specific question. The proposition only rejects the unargued step from such a local measure to a universal distance among economic positions.

Distance transformation prepares the next analytical problem. Two positions can be near or far along several dimensions while the existence of a plausible pathway between them remains a separate question. A technically compatible system can still be legally inaccessible; geographically adjacent institutions can lack a causal channel through which one affects the other; socially close actors can be unable to convert trust into authorized action. Relational distance therefore describes the structure of separation, while the following analysis of causal and generative accessibility asks which transitions, transmissions, and interventions are actually reachable through the configuration.

15.6 Causal and Generative Accessibility

Relational distance describes how positions are separated along geographic, institutional, social, epistemic, economic, and technological dimensions. Distance alone does not establish whether one position can affect another, whether a resource can reach a target, whether an intervention can propagate through a configuration, or whether a later state can be generated from an earlier one. This section develops *causal and generative accessibility* as the directed pathway structure through which such transitions become possible. Its role in Chapter 15 is to provide the bridge between relational distance and the later analysis of sequence, path dependence, delayed generation, propagation, and intervention. The objective is to distinguish structural reachability from established causal attribution while identifying how mediation, delay, blockage, history, and unequal position alter what can become reachable. The discussion proceeds through reachability, causal pathways, delayed accessibility, blocked pathways, mediated access, historical accessibility, and unequal accessibility. The method is structural and mechanism-oriented: accessibility claims identify plau-

sible pathways and enabling conditions, whereas stronger causal claims require evidence that a pathway was active in the case under study (Woodward 2003; Hedström and Ylikoski 2010; Beach and Pedersen 2019).

Definition 15.13 (Causal and generative accessibility). For a bounded economic configuration, a target position, event, state, or trajectory segment is *causally accessible* from a source when at least one directed and materially plausible pathway connects the source to the target under specified enabling conditions. A target is *generatively accessible* when such a pathway can, under the stated conditions, participate in producing or transforming economically relevant capacities, relations, institutions, constraints, value processes, or later option structures. Accessibility identifies structured possibility. It does not by itself establish that the pathway was activated, that the source caused an observed outcome, or that the accessible transition is desirable.

Definition 15.13 distinguishes three levels that should remain separate. A path can be structurally available, it can be activated in a particular history, and it can make a difference to the outcome or generative configuration under investigation. These levels correspond to increasingly demanding evidential claims. A transport corridor can make delivery accessible without any shipment occurring. An administrative appeal can be formally available while remaining practically unused. A communication channel can transmit information without changing a decision. Accessibility is therefore a condition of some causal and generative processes, while stronger attribution depends on mechanism evidence, timing, alternative explanations, and the evidential standards appropriate to the research design.

Table 15.6 summarizes the principal accessibility distinctions used in this section. The rows describe different properties of pathway structure rather than separate ontological domains. The same economic process can be reachable, mediated, delayed, historically created, and unequally accessible at once.

15.6.1 Reachability

Reachability is the minimal structural question of accessibility. Given a bounded configuration and a specified source and target, the analyst asks whether at least one materially plausible directed pathway exists under the conditions represented in the inquiry. The target may be a person, institution, resource, market, legal status, capability, event, state, or later trajectory segment. Reachability can therefore concern movement of goods, transmission of information, exercise of authority, conversion of rights into practical access, propagation of risk, or the possibility that an intervention affects a later configuration.

The concept is intentionally broader than physical connection. A household can be geographically near a hospital while lacking a reachable pathway to treatment because eligibility, payment, transport at the required time, documentation, language, or referral conditions are missing. A researcher can have network access to a dataset while being unable to use it because authorization, compute, technical compatibility, or legal permission is absent. Conversely, a distant actor can be reachable through stable logistics, interoperable standards, trusted intermediaries, and recognized institutional procedures.

Reachability is directional. The fact that position *A* can affect or access position *B*

Table 15.6: Analytical dimensions of causal and generative accessibility in GRE

Accessibility dimension	Primary question	Illustrative analytical concern
Reachability	Can a directed pathway connect source and target under stated conditions?	Structural possibility, feasible transition, intervention reach
Causal pathway	Through which mechanism could an effect be transmitted or produced?	Mechanism activation, evidential trace, attribution
Delayed accessibility	When does a pathway become usable or consequential?	Maturation, sequencing, latency, waiting conditions
Blocked pathway	Which missing or constraining condition prevents passage?	Bottleneck, prohibition, incompatibility, exhausted capacity
Mediated access	Which intermediary positions or interfaces make passage possible?	Brokerage, translation, authorization, platform or infrastructure dependence
Historical accessibility	How have earlier events created, removed, or reshaped pathways?	Inherited infrastructure, institutional memory, path dependence, prior investment
Unequal accessibility	Which positions can reach targets, pathways, or futures that others cannot?	Asymmetrical reach, unequal intervention capacity, exclusion, dependence

does not imply that B has equivalent access to A . A platform can reach users through ranking, notification, pricing, or account controls while users have limited ability to reach the platform's decision process. A regulator can demand information from a firm while the firm cannot compel equivalent disclosure from the regulator. A lender can alter a borrower's financing conditions while the borrower has little capacity to alter the lender's portfolio decisions. Direction therefore belongs to the accessibility claim rather than being inferred from the existence of a relation.

Reachability is also conditional. A pathway can exist only during certain times, under a given legal status, above a minimum level of infrastructure, or while complementary resources remain available. The relevant statement is consequently not that a target is reachable in the abstract, but that it is reachable *under specified conditions*. This qualification is especially important for intervention analysis. A policy instrument can have formal jurisdiction over an outcome while lacking the implementation capacity, information, cooperation, or conversion conditions required to reach it in practice.

A reachability representation can be binary for a tightly specified question, yet many empirical settings require a richer account. Accessibility can be uncertain, costly, fragile, intermittent, capacity-constrained, or available only through a narrow intermediary. GRE therefore treats binary reachability as a possible local simplification rather than the universal form of accessibility. Where the cost, reliability, delay, or reversibility of the path changes the substantive conclusion, those properties should remain visible.

15.6.2 Causal Pathways

A causal pathway is a directed sequence or partially ordered configuration of mechanisms through which a source condition can contribute to a target effect. Mechanism-based social-science explanation emphasizes that causal claims gain explanatory content when the analyst specifies how relevant entities, activities, relations, or institutional processes connect putative causes and outcomes (Hedström and Ylikoski 2010; Beach and Pedersen 2019). GRE adopts this requirement while preserving the distinction between representing a plausible pathway and demonstrating that the pathway was operative in a particular history.

Causal pathways can include heterogeneous components. A financial allocation can alter organizational staffing; staffing can change service capacity; changed capacity can alter waiting time; waiting time can affect participation or health; the resulting experience can alter trust in an institution. The pathway crosses financial, organizational, temporal, relational, and capability registers. Treating the final outcome as if it followed directly from the initial allocation would erase the mediating structure through which the effect became possible.

The pathway need not be a single linear chain. Several mechanisms can operate jointly, one mechanism can branch toward several effects, and several antecedent pathways can converge on the same target. Partial ordering becomes useful where some events must precede others while several mediating processes can occur concurrently. In such cases, causal accessibility concerns the directed architecture of possible influence rather than a narrative sequence in which each event has one unique predecessor.

Interventionist accounts of causation provide one useful precedent for distinguishing causal dependence from mere association by asking how outcomes would change under appropriately specified interventions (Woodward 2003). GRE uses the insight selectively. In historical and institutional settings, controlled intervention may be unavailable, ethically inappropriate, or conceptually ill-defined. Causal accessibility can still be studied through process tracing, comparative histories, natural variation, institutional evidence, simulation, or other locally adequate methods. The relevant principle is that stronger causal language requires stronger evidence about pathway activation and difference-making than a structural accessibility claim does.

Evidence for a causal pathway can include temporal ordering, traces of mechanism activation, documents, transaction records, observed intermediaries, institutional procedures, qualitative testimony, network flows, policy implementation records, or model-based implications. The appropriate evidence varies by mechanism. A pathway should not be treated as established merely because its steps are individually plausible. The analyst must also consider whether the steps were connected in the history under study and whether relevant alternatives remain viable.

This distinction matters for generative analysis. A source can be causally connected to an immediate outcome without generating the later capability, institution, or option structure of interest. Conversely, a generative mechanism can work through several intermediate outcomes whose individual causal contribution is modest while their cumulative configuration materially changes later possibilities. Causal accessibility therefore supplies the pathway grammar; generative accessibil-

ity adds the question of what the pathway changes about subsequent capacity to act, relate, maintain, adapt, or generate.

15.6.3 Delayed Accessibility

Accessibility can be temporally delayed. A pathway may be structurally present at one moment yet become usable or consequential only after a waiting period, maturation process, complementary investment, legal transition, accumulated learning, threshold crossing, or scheduled institutional event. Delayed accessibility differs from a delayed observed effect. In the former case, the pathway itself is not yet practically open; in the latter, the pathway may already have operated while its consequences become visible later.

Several forms of delay should be distinguished. *Maturation delay* arises when biological, educational, organizational, or technical capacity requires time to develop. *Procedural delay* arises from review, licensing, litigation, procurement, or other institutional sequences. *Complementarity delay* occurs when an initial resource or relation becomes effective only after another required condition appears. *Threshold delay* occurs when a pathway becomes viable only after accumulated scale, density, knowledge, or infrastructure crosses a relevant level. These mechanisms can produce similar chronological lags while having different implications for intervention.

Delayed accessibility can preserve options as well as postpone them. A cooling-off period, scientific review, staged release of funds, or reversible pilot can intentionally delay access to later actions in order to preserve learning, safety, or contestation. Delay therefore has no fixed normative sign. The analytical task is to identify what becomes accessible when, through which mechanism, and for whom.

Timing also affects who can use an eventual pathway. A legal entitlement that becomes operational after several years may be formally accessible to a claimant who cannot survive the waiting period economically. A technology whose price falls after widespread diffusion may become accessible to later entrants while early access remains concentrated among capital-rich organizations. Delayed accessibility therefore interacts with the heterogeneous presents analyzed in Section 15.4: actors with different capacities to wait or absorb interim costs can occupy different effective accessibility positions even when the final pathway is nominally common.

Long delays complicate attribution because the configuration can change while the pathway is opening. Institutions, preferences, technologies, intermediaries, and alternative opportunities may all change between initial condition and realized access. A delayed-accessibility claim should therefore specify which conditions are assumed to persist and which transformations are themselves part of the pathway.

15.6.4 Blocked Pathways

A blocked pathway is a directed route whose passage is prevented by a materially relevant condition. Blockage can arise from law, missing infrastructure, incompatible standards, insufficient capacity, resource scarcity, institutional refusal, informational opacity, social exclusion, ecological constraint, security rules, or the absence of a required intermediary. The concept directs attention away from the vague state-

ment that an outcome “failed to occur” and toward the specific condition that interrupted or prevented reachability.

Blockage should be distinguished from non-use. A path can remain open even if no actor chooses to traverse it. It should also be distinguished from high cost when passage remains practically feasible. Whether cost constitutes a block depends on the target position and the research question: a fee that is negligible for one organization can make a pathway effectively inaccessible to another. Blockage is consequently relational and position-dependent.

Some blocks are protective. Safety standards, judicial review, data-access restrictions, ecological limits, professional licensing, or conflict-of-interest rules can intentionally prevent certain transitions. A generative analysis should therefore avoid treating every removal of a block as increased welfare or generative improvement. The relevant questions are what the block prevents, what it protects, whose action it constrains, whose vulnerability it reduces, and what alternative pathways remain available.

Blocked pathways can reveal generative structure. If removing one condition repeatedly enables a previously absent transition, that condition may be a meaningful bottleneck or enabling requirement. Yet intervention on a block can also reorganize the system and create new constraints elsewhere. Removing a procurement rule can accelerate purchase while weakening accountability; bypassing a professional intermediary can reduce cost while eliminating a source of quality assurance; opening a data interface can enable innovation while increasing privacy or security exposure. The effect of unblocking therefore has to be followed beyond the immediate path-opening event.

The absence of observed passage is weak evidence of blockage unless observability is adequate. A pathway can operate through informal, undocumented, or distributed mechanisms that are difficult to observe. Conversely, an official pathway can appear open on paper while remaining unusable in practice. Claims about blocked pathways should therefore state whether blockage is inferred from formal rules, observed failed attempts, missing mechanism traces, counterfactual comparison, or another evidential basis.

15.6.5 Mediated Access

Many economically relevant pathways are accessible only through mediators. These can include persons, organizations, platforms, translators, banks, courts, standards bodies, logistical hubs, technical interfaces, brokers, professional associations, public agencies, or shared infrastructures. Mediation can reduce relational distance, convert one form of value or evidence into another, provide authorization, coordinate several positions, or make a target legible to a source.

Mediated access differs from indirectness alone. An intermediary is analytically relevant when its position or operation materially conditions whether passage occurs, under what terms, with what information, and with what consequences. A payment processor is not merely one more node when its rules determine who can transact. A credentialing body is not merely an administrative step when its recognition determines occupational access. A translator is not merely a communication

channel when interpretation determines whether evidence can enter an institutional decision.

Mediation can create both capacity and dependency. A trusted broker can connect otherwise distant communities and institutions, while repeated reliance on the broker can concentrate knowledge or control over the interface. A platform can make market entry easier while retaining power over ranking, fees, data, and account access. A public institution can make rights practically reachable while also becoming a bottleneck when staffing or procedural capacity is limited. The generative significance of mediation therefore depends on how the intermediary changes later options and relations, not only on whether it shortens an immediate path.

Mediators can transform what passes through them. Translation, classification, aggregation, pricing, legal interpretation, standardization, and technical conversion can change the form, visibility, or admissibility of the transmitted object. Section 15.5 treated these changes partly as distance transformation. Here the concern is accessibility: the mediator can make a path possible precisely by transforming the object into a form that the target can receive or act upon. The resulting access may therefore involve conversion loss, compression, or altered incidence.

Mediated pathways can also be redundant or substitutable. Multiple independent intermediaries can increase resilience and reduce dependence, while a single mandatory interface can create fragility or concentrated control. Accessibility analysis should therefore record whether a mediator is optional, substitutable, regulated, contestable, or required, and whether affected positions can bypass or replace it.

15.6.6 Historical Accessibility

Accessibility has a history. Present pathways are often inherited products of earlier infrastructure, institutions, investments, conflicts, classifications, settlements, technological standards, legal decisions, organizational learning, and accumulated relations. A target that appears readily reachable in the present may be accessible only because earlier generations built and maintained the pathway; another target may remain inaccessible because earlier decisions foreclosed complementary capacities or entrenched incompatible structures.

Historical accessibility therefore differs from present-state connectivity. Two configurations with similar current resources can possess different reachable futures because their inherited pathways differ. A region with established transport, legal institutions, trained personnel, and trusted interorganizational relations can convert a new investment into practical activity more rapidly than a region that lacks those inherited conditions. The difference is not exhausted by the amount of current funding. It lies partly in the historically accumulated architecture through which resources can become effective.

Research on path dependence provides one precedent for treating early sequence and reinforcement as consequential. This tradition is well established in comparative historical analysis (Mahoney and Rueschemeyer 2003). GRE uses historical accessibility more broadly. A pathway can persist through maintenance, legal precedent, organizational memory, shared standards, or ecological inheritance without requiring a narrow increasing-returns mechanism. Historical accessibility can likewise expand

through deliberate path creation, institutional reform, learning, or infrastructural investment rather than only through accidental early contingencies.

Historical pathways can also disappear. Skills can be lost, infrastructure can decay, legal authority can expire, trust can erode, ecological thresholds can be crossed, and technological standards can become obsolete. Accessibility is therefore maintained as well as created. A pathway that existed in an earlier period should not be treated as available today without evidence that its enabling conditions survived or were renewed.

Counterfactual reasoning about historical accessibility requires restraint. Observing that one pathway exists does not prove that every alternative was impossible. Historical reconstruction should distinguish pathways that were inaccessible, pathways that were accessible but not taken, pathways whose accessibility is uncertain, and pathways rendered visible only through later knowledge. This distinction will matter in later sections on path dependence, historical branching, and re-epistemization.

15.6.7 Unequal Accessibility

Accessibility is frequently distributed unevenly. Subjects, organizations, regions, and institutions can differ in which pathways they can enter, how reliably they can traverse them, how long they can wait, which mediators they can use, what costs they bear, and whether they can reverse or exit after entering a path. Unequal accessibility is therefore broader than unequal resource holdings. It concerns unequal practical reach into the configuration and its possible futures.

Several mechanisms can produce unequal accessibility. Wealth can finance entry costs or waiting periods. Institutional status can open authorization pathways. Social relations can provide referrals or trusted mediation. Expertise can reduce epistemic distance. Technical capability can make infrastructures usable. Legal status can determine whether formal rights are actionable. Organizational scale can make redundancy and alternative pathways affordable. These mechanisms can reinforce one another, but they should remain distinguishable where the inquiry requires it.

Unequal accessibility can be directional and strategic. A powerful organization may reach suppliers, workers, users, or communities through contracts, platforms, data, or regulation while those positions have limited access to the organization's decision processes. Such asymmetry can affect bargaining, accountability, contestation, and the distribution of risk. It can also shape knowledge: actors with greater reach can observe more of the system, intervene at more points, and learn from a wider range of outcomes.

Generative accessibility is especially consequential because unequal reach can cumulate over time. An actor that can access education, capital, infrastructure, institutional recognition, and high-quality information can generate further capabilities and options; another actor may face repeated blocks at conversion interfaces. This mechanism does not imply deterministic cumulative advantage. Public infrastructure, institutional redesign, collective organization, technical standardization, or targeted allocation can create new pathways and alter the accessibility structure. The relevant claim is historical and conditional: unequal access to generative pathways can become one mechanism through which unequal future possibility is reproduced.

Accessibility interventions should therefore be evaluated at more than the point of entry. Opening a pathway can change intermediary power, congestion, security, maintenance burdens, exclusion elsewhere, or the accessibility of alternative paths. The question is not only whether more positions can reach the immediate target, but how the intervention changes the architecture of later reachability.

Proposition 15.14 (Accessibility–attribution separation). *Evidence that a target is causally or generatively accessible from a source supports a claim of structured possibility of influence under stated conditions. A stronger claim that the source produced, mediated, or materially altered the target requires additional evidence that the relevant pathway was activated and that the proposed mechanism is supported relative to materially plausible alternatives. Accessibility analysis should therefore preserve the distinction among pathway existence, pathway activation, causal contribution, and downstream generative transformation.*

Proposition 15.14 gives accessibility analysis an evidential boundary. The proposition does not require one universal method for causal identification. Experimental intervention, natural variation, process tracing, longitudinal evidence, comparative history, simulation, and mixed-method inquiry can each be appropriate under different conditions. It requires only that structural reachability should not be silently upgraded into an empirical causal conclusion.

The accessibility framework also supplies the directional substrate for the next section. Once several transitions are reachable, the order in which they occur can change what remains accessible later. A pathway opened too early can create lock-in; a complementary condition arriving too late can render an earlier investment ineffective; simultaneous processes can interfere or reinforce one another; and a formally reversible sequence can become historically difficult to undo. The analysis therefore moves next from pathway availability to *sequence and temporal order*.

15.7 Sequence and Temporal Order

Accessibility identifies which transitions can become reachable under stated conditions. Sequence adds a further question: when several events or processes are accessible, how does their temporal ordering affect what they produce, what remains possible, and which later pathways stay open? This section develops sequence and temporal order as the organization of economically consequential precedence, timing, duration, recurrence, coordination, and concurrency. Its role in Chapter 15 is to connect the pathway architecture of Section 15.6 with the subsequent analysis of path dependence, delayed generation, and historical branching. The objective is to distinguish chronological succession from analytically relevant temporal order while showing how order effects can arise through complementarity, thresholds, institutional procedure, learning, capacity formation, and changing accessibility. The discussion proceeds through order effects, timing, duration, rhythm, synchronization, asynchrony, critical junctures, irreversibility, and partial temporal order. The method is process-sensitive and mechanism-oriented: temporal claims should identify the mechanism through which order or timing matters rather than infer consequence from chronology alone (Abbott 2001; Pierson 2000; Mahoney and Rueschemeyer 2003).

Definition 15.15 (Economic temporal order). For a bounded economic inquiry, an *economic temporal order* is a representation of precedence, concurrency, duration, or recurrence relations among events and processes whose temporal organization is materially relevant to the outcome, mechanism, accessibility structure, or later generative possibilities under study. Temporal order can coincide with clock chronology, but it may require additional distinctions such as generative precedence, institutional prerequisite, delayed activation, or unresolved concurrency. The representation does not by itself establish causal necessity or a unique complete ordering of history.

Definition 15.15 makes temporal order purpose-relative. A chronological record can be sufficient when the research question concerns dated occurrence. A richer representation becomes useful when an earlier event changes the interpretation or consequence of a later event, when two processes must overlap, when duration changes viability, or when several events are only partially ordered. Temporal order therefore adds analytical structure only where that structure changes the claim.

Table 15.7 summarizes the principal distinctions used in the section. The rows can overlap in the same process. A policy sequence can have an order effect, depend on timing, require a minimum duration, operate rhythmically, and interact asynchronously with another institutional process.

15.7.1 Order Effects

An order effect occurs when two histories containing similar elements produce materially different consequences because those elements occur in a different sequence. The analytical claim is stronger than observing that one event happened first. It requires a mechanism through which earlier occurrence changes the conditions under which the later event operates. Such mechanisms can include learning, complementary investment, institutional authorization, trust formation, depletion, capacity accumulation, expectation formation, or modification of the set of accessible later actions.

Consider two interventions, training and equipment provision. If usable equipment requires prior technical capability, training before delivery can produce a different result from delivery before training. The difference can disappear where equipment is storable, training is immediately available, and no depreciation or access loss occurs. Sequence matters conditionally. GRE therefore treats order sensitivity as an empirical and structural question rather than a universal property of economic processes.

Order effects can also arise through interpretation. An institutional reform announced after a credible enforcement change can be interpreted differently from the same announcement made before enforcement capacity exists. A subsidy introduced after suppliers have expanded capacity can have different incidence from the same subsidy introduced while supply is constrained. A disclosure received before a decision deadline can alter choice; the same disclosure received afterward may alter only retrospective evaluation. In each case, sequence changes the operative context of later events.

Path-dependence scholarship provides an established precedent for attention to timing and sequence, especially where earlier events alter later returns or institu-

Table 15.7: Analytical dimensions of sequence and temporal order in GRE

Temporal dimension	Primary question	Illustrative analytical concern
Order effect	Does changing event order change the resulting configuration?	Complementarity, sequencing, prerequisite formation, path opening
Timing	At what moment or phase does an intervention or event occur?	Windows of opportunity, readiness, congestion, institutional phase
Duration	How long must a condition persist or remain available?	Learning, maintenance, maturation, exposure, commitment
Rhythm	What pattern of recurrence or pacing organizes the process?	Review cycles, payment cycles, maintenance, seasonal or organizational cadence
Synchronization	Which processes require coordinated temporal alignment?	Complementary investment, handoff, shared deadlines, coupled operation
Asynchrony	Which processes operate at different speeds or phases?	Delay, buffering, temporal mismatch, sequential adaptation
Critical juncture	When can a bounded period disproportionately reshape later pathways?	Institutional choice, crisis response, path opening or closure
Irreversibility	Which earlier changes constrain practical restoration?	Sunk commitments, ecological damage, institutional embedding, option loss
Partial temporal order	Which precedence relations are supported without imposing a total sequence?	Concurrency, unresolved order, generative precedence, trajectory complexes

tional possibilities (Pierson 2000; Arthur 1989). Section 15.8 will examine path dependence directly. The narrower task here is to identify order sensitivity before deciding whether reinforcement, lock-in, hysteresis, or another stronger historical mechanism is present.

Order effects should also be distinguished from simple cumulative quantity. If two payments produce the same result whenever their total amount is unchanged, their order may be analytically irrelevant. If the first payment permits a recipient to avoid default and thereby preserves eligibility for the second, sequence becomes material. The relevant comparison is therefore between alternative admissible orders under sufficiently similar surrounding conditions, not merely between an observed history and an imagined chronology with no mechanism specification.

15.7.2 Timing

Timing concerns the location of an event or intervention within the evolving state of a process. Calendar date can matter, yet many timing problems are better indexed to process phase: before or after a threshold, during a liquidity shortage, before an authorization expires, after a skill becomes usable, during a seasonal demand peak,

or while a coalition remains capable of coordinated action. Timing is therefore relational to the process whose state gives the moment economic significance.

A temporally well-placed intervention can exploit readiness or preserve an accessible pathway. The same intervention can have weak effect when it arrives before complementary conditions exist or after a relevant window has closed. This structure appears in investment, maintenance, emergency response, education, institutional reform, infrastructure deployment, negotiation, and technological adoption. The value of timing is frequently inseparable from the conditions present at the moment of action.

Timing analysis should avoid treating a favorable observed moment as evidence of a universally optimal date. A policy implemented during one institutional configuration may encounter different constraints under another. A technological intervention that benefits early adopters under scarce supply may have different distributive effects after diffusion. Appropriate timing can therefore vary across positions and scales. What is early for a financing cycle can be late for ecological maintenance; what is timely for a central administration can arrive after a local organization has exhausted its reserves.

Timing also interacts with epistemic events. New evidence can alter which action appears justified before material conditions have changed. A warning, audit, forecast, or classification can change the transition-potential profile discussed in Section 15.3. The resulting temporal question concerns when evidence enters the decision process relative to commitment, revision, and exit points. Timeliness of knowledge is consequently distinct from accuracy alone.

15.7.3 Duration

Duration concerns how long a condition, relation, allocation, exposure, or institutional arrangement persists. Some economic effects depend primarily on occurrence; others require persistence. A one-time transfer can prevent an immediate failure, while capability formation may require sustained access to education, mentoring, equipment, health, or organizational support. Institutional legitimacy can likewise depend on repeated procedural performance over time rather than a single formal enactment.

The relevant duration is mechanism-specific. Longer exposure can permit learning, accumulation, maintenance, or trust formation. It can also deepen dependency, ecological depletion, lock-in, or harm. Duration should therefore be evaluated together with the process through which persistence changes the system. The statement that an intervention lasted five years is descriptive; the claim that five years was sufficient or excessive requires a model of maturation, decay, reinforcement, exposure, or institutional embedding.

Minimum and maximum effective durations can coexist. A training programme may require enough time for competence to form while excessive delay in transition to practice can allow acquired capability to decay. Temporary income support may preserve search capacity during a disruption, while indefinite eligibility under a poorly designed rule may alter incentives or administrative dependence. The examples illustrate a general point: duration is a structural parameter of a mechanism,

and its effect can be non-monotonic.

Duration also affects evidential interpretation. A short observation window can miss delayed generation, maintenance costs, or later dissipation. A long window can mix several mechanisms and institutional regimes, making attribution more difficult. Research design should therefore justify the temporal window in relation to the process being studied rather than treating longer observation as automatically more adequate.

15.7.4 Rhythm

Rhythm describes patterned recurrence or pacing in an economic process. It concerns the temporal spacing among repeated events rather than their mere frequency. Monthly payments, quarterly reporting, annual budgeting, seasonal harvests, maintenance cycles, school terms, electoral cycles, software releases, and inventory replenishment all impose recurrent temporal structures that can shape expectations, coordination, liquidity, and learning.

Two processes can have the same number of events over a year while differing substantially in rhythm. Regular small transfers can support predictable budgeting in ways that an irregular cluster of equally large transfers does not. Frequent review can support rapid adaptation while imposing administrative burden and encouraging short-horizon behavior. Infrequent review can permit stable execution while allowing emerging problems to persist. Rhythm therefore mediates the relation between recurrence and practical capacity.

Rhythms can become institutionally embedded. Payroll dates, tax periods, academic years, procurement cycles, and reporting schedules coordinate large populations precisely because participants can anticipate them. Such regularity can reduce uncertainty and transaction costs. It can also exclude processes whose temporal requirements do not fit the dominant cycle. Ecological regeneration, long research programmes, care relations, and infrastructure maintenance can be poorly served by short budget cycles even when funding levels appear sufficient.

Rhythm is also relational. A producer's cadence can interact with a buyer's payment cycle; a regulator's review interval can interact with the rate of technological change; a maintenance cycle can interact with material wear. Analysis should therefore ask how rhythms couple rather than treating each recurrence pattern in isolation.

15.7.5 Synchronization

Synchronization occurs when two or more processes require sufficiently aligned timing for a joint function to become feasible or effective. The relevant condition can involve simultaneous operation, coordinated handoff, overlapping availability, shared deadlines, or compatible phases. Synchronization is consequently a relational property of coupled processes rather than a general preference for simultaneity.

Complementary investment provides a simple example. Physical infrastructure, trained personnel, operating authority, maintenance funding, and user access can each be present, while the project remains ineffective if they become available at

incompatible times. The economic loss can take the form of idle capital, expired permits, personnel turnover, missed demand, or deteriorating trust. Synchronization analysis makes these coupling requirements visible.

Synchronization can also support collective action. Shared deadlines, common information releases, settlement times, or coordinated production schedules can reduce strategic uncertainty. Yet tighter synchronization can increase fragility when many actors depend on a common clock or bottleneck. A disruption at one synchronized point can propagate widely. Redundancy, buffering, staggered timing, or local discretion can therefore be preferable where resilience matters.

The analytical question is thus the degree and form of alignment required by the mechanism. Some processes need precise temporal coordination; others need only overlapping windows. Synchronization should be justified by functional dependence, not assumed as an inherent property of efficient organization.

15.7.6 Asynchrony

Asynchrony describes interaction among processes whose phases, speeds, update intervals, or operative horizons differ. Section 15.4 examined heterogeneous presents as unequal temporal positions. The present subsection focuses on the process relation: what happens when temporally heterogeneous processes interact without full synchronization.

Asynchrony can generate friction. A rapidly updating technology can encounter a slow certification regime; a household may face daily expenses while income arrives monthly; an ecological process may recover over decades while investment decisions are evaluated quarterly. Such mismatches can create waiting costs, liquidity stress, outdated rules, premature abandonment, or pressure to compress processes whose longer duration serves a substantive function.

Asynchrony can also be productive. Staggered review can prevent simultaneous failure, asynchronous experimentation can generate comparative learning, and buffers can allow one process to absorb volatility from another. Institutions sometimes deliberately separate decision moments to create reflection, appeal, or independent verification. The question is therefore whether the observed temporal mismatch impairs or supports the process under study.

Asynchronous systems often require interfaces. Credit bridges payment and income timing; inventories bridge production and demand; storage bridges seasonal supply and consumption; legal stays bridge decision and appeal; version compatibility bridges different technological update cycles. These interfaces can reduce temporal distance while creating new costs, dependencies, or control points. Temporal mediation should therefore be analyzed with the same attention to incidence and power that earlier chapters applied to value-conversion interfaces.

15.7.7 Critical Junctures

A critical juncture is a bounded period in which choices or events can have unusually large consequences for later pathways because constraints are temporarily loosened, alternatives become newly reachable, or subsequent reinforcement can make early

differences persist. The concept is useful only when the mechanism producing this heightened consequentiality is specified. Crisis, institutional vacancy, technological transition, political reorganization, demographic change, or sudden resource availability can create such periods, but dramatic events do not automatically constitute critical junctures.

Comparative historical analysis has long emphasized temporally situated episodes in which sequence and institutional choice shape later development (Mahoney and Rueschemeyer 2003; Pierson 2000). GRE retains this historical sensitivity while broadening the objects that can change during a juncture: relations, capabilities, conversion interfaces, infrastructure, value processes, ecological constraints, and generative opportunity can all be reconfigured.

Two features deserve separate attention. First, the width of the juncture is empirical. Some windows are brief, such as a liquidity event or emergency decision; others unfold across years of institutional restructuring. Second, heightened openness can coexist with unequal access. Some actors possess the information, resources, authority, or organizational capacity needed to act during the window, while others encounter the same period as constraint rather than opportunity.

Retrospective identification also requires caution. A later durable outcome can make an earlier moment appear decisive even when contemporaries faced several plausible pathways and incomplete information. Historical analysis should therefore reconstruct the alternatives, constraints, and knowledge available at the time, and should distinguish a genuinely consequential window from a narratively convenient turning point.

15.7.8 Irreversibility

Irreversibility concerns the extent to which an earlier temporal sequence constrains practical restoration of a prior configuration. The strongest cases involve material or ecological changes that cannot be restored within the relevant horizon. Many economic cases are better described as practical irreversibility: restoration remains technically conceivable while becoming inaccessible because capabilities have decayed, institutions have changed, sunk commitments accumulated, counterparties disappeared, legal rights expired, or the cost of reversal exceeds the resources available to affected positions.

Sequence matters because reversal can require more than performing earlier actions in reverse order. Training can be lost through disuse; trust can be damaged more quickly than rebuilt; infrastructure removal can induce relocation; institutional abolition can disperse expertise; ecological loss can alter later regeneration conditions. The history changes the state from which restoration would have to occur. A formal inverse operation therefore need not correspond to a practically available historical path.

Irreversibility should remain distinct from lock-in. Lock-in concerns persistence produced through specified mechanisms that make alternatives increasingly difficult or unattractive. Irreversibility concerns restoration or reversal under a stated horizon and position. A configuration can be strongly locked in while technically reversible, and a localized harm can be practically irreversible without producing

a self-reinforcing system-wide lock-in. Section 15.8 develops these path-dependent mechanisms directly.

Recognition of irreversibility changes intervention design. Where losses are difficult to restore, information requirements, precaution, staging, monitoring, reversibility provisions, and protection of exit options can acquire greater significance. This is an evaluative implication only after the relevant harms, affected positions, and decision framework are specified; irreversibility alone does not determine policy choice.

15.7.9 Partial Temporal Order

Economic histories are often represented as total sequences in which every event has a determinate position before or after every other event. Such a representation can be convenient, yet it can exceed the available evidence or distort processes that contain genuine concurrency. A *partial temporal order* records the precedence relations that are analytically supported while leaving unrelated, concurrent, or unresolved events incomparable in temporal order.

Several forms of precedence can justify an ordering relation. Chronological precedence follows from dated occurrence. Causal precedence can be supported when a mechanism requires one event to affect conditions for another. Institutional precedence can follow from authorization rules or procedural prerequisites. Generative precedence occurs when an event or process materially changes the capacities, relations, constraints, or accessibility structure required for a later generative transition. These relations can overlap, but they should not be treated as interchangeable without evidence.

Concurrency is consequently substantive rather than merely missing information. Two organizational changes can occur independently during the same period; several local experiments can proceed in parallel; value conversion in one domain can unfold while institutional learning occurs elsewhere. Forcing such events into a unique total order can manufacture sequence effects that the evidence does not support. Partial order preserves the distinctions that matter while declining to assert additional precedence.

The representation can also accommodate uncertainty. When available evidence cannot determine whether event e_i preceded e_j , the analysis can leave the pair unordered while still recording that both preceded a later event e_k . This is more informative than either inventing a total chronology or discarding temporal structure entirely. Additional evidence can later refine the order, making the representation compatible with historical re-epistemization.

Partial temporal order connects directly to the trajectory-complex formalism introduced in Section 15.3. Vertices can represent events whose boundaries satisfy the evidential criteria of Section 15.2; directed relations record supported precedence; higher-order structures can represent processes or coupled transformations. The resulting complex can therefore encode branching and concurrency without implying a physical causal set or a literal spacetime ontology.

Proposition 15.16 (Temporal-order adequacy). *A temporal representation is adequate to the extent that it preserves the precedence, concurrency, duration, and recur-*

rence distinctions materially necessary for the mechanism or historical claim under study. A total chronological sequence is sufficient when additional order structure does not alter the analysis. A partial or process-specific temporal order is warranted when forcing a total sequence would erase concurrency, invent unsupported precedence, or obscure order-sensitive changes in accessibility and later generative possibilities.

Proposition 15.16 supplies a scope condition for the chapter's later temporal formalisms. It does not privilege partial orders over ordinary chronology. It requires the representation to match the evidential and analytical structure of the problem. Where event order changes later reachability, the relevant precedence relations should be represented. Where order does not matter, additional formal complexity has no analytical benefit.

The temporal-order framework prepares the next section by clarifying the substrate on which path-dependent mechanisms operate. Initial conditions, early contingencies, reinforcement, lock-in, hysteresis, path breaking, path creation, and historical branching all presuppose some account of sequence. Section 15.8 therefore asks when temporal order becomes historically self-reinforcing enough that earlier developments systematically reshape the accessibility and relative viability of later alternatives.

15.8 Path Dependence

Sequence becomes historically consequential when earlier states, events, or choices modify the conditions under which later transitions occur. This section develops *path dependence* as a mechanism-specific form of historical dependence in which realized history alters later accessibility, incentives, capabilities, institutional configurations, or transition possibilities. Its role in Chapter 15 is to move beyond the order sensitivity developed in Section 15.7 toward a more demanding account of how economic histories can reinforce, constrain, redirect, or create later trajectories. The objective is to distinguish path dependence from generic historical sensitivity, persistence, irreversibility, and retrospective storytelling while preserving the possibility of path breaking and deliberate path creation. The discussion proceeds through initial conditions, early contingencies, reinforcement, lock-in, hysteresis, path breaking, path creation, and historical branching. The method is comparative-historical and mechanism-oriented: a path-dependent claim should identify the historical difference, the mechanism that transmits its effects, and the later transition structure that is thereby altered (Arthur 1989; Pierson 2000; Mahoney and Rueschemeyer 2003).

Definition 15.17 (Path dependence). For a bounded economic inquiry, *path dependence* is a condition in which the later configuration or transition structure depends materially on an earlier realized sequence through one or more identifiable mechanisms that preserve, amplify, convert, or otherwise carry forward historically generated differences. Path dependence does not require determinism, permanent lock-in, or a claim that an alternative history would necessarily have produced a uniquely specified outcome.

Definition 15.17 sets a stronger threshold than the statement that history matters. Most economic processes have antecedents, inherited conditions, and temporal con-

Table 15.8: Analytical dimensions of path dependence in GRE

Dimension	Primary question	Illustrative mechanism or diagnostic concern
Initial conditions	Which inherited conditions shape the feasible early transitions?	Infrastructure, institutions, capabilities, ecology, resource position, prior relations
Early contingencies	Which early events redirect later possibilities without fully determining them?	Timing, adoption sequence, shocks, coalition formation, unexpected opportunities
Reinforcement	Which mechanisms make a realized path progressively easier, more valuable, or harder to leave?	Learning, complementarity, coordination, increasing returns, expectations
Lock-in	When do switching costs and accumulated commitments strongly constrain alternatives?	Sunk investment, standards, network coordination, institutional embedding
Hysteresis	Which effects persist after the initiating condition has weakened or disappeared?	Capability loss, balance-sheet effects, organizational adaptation, trust erosion
Path breaking	Which changes weaken or interrupt inherited reinforcement mechanisms?	Reform, technological substitution, coalition change, crisis, institutional redesign
Path creation	How are new pathways actively constructed within inherited conditions?	Investment, standards, organization, experimentation, policy, collective action
Historical branching	Which alternative continuations were plausibly accessible at a given historical point?	Branch points, unrealized alternatives, uncertain accessibility, trajectory divergence

text. A path-dependent analysis asks whether differences in realized history continue to affect later possibilities through a mechanism that would be absent, weaker, or differently configured under a materially different path. Increasing returns, complementary investment, learning, expectations, institutional rules, sunk commitments, network effects, accumulated capabilities, ecological change, and relational stabilization are among the mechanisms that can support such persistence under appropriate conditions (Arthur 1989; Pierson 2000; North 1990).

Table 15.8 summarizes the analytical dimensions used in the section. They can occur together without being identical. Reinforcement can produce lock-in, yet reinforcement may remain reversible. Hysteresis can preserve an effect after the initiating condition disappears without producing a singular locked path. Path breaking can weaken an inherited trajectory, while path creation can construct a new one within constraints inherited from earlier history.

15.8.1 Initial Conditions

Initial conditions describe the inherited configuration from which a bounded path-dependent process is analyzed. They can include material endowments, infrastructure, institutions, legal status, technical standards, ecological conditions, capabilities, organizational routines, expectations, and established relations. Their relevance lies in how they alter the feasible early transitions of the process. An initial condition therefore matters analytically when it changes what can be done, at what cost, with which complements, or with what later consequences.

The term *initial* is relative to the analytical window. An industry's adoption process can begin from technical standards produced decades earlier; a household's employment trajectory can begin from capabilities and obligations generated before entry into the observed labour market; an institutional reform can begin from inherited legal and administrative arrangements. The starting point is consequently a research boundary rather than a claim about an absolute origin. Comparative historical analysis is particularly useful because it can make the boundary explicit and examine how inherited differences condition subsequent sequences (Mahoney and Rueschemeyer 2003).

Initial conditions should not be treated as destiny. Similar starting configurations can diverge because of later contingencies, agency, external changes, or different reinforcement mechanisms. Conversely, different starting conditions can converge where institutions, technology, transfers, or collective action reduce the significance of inherited differences. The analytical task is to identify which initial features materially condition later accessibility rather than to attribute every later difference to an arbitrarily chosen beginning.

GRE also distinguishes observed initial conditions from latent inherited structure. Two positions can appear similar in current income or formal legal status while differing in debt exposure, social relations, organizational experience, health, ecological vulnerability, or access to trusted intermediaries. These less visible inherited conditions can produce different responses to the same intervention. Path-dependent analysis should therefore justify which features belong to the initial configuration and how they enter the proposed mechanism.

15.8.2 Early Contingencies

Early contingencies are events or choices whose occurrence is not fixed by the initial conditions represented in the analysis and whose consequences can become amplified or stabilized later. Contingency does not require randomness. A decision can be deliberate and still be contingent relative to the model because several alternatives were practically accessible and the realized choice depended on information, timing, coalition, interpretation, or circumstance not determined by the selected starting variables.

The analytical importance of an early contingency depends on what follows it. A temporary adoption advantage matters for path dependence only if later learning, compatibility, complementary investment, expectations, or coordination make the early difference consequential. This logic is central to classic increasing-returns ac-

counts of technology adoption (Arthur 1989). It also helps explain why apparently similar early disturbances can produce little persistence in one setting and durable divergence in another.

Early contingency should therefore be separated from the rhetoric of a universally decisive “small event.” Some early events are large, some are minor, and many disappear without durable consequence. What matters is the relation between the event and the subsequent reinforcement architecture. An early procurement rule can shape a standard when suppliers invest around it; an initial organizational coalition can matter when it controls later appointments; an early infrastructure route can matter when complementary development accumulates around it. In each case, the contingency becomes historically important through later coupling.

Retrospective interpretation creates a further risk. Once a trajectory is known, analysts can select an earlier event and describe it as decisive because it precedes the outcome. A stronger analysis asks whether alternative early continuations were genuinely accessible, whether the event altered later incentives or constraints, and whether evidence supports the proposed transmission mechanism. The earlier the alleged contingency, the greater the need to avoid projecting later importance backward without mechanism evidence.

15.8.3 Reinforcement

Reinforcement describes processes through which movement along a realized path changes the conditions of later movement in ways that support continuation of that path. The support can arise through increasing returns, learning, coordination, complementary assets, institutional adaptation, expectation formation, trust, network expansion, accumulated capability, or reduced uncertainty. Reinforcement is therefore broader than a single economic mechanism, while each empirical claim should specify which mechanism is operating.

Increasing-returns analysis provides a canonical case. Once adoption, investment, or coordination has accumulated around a particular arrangement, further movement along the same path can become more attractive because users learn, complements develop, standards stabilize, and coordination becomes easier (Arthur 1989). Political and institutional analysis has extended similar reasoning to settings in which organizational density, collective-action asymmetries, institutional learning, or adaptive expectations can strengthen an established course (Pierson 2000). GRE retains the mechanism-specific character of these arguments rather than treating reinforcement as a generic label for persistence.

Reinforcement can be positive or negative relative to an evaluative standpoint. A public-health infrastructure can become more effective as repeated use builds expertise and trust. A harmful dependency can deepen as specialized assets and lost alternatives increase switching costs. A scientific collaboration can accumulate shared language and data infrastructure, while a monopolistic platform can accumulate complementary services that make exit more difficult. Reinforcement describes historical reproduction of a pathway; normative evaluation requires a separate account of who benefits, who bears burdens, and which alternatives remain accessible.

Reinforcement can also decay. Learning becomes obsolete, standards lose com-

patibility, complementary assets depreciate, expectations change, institutions lose legitimacy, and new technologies alter relative returns. A path-dependent process is therefore not synonymous with indefinite self-reproduction. The persistence of a path should be treated as an empirical question about the durability and interaction of its reinforcing mechanisms.

15.8.4 Lock-In

Lock-in describes a stronger condition in which accumulated commitments, coordination structures, complementarities, or switching costs substantially constrain movement toward alternatives that would otherwise be technically, institutionally, or economically conceivable. Historical events and increasing returns can contribute to such conditions, as emphasized in the economic literature on technology selection (Arthur 1989). GRE uses the concept cautiously because lock-in is frequently invoked more broadly than the evidence supports.

Lock-in should be distinguished from simple persistence. A practice can persist because it continues to perform well under current conditions, because alternatives offer little advantage, or because participants freely prefer it. A lock-in claim adds a historical mechanism through which earlier commitments make exit or switching materially more difficult than it would have been without those commitments. Relevant mechanisms include sunk investment, compatibility standards, network coordination, legal commitments, specialized skills, organizational routines, contractual dependence, and loss of alternative infrastructures.

Lock-in also differs from irreversibility. A locked configuration can be reversible in principle while remaining costly or institutionally difficult to leave. Conversely, an irreversible ecological loss can occur without a self-reinforcing coordination equilibrium. The concepts overlap in some histories but identify different mechanisms. Section 15.7 treated practical irreversibility as constrained restoration; lock-in concerns path-specific constraints on switching or reconfiguration.

The presence of lock-in does not by itself establish inefficiency or injustice. Stable standards can reduce coordination costs, durable institutions can support expectations, and long-lived infrastructure can enable capabilities precisely because participants do not continually switch. Evaluation therefore requires comparison of the benefits of stability with the costs, exclusions, dependencies, foreclosed alternatives, and distribution of switching burdens. The analytical diagnosis should precede the normative conclusion.

15.8.5 Hysteresis

Hysteresis concerns persistence of an effect after the initiating condition has weakened, reversed, or disappeared. The concept is useful when temporary disturbances leave durable changes in capabilities, relations, expectations, institutions, balance sheets, organizational structure, or ecological conditions. The relevant history is carried forward because the disturbance changed the system through which later conditions operate.

Consider a temporary economic contraction. If employment recovers immediately

once demand returns, the disturbance may leave little path-dependent residue. If prolonged unemployment erodes skills, professional relations, health, or employer perceptions, the later labour-market configuration can differ even after aggregate demand recovers. The persistence then requires explanation through those intervening mechanisms rather than through the original shock alone. Similar structures can arise where a temporary funding interruption dissolves a research team, where a short institutional crisis destroys trust, or where temporary ecological pressure crosses a regeneration threshold.

Hysteresis should be distinguished from persistence caused by a continuing present condition. If a barrier remains in force, continued exclusion need not be historically dependent; it may be generated anew each period by the still-active barrier. A hysteresis claim becomes stronger when the initiating condition has materially changed yet its earlier effects remain through altered state variables, relations, institutions, or accessible pathways.

The possibility of hysteresis also complicates restoration. Removing the original cause may be necessary while remaining insufficient. Rebuilding capabilities, relations, organizational memory, ecosystems, or alternatives can require additional intervention. This distinction matters for policy analysis because interventions designed only to reverse the initial shock can underestimate the work required to reverse its historically accumulated consequences.

15.8.6 Path Breaking

Path breaking concerns changes that weaken, interrupt, or reorganize mechanisms sustaining an inherited trajectory. Such changes can arise through institutional reform, technological substitution, new infrastructure, coalition change, external shock, ecological disruption, altered standards, learning, or deliberate withdrawal from existing arrangements. Path breaking is analytically stronger than temporary deviation: it changes the conditions that previously supported continuation of the path.

A path can be broken at several points. An intervention can reduce switching costs, provide missing complements for an alternative, change legal authorization, weaken a dominant intermediary, alter expectations, restore lost capability, or build interoperability between previously incompatible systems. Different mechanisms imply different durability. A subsidy can produce temporary experimentation without changing the underlying coordination structure; a standard that permits interoperability can alter the structure more persistently.

Path breaking need not restore an earlier state. Historical processes often transform the conditions of reversal. New capabilities, dependencies, ecological conditions, institutions, and expectations accumulate while a path persists. Leaving the path can therefore produce a third configuration rather than a return to the pre-path baseline. This point reinforces the distinction between path breaking and reversal and aligns with the chapter's broader treatment of history as transformation rather than movement within a fixed background.

Path-breaking claims should also avoid crisis romanticism. Crises can loosen constraints or discredit established arrangements, but they can also intensify existing

dependencies, concentrate authority, destroy capabilities, or narrow available alternatives. Whether a disruption breaks a path depends on how it modifies the mechanisms reproducing that path and which alternative pathways become practically accessible afterward.

15.8.7 Path Creation

Path creation concerns the active construction of new pathways through investment, institution building, organization, experimentation, standard setting, knowledge production, infrastructure, coalition formation, or other forms of coordinated action. The concept complements path dependence by preserving agency: historical inheritance constrains and enables action, yet actors can sometimes build conditions under which previously inaccessible trajectories become reachable.

Path creation is rarely creation from an empty background. New pathways draw on inherited resources, laws, technologies, capabilities, narratives, institutions, and relations. Institutional change, for example, occurs within existing rule structures and incentive environments rather than outside history (North 1990). A new technological path may require older transport infrastructure, scientific knowledge, financing institutions, or standards. A community-led economic path may depend on prior trust, legal recognition, land access, or organizational memory. The inherited configuration is therefore part of the path-creation process.

Deliberate action also does not imply complete design control. Actors can intend to establish one trajectory while later reinforcement, external response, learning, conflict, or unanticipated complementarity changes its direction. Path creation should therefore be analyzed as an intervention into a field of possibilities rather than as construction of a fully specified future. Its success depends on whether the new pathway becomes practically traversable, gains necessary complements, and remains maintainable under changing conditions.

Path creation can occur collectively and across scales. Governments can establish infrastructure or legal frameworks; firms can build standards and supply chains; communities can create institutions and commons; research networks can build shared epistemic infrastructure; transnational organizations can create interoperable rules. These efforts can also conflict. Creating one path can raise barriers to another, redistribute control over interfaces, or shift risks across positions. The generative analysis should therefore include both new accessibility and newly produced foreclosure.

15.8.8 Historical Branching

Historical branching represents points or intervals at which more than one materially distinct continuation is plausibly accessible from the reconstructed configuration. Branching is useful for analyzing path dependence because it prevents the realized trajectory from appearing retrospectively inevitable. It also provides a bridge to the trajectory-complex representation developed in Section 15.3, where alternative continuations can be represented without forcing them into one linear sequence.

A branch should not be added merely because an analyst can imagine an alterna-

tive. The relevant question is whether the alternative was plausibly accessible given the resources, capabilities, institutions, knowledge, relations, and constraints present at the time. Historical evidence can support different levels of confidence. Some alternatives were actively debated, funded, piloted, or legally available; others can be reconstructed as technically feasible but institutionally remote; still others are visible only with later knowledge and should be treated as retrospective counterfactual possibilities rather than contemporaneously accessible branches.

Branching can also occur gradually. Reinforcement can change relative accessibility without creating one discrete decision point. Several alternatives can coexist while one accumulates complements faster than others. A later threshold can then make divergence appear sudden even though the branch structure changed over a longer period. Historical analysis should therefore avoid forcing every divergence into a single critical juncture.

The branch structure itself can change. Path creation can introduce a new continuation; lock-in can close an old one; institutional reform can reopen an alternative; technological change can make previously remote paths accessible; ecological depletion can remove trajectories that once existed. Path dependence is consequently compatible with a changing possibility space rather than only movement among fixed alternatives.

This perspective also disciplines counterfactual evaluation. Comparing the realized path with an alternative requires stating when the alternative was accessible, what mechanism could have sustained it, and what evidence supports the comparison. The objective is not to reconstruct one uniquely correct unrealized history. It is to preserve the distinction between realized history, contemporaneously accessible alternatives, retrospectively imaginable alternatives, and branches whose accessibility remains uncertain.

Proposition 15.18 (Mechanism-specific adequacy of path-dependence claims). *A path-dependence claim is analytically adequate when, at the resolution appropriate to the inquiry, it identifies a historically differentiated starting state or sequence, a mechanism through which the realized history alters later conditions, and a later transition structure or configuration whose accessibility, cost, persistence, or generative potential depends materially on that mechanism. Such a claim should remain distinct from generic historical sensitivity, simple persistence, lock-in, irreversibility, and deterministic inevitability unless the additional mechanism-specific conditions for those stronger descriptions are independently supported.*

Proposition 15.18 gives path dependence a demanding evidential boundary. A historical narrative can be accurate without establishing path dependence, and a persistent outcome can be real without having been reinforced by its own history. Stronger attribution requires evidence connecting early difference, transmission mechanism, and later structural consequence. Comparative historical analysis, longitudinal evidence, process tracing, institutional records, counterfactual reconstruction, simulation, and formal models can contribute differently depending on the object and scale of inquiry (Mahoney and Rueschemeyer 2003).

Path dependence also prepares the next analytical problem. Historically generated effects often remain dormant before becoming observable or operative. Reinforce-

ment can accumulate below a threshold, capability can mature after a delay, institutional changes can require complementary developments, and earlier events can remain latent until a later configuration activates their consequences. The chapter therefore turns next to *delayed and latent generation*, where the focus shifts from the persistence of historically differentiated paths to the temporal separation between generative conditions, activation, realization, and observation.

15.9 Delayed and Latent Generation

Generative processes can be temporally separated from the effects through which their significance later becomes visible. A capability can be formed before an institutional opportunity allows its use; an infrastructure investment can alter a region's future accessibility before complementary activity develops; repeated small changes can accumulate below a threshold and become consequential only after later reinforcement; and an effect can already exist while remaining unobserved because the available indicators, categories, or measurement systems do not yet reveal it. This section develops a temporal grammar for such cases. Its role in Chapter 15 is to distinguish delayed and latent generation from the path dependence examined in Section 15.8: path dependence concerns how realized history alters later transition structure, whereas delayed and latent generation concerns temporal separation among generative conditions, activation, realization, observation, and attribution. The objective is to prevent these different temporal relations from being compressed into the vague statement that an effect “takes time.” The discussion proceeds through latent effects, delayed activation, accumulation, thresholds, long-horizon effects, intergenerational effects, delayed observation, and attribution across time. The method is mechanism-oriented and historically situated, drawing on process-sensitive approaches in which timing, sequence, duration, and slowly unfolding processes can materially alter explanation (Abbott 2001; Pierson 2000; Mahoney and Rueschemeyer 2003).

Definition 15.19 (Delayed and latent generation). For a bounded economic inquiry, *delayed and latent generation* describes a family of temporally structured generative processes in which the formation of a generative condition, its activation, the realization of its consequences, and their observation or recognition are materially separated in time. A delayed or latent generative claim should specify which of these stages is separated, the mechanism connecting them, and the conditions under which the later effect becomes operative or observable.

Definition 15.19 treats temporal delay as a structured relation rather than as one undifferentiated lag. Generation can occur early while realization is delayed; generation can itself require cumulative development; a pre-existing condition can remain dormant until a complementary event activates it; and an already operative effect can remain epistemically latent because observation arrives later. These cases support different causal and evaluative claims. Their distinction is especially important where long evaluation horizons, institutional delay, ecological processes, learning, infrastructure maturation, or intergenerational transmission are involved.

Table 15.9 summarizes the temporal distinctions used in the section. The categories

Table 15.9: Temporal structure of delayed and latent generation in GRE

Dimension	Primary temporal question	Diagnostic concern
Latent effect	Which generated condition exists before its practical consequence becomes active?	Dormancy, missing complements, unused capability, unexercised rights, stored knowledge
Delayed activation	Which later event or condition makes an earlier generative potential operative?	Trigger, authorization, complementary infrastructure, demand, institutional opening
Accumulation	Which small or repeated changes become consequential through temporal aggregation?	Cumulative learning, maintenance deficits, exposure, investment, capability formation
Threshold	When does accumulated change alter the operative regime or accessible trajectory?	Nonlinearity, saturation, minimum scale, coordination threshold, tipping condition
Long horizon	Which generative consequences require extended maturation or maintenance?	Infrastructure life cycle, institutional learning, ecological regeneration, research, education
Intergenerational	Which effects cross cohorts or generations through inherited conditions?	Knowledge, institutions, ecology, liabilities, infrastructure, norms, capabilities
Delayed observation	Which operative effects become visible only after measurement or recognition catches up?	Indicator lag, archival evidence, category change, delayed reporting, re-epistemization
Temporal attribution	How strongly can a later condition be attributed to an earlier process?	Provenance, mediators, competing causes, survival of mechanism, evidential decay

can overlap. A capability can accumulate gradually, cross a threshold, remain unused until institutional access changes, and become measurable only after an additional delay. The purpose of the table is therefore diagnostic rather than classificatory: it helps identify where the relevant temporal separation occurs and what evidence is needed to support the corresponding claim.

15.9.1 Latent Effects

A latent effect is an economically relevant consequence whose enabling or generative conditions have already been materially formed while the consequence remains dormant, unrealized, or practically inactive. Latency is therefore stronger than the absence of an effect and weaker than completed realization. It identifies a historically present capacity for later consequence that depends on additional conditions, activation, access, or use.

Latent effects are common where economic objects cannot be evaluated adequately through immediate output. Education can form capabilities before a

labour-market or institutional opportunity allows their exercise. Research can generate knowledge before an application, complementary technique, or organizational problem makes that knowledge practically valuable. Infrastructure can create accessibility before firms, households, or public services reorganize around it. A legal entitlement can exist before information, administrative access, or enforcement makes it usable. In each case, the earlier process changes the later possibility structure even when the expected consequence is not yet visible in ordinary outcome measures.

Latency should nevertheless be specified with discipline. Describing any unused resource or unrealized possibility as latent generation would make the concept too permissive. A stronger claim identifies a generated condition that has materially changed what could later become reachable under specified complementary conditions. Evidence can include acquired capability, installed infrastructure, legally established standing, stored knowledge, organizational routines, ecological regeneration, or a relational configuration that supports later coordination. The relevant question is whether the later consequence depends on something that was actually generated earlier rather than merely imagined retrospectively.

Latent conditions can also decay. Skills can atrophy, infrastructure can deteriorate, institutional rights can be weakened, relationships can lose trust, and stored knowledge can become obsolete. Latency therefore has a temporal durability profile. An earlier generative process can expand later accessibility for a period without preserving that accessibility indefinitely. Analysis should record maintenance requirements and decay mechanisms when they materially affect whether the latent condition remains available for later activation.

The concept is evaluatively neutral at this stage. Latent generation can concern harmful as well as beneficial consequences. A dependency can be formed before a later shock reveals its constraining effect; an ecological burden can accumulate before observable damage appears; an institutional rule can establish a vulnerability before it is exploited. The analytical priority is temporal provenance: what earlier condition was generated, how it persisted, and what later configuration made its consequence operative.

15.9.2 Delayed Activation

Delayed activation occurs when a generated condition becomes operative only after a later event, complement, authorization, demand, or environmental change satisfies an activation condition. The delay therefore lies between formation and activation. This differs from gradual accumulation because the relevant generative potential can already be substantially present before the later trigger changes its practical status.

Activation can take several forms. A technical capability can become economically significant when a compatible standard is adopted. A dormant contractual right can become operative when a contingency occurs. A transport link can acquire new value when complementary land use or logistics infrastructure develops. A previously marginalized body of knowledge can become salient when a new policy problem, scientific instrument, or classification makes it applicable. A community organization can mobilize accumulated trust and routines when an emergency creates

an immediate coordination need. The later event does not necessarily generate the underlying capacity; it can activate a condition generated earlier.

This distinction matters for attribution. If analysis assigns the whole later effect to the activating event, earlier investments in capability, infrastructure, knowledge, institutions, or relationships disappear from the causal history. If it assigns the whole effect to the earlier process, the role of the activating condition is similarly obscured. A provenance-sensitive account can therefore represent distributed generative roles: one process forms a potential, another maintains it, and a later event activates or redirects it.

Activation can also be selective. The same earlier condition can remain dormant for one position while becoming usable for another because access, complementary resources, legal status, technology, or institutional standing differ. Delayed activation is consequently relational as well as temporal. The question is not only when activation occurs, but for whom, through which interface, and under which enabling conditions.

The activation event can itself transform the earlier condition. Knowledge applied to a new domain can be modified in use; infrastructure can acquire a new function; institutions can reinterpret old rules; a capability can deepen through exercise. Activation is therefore not always a simple switch from inactive to active. In many cases it begins a new generative process whose later trajectory combines inherited potential with new learning, adaptation, and relational change.

15.9.3 Accumulation

Accumulation concerns effects that emerge through repeated or continuous changes whose individual contributions may be modest while their combined historical effect becomes material. The relevant temporal structure is cumulative: later conditions depend on what has been added, depleted, learned, reinforced, maintained, or neglected across multiple periods. Accumulation therefore provides one mechanism through which generation can be delayed even when no discrete activation event exists.

Capability formation often has this structure. Repeated practice, education, organizational experience, and exposure to increasingly difficult tasks can build capacities that are not attributable to one episode. Institutional credibility can accumulate through repeated rule application. Scientific capability can depend on long sequences of training, infrastructure investment, failed experiments, and tacit learning. Maintenance deficits can likewise accumulate until reliability declines. Ecological pressure can build through repeated extraction or pollution. The cumulative mechanism can therefore generate positive capacity, negative burden, or mixed consequences.

Cumulative analysis should identify what is being accumulated. A running total of monetary expenditure is not sufficient where the economically relevant stock is skill, trust, organizational memory, technical debt, ecological load, legitimacy, or relational dependence. The representation should follow the mechanism. Some accumulated conditions can be measured cardinally; others are more adequately represented by stages, qualitative histories, network structures, institutional records, or

mixed evidence.

Accumulation can also involve decay and replenishment simultaneously. Knowledge is learned and forgotten; infrastructure is built and depreciates; trust is formed and eroded; ecological stocks regenerate while being depleted. A useful analysis therefore avoids treating accumulation as mechanically monotonic. Net change can conceal substantial gross generation and dissipation, while a stable aggregate can mask redistribution among positions or transformation among value forms.

Temporal aggregation further raises a boundary problem. The analyst must decide which episodes belong to the accumulating process and over what horizon. Too narrow a window can make slow generation invisible; too broad a window can combine mechanisms that should remain distinct. The appropriate horizon depends on the process being studied and on evidence connecting repeated contributions to the later condition (Abbott 2001).

15.9.4 Thresholds

Thresholds describe situations in which accumulated or changing conditions produce a qualitatively different consequence after a critical level, combination, or configuration is reached. Threshold analysis is useful because delayed effects can appear sudden even when the underlying generative process has unfolded gradually. The visible transition may occur late while much of the relevant history lies in earlier accumulation.

Thresholds can be technical, institutional, relational, ecological, or coordinative. A network may become useful only after sufficient complementary adoption. A skill may become employable after a combination of competencies is acquired. A public institution may require minimum administrative capacity before a new mandate can be implemented. A coalition can become effective once enough actors coordinate. A debt burden can become destabilizing after liquidity buffers are exhausted. An ecosystem can cross a state-changing boundary after long cumulative pressure. These examples differ substantially, and the threshold should be justified within the relevant mechanism rather than borrowed as a generic metaphor.

A threshold need not be a precisely known scalar. Some thresholds can be measured experimentally or statistically; others are represented more adequately as ranges, configurations, necessary combinations, or probabilistic transition regions. False precision can be especially misleading when thresholds depend on heterogeneous actors, changing institutions, or uncertain ecological conditions. GRE therefore permits qualitative and mixed threshold representations where the evidence does not justify one numerical cutoff.

Crossing a threshold also does not establish that earlier increments were causally irrelevant. The last contribution can be highly visible because it coincides with the transition, while earlier accumulation supplied most of the enabling conditions. Attribution should distinguish the marginal trigger from the cumulative process. Conversely, an early investment that helped build the accumulated condition does not necessarily deserve exclusive attribution for the later transition. Threshold effects often involve distributed contribution over time.

Thresholds can move. Technological change, institutional reform, learning, social adaptation, and environmental conditions can lower or raise the amount of accumulated change required for activation. The threshold is therefore sometimes part of the evolving system rather than a fixed external boundary. This possibility becomes important in generative-spacetime analysis because history can transform both the state of the process and the conditions governing its transitions.

15.9.5 Long-Horizon Effects

Long-horizon effects are consequences whose economically relevant realization, propagation, or evaluation occurs over extended periods relative to the decision or generative process that helped produce them. Their importance is not established by temporal distance alone. A long-horizon claim requires a plausible mechanism through which earlier conditions survive, develop, propagate, or shape later configurations across the intervening period.

Education, infrastructure, research, institutional development, ecological restoration, demographic change, and technological standards commonly involve such horizons. The relevant time can exceed ordinary budgeting, electoral, reporting, or investment cycles. A road, archive, research facility, legal reform, or training system can continue to alter accessibility and capability long after the initiating expenditure has ended. Conversely, benefits anticipated at inception can disappear through neglect, obsolescence, capture, institutional change, or environmental disruption.

Long-horizon analysis therefore places maintenance and adaptation inside the causal history. A physical asset does not generate durable effects simply because it persists materially. Complementary institutions, repair, skills, financing, legal authorization, and changing demand can determine whether the asset remains usable. Similarly, institutional reforms can require repeated enactment before expectations change; research capacity can depend on succession and knowledge preservation; ecological recovery can require sustained protection over biological timescales.

Evaluation horizons can bias what becomes visible. Short horizons tend to privilege effects that appear quickly and can systematically underrepresent slow capability formation, prevention, institutional learning, ecological regeneration, or option preservation. Very long horizons create a different problem: attribution becomes increasingly difficult as additional causes, shocks, adaptations, and reinterpretations enter the trajectory. Adequate analysis should therefore match the horizon to the mechanism while making the increasing uncertainty of distant attribution explicit.

Long-horizon effects also invite premature discounting of heterogeneous consequences into one present metric. Discounting can be useful within a specified financial or decision protocol, but temporal distance does not make ecological, institutional, capability, or intergenerational effects automatically commensurable. Chapter 14's value architecture remains relevant: the temporal representation should preserve the value forms and affected positions needed for the inquiry rather than using time alone to decide their relative significance.

15.9.6 Intergenerational Effects

Intergenerational effects arise when an earlier generative process changes the material, institutional, ecological, epistemic, relational, capability, liability, or option conditions inherited by later cohorts or generations. The generative source and the later affected positions are therefore separated not only by time but often by identity, institutional role, and evaluative standpoint. Intergenerational analysis makes this distribution explicit.

Inheritance is broader than asset transfer. Later cohorts can inherit infrastructure, public debt, environmental conditions, legal arrangements, scientific knowledge, organizational routines, technological standards, social classifications, depleted resources, and institutional credibility. They can also inherit absences: lost biodiversity, foreclosed technological alternatives, weakened public capacity, destroyed archives, or skills no longer reproduced. What crosses generations is consequently a transformed starting configuration rather than a single conserved stock.

Intergenerational transmission can be direct or mediated. Families can transfer resources and capabilities directly; schools, states, firms, communities, and research institutions can transmit knowledge and institutions; ecological processes can carry consequences independently of organizational continuity. These pathways can interact. Educational institutions, for example, can reproduce or reduce family-level capability differences; public infrastructure can alter the value of inherited private assets; environmental degradation can constrain later use of otherwise valuable resources.

Generational boundaries themselves are analytical conventions. Economic processes rarely change neatly when one demographic cohort replaces another. Overlapping cohorts coexist, institutions bridge several generations, and decisions made by one group can be implemented or revised by another. The appropriate unit therefore depends on the inquiry: family generations, birth cohorts, organizational generations, political cohorts, technological generations, or another historically meaningful grouping may be relevant.

Intergenerational attribution also raises a problem of agency and representation. Later affected subjects did not participate in many earlier decisions, while earlier decision makers could not know every later consequence. Analysis should preserve both facts. It can identify inherited burdens or benefits and evaluate earlier decisions under historically appropriate knowledge while permitting later re-evaluation as evidence and values change. Intergenerational effects thus connect delayed generation to historical re-epistemization without treating later judgment as if it had been available at the origin.

15.9.7 Delayed Observation

Delayed observation occurs when an economically relevant effect is already operative but becomes measurable, reportable, interpretable, or institutionally recognized only later. This case differs fundamentally from delayed generation. The world can change before the available epistemic apparatus registers the change. Conflating the two can shift the inferred timing of a process and distort attribution.

Observation can be delayed because data arrive slowly, indicators respond only after cumulative change, affected subjects lack recognized reporting channels, categories omit the relevant phenomenon, archival evidence becomes available later, or measurement technology improves. An institution can deteriorate before formal performance metrics reveal the problem. A capability loss can precede an income decline. Ecological damage can begin before routine monitoring detects it. Conversely, a positive relational or institutional capacity can exist before conventional accounting recognizes it.

The distinction between event time and observation time should therefore be explicit where it materially affects the analysis. A record dated when an indicator crossed a reporting threshold may identify the first observation rather than the beginning of the underlying effect. Historical reconstruction can sometimes move the estimated onset earlier by using qualitative evidence, administrative records, retrospective interviews, technical traces, or revised measurement. Such revision is legitimate when its evidential basis is stated rather than silently replacing the earlier chronology.

Delayed observation can also be socially distributed. Some actors may observe a change before others because they possess better data, local knowledge, technical expertise, or privileged institutional access. An affected community can recognize a problem before a central authority records it; a platform can observe behavioral shifts before regulators or users do; firms can hold proprietary information about technological capability before public statistics reflect it. Epistemic asymmetry can therefore create unequal temporal positions in recognition and response.

Observation can in turn become generative. Once a previously latent or unrecognized condition is measured, classified, publicized, or institutionally acknowledged, behavior can change. Funding can be redirected, regulation revised, expectations updated, or new coalitions formed. The observation event should then be distinguished from the earlier effect while being analyzed as a subsequent epistemic event that can reweight later trajectories.

15.9.8 Attribution across Time

Attribution across time concerns the evidential problem of relating a later condition to an earlier generative process when activation, accumulation, mediation, realization, and observation may be separated by substantial temporal intervals. Temporal distance increases the number of plausible intervening causes and can weaken records of the earlier mechanism. A credible attribution therefore requires more than chronological sequence or retrospective similarity.

A provenance-sensitive analysis can distinguish several temporal roles. An *originating condition* creates or modifies a capability, relation, institution, resource configuration, or constraint. A *maintenance process* preserves that condition. An *activating event* makes it operative. *Mediating processes* transmit or transform its effects. A *realization event* marks the point at which the relevant consequence becomes economically effective. An *observation event* makes the consequence epistemically accessible to the analyst or institution. These roles can coincide in simple cases and diverge sharply in complex ones.

Attribution should follow the mechanism through these stages. Evidence that a training programme occurred years before a later innovation does not establish that the programme generated the innovation. Stronger attribution can draw on continuity of personnel or capability, documented use of acquired knowledge, comparison with plausible alternatives, institutional records, process tracing, intermediate outcomes, and evidence that the relevant capacity persisted until activation. Comparative-historical methods can be particularly useful when direct experimental control is unavailable and temporally extended mechanisms must be reconstructed (Mahoney and Rueschemeyer 2003).

Temporal attribution can also be distributed. A later outcome may depend on early formation, repeated maintenance, complementary investment, a threshold-crossing event, and favorable external conditions. Assigning exclusive causal ownership to the earliest contributor or the final visible trigger can erase the distributed generative architecture. GRE instead permits layered attribution in which different actors and episodes occupy distinct generative roles along the trajectory.

Uncertainty should increase where evidence weakens. Long temporal gaps can introduce missing records, changing categories, altered institutions, unobserved adaptation, and selection effects. Analysts can respond through explicit confidence levels, alternative historical reconstructions, sensitivity to boundary choice, triangulation among evidence types, and cautious language. The objective is not to eliminate historical uncertainty but to prevent uncertain temporal provenance from being presented as settled causal fact.

Attribution can also be revised. New archives, measurement systems, scientific knowledge, testimony, or formal models can change the estimated onset of an effect or the inferred role of an earlier event. Such re-epistemization does not imply that later knowledge changes the past process itself; it changes the best-supported reconstruction of that process. Recording the difference between original contemporaneous knowledge and later reconstructed knowledge preserves historical fairness while allowing scholarship to improve.

Proposition 15.20 summarizes the temporal discipline developed in the section.

Proposition 15.20 (Temporal adequacy of delayed generative attribution). *A delayed or latent generative attribution is analytically adequate when, at the resolution appropriate to the inquiry, it distinguishes the formation of the relevant generative condition from materially separate stages of accumulation, activation, realization, and observation; identifies a plausible mechanism connecting the earlier and later stages; records maintenance, mediating conditions, affected positions, and materially relevant competing explanations; and states uncertainty proportionately to the available temporal evidence. The existence of a long time interval, a later threshold crossing, or delayed observation does not by itself establish either delayed generation or exclusive causal attribution to the earliest identifiable event.*

Proposition 15.20 gives delayed and latent generation an evidential boundary that complements the path-dependence analysis of Section 15.8. Earlier history can matter because it changes transition structure, because a generated condition remains latent until later activation, because repeated changes accumulate toward a threshold, or because an already operative effect becomes observable only later. These mech-

anisms can coexist, yet each supports a different temporal claim. The next section extends the same spatiotemporal discipline into *spatial propagation*, asking how effects generated at one position spread, transform, attenuate, concentrate, or become blocked across geographic and relational space.

15.10 Spatial Propagation

Spatial propagation concerns the extension of economically consequential effects across locations, territories, infrastructures, networks, and jurisdictional boundaries. Its role in this chapter is to complement the temporal and relational analyses developed in Sections 15.4–15.9 by asking how a process that is generated or activated somewhere becomes consequential elsewhere. The objective is to distinguish several mechanisms that are often compressed into the language of “diffusion” or “spillover”: local propagation, mobility, infrastructural conveyance, networked transmission, territorial mediation, cross-border passage, concentration, and spatial spillover. The discussion is primarily conceptual and mechanism-oriented. It retains geographic distance where physical location matters while allowing economic propagation to follow relational, institutional, technological, and jurisdictional pathways that need not coincide with Euclidean proximity.

A spatial account of propagation should therefore identify at least four elements: an originating or already affected configuration, a pathway through which consequences can extend, a set of positions or places that become exposed or reachable, and a mechanism through which the propagated effect is transformed, attenuated, amplified, delayed, or blocked. The same originating event can propagate differently through transport systems, supply chains, financial relations, migration, legal jurisdictions, digital networks, or ecological processes. Spatial propagation is consequently neither simple physical movement nor a synonym for relational transmission. Physical movement can carry propagation, and propagation can occur with little movement of persons or goods when standards, prices, information, financial claims, legal rules, or digital services travel through other channels.

Definition 15.21 (Spatial propagation). *Spatial propagation* is the historically and relationally mediated extension of an economically consequential effect from an originating configuration to additional locations, territorial positions, network positions, or jurisdictional settings through one or more identifiable spatially organized pathways. A claim of spatial propagation should specify the propagated condition or effect, the relevant spatial or relational representation, the transmission mechanism, and the materially affected positions. Spatial propagation does not by itself establish uniform diffusion, geographic contiguity, or causal attribution to distance alone.

Table 15.10 summarizes the principal distinctions developed in this section. The categories can overlap. A cross-border process may depend on infrastructure, mobility, and networked space simultaneously, while concentration can alter the probability and direction of later spillovers.

Table 15.10: Analytical architecture of spatial propagation in GRE.

Dimension	Principal mechanism	Diagnostic question
Local propagation	Proximity, repeated contact, shared facilities, localized external effects	Which nearby positions become materially affected, and through what local pathway?
Mobility	Movement of persons, goods, capital, knowledge carriers, or organizational activity	What moves, who can move, and what is transformed by movement?
Infrastructure	Shared physical, digital, informational, or institutional systems	Which downstream activities become reachable or constrained through the infrastructure?
Networked space	Topological position and relational pathways	Does effective reach follow network connectivity more closely than geographic distance?
Territorial structure	Area-based authority, jurisdiction, zoning, borders, and territorial institutions	How do territorial rules channel, contain, or redirect propagation?
Cross-border propagation	Passage across legal, monetary, regulatory, linguistic, or political boundaries	Which border interfaces mediate the process and with what conversion costs or asymmetries?
Spatial concentration	Co-location, clustering, cumulative attraction, and localized dependence	Does concentration amplify generation, vulnerability, exclusion, or later reach?
Spatial spillover	Consequences extending beyond the initiating boundary or target set	Which effects fall outside the original spatial accounting boundary, and for whom?

15.10.1 Local Propagation

Local propagation concerns effects whose extension is materially shaped by geographic proximity or by repeated interaction within a bounded locality. The locality can be a neighborhood, workplace, industrial district, watershed, campus, transport catchment, or another empirically justified spatial unit. The analytical point is not that nearby things are necessarily similar, but that some mechanisms depend on short physical distance, common facilities, shared environmental conditions, face-to-face interaction, or locally dense coordination. Tobler's well-known formulation concerning geographic proximity remains useful as a methodological reminder that spatial dependence can matter, provided it is treated as an empirical regularity rather than a universal law (Tobler 1970).

Local propagation can operate through several pathways. A new transit connection can alter footfall and land use around stations. A firm's hiring can affect nearby labor markets and service demand. Pollution can impose geographically localized burdens. Knowledge can circulate through repeated encounters among organizations located near one another. A school, clinic, research facility, or public space can generate effects extending beyond its formal users because its presence changes accessibility and local coordination. These mechanisms differ, so local propagation should be specified rather than inferred from spatial adjacency alone.

The relevant local boundary is often endogenous to the process. A ten-kilometer

radius can be appropriate for one transport problem and meaningless for another. Walking accessibility, school catchments, commuting patterns, administrative wards, ecological boundaries, and digital service areas can each define different local spaces. Anselin's treatment of spatial dependence and heterogeneity illustrates why quantitative spatial analysis needs an explicit account of the spatial structure being modeled rather than an unexamined neighborhood convention (Anselin 1988). GRE generalizes that caution: the spatial unit should follow the mechanism and research question.

Local propagation can also be unequal within the same geographic area. Residents may differ in mobility, legal status, information, income, disability, language, organizational membership, or network position. A facility can therefore be geographically close while remaining practically distant. Section 15.5 developed this distinction through multidimensional relational distance. Local propagation adds the directional question: which nearby positions actually become exposed to or able to use the propagated effect, and through which pathways?

Finally, local effects can be cumulative. Repeated investment, repeated neglect, clustering, ecological burden, or neighborhood reputation can produce trajectories that exceed any single event. Local propagation should therefore be connected to the path-dependent and delayed-generation structures developed in Sections 15.8 and 15.9. Geographic proximity can condition the pathway, while history determines how the local configuration responds.

15.10.2 Mobility

Mobility is one mechanism through which spatial propagation occurs. The moving element can be a person, good, service provider, machine, financial claim, biological material, document, dataset, organizational practice, or another carrier of economically relevant conditions. The analytical object is therefore broader than transportation volume. Mobility concerns who or what can change spatial position, under which constraints, at what cost, and with what consequences for the origin, destination, and intermediate positions.

Movement can transmit more than the object that visibly moves. Labor mobility can carry skills, expectations, professional ties, remittances, and institutional experience. Migration can alter household structures and local service demand at both origin and destination. Goods movement can transmit standards, production dependencies, environmental burdens, and logistical risk. Mobile capital can alter financing conditions without requiring equivalent movement of productive capacity. A traveling professional can connect organizations; a relocated firm can carry routines and supplier relations. The propagated consequence therefore depends on the relational and institutional attributes carried with mobility.

Mobility is also stratified. Visa regimes, transportation costs, care responsibilities, health, wealth, passport status, licensing requirements, information, and digital access affect the capacity to move. Mobility for one actor can depend on immobility for another, as when care, logistics, maintenance, or territorial infrastructure remain fixed. A useful GRE analysis therefore asks both who can move and who sustains the conditions that make movement possible.

The direction of mobility matters as well. Movement can redistribute capabilities and resources among places, create return flows, produce brain circulation or depletion, alter congestion, or change bargaining conditions. A destination can benefit from incoming skills while an origin loses locally embedded capacity; remittances and return migration can later reverse or transform part of that effect. The appropriate unit is a trajectory of movement and consequence rather than one spatial transfer considered in isolation.

Mobility can reduce some distances while increasing others. Faster transport can shorten travel time but increase dependence on centralized hubs. Digital mobility of information can expand reach while excluding actors who lack compatible standards or authentication. Spatial propagation through mobility should therefore be interpreted jointly with infrastructure, institutional distance, and unequal accessibility rather than equated with generalized spatial integration.

15.10.3 Infrastructure

Infrastructure organizes spatial propagation by providing durable pathways through which heterogeneous downstream activities become possible. Roads, railways, ports, electricity grids, water systems, broadband networks, payment systems, data centers, logistics hubs, public records, standards, and legal-administrative systems can all function infrastructurally when they support multiple downstream uses. Frischmann's demand-side analysis is particularly relevant because it emphasizes shared infrastructural resources as inputs into diverse productive and social activities rather than valuing them only through one immediate output (Frischmann 2012).

Infrastructure affects propagation through reach, capacity, reliability, interoperability, access rules, and topology. A transport network changes which locations can exchange people and goods at tolerable cost. A grid makes energy available across distance but can also concentrate vulnerability at critical nodes. Digital infrastructure can support nearly instantaneous communication while depending on geographically concentrated data centers, cables, energy systems, and standards. Institutional infrastructure can make credentials, contracts, or identities portable across jurisdictions. Spatial propagation is therefore shaped by both visible physical networks and less visible institutional systems.

Infrastructure can amplify and transform rather than merely carry an effect. A research finding propagated through open digital infrastructure may become usable by distant laboratories; the same finding behind restrictive access or incompatible standards may remain locally confined. A port does not merely move goods faster; it reorganizes supplier geography, land use, labor demand, and exposure to disruption. Infrastructure can consequently alter the geometry of the relevant economic space.

Infrastructure also creates spatial asymmetries. Nodes with high connectivity or service quality can acquire cumulative advantages, while bypassed locations face higher costs or reduced accessibility. Maintenance allocation can generate unequal reliability across territories. Pricing, ownership, technical standards, or security requirements can restrict use even where the physical asset is present. Analysis should therefore distinguish infrastructure presence from effective infrastructural access.

The historical character of infrastructure is equally important. Durable systems embody previous technological standards, territorial priorities, financing decisions, and political settlements. These inheritances can lower the cost of some later trajectories while making alternatives expensive. Infrastructure is thus simultaneously a pathway of propagation and a material carrier of path dependence. Its spatial effects should be analyzed through construction, maintenance, adaptation, obsolescence, and replacement rather than through installation alone.

15.10.4 Networked Space

Networked space represents economic proximity through relational connectivity rather than geographic adjacency alone. Actors that are physically distant can be closely connected through supply chains, financial relations, organizational collaboration, digital platforms, professional networks, or shared standards. Conversely, neighboring actors can occupy distant network positions if few consequential relations connect them. A network representation is therefore useful when pathways of interaction are better described by topology than by physical distance.

Networked propagation depends on more than the existence of ties. Direction, weight, capacity, reliability, multiplexity, and higher-order coordination can matter. A supply relationship transmits different effects from a knowledge-sharing relation; a platform connection differs from a governance relation. Powell's analysis of network forms of organization supports the broader point that recurring relational structures can organize economic coordination in ways not reducible to spot markets or hierarchical command (Powell 1990). Networked space consequently has institutional content as well as topology.

Propagation through networks can be uneven. Central or bridging positions can receive information earlier, coordinate across otherwise separated groups, or become bottlenecks through which many pathways pass. Peripheral positions can be formally connected while facing longer or less reliable paths. Network growth can also alter the meaning of distance over time, and higher-order coordination can make group-level configurations consequential beyond pairwise ties. The appropriate representation should therefore match the process being studied rather than assuming one network metric captures spatial reach.

Networked space can coexist with territorial space. A multinational production network remains physically located in factories, ports, warehouses, offices, homes, and ecological systems. Digital platforms depend on territorial law, energy, cables, and data infrastructure. Financial networks operate through institutions subject to jurisdictions. Relational topology can therefore reorganize spatial reach without abolishing geography.

For GRE, the important question is how network structure changes accessibility and propagation. An innovation, shock, standard, or resource can move rapidly across well-connected pathways while barely reaching geographically nearby but disconnected positions. Spatial analysis should accordingly be able to move between geographic maps and relational graphs, preserving the possibility that each reveals a different part of the propagation mechanism.

15.10.5 Territorial Structure

Territorial structure concerns the organization of economic processes through bounded areas, jurisdictions, zones, property regimes, and area-based authority. Territory is not merely a container within which economic activity happens. Sack's account of territoriality is useful here because it treats area-based control as a strategy for controlling access to people and things (Sack 1986). Economic propagation can therefore be enabled, redirected, slowed, taxed, prohibited, or differentiated by territorial institutions.

Territorial mechanisms include zoning, customs boundaries, tax jurisdictions, environmental regulation, licensing areas, property boundaries, municipal service districts, special economic zones, and sovereign borders. A spatial effect that would otherwise travel through physical proximity or network connection can be transformed when it enters a different territorial regime. Territorial boundaries can also protect local capacities by limiting extraction, congestion, ecological burden, or uncontrolled exposure.

Territorial units operate at multiple scales. Municipalities, regions, states, supranational areas, Indigenous territories, and special-purpose districts can overlap. Brenner's methodological work on scale is relevant because it warns against collapsing geographical scale into place, territory, or locality and emphasizes scalar structuration as a process rather than a fixed ladder (Brenner 2001). GRE accordingly treats territorial scale as historically organized and potentially contested.

Territorial propagation can generate boundary effects. Firms may locate just inside or outside a tax or regulatory boundary. Infrastructure can terminate at jurisdictional edges. Social services can depend on residence. Environmental effects can cross borders even where regulatory authority does not. A spatial analysis should therefore distinguish the territory of authority from the territory of incidence.

Territorial structures can themselves change through annexation, decentralization, harmonization, secession, zoning reform, jurisdictional cooperation, or the creation of new administrative categories. Spatial propagation can contribute to such changes by making existing territorial arrangements increasingly misaligned with economic pathways. Territory is thus both a condition of propagation and a possible object of transformation.

15.10.6 Cross-Border Propagation

Cross-border propagation occurs when economically consequential effects pass between distinct legal, political, monetary, regulatory, linguistic, or administrative regimes. The relevant border can be international, subnational, organizational, or otherwise jurisdictional. The analytical significance of the border lies in the conversion and mediation it requires, not in the cartographic line alone.

Goods crossing a border can face customs procedures, standards, inspection, tariffs, documentation, and currency conversion. Capital flows can encounter financial regulation, reporting rules, settlement infrastructure, and exchange-rate risk. Labor mobility can depend on visas, professional recognition, language, social protection, and residency. Data flows can encounter privacy, localization, cybersecurity, and

platform rules. Cross-border propagation therefore often combines spatial movement with institutional and value-form conversion.

International financial integration provides a clear example of propagation across jurisdictional boundaries. Historical datasets on external assets and liabilities document extensive cross-border financial positions and changing forms of international integration (Lane and Milesi-Ferretti 2006). Such integration can transmit financing conditions and shocks across distance, yet its incidence depends on balance-sheet composition, regulation, currency structure, and domestic institutional conditions. Cross-border reach should consequently not be equated with uniform exposure.

Borders can attenuate, redirect, or amplify propagation. Regulatory differences may shield a jurisdiction from one mechanism while creating arbitrage through another. Harmonized standards can reduce institutional distance while increasing dependence on common infrastructures. Capital controls, customs systems, public-health rules, or environmental regulations can intentionally alter propagation. Whether such mediation is beneficial depends on the evaluative problem; lower friction is not automatically superior.

Cross-border effects also raise attribution and governance questions because the originating authority and affected territory may differ. Pollution, financial instability, migration pressures, platform rules, supply disruptions, and technological standards can produce consequences beyond the jurisdiction that generated them. Analysis therefore needs to preserve both the path of propagation and the distribution of authority to regulate, compensate, or contest it.

15.10.7 Spatial Concentration

Spatial concentration concerns the clustering of value-bearing conditions, productive capacity, institutions, infrastructure, knowledge, or population in a limited set of locations. Concentration can alter propagation because dense co-location can increase repeated interaction, shared infrastructure, specialized labor pools, supplier depth, and informational exchange. It can also create bottlenecks, exclusion, congestion, high entry costs, ecological pressure, and vulnerability to localized disruption.

The relevant question is therefore not whether concentration is intrinsically efficient or harmful. It is which mechanisms concentration enables and which burdens it creates under particular conditions. Marshall's classical discussion of localized industry remains historically important for understanding how specialized labor, suppliers, and knowledge can support industrial concentration (Marshall 1890). Contemporary concentration can involve different mechanisms, including digital infrastructure, research institutions, finance, regulation, amenities, or platform ecosystems.

Concentration can become self-reinforcing. Existing capabilities attract complementary actors; complementary actors increase the value of existing infrastructure; accumulated infrastructure lowers entry costs for related activity. These feedbacks connect spatial concentration to path dependence. Yet concentration can also decay if congestion, high costs, technological substitution, policy change, environmental risk, or changing demand weaken the reinforcing mechanism.

Spatial concentration affects who can participate. Actors outside major hubs

can face greater travel, information, financing, or network costs. At the same time, remote technologies and distributed infrastructure can reduce some disadvantages without eliminating others. A worker can participate digitally in a distant cluster while remaining excluded from informal networks, local public goods, or career mobility. Spatial concentration therefore interacts with the relational-distance architecture of Section 15.5.

Concentration can also shape resilience. Redundancy distributed across locations may reduce exposure to local shocks, while concentration can support deep specialization and rapid coordination. There is no universal optimal spatial pattern independent of the relevant process, risks, and value criteria. GRE therefore treats concentration as a generative configuration to be analyzed through its mechanisms, incidence, and later trajectory.

15.10.8 Spatial Spillover

Spatial spillover concerns consequences that extend beyond the spatial boundary, target set, or accounting frame within which an initiating action is evaluated. The concept is useful when benefits, harms, knowledge, prices, ecological effects, congestion, reputation, or institutional changes affect positions not directly included in the originating transaction or intervention. Spillover is therefore boundary-relative: the same effect can be internal to one analytical region and external to another.

A spillover claim should identify the propagated effect and the pathway through which it reaches additional positions. Geographic adjacency can be one mechanism, but network connectivity, infrastructure, labor mobility, supply chains, finance, and ecological systems can also generate spatial spillovers. Anselin's spatial-econometric framework is relevant because it formalizes situations in which observations across locations are interdependent rather than statistically isolated (Anselin 1988). GRE extends the conceptual question beyond statistical dependence to the generative pathways producing that dependence.

Spillovers can be positive, negative, or mixed under a stated evaluative frame. Knowledge generated in one research center can support firms elsewhere. Public transport can reduce congestion beyond its immediate users. A local environmental burden can be exported downstream. A major employer can raise nearby incomes while increasing housing pressure. A regulatory decision can shift activity across a border. The same process can therefore generate differently signed spillovers across affected positions and value forms.

Spatial spillover should be distinguished from spatial propagation in general. Propagation names the broader extension of consequences across spatially organized pathways. Spillover specifically emphasizes that some consequences fall outside the boundary or incidence set used to define the initiating activity. Changing the accounting boundary can therefore change what appears as a spillover without changing the underlying process.

This boundary sensitivity has governance implications. If jurisdictions, firms, or projects are evaluated only within narrow territorial boundaries, they can externalize benefits or burdens that remain economically material elsewhere. Broader accounting can make these effects visible, although widening the boundary indefinitely

would be analytically unmanageable. The appropriate boundary should follow the decision problem, the plausible propagation mechanism, and the materiality of affected positions.

Proposition 15.22 (Mechanism-specific adequacy of spatial-propagation claims). *A spatial-propagation claim is adequately specified, at the resolution appropriate to the inquiry, when it identifies the propagated condition or effect, the relevant spatial or relational representation, the pathway through which propagation occurs, the affected positions or territories, and materially relevant mechanisms of attenuation, amplification, conversion, blockage, or spillover. Geographic proximity alone does not establish propagation, and observed spatial association alone does not establish the pathway that generated it.*

Proposition 15.22 preserves the distinction between spatial pattern and generative mechanism. It also prepares the next step in the chapter. Once propagation is treated as capable of changing connectivity, territorial boundaries, infrastructures, capacities, and later accessibility, the relevant question becomes structural: propagation can transform the spacetime through which subsequent economic processes unfold. Section 15.11 therefore turns to structural transformation in generative spacetime.

15.11 Structural Transformation in Spacetime

Structural transformation concerns changes in the organization of economic possibility itself. Its role in this chapter is to distinguish a trajectory that moves through an approximately stable configuration space from a transformation that changes the relations, constraints, boundaries, capacities, or transition conditions through which later trajectories become available. The objective is to provide a disciplined vocabulary for analyzing transformations of topology, constraints, capacities, institutions, boundaries, degrees of freedom, generative rules, and admissible futures. The discussion is primarily conceptual and structural. Formal notation is used only to identify which parts of the representation are allowed to change; it does not imply that an economy possesses a literal physical spacetime or a fixed universal state space.

This distinction matters because an observed change can be large while remaining structurally ordinary, and a comparatively modest intervention can be structurally consequential if it changes who can connect, which actions are permitted, which capacities become usable, or which future configurations become reachable. A price shock can move many quantities while leaving the basic institutional and relational architecture intact. A new legal status, interoperable standard, public infrastructure, organizational form, or technical capability can instead create relations and possibilities that previously had no operative place in the represented system. Structural transformation therefore concerns changes in the architecture of later generation rather than magnitude alone.

A compact representation is useful for keeping these dimensions separate. Let a bounded economic-spacetime representation at analytical time t be summarized by the structural record in Equation 15.3.

$$\mathfrak{S}_t = (\mathcal{P}_t, \mathcal{R}_t, \mathcal{C}_t, \mathcal{K}_t, \mathcal{B}_t, \mathcal{D}_t, \mathcal{G}_t), \quad (15.3)$$

where $\mathcal{P}_t$ denotes the represented positions or entities, $\mathcal{R}_t$ their economically relevant relations, $\mathcal{C}_t$ materially relevant constraints and enabling conditions, $\mathcal{K}_t$ materially relevant capacities or capabilities, $\mathcal{B}_t$ the operative analytical or institutional boundaries, $\mathcal{D}_t$ the available degrees of freedom in the sense developed below, and $\mathcal{G}_t$ a representation of the rules or mechanisms governing admissible local continuations. Equation 15.3 is a bookkeeping device. Each component can be represented qualitatively, institutionally, graphically, computationally, or mathematically at the resolution appropriate to the inquiry.

Definition 15.23 (Structural transformation in generative spacetime). A *structural transformation in generative spacetime* is a historically situated change in one or more components of the represented economic structure such that the organization of materially relevant relations, constraints, boundaries, capacities, degrees of freedom, or admissible continuations differs in a way that changes later accessibility or generative possibility. Structural transformation is therefore stronger than a change in observed state variables alone. It is indexed to the analytical boundary, scale, and representation used in the inquiry.

Table 15.11 summarizes the dimensions developed in this section. The categories overlap. Institutional transformation can alter constraints and boundaries; capacity transformation can create new degrees of freedom; topological transformation can change the practical meaning of distance; and a transformation of the generative rule can reorganize several dimensions simultaneously.

15.11.1 Topological Transformation

Topological transformation concerns a change in the pattern of economically consequential connectivity. In a network representation, this can involve the creation or removal of ties, hubs, bridges, bottlenecks, layers, group interactions, or higher-order relations. In an institutional representation, it can involve new pathways of authorization, recognition, contracting, appeal, or resource transmission. The analytical point is broader than graph topology in the strict mathematical sense. GRE uses topology here to refer to the organization of relational reach and composition at the resolution appropriate to the problem.

The same set of actors can therefore inhabit a structurally different economic configuration after connectivity changes. A new payment rail can connect firms that previously relied on costly intermediaries. Mutual recognition of professional credentials can create a path between labor markets. A common technical standard can make previously incompatible systems interoperable. A bridge, rail line, data exchange, or public registry can turn two previously separated clusters into one connected system. Conversely, the closure of an intermediary, border, platform interface, or legal recognition channel can fragment an apparently unchanged set of positions.

Network science provides a useful formal language for some of these cases because changes in connectivity, centrality, clustering, and path structure can be represented explicitly (Newman 2003). Higher-order network representations are relevant when consequential interactions involve groups, institutions, or coordinated configurations that cannot be reduced adequately to pairwise ties (Battiston et al. 2020). GRE

Table 15.11: Analytical dimensions of structural transformation in generative space-time.

Dimension	Structural object	Diagnostic question
Topological transformation	Connectivity, adjacency, higher-order relations, bottlenecks	Have the pathways among positions changed in kind or organization?
Constraint transformation	Prohibitions, requirements, costs, enabling conditions	Has the feasible or practically reachable action set changed through a transformed constraint architecture?
Capacity transformation	Effective ability to act, coordinate, convert, learn, or maintain	Have positions acquired or lost capabilities that alter later trajectories?
Institutional transformation	Rules, roles, standing, authority, procedures, enforcement	Has the institutional organization of action and recognition changed?
Boundary transformation	Membership, jurisdiction, system limits, inclusion and exclusion	Has the operative boundary of the process or institution changed?
Emergent degrees of freedom	Newly meaningful dimensions of action or configuration	Are there economically relevant possibilities that were previously absent from the represented action space?
Generative-rule transformation	Mechanisms governing admissible continuations	Have the conditions that generate later transitions themselves changed?
History-support and admissibility transformation	Represented support and practical accessibility of possible futures	Have represented support or the admissibility and accessibility of future histories changed, and which kind of change occurred?

adopts these tools selectively. A topological change matters economically when it changes practical accessibility, coordination, dependence, transmission, conversion, or the distribution of control.

Topological transformation can also be qualitative. A relation that previously carried information can acquire authority; a supplier relation can become a financing relation; a digital connection can become an identity or payment infrastructure. The existence of a tie is therefore insufficient to establish topological continuity if the type and operative capacity of the relation have changed. Multiplexity, direction, capacity, and institutional meaning may be materially relevant parts of the topology.

Topological transformation should also be distinguished from temporary traffic through an unchanged network. A surge in transactions can substantially increase activity while leaving the underlying pathway structure intact. Structural analysis asks whether the pattern of possible connection has changed, whether new positions have become reachable, whether old bottlenecks have disappeared or intensified, and whether control over pathways has shifted. These questions connect topology directly to the accessibility architecture developed in Section 15.6.

15.11.2 Constraint Transformation

Constraint transformation concerns changes in the conditions that delimit or enable economically relevant action. Constraints can be material, financial, legal, institutional, informational, technological, ecological, organizational, temporal, or relational. They can prohibit actions, make them costly, condition them on complementary resources, or enable them by supplying stable rules and shared infrastructure. A structural account therefore treats constraints as part of the generative architecture rather than simply as external obstacles.

North's institutional analysis is relevant because institutions organize incentives and uncertainty by structuring interaction through formal and informal constraints (North 1990). For GRE, the important extension is that changing a constraint can transform later trajectories even when current resources remain similar. A licensing reform can change who is authorized to enter a profession. A public guarantee can alter financing accessibility. A new data standard can reduce interoperability constraints. Environmental degradation can impose new material limits on production. Care responsibilities can constrain labor mobility even when formal employment opportunities exist.

Constraint transformation can expand or contract possibility, and these directions need not coincide with normative improvement or deterioration. A safety regulation can restrict one action while enabling trust and wider participation. A capital requirement can narrow short-term financial choices while reducing fragility. Removal of a protective constraint can expand formal choice while increasing exposure to extraction or risk. The analysis should therefore identify the function of the constraint, the positions affected, and the later options that become more or less reachable.

Constraints can also migrate across forms. A technological constraint can become an institutional one if a proprietary standard is embedded in regulation. A financial constraint can become a capability constraint when prolonged underinvestment erodes skills or maintenance capacity. A legal restriction can become a relational constraint if it prevents the formation of durable partnerships. Structural transformation can therefore involve conversion among constraint types as well as simple relaxation or tightening.

The temporal dimension is important. A constraint removed today can continue to shape behavior through hysteresis, sunk investments, expectations, or depleted capabilities. A new constraint may take time to become effective because implementation, enforcement, learning, and institutional adaptation are delayed. Constraint transformation should therefore be traced through the event and process architecture developed in Sections 15.2 and 15.9, rather than inferred from formal rule change alone.

15.11.3 Capacity Transformation

Capacity transformation concerns changes in what subjects, organizations, institutions, or collectives are effectively able to do. The object is broader than possession of a resource. A new capability can depend on skills, complementary infrastructure, legal standing, organizational routines, relationships, information, or institutional recognition. A structural transformation occurs when these changes alter the set of

practical operations or future trajectories available to a position or collective.

Capacity formation can transform economic spacetime because it changes accessibility. A community that acquires technical expertise can maintain infrastructure that previously required external providers. An organization that develops data-analysis capacity can interpret information that previously existed but was unusable. A new translation capability can connect previously separated knowledge communities. Public legal assistance can convert formal rights into practical procedural capacity. In each case, a new action becomes reachable without necessarily changing the nominal object being acted upon.

Capacity transformation can also be collective. The relevant capability may reside in coordination among several positions rather than in one actor. A laboratory requires equipment, expertise, standards, funding, maintenance, and institutional support. A disaster-response system depends on communication, logistics, authority, local knowledge, and public trust. A cooperative capacity can emerge from governance rules and repeated relations that no member possesses individually. This is one reason GRE avoids reducing capacity to an individual stock.

Loss of capacity can be structurally transformative as well. Skill erosion, institutional memory loss, infrastructure decay, ecological degradation, or the departure of bridging personnel can make previously reachable trajectories inaccessible. The current configuration can look superficially similar while losing the ability to reproduce or adapt itself. Structural analysis therefore includes maintenance and regeneration, not only acquisition.

Capacity transformation also interacts with path dependence. Once new capacities are formed, later investments and institutions may organize around them; once capacities are lost, rebuilding can require more than restoring the original resource. Arthur's analysis of increasing returns and historical lock-in provides a useful mechanism-level precedent for understanding why early capability differences can become consequential under reinforcing processes (Arthur 1989). GRE generalizes the point beyond technology choice to relational and institutional capacities while retaining mechanism-specific evidence requirements.

15.11.4 Institutional Transformation

Institutional transformation concerns changes in the rules, roles, rights, procedures, recognized categories, enforcement mechanisms, and authority relations through which economic action is organized. Institutional change becomes structurally transformative when it alters who can act, who is recognized, which claims count, how resources can be converted, or which pathways of coordination and contestation are available. Formal legal amendment is one possible mechanism, but operative institutional transformation can also occur through organizational practice, standards, administrative interpretation, collective governance, or changing informal rules.

Institutions can transform topology and constraints simultaneously. A new procurement rule can connect smaller firms to public demand. Recognition of a new legal entity can create contractual and financing capacities. A revised appeals procedure can alter the path through which decisions are contested. An open-data regime can create new informational pathways. A platform's rule change can reorganize

market access even without changing formal state law. Institutional transformation therefore belongs inside the spatiotemporal architecture rather than outside it as contextual background.

Sewell's account of structure in terms of schemas and resources is useful here because it treats structural reproduction and transformation as connected to agency, interpretation, and the transposability of rules and resources (Sewell 1992). His analysis of transformative historical events likewise emphasizes that events can change the conditions under which subsequent action becomes meaningful and possible (Sewell 1996). GRE retains this historical sensitivity while specifying economic mechanisms such as authorization, conversion, allocation, contracting, recognition, and access.

Institutional transformation should be distinguished from symbolic renaming. An institution can adopt new language while preserving the operative distribution of authority and access. Conversely, an apparently technical procedural change can be structurally important if it changes standing, evidentiary requirements, default rules, or enforceability. Adequate analysis therefore asks which operative pathways changed and whether affected positions acquired or lost practical capabilities.

Institutional transformation can also redistribute temporal and spatial structure. Shorter approval times can alter who can participate when actors differ in liquidity or waiting capacity. Remote procedures can reduce geographic barriers while increasing technological distance for actors lacking compatible access. Cross-jurisdictional recognition can transform transnational space. Institutional change is therefore rarely confined to one dimension of the structural record in Equation 15.3.

15.11.5 Boundary Transformation

Boundary transformation concerns changes in the lines that organize membership, jurisdiction, inclusion, exclusion, responsibility, accounting, or analytical scope. Boundaries can be territorial, organizational, legal, technological, social, ecological, or conceptual. They matter because they determine which positions are inside a decision process, which effects count as internal, who bears obligations, who can claim rights, and which flows are treated as crossing an interface.

Holland's emphasis on signals and boundaries in complex adaptive systems provides one useful structural precedent for treating boundaries as active components of organized systems rather than passive descriptive lines (Holland 2012). In economic settings, a boundary can regulate passage, transform what crosses it, or determine which rules apply. A customs border changes the conditions under which goods move. An organizational boundary determines authority and accounting. A platform boundary determines who can access an ecosystem and under which technical conditions. A community boundary can define membership rights and collective obligations.

Boundary transformation can occur through expansion, contraction, permeability change, nesting, merger, fragmentation, or reclassification. A regional agreement can make a previous cross-border transaction institutionally internal to a shared regime. A firm can vertically integrate a supplier, turning an external contract into an internal organizational relation. A public service can redefine eligibility. A digital standard can create a new compatibility boundary. An ecological event can reveal that an ad-

ministrative boundary was too narrow for the relevant propagation process.

Changing a boundary can transform measured outcomes without changing the underlying material process. An externality can disappear from an accounting category when the boundary widens, even though the effect persists. A population can appear to improve when eligibility rules exclude the most disadvantaged cases. A firm's productivity can change when activities are outsourced beyond the organizational boundary. Boundary transformation therefore requires provenance: the analysis should distinguish change in the world from change in the frame used to represent it.

Boundaries also interact with power and governance. The authority to define membership, jurisdiction, accounting scope, or interoperability can shape whose effects are visible and whose claims are actionable. This section does not yet develop a full theory of boundary power, which belongs to later parts of the book, but it establishes boundary transformation as a structurally generative process that can change later accessibility and incidence.

15.11.6 Emergent Degrees of Freedom

An emergent degree of freedom is a newly relevant dimension along which an economic position or configuration can vary, act, coordinate, or be organized. The phrase is borrowed at a high level from scientific uses of degrees of freedom, yet GRE employs it as a structural analogy rather than a physical identity. It refers to possibilities that become economically meaningful only after a transformation in technology, institutions, relations, capacities, or representation.

Examples are easy to state. Before interoperable digital identity exists, a class of remote transactions may be practically unavailable; after it exists, identity-mediated remote participation becomes a new dimension of action. Before a legal category recognizes a new organizational form, actors may lack a pathway for holding assets or contracting collectively; after recognition, that organizational dimension becomes available. Before a scientific technique is developed, a production or diagnostic choice cannot be exercised in practice. Before a transport connection exists, commuting between two locations may be outside the feasible action set for many people.

The analytical claim should be stronger than saying that an existing option became cheaper. A degree of freedom is emergent when the representation requires a new dimension, category, or relational possibility to describe actions that were previously absent, undefined, or practically inaccessible within the relevant boundary. This remains scale-dependent. A possibility can be new to one community while familiar elsewhere; it can be new institutionally even if technically possible; it can be new for a subject because complementary capabilities have changed.

Anderson's methodological argument that higher levels of organization can require concepts that are not exhausted by lower-level descriptions offers a useful anti-reductionist precedent (Anderson 1972). GRE does not infer a physical law of emergence from this precedent. The relevant lesson is narrower: structural novelty can require additional analytical variables even when earlier material components remain present. A new institutional role, collective capacity, or relational configuration can therefore warrant representation as a new degree of freedom.

Emergent degrees of freedom can increase, decrease, or reorganize effective option space. New technology can create opportunities while making older skills less valuable. A new legal pathway can expand participation while imposing new compliance requirements. Collective organization can create bargaining or governance capacities while binding members to shared rules. The normative meaning of emergence consequently remains separate from the descriptive claim that the space of possible action has acquired a new dimension.

15.11.7 Transformation of the Generative Rule

A higher-order form of structural transformation considered here concerns the rule or mechanism through which later configurations become reachable. A generative rule in GRE is a representation of the conditions governing local continuation: which transitions are admissible, how their accessibility depends on current relations and capacities, and which mechanisms can produce new relations, constraints, or options. It need not be a single deterministic function. It can be a qualitative rule set, institutional procedure, stochastic model, transition relation, simulation architecture, or another locally justified representation.

The distinction between state change and rule change can be expressed compactly through Equation 15.4. Let $\mathfrak{S}_{t-}$ denote the pre-transformation structural record and let ξ denote an event or process associated with a change in structure. A structural transformation can be represented as follows.

$$\mathfrak{S}_{t+} = \mathcal{T}_{\xi}(\mathfrak{S}_{t-}). \quad (15.4)$$

Here $\mathcal{T}_{\xi}$ denotes an explicitly interpreted structural transformation associated with the event or process ξ . Equation 15.4 permits $\mathcal{G}_{t+}$ to differ from $\mathcal{G}_{t-}$ in its domain, codomain, or transition structure. It is deliberately more general than a parameter update inside a fixed model. If only a parameter changes while the set of variables, constraints, and admissible transitions remains stable, a state or parameter update can be sufficient. A transformation of the generative rule becomes relevant when the categories of action, the transition relation, the relevant boundary, or the mechanism of continuation itself changes.

Institutional reform can transform a generative rule when a new procedure creates previously unavailable decision paths. Technological change can transform the rule when new production combinations become possible. A platform can alter the generative rule of a market by changing matching, ranking, access, or interoperability. Collective organization can alter bargaining dynamics by creating a new coordinated actor. Ecological degradation can transform the rule negatively by eliminating processes that previously supported regeneration.

Generative-rule transformation is also a demanding empirical claim. Observing a new outcome does not by itself show that the rule changed. The analyst should identify what previously governed continuation, what mechanism altered it, and what new or lost transitions follow from the change. Model comparison, institutional analysis, historical reconstruction, qualitative process tracing, simulation, or formal analysis can each contribute depending on the problem.

This concept also clarifies the relation between intervention and structure. An intervention can move a system within an existing rule, or it can change the rule through which later interventions and endogenous processes operate. The latter case is especially important for governance because a policy that creates durable institutional capacity, interoperability, rights, or new organizational forms can change the space in which subsequent decisions are made.

15.11.8 History Support and Admissible Futures

Changes relevant to structural analysis can affect represented or decision support among possible histories, practical accessibility within an existing family of histories, or the family of admissible histories itself. Section 15.3 distinguished typed history weights and transition potentials. The present subsection adds a structural criterion: a change in represented support is not by itself a structural transformation, whereas a change in practical accessibility can be structurally relevant and a transformation of the admissible history family changes the possibility architecture directly.

A change in information, belief, forecast, or evaluation can alter which future appears more plausible or desirable while leaving the underlying action space intact. By contrast, a new institution, technology, capability, boundary, or legal status can make a previously unavailable trajectory practically reachable. Destruction of infrastructure, institutional collapse, environmental loss, or withdrawal of recognition can remove trajectories that were previously available. Structural transformation therefore concerns the conditions under which practical accessibility or the admissibility architecture of futures changes. Reweighting of evidence or evaluation remains epistemic unless it enters the world through expectations, authorization, coordination, investment, behavior, or another mechanism that changes those conditions.

The distinction is important for historical interpretation. Once a new pathway exists, later observers can mistakenly project it backward and assume that earlier actors faced the same possibilities. Conversely, after a pathway disappears, analysts can forget that it was once genuinely available. A generative-spacetime representation should preserve the history of accessibility rather than treating the current option set as timeless.

History weights can also change through re-epistemization. New evidence can revise the interpretation of earlier events, alter confidence in causal pathways, or change the evaluative meaning assigned to possible futures. Such revision need not change material accessibility immediately. Yet when re-epistemization influences institutions, investment, expectations, or collective action, it can become part of a later structural transformation. The epistemic and material levels should therefore be distinguished while their interaction remains traceable.

The section's central claim is scoped accordingly. Structural transformation need not require dramatic rupture, and an important event need not transform structure. Structural transformation is present when the architecture governing materially relevant relations, constraints, capacities, boundaries, degrees of freedom, or admissible continuations changes at the scale of inquiry. The change can be gradual, cumulative, contested, partial, or reversible. What matters is whether later trajectories are generated under a materially different structural record.

Proposition 15.24 (Structural-transformation adequacy). *A claim of structural transformation in generative spacetime is adequately specified, at the resolution appropriate to the inquiry, when it identifies the structural component or components that changed, the event or process through which the change occurred, the evidence distinguishing structural transformation from ordinary state variation, and the resulting change in materially relevant accessibility, constraints, capacities, boundaries, degrees of freedom, transition rules, or admissible futures. The claim should preserve the scale and analytical boundary at which the transformation is asserted and should avoid inferring normative improvement from structural novelty alone.*

Proposition 15.24 provides the scope condition for the section. It also prepares the next analytical step. Structural transformation rarely occurs at one scale only. A change in individual capability can depend on organizational routines; organizational transformation can depend on institutional time; national policy can propagate through local infrastructure; technological standards can couple transnational networks to household practices. The next section therefore turns to multiscale spacetime and the problem of representing economic processes whose temporal and spatial structures interact across levels.

15.12 Multiscale Spacetime

Economic processes unfold through several temporal and spatial resolutions at once. A household decision can depend on an organizational deadline; an organizational strategy can depend on an institutional rule whose revision cycle is much slower; an infrastructure investment can alter conditions inherited by a later generation; and a locally situated production process can depend on transnational finance, standards, data, migration, or supply relations. The role of this section is to make these interacting resolutions explicit within the generative-spacetime framework. Its objective is to distinguish individual, organizational, institutional, generational, and historical temporalities together with local and transnational spatial organization, and then to specify how processes at these scales become coupled. The discussion is analytical rather than ontological. Scale identifies a resolution, field of organization, or historically constituted level relevant to a research problem; it does not imply that economic reality is partitioned into a fixed hierarchy of naturally nested layers.

The multiscale problem extends the heterogeneous-present analysis of Section 15.4. Heterogeneous presents showed that contemporaneous actors can occupy different operative temporal positions. Multiscale spacetime adds a second question: which temporal and spatial processes are represented at different resolutions, and how do they interact? An individual can face a weekly liquidity horizon while an employer operates on an annual budget, a regulator on a multi-year rulemaking cycle, and an infrastructure system on a multi-decade maintenance horizon. These temporalities coexist, but their units, mechanisms, and relevant events differ. The same applies spatially. A neighborhood, metropolitan labor market, national jurisdiction, platform network, and transnational supply chain can all be relevant to one economic trajectory without forming a simple sequence from small to large.

Process-sensitive social theory provides useful precedents for taking temporal

organization seriously rather than treating time as a neutral container (Abbott 2001). Work on institutional development similarly shows how slow-moving structures, feedback, and accumulated commitments can shape later political-economic possibilities (Pierson 2000). In spatial analysis, relational conceptions of space and methodological attention to scalar structuration caution against treating places and scales as self-evident containers (Massey 1994; Brenner 2001). GRE uses these resources to construct a selective multiscale representation: only those scales whose differences materially affect explanation, accessibility, incidence, or intervention need to be retained.

Definition 15.25 (Multiscale generative spacetime). Within the present framework, *multiscale generative spacetime* is a bounded representation of economic processes in which materially relevant events, relations, constraints, capacities, institutions, and possible continuations are organized at more than one temporal or spatial scale, together with the couplings through which change at one scale affects accessibility, conditions, or trajectories at another. The represented scales are inquiry-relative and need not form a single nested hierarchy.

Definition 15.25 gives the section a scope condition. Multiscale analysis is useful when aggregation or disaggregation changes the explanatory result. It is unnecessary when a single resolution preserves the distinctions relevant to the problem. The definition also keeps scale separate from mere size. A multinational corporation can be analyzed at an organizational scale even when it is geographically dispersed, while a small local authority can operate through institutional rules with long historical depth. Scale therefore concerns the organization of processes as much as their physical extent.

Table 15.12 summarizes the dimensions developed below. The rows identify recurrent scales of analysis rather than exhaustive levels of reality. A concrete inquiry can require only a subset, and other scales can be introduced when the research object warrants them.

15.12.1 Individual Time

Individual time concerns temporal structures that are materially organized around persons or other individually represented subjects. These structures include attention, working time, care obligations, learning, fatigue, health, liquidity, waiting capacity, life-course position, and expectations about future opportunity. The category is useful because an economic action that appears instantaneous at an organizational or market scale can require a long preparatory history at the level of an individual. Acquiring a credential, building professional trust, recovering from a shock, learning a language, accumulating savings, or sustaining unpaid care can each alter later economic accessibility through durations that disappear in a snapshot of the final transaction.

Individual time should not be equated with subjective experience alone. It has institutional and material organization. Working hours are regulated; loan maturities constrain household decisions; immigration status can impose waiting periods; educational calendars structure learning; care needs allocate time unevenly; and access to transport or digital infrastructure changes the effective duration of partici-

Table 15.12: Analytical dimensions of multiscale generative spacetime

Scale	Characteristic organization	Representative temporal or spatial issue	Characteristic coupling problem
Individual	Life-course, attention, liquidity, learning, care, work, and waiting capacity	Short and long personal horizons; accumulated capability and obligation	Individual action depends on organizations, institutions, households, and infrastructures
Organizational	Routines, projects, budgets, staffing, strategy, and maintenance	Operational cadence, project duration, investment and learning cycles	Organizational schedules condition individuals and depend on institutional and market environments
Institutional	Rules, rights, classifications, procedures, standards, and enforcement	Rule persistence, review cycles, legitimacy, reform, and implementation delay	Institutional change restructures organizational and individual possibility while depending on enacted practice
Generational	Cohorts linked through inheritance, education, ecology, infrastructure, debt, and memory	Long-horizon transmission and unequal inherited starting conditions	Present action redistributes capacities, burdens, and options across cohorts
Historical	Long-duration transformation of categories, technologies, institutions, relations, and environments	Path dependence, regime transformation, re-epistemization, and structural change	Historical structures shape current scales while current events can become later historical conditions
Local space	Place-bound infrastructures, ecologies, jurisdictions, repeated relations, and material proximity	Accessibility, concentration, local spillover, territorial constraint, and situated capability	Local processes depend on wider networks while producing spatially uneven incidence
Transnational space	Cross-border finance, trade, migration, standards, platforms, data, law, and supply networks	Jurisdictional crossing, distant coordination, exposure, and conversion across regimes	Transnational structures enter local and organizational processes through mediated channels
Cross-scale coupling	Directional relation among scale-specific processes	Lag, amplification, attenuation, translation, feedback, and mismatch across scales	Effects can move upward, downward, or laterally without preserving form or timing

pation. The temporal position of an individual is therefore partly relational. The same hour has different economic consequences for subjects with different liquidity

buffers, health conditions, care responsibilities, legal statuses, or capacities to postpone action.

A useful implication is that individual action can be temporally constrained even when formal choice is present. A worker may legally be able to change employment but lack the savings needed to survive a search period. A household may have access to a training programme but not the spare time required to complete it. A person may possess information yet face a deadline too short for meaningful deliberation. In each case, the relevant economic variable is not simply clock duration but the relation between available time, required time, and the subject's capacity to reorganize obligations.

Life-course structure adds a longer horizon. Early education, occupational entry, health, family formation, migration, and exposure to shocks can influence later capability and option space. GRE should avoid converting these patterns into deterministic life-course laws. The analytical point is narrower: the timing of an event relative to a subject's accumulated capabilities, obligations, and remaining horizon can alter its consequence. The same resource or institutional opportunity can therefore carry different generative potential at different individual temporal positions.

15.12.2 Organizational Time

Organizations operate through temporal structures that differ from individual schedules. Budgets, reporting periods, staffing cycles, product development, procurement, maintenance, strategic planning, grant periods, project milestones, and governance meetings can each define an organizational cadence. These cadences coordinate action, but they can also create temporal rigidities. A maintenance need can emerge continuously while funding is allocated annually; a hiring decision can require several approvals while the underlying project evolves rapidly; a research programme can need long-duration capability building while evaluation occurs through short reporting cycles.

Organizational time also reflects memory. Routines, archives, technical systems, contracts, and established divisions of labor preserve earlier decisions and make some actions easier to repeat than others. Network forms of organization add another temporal dimension because recurring interorganizational relations can sustain coordination beyond discrete transactions (Powell 1990). What appears as a present organizational capability can therefore depend on a history of repeated interaction, accumulated knowledge, and durable expectations.

Differences between organizational and individual time can create friction. An organization can demand immediate availability from individuals while preserving long internal decision cycles for itself. Temporary workers can face weekly income risk while a firm optimizes across multi-year investment horizons. Conversely, an organization can depend on expertise whose individual formation took years, even when the organization encounters that expertise only at the moment of recruitment. Multiscale analysis makes these temporal asymmetries visible without reducing one scale to the other.

Organizational time is also heterogeneous internally. Finance, engineering, legal, research, operations, and executive functions can work on different cycles. A single

organization therefore need not have one clock. Coordination problems can arise because the relevant temporal units differ across internal functions, or because one function's deadline becomes another function's constraint. The appropriate unit of analysis follows the mechanism under study rather than an assumed organizational unity.

15.12.3 Institutional Time

Institutional time concerns the persistence, revision, enactment, and temporal reach of rules, rights, classifications, procedures, standards, and recognized roles. Institutions often move at a different cadence from markets, technologies, or organizations. Formal rules can persist for decades while the practices they regulate change quickly; emergency procedures can be enacted rapidly while ordinary reform requires prolonged consultation; legal recognition can occur at one date while effective access develops only through later implementation.

Institutional persistence has historical depth. North's account of institutions emphasizes how formal rules and informal constraints structure exchange and how institutional change is shaped by inherited arrangements (North 1990). GRE retains this process-sensitive insight while distinguishing institutional durability from institutional immutability. A rule can remain formally stable while its interpretation, enforcement, technological environment, or relation to other institutions changes substantially.

Institutional time also includes sequencing. Authorization can precede implementation; implementation can precede normalized practice; normalized practice can precede public recognition of consequences. A policy evaluated immediately after enactment can therefore be judged before the institutional process it initiated has matured. Conversely, a rule can produce immediate anticipatory effects before formal implementation because organizations and individuals adjust expectations in advance.

Institutional and organizational time interact continuously. Organizations translate rules into routines, while organizational practices can expose institutional gaps and create pressure for reform. Individuals encounter institutions through concrete waiting periods, eligibility windows, deadlines, review procedures, and rights of appeal. The institutional scale is therefore neither above nor outside organizational and individual processes. It is one temporally organized field whose effects are mediated through them.

15.12.4 Generational Time

Generational time concerns economic processes whose consequences extend across cohorts linked through inheritance, education, debt, infrastructure, institutions, ecology, knowledge, and collective memory. The relevant generation need not be defined by a fixed number of years. It can be a birth cohort, a cohort entering an institution under similar conditions, a technological generation, or another empirically justified grouping whose shared temporal position affects economic opportunity and obligation.

Generational analysis is useful when current action changes the starting configuration inherited by later cohorts. Infrastructure can reduce future transaction costs or create maintenance burdens. Education can transmit capability. Ecological degradation can reduce future option space. Public debt can distribute fiscal obligations across time. Institutional reform can create rights that later cohorts treat as ordinary background conditions. The transmitted object is rarely unchanged; later generations inherit transformed material, relational, institutional, and epistemic configurations.

Generational time also clarifies asymmetry between decision authority and burden incidence. Present actors can make choices whose consequences fall partly on subjects who cannot participate in the current decision. The normative implications belong to later discussions of power and justice, but the spatiotemporal structure is already visible here. Multiscale representation should identify when the actors who choose, the actors who initially benefit, and the actors who later bear maintenance, risk, or loss occupy different temporal positions.

Generational boundaries should remain analytically modest. Individuals from different cohorts coexist, cooperate, compete, inherit from one another, and participate in common institutions. A generational representation should therefore preserve overlap rather than portraying history as a succession of isolated blocks. The important object is the transmission and transformation of conditions across temporal cohorts, together with the relations through which those conditions are inherited, contested, or revised.

15.12.5 Historical Time

Historical time extends analysis beyond the horizons of individual projects, organizations, or cohorts to transformations whose explanatory force depends on longer sequences of institutional, technological, ecological, relational, and epistemic change. Historical time is not simply a larger chronological window. It concerns the persistence and transformation of structures that make later events intelligible as part of a history rather than as isolated observations.

Path dependence, structural transformation, and re-epistemization all require this longer horizon. A present market structure can encode earlier infrastructure decisions, legal settlements, standards, migration patterns, or geopolitical changes. Categories used to measure the present can themselves be historical products. Expectations about future development are similarly shaped by historically situated relations between experience and anticipation (Koselleck 2004). Historical time therefore includes both material inheritance and changing interpretation.

The historical scale can reveal processes invisible at shorter resolutions. A sequence that appears as stable institutional reproduction over five years can be part of gradual erosion over fifty. A dramatic technological shift can rest on decades of public research and infrastructure. A localized crisis can become historically consequential if it changes law, organizational practice, collective memory, or later expectations. Conversely, an event that dominates contemporary attention can leave little durable structural trace.

Historical explanation should still preserve shorter-scale agency. Long-duration

structures do not act independently of concrete subjects, organizations, and institutions. They are reproduced, translated, contested, and transformed through events and practices at shorter scales. Multiscale historical analysis therefore avoids two symmetrical reductions: explaining the present only through immediate decisions, and treating long-run structure as if it operated without localized mechanisms.

15.12.6 Local Space

Local space concerns spatial organization at a scale where proximity, shared infrastructure, territorial rules, repeated interaction, ecological conditions, or embodied mobility materially affect economic processes. The relevant locality can be a neighborhood, municipality, industrial district, campus, watershed, commuting area, platform-mediated service zone, or another process-specific field. Locality is therefore an analytical boundary grounded in mechanism rather than a universal administrative unit.

Relational conceptions of space are useful because local economic life is produced through intersecting social and material relations rather than through location alone (Massey 1994). A neighborhood can depend on distant finance, migration, digital platforms, or supply systems. A local firm can participate in a global production network. Local space consequently combines proximate relations with connections extending beyond the locality.

Local infrastructure gives this scale particular generative significance. Transport, schools, clinics, energy, water, broadband, public space, logistics, records, and civic institutions can jointly condition what individuals and organizations are able to do. Their effects can accumulate through repeated use and shared dependence. A local capability can therefore be a property of a configuration rather than of one isolated actor.

The boundary of local incidence should remain explicit. A local intervention can displace burdens elsewhere, depend on imported resources, attract activity from neighboring areas, or generate benefits that extend beyond the administrative boundary. Treating locality as a closed container can consequently misattribute both generation and cost. Local space is a scale of organization embedded in wider spatial relations.

15.12.7 Transnational Space

Transnational space concerns economic relations whose organization crosses national jurisdictions and whose practical operation depends on connections among legal systems, currencies, standards, infrastructures, organizations, platforms, supply networks, migration regimes, or financial arrangements. The category is broader than international exchange between national aggregates. It includes economic fields in which relevant relations are organized across borders and cannot be understood adequately by assigning each process to a single national container.

Cross-border finance provides a clear example. External asset and liability positions connect domestic balance sheets to institutions and markets located elsewhere, creating channels through which financing conditions and risks can propagate

across jurisdictions (Lane and Milesi-Ferretti 2006). Supply chains, data infrastructures, multinational organizations, scientific collaboration, labor migration, and standards systems create other transnational fields with distinct legal and technical architectures.

Transnational space does not erase territory. Border controls, tax systems, licensing, data localization, sanctions, immigration law, currency regimes, and regulatory authority can strongly shape the pathways through which transnational relations operate. Territorial institutions and transnational networks therefore intersect. A process can be globally connected while remaining highly sensitive to specific ports, data centers, border procedures, courts, or local labor markets.

Transnational coupling can also generate unequal exposure. Organizations with diversified suppliers, multiple currencies, or alternative legal structures can respond differently to the same cross-border disruption than actors tied to one channel. Smaller organizations or households can participate in transnational systems through platforms or intermediaries while possessing little control over standards, fees, dispute resolution, or technological architecture. Spatial reach and control over the conditions of reach are therefore analytically distinct.

15.12.8 Cross-Scale Coupling

Cross-scale coupling concerns mechanisms through which processes represented at one temporal or spatial scale alter conditions, accessibility, or trajectories represented at another. The coupling can be upward, downward, or lateral. Individual learning can aggregate into organizational capability; organizational practice can influence institutional reform; institutional rules can restructure household time; local ecological change can affect regional production; transnational standards can reorganize local technical practice; and local innovations can diffuse through wider networks. These directions describe analytical relations rather than a fixed hierarchy.

A compact representation can help record the architecture without assuming that the scales share one state space. Let Σ denote the set of represented scales, let $\mathfrak{S}^{(\sigma)}$ denote the scale-specific structural record at scale σ , let $\Xi \subseteq \Sigma \times \Sigma$ denote the represented directed scale couplings, and let $\mathcal{L}_{\sigma \rightarrow \rho}$ denote a materially relevant coupling from scale σ to scale ρ for $(\sigma, \rho) \in \Xi$. The multiscale record is stated in Equation 15.5.

$$\mathfrak{M} = \left(\left\{ \mathfrak{S}^{(\sigma)} \right\}_{\sigma \in \Sigma}, \left\{ \mathcal{L}_{\sigma \rightarrow \rho} \right\}_{(\sigma, \rho) \in \Xi} \right). \quad (15.5)$$

Equation 15.5 is a structural bookkeeping device. The couplings can represent institutional translation, resource transmission, aggregation, delegation, infrastructural dependence, learning, legal incorporation, financial exposure, ecological propagation, or another empirically justified mechanism. They need not be linear, symmetric, instantaneous, or quantitative. A coupling can also include delay, attenuation, amplification, threshold effects, or conversion between different representations.

Cross-scale coupling creates several recurring analytical problems. The first is *temporal mismatch*. An individual can face an immediate liquidity constraint while an institutional remedy requires years. The second is *aggregation mismatch*. An aver-

age national improvement can coexist with severe local deterioration. The third is *translation mismatch*. Information generated at one scale can lose meaning when converted into a category used at another. The fourth is *feedback*. A rule adopted at an institutional scale changes organizational behavior, which changes measured outcomes, which then alters later institutional evaluation. These problems show why scale should be part of causal and generative provenance rather than a descriptive label added after the analysis.

Cross-scale coupling also limits simple upward and downward explanations. A macro-level outcome can emerge from many local interactions without being reducible to one representative individual, while local behavior can be conditioned by institutions, infrastructures, and histories that no individual controls. Organizational and institutional structures can possess causal relevance because they organize relations among many positions and persist across particular participants. At the same time, these structures are enacted through concrete practices. Multiscale explanation therefore seeks mechanism-specific relations among scales rather than choosing one scale as universally fundamental.

Scalar transformation can itself become generative. A local practice can acquire new effects after standardization at a national or transnational scale. An institutional entitlement can become practically meaningful only when organizational routines and individual capabilities develop around it. A transnational technological standard can create local interoperability while simultaneously narrowing alternative technical trajectories. Scale change can therefore transform both reach and meaning.

Stronger multiscale claims require evidence about the coupling mechanism. Correlation between a national indicator and an individual outcome does not by itself identify a cross-scale pathway. Nor does a local case automatically generalize to a wider scale. Historical reconstruction, comparative analysis, network analysis, institutional study, spatial methods, quantitative multilevel models, simulation, and qualitative process tracing can each contribute when their assumptions match the question. GRE's methodological pluralism is especially important here because different scales can leave different forms of evidence.

Proposition 15.26 (Multiscale adequacy). *A multiscale generative-spacetime representation is adequate, at the resolution appropriate to the inquiry, when it identifies the temporal and spatial scales whose differences materially affect the claim, specifies the mechanism or mechanisms coupling those scales, preserves relevant directionality and delay, and distinguishes scale-specific variation from transformation transmitted across scales. The representation should avoid assuming a universal hierarchy of scales, inferring cross-scale causation from aggregate association alone, or treating aggregation as lossless when materially relevant heterogeneity is compressed.*

Proposition 15.26 provides the section's scope condition. Multiscale analysis should be as rich as the mechanism requires and no richer. When individual, organizational, institutional, historical, local, and transnational processes materially interact, their coupling belongs to the explanatory object. When one scale is sufficient, adding levels for completeness can obscure rather than clarify the argument. The multiscale architecture developed here provides the spatial and temporal scaffold for the next substantive step, which examines how value generation, propagation, conversion, recirculation, accumulation, dissipation, extraction, return, and

transfer incidence occupy this generative spacetime.

15.13 Spacetime of Value

Chapter 14 developed value as plural, relational, generative, transmissible, convertible, recirculating, cumulative, vulnerable to dissipation and extraction, and capable of returning through later processes. The role of the present section is to place those value processes inside the spatiotemporal grammar developed in this chapter. Its objective is to identify how generation, propagation, transmission and transfer, conversion, recirculation, accumulation, dissipation, extraction, long-horizon return, and transfer incidence acquire different meanings when event order, relational distance, accessibility, scale, delay, and historical transformation are retained. The discussion proceeds process by process and then integrates them through a bounded value-spacetime record. The method is conceptual and mechanism-oriented. It preserves heterogeneous value forms and provenance while avoiding any assumption that value is a conserved scalar substance moving through a literal physical spacetime.

The need for such an integration appears whenever the same value-bearing condition occupies different positions at different stages of its history. Knowledge can be generated in one organization, recognized by another, converted into a credential or standard, propagated across a professional network, and later contribute to institutional capacity. A public investment can generate local infrastructure while its financial burdens, ecological consequences, capability effects, and later returns unfold at different scales and with different delays. A payment can be transferred immediately while the capabilities it supports mature slowly. Conversely, extraction can occur rapidly while generative depletion becomes visible only after maintenance capacity, ecological resilience, or institutional knowledge has deteriorated. A static account can record the presence of value at selected moments. A spatiotemporal account reconstructs how value-bearing conditions become connected through historically ordered processes.

This perspective does not replace the distinctions developed in Chapter 14. It gives them a temporal and spatial address. Generation concerns the formation or expansion of a value-bearing condition. Propagation concerns extension of its effects. Transmission concerns mediated passage across positions; transfer concerns bounded reassignment or provision. Conversion concerns transformation among forms or practical registers. Recirculation concerns re-entry into later generative processes. Accumulation concerns historically cumulative retention or expansion. Dissipation and extraction concern different forms of loss, erosion, diversion, or appropriation. Generative return concerns later re-entry of generated value-bearing effects. The present section asks where, when, through which pathways, and at which scales these processes occur, and how their incidence can differ from the formal boundaries of a transaction or intervention.

Network and higher-order representations are useful precedents when pathway structure affects the reach or transformation of economic processes (Wasserman and Faust 1994; Bick et al. 2023). Capability analysis provides a further reminder that pos-

session or receipt and practical realization can diverge across subjects and contexts (Sen 1999). The generative-justice literature similarly motivates attention to whether value returns to communities and generative systems rather than being captured at extraction interfaces (Eglash 2016; Eglash et al. 2024). GRE combines these concerns with the historical, partial-order, relational-distance, and multiscale framework developed in this chapter.

Definition 15.27 (Value-spacetime record). Within GRE, a *value-spacetime record* is a bounded representation of value-relevant events, their supported temporal or generative ordering, the positions and pathways through which value-bearing conditions become effective, the value forms represented at those events, the spatial or organizational scales at which they operate, and the materially relevant incidence that emerges across the represented history. The record preserves provenance and transformation without presuming conservation, commensurability, or a literal physical spacetime ontology.

A compact record is stated in Equation 15.6.

$$\mathfrak{V} = (E_V, \preceq_V, \mathcal{P}_V, \nu, \sigma, \iota). \quad (15.6)$$

Here E_V denotes represented value-relevant events, $\preceq_V$ the supported partial order among them, $\mathcal{P}_V$ the represented transmission, transfer, conversion, propagation, or return paths, ν the value-form and provenance labels, σ the relevant scale or location labels, and ι the represented incidence across affected positions. Equation 15.6 is a bookkeeping device. Each component can be qualitative, categorical, narrative, quantitative, network-based, or mixed according to the evidence and research question. The equation neither requires one metric space nor assigns a common numerical magnitude to heterogeneous value forms.

Table 15.13 summarizes the principal processes developed below. The rows should be read as diagnostic distinctions rather than sequential stages that every value process must traverse.

15.13.1 Generation

Generation acquires a spatiotemporal structure when the formation of value-bearing conditions cannot be assigned adequately to one point, actor, or moment. Material transformation can occur at a production site, capability formation across a long learning trajectory, relational value through repeated interactions, epistemic value through distributed inquiry, and institutional value through enactment, recognition, and stabilization. The event at which value becomes visible can therefore differ from the history through which the relevant condition was generated.

This distinction is particularly important for delayed and latent processes. Earlier sections showed that a condition can be formed before it is activated, realized, or observed. A skill acquired through education can remain latent until an organizational opportunity appears. Knowledge can be produced before a standard or policy makes it consequential. Infrastructure can exist before complementary institutions make it usable. In each case, locating generation at the moment of later realization would erase the temporal provenance that explains why the later effect became possible.

Table 15.13: Spatiotemporal architecture of value processes in GRE

Process	Spatiotemporal question	Characteristic mechanism	Characteristic caution
Generation	Where and when does a value-bearing condition become formed or expanded?	Capability formation, knowledge production, institutional formation, relation formation, material transformation	Later recognition should not be mistaken for the time of generation
Propagation	Through which paths and scales do consequences extend?	Networks, infrastructures, mobility, imitation, ecological processes, institutional diffusion	Reach does not establish unchanged transmission of value form
Transmission and transfer	How does value become available or reassigned across positions?	Contracts, organizations, platforms, standards, intermediaries, rights, payments	Formal receipt can differ from effective realization and later incidence
Conversion	Where does one form become effective in another register?	Translation, certification, monetization, institutional recognition, capability conversion	Conversion can be lossy, asymmetric, and non-reversible
Recirculation	How does generated value re-enter later processes?	Reinvestment, maintenance, learning, community return, institutional reuse	Re-entry can transform form, recipient, scale, and timing
Accumulation	How do value-bearing conditions become historically cumulative?	Retention, reinforcement, complementary investment, learning, institutional embedding	Accumulation and concentration remain analytically separable
Dissipation and extraction	Where are value-bearing conditions lost, degraded, diverted, or appropriated?	Depreciation, leakage, capture, depletion, gatekeeping, asymmetric control	Loss and appropriation require process-specific diagnosis
Long-horizon return	When and where do generated conditions become later inputs?	Capability maturation, institutional learning, ecological regeneration, knowledge reuse	Delayed observation should not be confused with delayed generation
Transfer incidence	Which positions ultimately benefit, bear burdens, maintain, lose access, or gain control?	Direct and indirect effects across relations, time, and scale	The formal recipient need not exhaust the incidence boundary

Generation can also be distributed spatially and institutionally. A technological capability may depend on research conducted in one jurisdiction, components produced elsewhere, standards defined by another organization, finance raised through transnational markets, and workers trained in several institutions. The resulting value-bearing condition has no single economically sufficient location. Its provenance is better represented as a path or complex of contributing events whose relevance depends on the research question.

The spatiotemporal framing also prevents exclusive causal ownership from being inferred from early contribution. A foundational event can be important without being sufficient. Later maintenance, conversion, complementary investment, institutional authorization, and user adaptation can each contribute materially to realization. GRE therefore treats generation provenance as potentially distributed across events and scales. Attribution should preserve the distinction between initiating, enabling, maintaining, activating, and realizing contributions when those distinctions materially affect the claim.

A further implication concerns negative and mixed generation. Economic processes can generate capabilities and dependencies at the same time, or produce financial value while depleting ecological or relational conditions. Spacetime does not solve the normative problem by itself. It helps locate where different value-bearing and harm-bearing processes arise, how they coexist, and when their consequences become visible. Evaluation still requires an explicit standpoint and preservation of

heterogeneous value forms.

15.13.2 Propagation

Propagation concerns the extension, reproduction, or widening incidence of value-bearing effects beyond an initial site or relation. In spatiotemporal terms, the key object is the architecture of reach. A value-bearing effect can propagate through social or organizational networks, shared infrastructure, mobility, imitation, standards, financial relations, ecological pathways, or institutional diffusion. The relevant path can cross geographical and organizational boundaries while changing speed, form, accessibility, and incidence.

Propagation therefore combines the spatial analysis of Section 15.10 with the pathway analysis of causal and generative accessibility. Geographic distance can matter through transport cost or material delay, while relational distance can matter through institutional incompatibility, social separation, epistemic translation, economic exclusion, or technological non-interoperability. A propagation process can shorten one kind of distance while increasing another. Digital distribution can reduce geographic friction while dependence on a platform or technical standard increases institutional or technological distance from alternative channels.

The propagation of value-bearing effects should also be distinguished from replication of the underlying object. Knowledge can propagate without the source losing possession. A standard can propagate through adoption. Trust can propagate indirectly through reputation, while the relational value of trust remains embedded in specific relations. Financial distress can propagate through contractual exposures even though the financial asset itself is not transferred to every affected party. Propagation analysis therefore identifies the mechanism by which consequences extend rather than assuming one substance physically moves through the system.

Temporal ordering matters because propagation can be immediate, recurrent, delayed, or threshold-dependent. A payment network can transmit effects within seconds, while a regulatory standard can reshape investment over years. Ecological consequences can propagate slowly through material systems. Organizational practices can diffuse through repeated observation and imitation. The speed of propagation is itself economically consequential when actors differ in their ability to react, hedge, exit, or learn.

Propagation can generate new pathways as it proceeds. Adoption of a common standard can increase interoperability and thereby enable further propagation. Network effects can expand access for some positions while reinforcing dependence on a dominant interface. Institutional diffusion can create compatibility across jurisdictions while narrowing alternative designs. A spatiotemporal representation should therefore allow propagation to transform the structure through which later propagation occurs.

15.13.3 Transmission and Transfer Paths

Transmission and transfer become distinct spatiotemporal objects when formal reassignment and effective passage follow different paths. A transfer identifies

a bounded provision, reassignment, payment, entitlement, asset, right, or access condition. Transmission concerns the mediated process through which something value-bearing becomes available or effective elsewhere. The transfer can be recorded at one moment, while transmission unfolds through several intermediaries and conversions.

Consider a cross-border payment. The formal transfer can be specified by sender, amount, recipient, and settlement record. Its transmission path can include banks, payment systems, currency conversion, compliance checks, fees, waiting periods, identification requirements, technological interfaces, and local access to cash or accounts. The recipient's effective realization can therefore differ from the nominal transfer in timing, cost, usability, and control. A similar structure appears in knowledge transfer, credential recognition, technology transfer, rights implementation, and infrastructure access.

Path structure matters because intermediaries can enable, transform, condition, delay, or capture. Intermediation is not intrinsically extractive. Banks can reduce settlement risk; translators can make knowledge usable; certifiers can reduce uncertainty; platforms can coordinate participants. The same positions can also impose fees, standards, surveillance, lock-in, or asymmetric terms. The relevant question is which functions the intermediary performs, what alternatives exist, and how the path changes incidence and future generative opportunity.

Transmission paths can also be plural. A recipient can have several routes to the same formal object, or one route can fail while another remains available. Redundancy can support resilience; fragmentation can raise coordination costs. Dominance by one pathway can simplify interaction while creating concentration and vulnerability. A path-sensitive representation can therefore record alternatives, bottlenecks, and switching conditions rather than treating the transfer edge as homogeneous.

The distinction between source, generator, sender, recipient, intermediary, bearer of burden, and downstream beneficiary remains important across time. These positions need not coincide. A community can generate knowledge, an institution can formalize it, a firm can transmit a product based on it, and distant users can receive benefits while the originating community receives little return. Transfer provenance should therefore be reconstructed across the represented path rather than inferred from the final transaction alone.

15.13.4 Conversion

Conversion introduces a change of value form, practical register, or domain within a value-spacetime history. Chapter 14 treated conversion as distinct from transmission and commensuration. The spatiotemporal question is where and when conversion occurs, which interface performs it, which conditions enable it, which positions control it, and which remainders persist after it.

A financial resource can be converted into capability only through time, access, complementary services, health, knowledge, infrastructure, and subject-specific conversion conditions. A credential can convert educational history into institutional recognition through a certification regime. Scientific evidence can convert into administrative action through legal and organizational procedures. Relational trust can

reduce coordination costs, but such conversion depends on context and can fail outside the relation in which trust was generated. Conversion consequently has a location in a relational and institutional architecture even when no physical place is analytically central.

Conversion can involve delay. A grant can be transferred immediately while conversion into research capability takes months or years. Legal recognition can occur before organizational procedures adapt. Knowledge can exist before translation, documentation, or compatible infrastructure makes it usable. The time between receipt and effective conversion should therefore remain visible when it affects evaluation or attribution.

Conversion can also change scale. Local knowledge can be translated into a national standard; individual capabilities can be aggregated into organizational capacity; institutional recognition can enable access to transnational networks. Such transitions can broaden reach while compressing local specificity. Cross-scale conversion therefore involves both transformation of value form and transformation of representation.

Loss and remainder are similarly spatiotemporal. What appears as a successful conversion at the endpoint can conceal earlier costs, excluded meanings, ecological burdens, maintenance requirements, or foreclosed alternatives. A provenance-preserving account retains the source form, target form, interface, delay, affected positions, and relevant remainder rather than evaluating conversion solely through the target representation.

15.13.5 Recirculation

Recirculation concerns re-entry of value-bearing conditions into later processes of maintenance, coordination, regeneration, or generation. Its spatiotemporal structure is recursive rather than circular in a literal geometric sense. The condition that returns can differ in form, recipient, location, scale, and timing from the condition that entered the earlier process.

A community investment can generate capability that later supports new organizations; organizational learning can return through improved routines; public research can re-enter later production and policy; financial returns can be reinvested; ecological restoration can improve later productive conditions. Each process contains a return path, but the later configuration is historically changed. Recirculation should therefore be represented as re-entry into a successor configuration rather than as motion around an unchanged loop.

The location of return is analytically important. A process can generate value locally while returns accrue elsewhere. Financial returns can leave the community in which productive or social conditions were generated. Knowledge generated through public institutions can re-enter through private interfaces. Conversely, transnational resources can support local capabilities that later recirculate through community institutions. Recirculation analysis therefore asks where generated value re-enters, who can access it, and which generative system is maintained or expanded.

Time matters because return horizons differ among value forms. Financial return

can appear quickly while capability, institutional, ecological, and relational returns mature slowly. A process evaluated only over a short horizon can therefore appear successful while eroding long-horizon generative conditions, or appear unsuccessful before slower returns become visible. Multiple overlapping return cycles can also create temporal mismatch when maintenance needs occur before returns are realized.

Recirculation can transform future pathways. Reinvestment can create complementary assets, learning can change organizational rules, institutional memory can improve later response, and returned knowledge can open new technical possibilities. The analysis should consequently distinguish simple repetition from recursive transformation. A value process can reproduce an existing structure, stabilize it, diversify it, or change the rules under which later recirculation occurs.

15.13.6 Accumulation

Accumulation is inherently historical because the relevant condition is constituted through retention, reinforcement, or repeated generation across time. Material stocks, financial assets, capabilities, relationships, institutional authority, knowledge, infrastructure, and option structures can accumulate through different mechanisms. Their spatiotemporal patterns need not coincide.

The location of accumulation can differ from the location of generation. Value can be generated across many sites while ownership, control, institutional recognition, or financial return becomes concentrated elsewhere. Conversely, broadly distributed infrastructures or public knowledge can accumulate generative capacity without concentration in one actor. Spatiotemporal analysis therefore retains the distinction between accumulation and concentration developed in Chapter 14.

Accumulation can also be path-dependent. Early complementary investments can make later investments more valuable; organizational learning can increase the productivity of subsequent learning; network participation can create access to further relations; institutional authority can become self-reinforcing. Existing work on increasing returns and path dependence provides relevant precedents for these cumulative mechanisms (Arthur 1989; Pierson 2000). The analytical claim, however, should identify the reinforcement mechanism rather than infer path dependence from persistence alone.

Cross-scale accumulation deserves particular attention. Individual capability can become organizational capability only through routines, coordination, retention, and institutionalization. Local infrastructure can contribute to regional agglomeration; organizational knowledge can become an industry standard; accumulated ecological depletion can become a system-level constraint. Aggregation across scale is therefore a transformation process, not a lossless summation.

Accumulation also changes later accessibility. A position with accumulated capabilities, reserves, relationships, or institutional recognition can absorb delay, enter new pathways, and withstand shocks that are inaccessible to a position with similar current income but a thinner historical base. Present-state comparisons can consequently understate historically accumulated differences in generative opportunity.

15.13.7 Dissipation

Dissipation concerns decline in practical availability, organization, convertibility, durability, or generative efficacy without requiring an identifiable beneficiary. Its spatiotemporal structure matters because dissipation can occur gradually, at interfaces, during transmission, through failed maintenance, or after an apparently successful period of production.

Material assets depreciate; organizational knowledge can disappear through turnover; relational trust can erode; institutional memory can be lost; ecological capacity can decline; skills can become obsolete. These processes have different temporal profiles. Some are continuous, some episodic, and some remain latent until a threshold exposes the loss. A snapshot near the endpoint can therefore conceal the history through which generative capacity was dissipated.

Dissipation can also be displaced spatially. A production process can preserve profitability at one site while exporting ecological burdens or maintenance deficits elsewhere. An organization can externalize training costs to public institutions while retaining the resulting capability. Whether such processes count as dissipation, leakage, transfer, or extraction depends on the represented boundary and the presence or absence of appropriation. The categories should therefore remain mechanism-specific.

Maintenance is central to dissipation analysis. Infrastructure, capabilities, relations, institutions, and knowledge often require recurrent expenditure, renewal, documentation, care, repair, or practice. Failure to represent maintenance time can make an apparently productive system look generative when it is consuming inherited capacity faster than it reproduces it. Spacetime makes that maintenance burden visible as part of the history rather than a residual cost outside the focal transaction.

Dissipation can finally alter future option structure. Loss of tacit knowledge, closure of infrastructure, ecological degradation, or erosion of trust can remove pathways that were formerly reachable. The relevant harm can therefore exceed the contemporaneous value lost and include later capability or option foreclosure. This connection prepares the distinction between dissipation and the stronger process of extraction.

15.13.8 Extraction

Extraction concerns asymmetrical appropriation or control of value generated with material contribution from another position or shared generative configuration, accompanied by a materially relevant source-side loss of control, return, options, maintenance capacity, or future generative capacity. The spatiotemporal perspective asks how extraction is organized across pathways and horizons rather than locating it only at the moment of final appropriation.

Extraction can be spatially separated from its source. Resource extraction is the most visible case, but epistemic, relational, institutional, and data-related forms can also involve distant appropriation. Knowledge generated through local or public processes can be captured through proprietary interfaces; relational trust can be monetized by an intermediary; community-generated data can support commercial

models while governance and return remain elsewhere. The diagnosis requires evidence about provenance, control, return, and source-side consequences rather than a generic claim that value moved across a boundary.

Temporal separation can similarly obscure extraction. Immediate compensation can coexist with long-horizon depletion. A contract can appear balanced at the transfer moment while switching costs, dependency, ecological burden, capability erosion, or loss of future options emerge later. Conversely, a large intermediary return is not sufficient evidence of extraction if the intermediary performs indispensable functions under contestable and non-depleting conditions. The evaluative and mechanism-specific distinctions developed in Chapter 14 remain necessary.

Extraction can also be reproduced through institutional architecture. Property rights, licensing rules, platform standards, credential systems, procurement practices, debt contracts, and data governance can condition which positions can appropriate returns and which positions supply generative inputs. Such arrangements operate across time because they shape repeated transactions and future alternatives. Control over a pathway can therefore be more consequential than appropriation within any single episode.

The spatiotemporal representation makes return paths diagnostically important. Where value is generated, where it is appropriated, where burdens remain, and where later returns re-enter need not coincide. An extraction claim becomes stronger when these pathways can be reconstructed and when source-side generative depletion or asymmetric control persists across repeated histories.

15.13.9 Long-Horizon Return

Long-horizon return concerns value-bearing effects that become inputs into later generation, maintenance, coordination, adaptation, or transformation over extended periods. The spatiotemporal framework developed in this chapter is particularly important here because the originating process, maturation period, realization event, observation event, and later re-entry can be widely separated.

The relevant return can be financial, capability-based, relational, epistemic, institutional, ecological, or option-related. Public education can influence later organizational and civic capabilities; scientific knowledge can be reused across several technological generations; ecological restoration can support later resilience; institutional reforms can accumulate legitimacy or learning. These processes should be evaluated with time horizons appropriate to their mechanisms rather than with a universal cycle length.

Long-horizon return also creates attribution problems. Later outcomes usually have several contributing histories. An early investment can be enabling without being sufficient; maintenance can preserve a condition; later institutions can activate it; complementary innovations can transform its use. The originating actor therefore should not automatically receive exclusive causal or normative ownership of the later return. Temporal provenance should distinguish initiating, maintaining, activating, converting, and realizing contributions where the evidence supports those distinctions.

Intergenerational return adds a further scale transformation. Later cohorts can inherit infrastructure, knowledge, institutions, ecological conditions, liabilities, technical standards, and option structures. What returns across generations is often a transformed starting configuration rather than a conserved asset. The evaluative standpoint also can change, making re-epistemization part of the long-horizon history.

Uncertainty remains intrinsic. Later returns can depend on political stability, ecological conditions, technological change, complementary investments, maintenance, and future institutions that are unknown at the time of the originating decision. Scenario analysis, sensitivity analysis, historical comparison, and explicit uncertainty can therefore be more appropriate than a single forecast. Spatiotemporal richness should increase when the uncertainty arises from pathway structure rather than merely from noisy numerical parameters.

15.13.10 Transfer Incidence across Time and Scale

Transfer incidence integrates the preceding processes by asking which positions ultimately receive benefits, bear burdens, maintain conditions, lose access, gain control, or acquire later generative opportunity after a transfer or transmission process unfolds. The formal recipient is one position within this wider incidence architecture. A payment to an organization can affect employees, suppliers, communities, creditors, public institutions, and future users; a technology transfer can alter capability, dependency, standards, and labor demand; a legal entitlement can redistribute administrative burdens and later bargaining positions.

Incidence is therefore both temporal and multiscale. Immediate receipt can differ from later realization. A local benefit can produce a regional burden; a national rule can create heterogeneous organizational and household effects; a transnational standard can reshape local technological options; a present investment can create obligations or capabilities inherited by later cohorts. The appropriate incidence boundary depends on the research question, yet the boundary should be wide enough to retain materially relevant consequences rather than merely the easiest observable transaction.

The dimensions summarized by the value-spacetime record in Equation 15.6 provide a practical audit. Analysts can identify the value-relevant events, retain supported temporal order, reconstruct materially relevant paths, preserve value-form and provenance labels, identify scale transitions, and record distributed incidence. Different empirical methods can populate different parts of the record. Financial accounts can trace formal transfers; network analysis can reconstruct pathways; qualitative process tracing can identify mediation and conversion; spatial analysis can detect spillovers; longitudinal data can reveal delayed effects; historical inquiry can reconstruct institutional and generational incidence.

Transfer incidence should also retain non-recipients. A position can be affected because it finances maintenance, absorbs environmental burden, loses access, faces new competition, becomes dependent on an interface, or inherits a liability. Conversely, a position can benefit through spillover or capability formation without appearing in the transfer contract. The incidence problem is consequently broader than

distribution of the transferred object.

A further distinction concerns incidence and evaluation. Identifying who gains or loses access, capability, control, burden, or future opportunity does not settle how those effects should be judged. Heterogeneous value forms can create mixed incidence, and affected subjects can evaluate the same change differently. GRE therefore separates reconstruction of incidence from normative aggregation while preserving the information required for later justice and governance analysis.

The final analytical issue is closure. Tracing every downstream consequence indefinitely would make the framework unusable. Incidence analysis therefore needs a materiality criterion. The represented history can stop when additional positions, scales, or delays are unlikely to alter the claim being tested or the decision under consideration. This is the same proportionality principle used throughout the book: preserve the distinctions that materially affect explanation or evaluation, and avoid complexity that does not change the substantive result.

Proposition 15.28 (Spatiotemporal adequacy of value-process reconstruction). *A spatiotemporal reconstruction of value processes is adequate, at the resolution appropriate to the inquiry, when it distinguishes materially relevant moments of generation, transmission, transfer, conversion, propagation, recirculation, accumulation, dissipation, extraction, and return; preserves supported pathway and temporal-order relations; identifies relevant changes of scale and value form; and traces transfer incidence far enough to include materially affected positions and horizons. The reconstruction should avoid treating formal receipt as exhaustive incidence, later observation as the time of generation, propagation as conservation of value, or cross-scale aggregation as lossless when those assumptions would alter the claim.*

Proposition 15.28 gives the section its scope condition. A simple transfer can remain a simple transfer when pathway, delay, scale, and downstream incidence do not materially affect the question. A richer value-spacetime representation becomes appropriate when these dimensions change who receives value, who bears burdens, how value changes form, which pathways remain reachable, or which later possibilities are created or foreclosed. The framework thereby connects the value architecture of Chapter 14 with the event, trajectory, accessibility, sequence, spatial, and multiscale structures of Chapter 15. The next substantive step concerns intervention: how an intervention enters this spatiotemporal architecture, how its effects propagate, and how evidence can reweight the histories that remain admissible.

15.14 Spacetime of Intervention

Intervention is already a central practical concern of GRE, but generative-spacetime analysis changes what counts as an adequate representation of intervention. For many GRE questions, the action formally authorized at one moment does not exhaust the relevant intervention history. It enters a historically structured configuration through a particular point or interface, acts under temporal and spatial constraints, propagates through relations and institutions, encounters delay, generates feedback, and can alter the accessibility of later trajectories. The role of this section is to reconstruct intervention through these spatiotemporal dimensions. Its objective is to

distinguish intervention point, timing, scale, reach, delay, feedback, reversibility, historical consequence, epistemic events within intervention, and reweighting of admissible histories. The method is structural and process-oriented: it specifies what an intervention analysis should preserve when static treatment would erase materially relevant sequence, pathway, or history.

The resulting account extends the intervention methodology developed in Chapter 11 without replacing it. Earlier analysis emphasized incomplete knowledge, reversibility, monitoring, and responsible action. Generative spacetime adds a more explicit representation of where intervention enters a trajectory and how its consequences unfold through partial temporal order, relational distance, multiscale coupling, and changing accessibility. An intervention can be carefully designed in its immediate administrative form and still fail because the relevant pathway is blocked, the activation delay exceeds the institutional horizon, the intervention occurs at a mismatched scale, or feedback arrives only after practical reversibility has been lost.

Interventionist accounts of causation provide one useful methodological precedent because they distinguish causal dependence from mere association by asking how appropriately specified interventions would change outcomes (Woodward 2003). GRE uses this precedent selectively. Historical, institutional, and relational interventions are often poorly represented as isolated manipulations of one variable while all surrounding conditions remain fixed. Process-tracing and historical institutional research similarly emphasize mechanisms, sequence, and the persistence of earlier choices (Beach and Pedersen 2019; Pierson 2000). Within GRE, these traditions support a bounded intervention analysis in which the action, pathway, response, and later structural consequences remain analytically separable.

Definition 15.29 (Spatiotemporally situated intervention). Building on the book's broader intervention framework, a *spatiotemporally situated intervention* is an intervention represented together with its intervention point, temporal position, scale, accessible pathways, delays, feedback structure, reversibility conditions, and materially relevant consequences for later trajectories. The represented intervention can change, sustain, activate, suppress, redirect, or recombine relations and conditions; it need not appear only as a discrete perturbation. The representation does not imply that the intervention is exogenous to the history in which it occurs or that its consequences are uniquely attributable to the intervening actor.

Definition 15.29 gives intervention analysis a provenance requirement. The same nominal action can have different effects when introduced through different institutions, at different historical moments, or into configurations with different inherited capacities and constraints. Conversely, interventions that look different administratively can perform similar structural functions when they enter equivalent bottlenecks or alter the same accessibility relation. The analytical task is therefore to reconstruct how an intervention enters and modifies a configuration rather than to classify interventions only by policy instrument.

Table 15.14 summarizes the dimensions developed below. The table is diagnostic rather than exhaustive. A routine intervention may require only timing and reach, while a historically consequential intervention can require the full architecture.

Table 15.14: Analytical dimensions of intervention in generative spacetime

Dimension	Principal question	Representative mechanism	Characteristic analytical risk
Intervention point	Where in the represented configuration does the action enter?	Rule, interface, resource, relation, information, infrastructure, or boundary modification	Formal target can differ from operative entry point
Timing	When in the trajectory does intervention occur?	Sequence, critical window, deadline, maturity, waiting capacity	Calendar date can conceal process phase
Scale	At which resolution is action specified and realized?	Individual, organizational, institutional, territorial, transnational coupling	Intervention scale can differ from incidence scale
Reach	Which positions and pathways are practically accessible?	Networks, institutions, infrastructure, law, finance, communication	Intended scope can exceed actual accessibility
Delay	How long separates intervention, activation, realization, and observation?	Latency, accumulation, procedural lag, implementation, learning	Early evaluation can misclassify slow effects
Feedback	How do observed responses alter later action?	Monitoring, learning, adaptation, strategic response, institutional revision	Measured response can itself change the process
Reversibility	Which consequences can be withdrawn, restored, or compensated?	Exit, rollback, redundancy, restoration, switching, sunset design	Formal repeal can differ from practical reversibility
Historical consequence	How does intervention modify later starting conditions?	Capability, institution, expectation, standard, infrastructure, path dependence	Immediate outcome can understate structural consequence
Epistemic event	How does new evidence change intervention or interpretation?	Measurement, classification, discovery, testimony, model revision	Observation can be confused with underlying material change
Admissible histories	Does intervention reweight existing paths or alter which paths remain possible?	Transition-potential update, option creation, foreclosure, rule transformation	Reweighting and possibility-space transformation can be conflated

15.14.1 Intervention Point

The intervention point identifies the location in the represented economic configuration through which deliberate action first becomes operative. It can be a legal rule, organizational procedure, contractual interface, resource allocation, information channel, infrastructure node, social relation, technical standard, or boundary

condition. The administrative addressee and the operative intervention point often differ. A subsidy can be paid to a firm while its operative effect enters through financing constraints, labor retention, technology adoption, or supplier relations. A legal entitlement can be enacted centrally while practical access depends on local administrative interfaces.

This distinction is important because intervention effects depend on the structure surrounding the point of entry. An identical financial transfer can support capability formation where complementary services and institutions exist and remain weakly generative where they do not. A regulation applied to a central network intermediary can propagate widely, while a formally broad rule can have limited effect when implementation pathways are fragmented. The intervention point should therefore be represented together with the local capacities, constraints, and relations through which the action can become effective.

Intervention points can also be plural. Complex interventions often enter through several interfaces at once: finance, information, legal authority, infrastructure, and organizational practice can be deliberately coordinated. The analytical benefit of identifying the points separately is that failure or unintended consequence can then be localized. A programme can succeed at legal authorization and fail at administrative conversion; infrastructure can be built while maintenance capacity remains absent; information can be supplied while institutional incentives prevent use.

The concept should remain scale-sensitive. A node that is central in one representation can be peripheral in another. An individual school, clinic, platform, bank, ministry, community organization, or border checkpoint can each become a consequential intervention point depending on the process under study. Centrality should be established through the represented pathways rather than assumed from formal status.

15.14.2 Timing

Timing concerns the position of intervention within an unfolding process. The same action can have different consequences when introduced before a commitment, during rapid adjustment, after complementary capacities have formed, or once reinforcement has substantially narrowed alternatives. Timing therefore concerns process phase as well as calendar date.

Critical-window reasoning is relevant when a configuration is unusually sensitive to action during a bounded period. A temporary liquidity intervention can be effective before a cascade of defaults and much less effective after organizational relationships have dissolved. Educational or capability interventions can interact with life-course stages and institutional deadlines. Regulatory action can occur before a technical standard becomes widely embedded or after complementary investments make switching costly. Such examples do not establish a universal rule that earlier intervention is superior. Early action can be poorly informed, premature, or directed at a process that would have self-corrected.

Timing also interacts with heterogeneous presents. The actor deciding to intervene can operate on a different horizon from the actor bearing consequences. A ministry can face an annual budget cycle while infrastructure requires decades of

maintenance; a firm can face quarterly financing constraints while worker capability formation has a longer horizon; a household can face immediate liquidity needs while a legal remedy proceeds slowly. An intervention that is timely for one position can therefore be late or premature for another.

An adequate timing analysis should identify the process whose phase matters. Phrases such as “timely intervention” remain incomplete unless the relevant clock, sequence, threshold, deadline, or opportunity window is specified. Section 15.7 established that chronological, causal, institutional, and generative precedence are distinct. Intervention timing inherits that distinction.

15.14.3 Scale

Intervention scale concerns the resolution at which action is designed, authorized, implemented, and experienced. These scales can differ. A national policy can be implemented through municipalities, organizations, and households; an organizational intervention can have industry-wide consequences through standards or labor mobility; a local infrastructural investment can alter transnational supply or data pathways. Scale therefore identifies a relation among levels of organization rather than a simple geographic size.

Multiscale analysis is especially important when intervention authority and relevant knowledge are located at different scales. Centralized institutions can possess fiscal capacity or legal authority while local actors possess contextual knowledge. Local implementation can adapt general rules but also introduce variation, unequal access, or accountability gaps. A multiscale intervention can therefore require mechanisms for translation, coordination, feedback, and contestation across levels.

Scale mismatch occurs when the action is specified at a resolution that does not align with the process generating the problem. Individual incentives can be weak responses to institutional constraints; local interventions can be overwhelmed by transnational financial or technological structures; broad national rules can miss highly localized ecological or infrastructural conditions. The existence of mismatch does not imply that the intervention should simply move to a larger scale. Appropriate action can require coupled interventions operating at several scales.

Section 15.12 represented cross-scale coupling as directional, lag-sensitive, and potentially transformative. Intervention analysis should retain the same caution. Effects that move across scales can change form during aggregation or translation. Organizational compliance, for example, can produce individual burdens that disappear in aggregate performance indicators, while local experimentation can become institutional reform only after translation into recognized categories and procedures.

15.14.4 Reach

Reach concerns the set of positions, relations, and possible continuations that an intervention can practically affect through available pathways. Intended coverage and practical reach can differ substantially. A formally universal programme can fail to reach subjects who lack documentation, mobility, language access, digital connectivity, institutional trust, or compatible technical systems. A narrowly targeted in-

intervention can propagate more widely through networks, supply chains, imitation, expectations, or ecological pathways.

Reach is directional and mechanism-specific. An institution can transmit a rule to subordinate organizations while feedback in the opposite direction remains weak. Financial resources can reach a recipient while the knowledge required for effective conversion does not. Information can propagate widely while legal authority remains local. The relevant question is therefore which component of the intervention reaches which position through which pathway.

Causal and generative accessibility, developed in Section 15.6, provides the appropriate evidential boundary. A reachable position is not automatically affected, and observed change at a reachable position is not automatically caused by the intervention. Stronger attribution requires evidence that the relevant pathway was activated and contributed to the effect. Reach analysis identifies the architecture within which such causal claims can be investigated.

Intervention reach can also transform itself. Infrastructure can create new access paths; standardization can increase interoperability; trust-building can reduce relational distance; legal recognition can open institutional pathways. Conversely, exclusionary design, technical lock-in, destroyed infrastructure, or loss of trust can narrow future reach. Intervention therefore can modify the accessibility structure through which later intervention becomes possible.

15.14.5 Delay

Delay separates intervention from activation, realization, observation, or feedback. These delays have different meanings. Administrative authorization can precede implementation; implementation can precede capability formation; material effects can precede measurement; monitoring can identify change only after the process has already moved into a less reversible state. Treating these lags as one generic delay can obscure both causal attribution and practical decision making.

The delayed-generation grammar of Section 15.9 is therefore directly relevant. An intervention can create a latent capacity that is activated only when complementary conditions appear. Repeated interventions can accumulate until a threshold is crossed. A long-horizon consequence can be generated through continued maintenance rather than at the initial intervention moment. Observation can lag behind material change because data, categories, or institutional recognition are delayed.

Delay also affects intervention evaluation. Early evaluation can classify a slow intervention as ineffective; late evaluation can attribute outcomes to an intervention after competing processes have become important. A fixed evaluation date can therefore be inappropriate when value forms and harms mature on different horizons. Financial stabilization, capability formation, ecological restoration, institutional trust, and knowledge production can each have different temporal profiles.

Delay can itself be distributed unequally. Subjects with reserves, legal support, social networks, or institutional recognition can survive waiting periods that others cannot. A delayed benefit can therefore be effectively inaccessible to positions facing immediate liquidity, health, housing, or legal constraints. The evaluation of interven-

tion delay should include who can wait, who bears interim burdens, and whether the intervention preserves viable participation during the delay.

15.14.6 Feedback

Feedback concerns information generated by the intervention process that enters later interpretation or action. It can include outcome measures, complaints, behavioral adaptation, market response, institutional learning, implementation data, scientific evidence, and affected-subject testimony. Feedback can support revision, continuation, scaling, rollback, or reinterpretation.

Feedback should be distinguished from monitoring alone. Monitoring produces or collects observations; feedback exists when those observations materially influence later decision or process. The distinction matters because institutions can collect extensive data without changing action. Conversely, informal feedback through worker behavior, community response, market exit, or organizational adaptation can alter the intervention even when formal monitoring is limited.

Feedback is also potentially endogenous. Subjects respond strategically to rules, indicators, incentives, and expectations. A measurement that controls funding can alter behavior toward the measured criterion. Public anticipation of policy can change market behavior before implementation. The intervention therefore can modify the evidence subsequently used to evaluate it. Such feedback does not invalidate evaluation, but it requires the measurement process to be treated as part of the intervention history rather than as an external observation window.

Adaptive intervention benefits from feedback when revision rules remain proportionate to uncertainty. Excessively rapid response can convert noise into policy volatility, while delayed response can allow avoidable harm or lock-in to accumulate. The appropriate feedback cadence depends on the speed of the underlying process, the reliability of measurement, the cost of revision, and the consequences of waiting.

15.14.7 Reversibility

Reversibility concerns the practical possibility of withdrawing, modifying, compensating, or restoring the consequences of an intervention. Formal reversibility is only one part of this problem. Repealing a rule does not automatically restore capabilities lost during its operation, dissolve investments organized around it, recreate closed organizations, rebuild trust, restore ecological conditions, or recover foreclosed options.

Practical reversibility is therefore path-sensitive. An intervention can become progressively harder to reverse as complementary investments accumulate, expectations stabilize, contracts are signed, infrastructures are built, or skills and organizations reorganize around the new arrangement. Increasing-returns and path-dependence research provides relevant precedents for such reinforcement (Arthur 1989; Pierson 2000). The appropriate claim is mechanism-specific: persistence or political difficulty alone does not establish lock-in or irreversibility.

Reversibility can be designed. Pilot programmes, sunset clauses, modular infrastructure, redundancy, staged commitments, exit rights, data portability, compensa-

tion mechanisms, and preserved alternatives can reduce the cost of correction. Such design is particularly valuable under substantial uncertainty. It does not eliminate risk, and some interventions cannot be made fully reversible, but it changes the distribution of future options.

Reversibility also has an incidence structure. A policy can be reversible for the institution that authorized it and effectively irreversible for subjects who reorganized their lives around it. A technology can be replaceable for a large organization and prohibitively costly to replace for dependent users. Analysis should therefore ask reversible for whom, over what horizon, at what cost, and with respect to which value-bearing conditions.

15.14.8 Historical Consequence

Historical consequence concerns the way an intervention changes the starting conditions inherited by later action. Immediate success or failure is only one component. An intervention can alter capabilities, institutions, expectations, infrastructures, standards, relations, ecological conditions, and option structures in ways that remain active after the original programme or decision has ended.

This historical perspective prevents evaluation from treating the post-intervention configuration as if it were independent of the intervention's process. Training can leave capability even when the original job programme ends. Infrastructure can reorganize settlement or investment. Emergency institutions can become permanent routines. A temporary rule can establish a technical standard around which later complementary investment accumulates. Conversely, an intervention can generate distrust, dependency, maintenance liabilities, or institutional burdens that persist after its immediate objective has been met.

Historical consequence should be attributed with care. Long-term change can reflect many subsequent events, and temporal distance weakens simple causal inference. Stronger claims require a plausible transmission mechanism and evidence of continuity, reinforcement, or institutionalization. Comparative and process-sensitive methods can help reconstruct such paths (Abbott 2001; Beach and Pedersen 2019). GRE uses historical consequence to widen the evaluation window without converting every later event into an effect of the original intervention.

Historical consequence also changes the baseline for later intervention. Once capabilities, institutions, expectations, or pathways have changed, a later policy acts on a different configuration. Repeated intervention should therefore not be evaluated as independent trials drawn from an unchanged population. Earlier intervention can alter both the process and the subjects through which later intervention operates.

15.14.9 Epistemic Events within Intervention

Intervention can contain epistemic events that materially change how the process is understood or governed. New evidence, revised categories, measurement, testimony, discovery of an unintended consequence, or a model failure can change the interpretation of the current configuration even before material resources or formal rules change.

These epistemic events can affect several layers at once. They can revise the estimated effectiveness of an intervention, change which subjects are recognized as affected, reveal a blocked pathway, alter risk assessment, or redefine the object being governed. An unemployment programme, for example, can be reinterpreted when evidence shows that observed non-participation reflects care obligations or documentation barriers rather than unwillingness to work. The epistemic event changes the represented problem and therefore the set of plausible interventions.

The timing of epistemic events matters. Evidence discovered before a commitment can shape design; evidence discovered during implementation can support adaptation; evidence discovered after practical irreversibility can support compensation or institutional learning but cannot restore every foreclosed option. The value of information is therefore partly spatiotemporal: the same evidence can have different practical significance depending on when it becomes available and which pathways remain open.

Epistemic events should also be distinguished from the underlying material events they reveal. A newly observed harm can have existed before observation. A new category can improve recognition without creating the underlying condition at that moment. At the same time, classification and measurement can become intervention events themselves when they alter eligibility, funding, legitimacy, or behavior. The epistemic architecture is therefore reflexive rather than merely observational.

15.14.10 Support and Admissibility of Future Histories

The final spatiotemporal question concerns how intervention changes the represented set of future histories. Section 15.3 distinguished history weights from the deeper transformation of admissible trajectories. An intervention can alter the relative support for already accessible continuations, or it can change the accessibility structure so that some histories become newly possible while others become practically foreclosed.

Epistemic events provide a clear case of evidential or decision-support reweighting without immediate structural change. Equation 15.2 represented new evidence as an update to a typed transition-potential profile. A credible warning, new measurement, or revised forecast can make one policy path more strongly supported and another less strongly supported even before institutions or material resources change. At this stage the change is in represented or decision support. Where the epistemic event subsequently changes expectations, authorization, coordination, investment, or behavior, it can also change practical accessibility. Neither case implies that the world literally contains numerical history weights.

Interventions can also alter the admissible history family itself. New infrastructure can create routes that did not previously exist; legal recognition can make participation institutionally possible; capability formation can open occupations or organizational roles; destroyed infrastructure can close paths; new technical standards can enable interoperability while foreclosing incompatible alternatives. Section 15.11 treated these changes as structural transformation rather than simple movement inside an unchanged possibility space.

The distinction matters for evaluation. An intervention can improve an immedi-

ate outcome while narrowing later histories, or impose a short-term burden while preserving or expanding future options. It can reduce uncertainty by stabilizing one pathway, yet stabilization can also create lock-in. An adequate assessment therefore asks which histories become more or less supported, which become newly accessible or inaccessible, who controls that transformation, and how reversible the change remains.

Proposition 15.30 (Intervention-history adequacy). *A spatiotemporally adequate intervention analysis should preserve, at the resolution appropriate to the inquiry, the intervention point, timing, scale, reachable pathways, materially relevant delays and feedback, reversibility conditions, and consequences for later trajectories. Where new evidence changes decision support, the analysis should distinguish reweighting of represented support, change in practical accessibility among already admissible histories, and structural change in the set of admissible histories. These requirements strengthen intervention analysis without establishing exclusive causal attribution, universal controllability, or the normative desirability of intervention.*

Proposition 15.30 gives the section a proportionality principle. Simple interventions in stable environments can be analyzed with much less structure. Greater spatiotemporal resolution becomes necessary when sequence, delay, reach, scale, feedback, reversibility, or transformation of future accessibility materially changes the explanatory or practical conclusion. In this way, generative spacetime does not make intervention analysis maximally complex by default. It specifies which historical distinctions should remain visible when intervention itself becomes part of the process through which later economic possibility is generated.

15.15 Historical Re-Epistemization

This section develops historical re-epistemization as the closing epistemic problem of generative-spacetime analysis. Its role is to explain how later evidence, categories, models, evaluative standpoints, and reconstructive methods can change what can responsibly be known or claimed about an earlier economic trajectory without implying that the earlier material history has itself been rewritten. The objective is to distinguish revision in the warranted reconstruction of the past from a claim that the underlying past process itself changed merely because the present epistemic relation to it changed. The discussion proceeds through changing evidence, categories, models, evaluation, retrospective reconstruction, future recognizability, and preservation of historical trace. The method is historical and reflexive: present inquiry is itself located within a later configuration whose concepts, records, institutions, technologies, and practical concerns differ from those available to earlier actors.

This distinction matters throughout GRE. A harm can have existed before it was measured. A capacity can have been economically consequential before a statistical category represented it. An institution can have shaped access before researchers possessed a model able to reconstruct the mechanism. Conversely, later evidence can overturn an earlier interpretation without establishing that contemporary actors could reasonably have reached the same conclusion from the evidence available to them. Historical inquiry therefore requires at least three temporal distinctions: the

time of the economic condition or event, the time at which evidence about it became available or preservable, and the later time at which that evidence is interpreted, recombined, or judged.

Process-sensitive social inquiry already emphasizes that temporality is not a decorative dimension added after causal analysis; the organization of evidence, cases, events, and sequences affects the claims that can be sustained (Abbott 2001; Beach and Pedersen 2019). Conceptual history likewise shows that the categories through which actors understand historical time can themselves change (Koselleck 2004). Classification studies add a related point: categories and standards are infrastructures of visibility and administration rather than neutral labels attached to a fully pre-given world (Bowker and Star 1999). GRE draws on these traditions for a narrower purpose. It treats historical knowledge about economic processes as revisable while preserving provenance concerning what was observed, classified, modeled, or evaluatively available at different moments.

Definition 15.31 (Re-epistemization). Specializing the earlier book-wide definition to generative-spacetime analysis, *historical re-epistemization* is a historically situated revision of the evidential, classificatory, model-based, interpretive, or evaluative conditions under which an earlier economic trajectory can be responsibly represented and assessed. Re-epistemization can change the warranted description, reconstructed event sequence, explanation, attribution, or evaluation of the past without implying that the underlying past process changed merely because its later representation changed. An adequate reconstruction preserves, where materially relevant, the provenance of earlier evidence and categories together with the later grounds for revision.

Definition 15.31 makes revision compatible with historical restraint. The later standpoint may possess better data, stronger methods, broader testimony, or concepts unavailable earlier. It can therefore support claims that an earlier standpoint could not. Yet later inquiry should avoid replacing the earlier epistemic situation with the present one. A well-specified re-epistemization states both what is newly knowable and why that knowledge became available only later.

Table 15.15 summarizes the principal dimensions developed in this section.

15.15.1 Changing Evidence

Available evidence and the warranted reconstruction of an earlier economic trajectory can change without implying that the underlying historical process itself changed. New archives can become available; administrative records can be digitized; datasets can be linked across institutions; oral testimony can be collected; previously inaccessible corporate or governmental records can be released; and improved measurement can reveal a condition that earlier instruments recorded poorly. Historical re-epistemization therefore begins by distinguishing the production, preservation, availability, and interpretation of evidence.

The distinction between newly generated evidence and newly accessible historical evidence is important. A contemporary survey about a past event is new evidence produced later, whereas an archival ledger opened after a confidentiality period is older evidence newly accessible to inquiry. A newly constructed longitudinal dataset

Table 15.15: Analytical dimensions of historical re-epistemization in GRE

Dimension	Epistemic change	Diagnostic question
Evidence	New, recovered, linked, or reinterpreted records	What became observable later, and why was it absent, inaccessible, or differently interpreted earlier?
Categories	Revised classifications and conceptual boundaries	Which phenomena become newly visible, grouped, separated, or administratively consequential under the revised category?
Models	Changed explanatory or representational structure	Which earlier observations acquire a different interpretation under the revised model, and what assumptions changed?
Evaluation	Revised standards, affected positions, or value frames	Did the empirical description change, the normative appraisal change, or both?
Reconstruction	New ordering, mechanism, or trajectory account	Which parts of the reconstructed history are observed, inferred, contested, or still unresolved?
Future recognizability	Conditions for later detection and interpretation	Which present processes are likely to remain legible to future inquiry, and which may disappear from the record?
Historical trace	Preservation of provenance and earlier representations	Which records, categories, model versions, uncertainties, and institutional contexts need to remain recoverable for later revision?

may combine historical records that existed separately but whose joint pattern had not previously been visible. Each case has different inferential limitations. Memory can degrade or be reconstructed; archival records reflect the institutional purposes for which they were created; linked datasets inherit classification changes and missingness; and records surviving into the present need not constitute a neutral sample of the activity that occurred. Documentary research therefore requires attention to provenance, institutional production, authenticity, representativeness, and the conditions of preservation (Scott 1990).

Later evidence can also alter causal reconstruction. A policy once understood primarily through aggregate outcomes can be reinterpreted when disaggregated records reveal heterogeneous incidence. A programme that appeared ineffective can look different once implementation records show that intended services never reached large parts of the target population. Conversely, apparently compelling retrospective associations can weaken when new evidence reveals prior trends, alternative mechanisms, or institutional changes that occurred between the nominal intervention and the measured outcome. Process tracing is useful here because the strength of the revised claim depends on the relation between evidence and a specified mechanism rather than on chronology alone (Beach and Pedersen 2019).

Changing evidence should not erase the earlier information set. For intervention and responsibility analysis, what later researchers know can differ substantially from what earlier decision makers could reasonably have known. A later-discovered risk can justify revision of present understanding and future policy while leaving open a separate question about the epistemic responsibility of actors who acted before the

evidence existed or became credible. GRE therefore records both the later evidential update and the historical availability of the evidence when the earlier decision was made.

This temporal provenance also matters for long-horizon processes. Ecological depletion, cumulative health effects, institutional erosion, technological dependence, and intergenerational capability changes can become detectable only after a long observational lag. Delayed observation should be separated from delayed generation, as Section 15.9 established. Historical re-epistemization begins when later evidence changes the warranted account of when the process began, through which pathway it propagated, or which earlier signs were visible but unrecognized.

15.15.2 Changing Categories

Economic history is recorded through categories. Employment, household, occupation, disability, firm, migration status, sector, asset, debt, care work, environmental loss, and many other objects of analysis depend on classificatory decisions. When categories change, the same historical record can become differently legible. Historical re-epistemization therefore requires attention not only to more data but also to the conceptual and institutional vocabulary through which data were produced.

Categories have at least three roles. They organize observation, structure administration, and shape practical consequences. A classification can determine which cases enter a dataset, who becomes eligible for support, how an institution assigns responsibility, or which activities count as productive. Bowker and Star's analysis of classification and standards is especially relevant because it shows how classificatory infrastructures organize visibility while becoming difficult to see precisely when they function routinely (Bowker and Star 1999). Hacking's historical work similarly emphasizes that categories and styles of reasoning can emerge historically rather than merely name timeless kinds (Hacking 2002).

A later category can reveal a pattern that earlier categories obscured. Historical records may, for example, contain activities later recognized as unpaid care, precarious work, environmental liability, platform labor, or a distinct form of institutional exclusion even when contemporary administrators did not classify them that way. Reclassification can make previously dispersed observations analytically coherent. Yet it also creates a risk of anachronism. A present category may not map cleanly onto earlier institutions, practices, identities, or meanings. The task is therefore to preserve both the analytical gain of the new category and the historical specificity of the older one.

Category revision can also change the represented population. When a statistical office changes an occupational classification, a legal system revises the definition of a worker, or a health institution changes a diagnostic category, time-series discontinuities can appear even if the underlying population changes little. Conversely, apparent continuity can be produced by maintaining a category whose practical meaning has changed. Historical re-epistemization should therefore record category versions, inclusion rules, boundary changes, and bridge mappings where they exist rather than treating labels as temporally invariant variables.

The economic consequences of categories further complicate retrospective in-

terpretation. Once categories control eligibility, taxation, credit, migration status, credentialing, insurance, or access to services, classification becomes part of the process being studied. Later researchers then confront a reflexive history: the category shaped behavior and resource allocation, while the resulting records subsequently appear to describe the population that the category helped constitute. Re-epistemization should keep this performative relation visible rather than treating classifications as passive descriptors.

15.15.3 Changing Models

Models organize relationships among evidence, mechanisms, states, and possible histories. When a model changes, earlier observations can acquire a different explanatory significance even when the observations themselves remain unchanged. Historical re-epistemization therefore includes model revision as a distinct source of changed knowledge.

The relevant change can be modest. A revised statistical specification can alter estimated relationships after accounting for previously omitted heterogeneity. A network representation can reveal dependence that aggregate averages conceal. A partial-order reconstruction can avoid an unsupported total chronology. A multi-scale representation can show that a local process and a national trend were not contradictory but operated at different resolutions. In each case, a changed representational structure alters what can be responsibly inferred from earlier evidence.

More substantial revisions can change the questions that a model makes possible. An equilibrium model can foreground coordination among contemporaneous variables, while a path-dependent model foregrounds reinforcement and historical sequence. A fixed-state-space model represents movement among predefined states, whereas the structural-transformation framework of Section 15.11 allows the set of relevant degrees of freedom or admissible futures itself to change. These representations need not be ranked universally. Their adequacy depends on the local research problem, and model revision should be justified by explanatory or evidential need rather than by formal novelty.

Scientific inquiry has long recognized that problem selection, evidence interpretation, and acceptable explanation can depend on historically situated theoretical commitments (Kuhn 1962). GRE adopts a modest implication rather than a complete philosophy of scientific change: an earlier model should be interpreted through the assumptions and evidence under which it was used, while a later model can be assessed for whether it preserves, revises, or rejects those assumptions. Re-epistemization is weakened when the new model silently inherits parameters, categories, or causal meanings that belonged to the old one.

Model plurality is particularly important in retrospective reconstruction. Several models can remain compatible with the same historical observations while implying different mechanisms or counterfactuals. Later evidence can narrow the set, yet underdetermination may remain. The goal of re-epistemization is therefore not always convergence on one final model. It can instead clarify which interpretations remain viable, which have lost evidential support, which distinctions were previously unavailable, and where uncertainty remains structurally unresolved.

15.15.4 Changing Evaluation

Historical evaluation can change even when the empirical reconstruction changes little. Later societies, institutions, or affected groups can apply different evaluative standards to an earlier allocation, technology, labor relation, environmental practice, or institutional arrangement. GRE therefore distinguishes changed evaluation from changed evidence and from changed causal explanation.

This distinction is essential because an evaluative revision can be warranted without implying that earlier observers misunderstood every empirical fact. A production system can have been efficient under a narrow output criterion while later being judged harmful once ecological depletion, unpaid care burdens, health effects, or intergenerational liabilities become normatively relevant. A policy can have achieved its stated administrative target while later evidence and broader affected-subject participation reveal distributive or relational harms outside the original evaluation boundary. The evaluative frame has widened, even if some earlier factual claims remain correct.

Valuation research shows that metrics, rankings, monetary representations, and evaluative categories are socially organized and can shape the practices they evaluate (Espeland and Stevens 1998; Espeland and Sauder 2007; Lamont 2012). Historical re-epistemization therefore asks which evaluative devices were available at the time, what they made visible, what they excluded, and how later evaluative frameworks reorganize the interpretation of earlier outcomes. The later framework should not be treated as neutral simply because it is newer. It also has categories, exclusions, and institutional interests that require scrutiny.

Changing evaluation can arise from new affected positions entering the evaluative process. Workers, communities, future generations represented through present institutions, or groups previously excluded from formal decision making can supply evidence and normative claims that alter what counts as a relevant consequence. This can be epistemic as well as normative. Testimony can reveal mechanisms or burdens that aggregate indicators missed. GRE therefore avoids a sharp separation in which facts belong to experts and values belong to stakeholders; affected positions can contribute to both evidential and evaluative revision, while neither contribution becomes automatically decisive.

Historical judgment should preserve the difference between evaluating an earlier outcome from a later standpoint and assigning responsibility to earlier actors. The first asks how the trajectory appears under a later and perhaps better-supported value framework. The second asks what obligations, alternatives, and knowledge were available to actors at the time. These questions can support different conclusions. Re-epistemization is historically disciplined when it makes that difference explicit.

15.15.5 Retrospective Reconstruction

Retrospective reconstruction combines evidence, categories, models, and evaluation into a later account of an earlier trajectory. Its distinctive problem is that the endpoint is already known. That knowledge can improve inquiry by identifying consequences

that require explanation, while also creating hindsight bias by making realized paths appear more inevitable, more visible, or more coherent than they were prospectively.

A disciplined reconstruction therefore distinguishes the realized history from the set of alternatives that were plausibly accessible at earlier moments. Section 15.8 treated historical branching in this way: unrealized alternatives should be retained only when historical evidence supports their practical accessibility. Later knowledge of the realized outcome should not be projected backward as though earlier actors knew which branch would prevail.

Retrospective reconstruction also requires explicit evidential status. Some events are directly recorded; others are inferred from traces; some order relations are strongly established while others remain uncertain; and some causal links are model-dependent. The trajectory-complex framework of Section 15.3 is useful precisely because it can leave unresolved relations unordered and distinguish observed from reconstructed components. A coherent narrative is not strengthened by hiding uncertainty that the evidence cannot resolve.

The method can be represented as a layered provenance record rather than a single definitive narrative. At a minimum, a strong reconstruction identifies the historical event or condition, the surviving trace, the later evidential operation through which the trace becomes usable, the categories and models applied, and the level of confidence attached to the resulting claim. This preserves the difference between archival survival and evidential sufficiency, as well as between an interpretation and the record that supports it.

Comparative historical analysis and process tracing provide methodological precedents for this discipline because both make temporally situated cases, mechanisms, sequence, and causal evidence explicit (Mahoney and Rueschemeyer 2003; Beach and Pedersen 2019). GRE extends the concern to generative spacetime: retrospective reconstruction should ask not only what happened and why, but also which capabilities, relations, constraints, boundaries, and future pathways were transformed along the way.

15.15.6 Future Recognizability

Historical re-epistemization has a prospective implication. Future researchers can reinterpret present processes only if enough of the present becomes recognizable later. *Future recognizability* concerns the conditions under which a process occurring now leaves traces that later inquiry can identify, contextualize, and relate to subsequent trajectories.

Recognizability depends on more than data volume. A process can generate enormous quantities of records while remaining difficult to reconstruct if identifiers change, metadata are missing, categories drift, proprietary systems disappear, or records cannot be linked across institutions. Conversely, a relatively small but well-documented archive can preserve high analytical value when provenance, definitions, version history, and institutional context remain available. The design of records is therefore part of the future epistemic accessibility of the present.

Some economically consequential processes are systematically easier to record

than others. Formal transactions, registered employment, audited financial flows, and legally documented ownership often leave durable traces. Informal care, tacit knowledge, relational maintenance, unrecorded exclusion, environmental degradation outside monitored indicators, and failed or abandoned alternatives can be much less visible. Historical archives can therefore inherit the asymmetries of the institutions that produced them. Future recognizability is unequal before future interpretation begins.

This asymmetry can become power-relevant. Actors controlling platforms, archives, administrative systems, proprietary data, or classification infrastructures can influence which histories remain reconstructable. Data retention, documentation standards, public records, interoperable metadata, and institutional memory therefore have implications beyond administrative convenience. They shape the future evidential field through which accountability, learning, and historical attribution become possible.

Future recognizability should not be maximized without qualification. Preservation can conflict with privacy, confidentiality, safety, intellectual property, or the legitimate interests of people who should not remain indefinitely exposed through historical records. GRE therefore treats recognizability as a design problem involving selective preservation, governed access, provenance, and proportionality. The objective is sufficient trace for responsible future reconstruction, not indiscriminate retention of every available datum.

The concept also applies to unrealized alternatives. Institutions usually document what was authorized, funded, or implemented more carefully than what was considered and rejected. Yet later analysis of path dependence, critical junctures, or intervention can require evidence about alternatives that were plausibly available but not chosen. Preserving decision rationales, option sets, dissent, uncertainty, and rejected proposals can therefore increase the recognizability of historical branching without claiming that every imagined alternative was practically accessible.

15.15.7 Preservation of Historical Trace

Preservation of historical trace provides the practical counterpart to future recognizability. A historical trace is any surviving record, material remainder, institutional memory, dataset, document, testimony, classification, model version, or other evidential residue through which a later inquiry can reconstruct part of an earlier trajectory. Preservation concerns not only keeping records but retaining enough provenance for their meaning to remain interpretable.

A robust trace architecture preserves layers rather than only final outputs. A later model should ideally be distinguishable from the data used to construct it. Revised categories should not erase earlier category definitions. Cleaned datasets should retain documentation of transformation from source records. Updated indicators should preserve version histories and bridge rules where possible. Institutional decisions should preserve the rationale, uncertainty, and alternatives that shaped them rather than only the final authorization. These practices allow future re-epistemization to reconstruct how knowledge changed rather than merely comparing two final conclusions.

Historical trace also includes absence. Missing records, destroyed archives, unmeasured processes, undocumented populations, and categories that excluded relevant activity are themselves part of the epistemic history when their absence can be established. The goal is not to infer freely from silence. It is to record where the evidential field is incomplete and to avoid converting archival survival into a claim that only recorded processes mattered.

Preservation has costs and risks. Storage, curation, migration, documentation, privacy protection, legal compliance, and institutional continuity all require resources. Some records contain sensitive information or can expose affected subjects to future harm. A responsible trace architecture therefore needs retention rules, access governance, anonymization or controlled disclosure where appropriate, and explicit decisions about what should not be preserved. The historical value of a trace does not automatically override other ethical or legal obligations.

GRE's broader methodological implication is that epistemic infrastructures participate in generative spacetime. Records, classifications, model versions, and archives affect what later societies can learn from earlier interventions, value processes, institutional changes, and harms. They can therefore influence future policy, accountability, compensation, institutional memory, and the reweighting of later histories. Preservation is not neutral, but neither is forgetting.

Proposition 15.32 (Trace-preserving re-epistemization). *A historically adequate re-epistemization should distinguish revisions in the warranted reconstruction of a past trajectory from changes attributed to the underlying historical process; preserve the provenance and historical availability of materially relevant evidence; mark the inferential status of reconstructed events and pathways; and retain enough trace to make later revision intelligible without treating archival completeness as attainable or unrestricted preservation as automatically desirable. Where later knowledge alters present judgment of an earlier process, the analysis should state which part of the revision concerns empirical description, causal explanation, normative evaluation, or the recognizability of previously obscured positions.*

Proposition 15.32 gives the section a proportionality principle. Modest trace requirements can suffice when categories, records, and causal interpretations are stable. Greater provenance is warranted when later evidence changes responsibility, classifications are performative, records are unevenly preserved, or model revision alters the represented mechanism. Re-epistemization disciplines revision without claiming a final view from nowhere.

15.16 Power and Governance in Generative Spacetime

Generative spacetime becomes economically consequential for power and governance when positions within the same relational configuration differ in their temporal flexibility, practical reach, ability to impose or survive delay, access to viable exit, and influence over the future pathways available to others. This section closes Chapter 15 by identifying these power-relevant asymmetries while preserving a boundary between spatiotemporal description and the fuller theory of power developed in Chapter 16. Its objective is therefore diagnostic and synthetic: to show how

the temporal, spatial, relational, and historical structures developed across this chapter can distribute effective possibility unevenly. The discussion proceeds through unequal temporal position, reach, delay capacity, exit capacity, and influence over future options before stating the interface among generative spacetime, power, justice, and governance. The method is structural and relational. Spatiotemporal asymmetry is treated as a condition that can contribute to power under specified relations; it is not treated as sufficient evidence of power, domination, injustice, or defective governance.

The analysis reuses the architecture already established in this chapter. Heterogeneous presents identify unequal temporal positions; causal and generative accessibility identify differentiated reachability; sequence and delayed generation identify the consequences of timing and latency; path dependence identifies historically produced switching constraints; structural transformation identifies changes in constraints, capacities, boundaries, generative rules, and admissible futures; intervention analysis identifies reach, delay, reversibility, and the reweighting of histories. Section 15.16 therefore introduces no independent ontology of power. It asks what follows when these previously defined dimensions are distributed asymmetrically across actors, organizations, institutions, or other economically relevant positions.

Definition 15.33 (Generative-spacetime asymmetry). A *generative-spacetime asymmetry* is a relational difference among economically interacting positions in one or more of the following dimensions: temporal flexibility or exposure, practical reach through causal or generative pathways, capacity to impose or absorb delay, access to viable exit pathways, or capacity to alter the accessibility, support, or persistence of future trajectories. The definition identifies an asymmetry in effective position within a generative-spacetime configuration. Whether that asymmetry constitutes, supports, or reproduces power requires additional analysis of dependence, control, constraint, authorization, institutionalization, historical reproduction, or other mechanisms relevant to the case.

Definition 15.33 preserves an important analytical separation. A difference in timing, reach, or exit can be benign, temporary, functionally appropriate, or voluntarily accepted. A hospital may legitimately prioritize urgent patients; a regulator may possess wider inspection reach than a regulated firm; an emergency authority may temporarily accelerate decisions that normally require longer review. The existence of an asymmetry therefore does not settle its normative or political meaning. The definition marks where the spacetime architecture becomes relevant to later analysis of power.

Table 15.16 summarizes the principal dimensions considered in this closing section. The dimensions frequently interact. Limited exit can increase exposure to delay; unequal reach can make future alternatives visible to one position and obscure them from another; temporal advantage can be converted into earlier access to scarce pathways; control over standards or infrastructure can alter the future option structure of many positions at once. The table should therefore be read as an analytical map of coupled asymmetries rather than as a list of independent forms of power.

Table 15.16: Power-relevant asymmetries in generative spacetime

Dimension	Spatiotemporal question	Power- and governance-relevant implication
Temporal position	Who can wait, accelerate, defer, revise, or sustain long horizons?	Unequal urgency and flexibility can change bargaining positions and effective opportunity.
Reach	Which positions, resources, institutions, information, and decision points can be reached, and in which direction?	Directional access can distribute intervention capacity, observation, contestation, and learning unevenly.
Delay capacity	Who can impose delay, survive it, shift its costs, or benefit from it?	Waiting can become a relational burden whose incidence changes feasible action.
Exit capacity	Which alternative relations or pathways remain practically reachable, and at what switching cost?	Restricted exit can deepen dependence even where formal choice remains available.
Future options	Who can reweight, create, close, or stabilize admissible trajectories?	Influence over future possibility can extend beyond control of present resources or commands.
Governance interface	Which rules and institutions organize these asymmetries and their revision?	Governance affects the architecture through which power-relevant temporal and accessibility differences are produced, limited, contested, or transformed.

15.16.1 Unequal Temporal Position

Unequal temporal position is the first route through which generative spacetime becomes power-relevant. Section 15.4 defined heterogeneous presents as contemporaneous configurations in which interacting positions differ in horizons, deadlines, inherited commitments, update frequencies, waiting times, or anticipated futures. Such differences can remain descriptively modest until temporal flexibility affects who can refuse, postpone, accelerate, reconsider, or continue participating in an economic relation. At that point, time becomes part of the effective structure of action.

The simplest case concerns unequal urgency. A household facing an immediate rent payment, a worker whose visa or income depends on rapid acceptance of an offer, a small organization approaching the end of a grant, and a large institution with substantial reserves can all encounter the same nominal choice while occupying different temporal positions. The position able to wait may preserve alternatives that disappear for the position facing an approaching deadline. The resulting asymmetry can alter bargaining even when the formal menu of options appears identical. The economically relevant difference lies in how long each option remains viable and which costs accumulate while a decision is deferred.

Temporal advantage can also arise through acceleration. Earlier access to finance, administrative authorization, transport capacity, information, compute, legal advice, or technical deployment can allow one position to act before others. Where sequence matters, earlier action can secure scarce resources, establish standards, occupy net-

work positions, shape expectations, or create complementary investments that later entrants must accommodate. Sections 15.7 and 15.8 showed that order and historical reinforcement can change later accessibility. Temporal position can therefore have effects that persist after the original timing difference has disappeared.

Long horizons provide another form of temporal flexibility. An actor that can sustain investment, litigation, negotiation, research, or institutional participation across a long period can remain active while positions with shorter survival horizons exit. This does not imply that long horizons are intrinsically advantageous. Extended commitments can reduce adaptability, and rapid action can be valuable where conditions change quickly. The analytical point is relational: horizon length matters when it changes which strategies remain available relative to other positions in the same process.

Temporal asymmetry can also be institutionally produced. Payment schedules, review periods, waiting lists, licensing timelines, procurement rules, reporting cycles, debt maturities, and appeal procedures distribute urgency and patience unevenly. An institution can therefore alter bargaining conditions without changing the nominal rights or resource holdings of the affected positions. A remedy available only after a prolonged process may remain legally real while becoming economically unusable for a claimant unable to survive the interval. Conversely, procedural delay can protect deliberation, evidence gathering, due process, or safety. Evaluation should identify the function of the temporal arrangement and the incidence of its burdens before assigning a normative status.

The power relevance of unequal temporal position therefore lies in its effect on effective possibility. A position with greater temporal flexibility can sometimes preserve more branches of action, tolerate uncertainty longer, gather more information, or wait until another position's alternatives contract. A position under temporal pressure may accept terms that it would reject under a longer horizon. These mechanisms provide one bridge from spacetime to power, while the existence of temporal inequality alone remains insufficient to define the resulting relation as power. Chapter 16 will require the additional analysis of dependence, control, constraint, and institutional reproduction.

15.16.2 Unequal Reach

Unequal reach concerns differences in the practical ability to enter, traverse, activate, or influence causal and generative pathways. Section 15.6 distinguished structural reachability from activated pathways and from demonstrated causal contribution. The present concern is the distribution of that reachability across positions. Two actors can participate in the same economic field while one can access more institutions, resources, audiences, infrastructures, jurisdictions, datasets, or decision points than the other.

Reach is frequently directional. A platform can transmit rules or interface changes to users while individual users possess limited access to the platform's internal decision process. A lender can observe extensive financial information about borrowers while borrowers have little visibility into the lender's model or portfolio logic. A central organization can coordinate local units across a network while local par-

ticipants can communicate upward only through narrow reporting channels. Directional reach can therefore separate the capacity to affect others from the capacity to contest, observe, or revise the relation through which that effect occurs.

Generative reach matters particularly because it can alter later capacity. Access to education, finance, infrastructure, institutional recognition, professional networks, or interoperable technologies can create further pathways. Repeated access can generate capabilities that expand subsequent reach, while repeated blockage can reduce the practicality of future participation. This is one route through which accessibility and path dependence can become coupled. The mechanism remains conditional: public infrastructure, collective organization, legal reform, technical standardization, or new institutional interfaces can widen reach and interrupt cumulative disadvantage.

Unequal reach also has an epistemic dimension. Positions able to interact with more parts of a system may observe a wider range of outcomes, compare more cases, and learn more rapidly from variation. Wider reach can therefore improve strategic adaptation. Positions with narrow reach may experience only a local fragment of the configuration and may have difficulty identifying whether an adverse outcome is local, systemic, temporary, or deliberately structured. This asymmetry does not guarantee superior knowledge for the position with greater reach; large organizations can misclassify, aggregate poorly, or ignore local information. It does indicate that the architecture of observation and intervention can be unevenly distributed.

Institutional boundaries can make reach selective. Membership rules, credential requirements, jurisdiction, language, documentation, technical compatibility, property rights, and authorization procedures can open some pathways while closing others. Such boundaries can serve legitimate functions including safety, privacy, specialization, accountability, or capacity management. Their power relevance arises when access to consequential pathways is distributed in ways that shape dependence, contestability, or future capability. The analysis should therefore specify which pathway is blocked or mediated, by which institutional rule or relation, and with what consequences for later action.

Reach should also be distinguished from command. A position can possess substantial reach without directly ordering another actor to act. Infrastructure ownership, standard setting, interface design, data access, certification, intermediation, or control of key gateways can shape which interactions are possible without issuing explicit commands. This observation prepares the analysis of power without direct command in Chapter 16 while remaining within the narrower spacetime claim: the distribution and direction of access pathways can structure effective possibility before any explicit theory of power is applied.

15.16.3 Unequal Capacity to Delay

Delay becomes power-relevant when the capacity to impose, absorb, redirect, or benefit from waiting is distributed unevenly. Section 15.14 distinguished delays between authorization, implementation, activation, realization, observation, and feedback. These lags can affect actors differently. A position able to sustain the interval can retain participation until a later benefit, remedy, or decision arrives; another

can lose housing, liquidity, health, market access, legal standing, or organizational continuity before the same interval ends.

The capacity to delay should be separated into at least three relations. One position may be able to *survive delay*; another may be able to *impose delay* on a shared process; and a third may be able to *shift the costs of delay* onto others. These capacities can coincide, but they need not. A large organization may be able to prolong negotiation while preserving its own alternatives. A public agency may impose procedural waiting because of evidential or legal requirements without receiving a strategic benefit. A contractor may experience delay caused elsewhere while passing part of the financial burden to subcontractors. The incidence of waiting therefore matters as much as its duration.

Delay can transform the effective content of a right or option. A formal entitlement that is realized only after a long administrative process may be practically unavailable to a position facing immediate need. An appeal that arrives after an irreversible decision can preserve procedural form while failing to restore the lost opportunity. A payment received after a small firm has failed does not have the same generative effect as the same payment received while production can still continue. Timing and delay therefore affect the conversion of formal possibility into practical possibility.

Strategic delay can also change other actors' option structures. Waiting can allow a position to gather information, exhaust another participant's reserves, permit complementary investments to mature, or allow a temporary condition to become normalized. Yet delay can equally weaken the position that imposes it when opportunities expire or counterparties find alternatives. The effects are process-specific. A strong analysis should identify what changes during the waiting period rather than treating time itself as a resource with uniform value.

Governance can shape the distribution of delay capacity. Timelines, service standards, interim support, automatic escalation, emergency procedures, payment rules, provisional remedies, sunset clauses, and appeal design can change who bears waiting costs. Such arrangements require trade-offs. Accelerating every decision can reduce procedural quality or safety; extending every process can privilege positions able to wait. The relevant governance question is how temporal burdens and protections are distributed across the affected relations and whether the procedure preserves meaningful participation during the interval.

Unequal capacity to delay therefore links temporal structure to dependence while preserving power as a broader relational category. Delay becomes especially consequential where one position can maintain its own option set while another's contracts as time passes. This relation will reappear in Chapter 16 as one component of temporal power. Within Chapter 15, the narrower conclusion is that waiting has an incidence structure and can alter the accessibility of future trajectories asymmetrically.

15.16.4 Unequal Capacity to Exit

Exit is a spatiotemporal problem because leaving a relation requires an alternative pathway that is practically reachable over a relevant horizon. Formal permission to exit is therefore only one component of effective exit capacity. A worker can legally resign while lacking another source of income; a user can close an account while los-

ing access to an incompatible network; a locality can terminate a supplier contract while lacking substitute infrastructure; a borrower can refinance in principle while switching costs make the alternative inaccessible. Effective exit depends on the relation between current constraints and reachable continuations.

Path dependence sharpens this point. Section 15.8 treated lock-in as a condition in which accumulated commitments, complementarities, switching costs, or coordination structures substantially constrain movement toward otherwise conceivable alternatives. Exit capacity can therefore decline historically even when formal rules remain unchanged. Specialized skills, proprietary formats, sunk investment, network coordination, legal obligations, reputational dependence, or infrastructure loss can make alternatives progressively more costly to reach.

Exit also has a temporal dimension. An alternative may exist eventually while remaining unavailable before a critical deadline. A worker may be able to retrain over two years but cannot bridge two months without income. A public institution may be able to replace infrastructure over a decade but cannot interrupt essential services during transition. A country may possess long-run capacity to diversify a supply chain while remaining exposed to short-run disruption. The relevant measure is therefore the accessibility of an alternative within the horizon in which the current relation constrains action.

Exit capacity can be asymmetric within the same relation. A platform can terminate a user account at low cost while the user loses accumulated contacts, records, reputation, or access to a network. A buyer can switch suppliers while a supplier that has specialized around the buyer faces large conversion costs. A public authority can redesign a programme while households or organizations that organized around its continuation bear adjustment costs. Such cases illustrate why reversibility should be analyzed for each position, as Section 15.14 emphasized, rather than assigned to a policy or institution as a single global property.

Exit remains complementary to voice, participation, and governance. Some relations concern essential goods, public institutions, territorial membership, ecological conditions, or infrastructures for which individual exit is costly, unavailable, or collectively undesirable. Exit can also shift burdens onto those who remain. A governance architecture therefore cannot be evaluated solely by maximizing individual departure options. The narrower spacetime question is whether affected positions retain viable alternative trajectories and whether the costs of switching are distributed in ways that materially alter dependence.

Exit capacity is consequently a bridge between accessibility and power. Positions with credible alternatives can often resist adverse terms more effectively because the current relation is not their only reachable continuation. Positions whose alternatives have been historically closed, delayed, or made prohibitively costly can become more dependent even in the absence of direct coercion. Chapter 16 will examine when and how this asymmetry becomes exit power or manufactured vulnerability. The present section identifies the underlying spacetime condition: alternatives have to exist, remain reachable, and remain reachable in time to matter.

15.16.5 Influence over Future Options

A particularly important connection between generative spacetime and power appears when one position can materially alter the future option structure of another. Sections 15.11 and 15.14 distinguished changes in represented or decision support, changes in practical accessibility, and structural changes in which trajectories become newly admissible or practically foreclosed. Influence over future options concerns effects on this architecture of accessibility rather than prediction of a single future outcome.

Influence over future options should not be conflated with complete control. Economic actors rarely determine future histories completely. Outcomes can remain contingent on other agents, ecological conditions, institutional responses, technological change, and events outside the relevant field. The analytically useful claim is narrower: a position can sometimes change which continuations are reachable, how costly they are, how durable they remain, or how strongly they are supported. Standards, contracts, infrastructure, credit, licensing, platform rules, organizational membership, data access, property arrangements, and public policy can each affect the future pathways available to other positions.

Several levels of influence should be distinguished. First, an actor can affect a decision inside an existing option set, for example by changing the price or timing of one alternative. Second, an actor can gate access to a pathway, making entry conditional on authorization, payment, credential, compatibility, or membership. Third, an actor can reweight a broader family of histories by changing expectations, information, incentives, or coordination. Fourth, an actor or institution can contribute to structural transformation by creating or closing pathways, changing boundaries, producing capabilities, or altering the generative rule through which later possibilities are formed. These levels differ in strength and evidential burden.

Influence over future options can extend across time. A present decision can bind later actors through debt, infrastructure, environmental change, institutional design, intellectual property, long-term contracts, or technological standards. Some commitments are valuable precisely because they stabilize expectations and make cooperation possible. Long-lived institutions, durable infrastructure, and enforceable contracts can expand collective possibilities by reducing uncertainty. The power-relevant question is therefore not simply whether present action shapes the future; many consequential economic actions do. It is how influence over future possibility is distributed, whose alternatives are preserved or foreclosed, and whether affected positions can participate in, contest, revise, or exit the relevant arrangements.

Historical branching provides a useful discipline. A claim that an actor closed an alternative should be supported by evidence that the alternative was plausibly accessible before the relevant intervention or transformation. Imagined counterfactuals should not be treated as lost options merely because they can be conceived retrospectively. Conversely, historical analysis should avoid presenting the realized path as inevitable when contemporaneous evidence shows that other continuations were materially available. A claim of influence over future options is therefore both structural and evidential.

The future-option perspective also extends analysis beyond present resource dis-

tribution. A position can possess modest current resources yet occupy a gatekeeping point that conditions access to infrastructure, credentials, standards, records, or institutional membership. Another position can hold substantial resources while having little influence over the rules that shape its long-run options. Resource holdings, reach, temporal position, exit, and option-structure influence can therefore diverge. Their conversion into distinct forms of economic power is the subject of Chapter 16.

15.16.6 Power, Justice, and Governance

The preceding analysis establishes a boundary condition for the transition from generative spacetime to power, justice, and governance. Generative spacetime identifies where positions differ in time, reach, delay, exit, and future accessibility. Power analysis becomes relevant when these differences are connected to dependence, control, constraint, and the capacity of one position to shape another's feasible action or future possibilities. Justice analysis becomes relevant when the distribution, formation, persistence, and consequences of these relations become objects of normative evaluation. Governance analysis examines institutions, rules, procedures, and collective interventions as mechanisms that organize, protect, contest, or transform the relevant relations.

These analytical tasks should remain distinguishable. Spatiotemporal asymmetry does not by itself establish power. Power does not by itself establish injustice. Governance is not reducible to restricting power, because governance can also create capabilities, coordinate collective action, preserve public goods, protect procedural conditions, maintain infrastructures, and stabilize expectations. Conversely, governance can generate or reproduce asymmetries through authorization, classification, timing, boundary design, infrastructure, and differential access. The same institutional arrangement can therefore enable one relation while constraining another.

The spacetime perspective highlights several considerations for later power analysis. First, power can operate through timing as well as through direct command. Second, dependence can arise through restricted reach or exit even where formal rights remain intact. Third, historically generated structures can preserve asymmetry after the initiating actor or event has disappeared. Fourth, influence over future options can matter even where present allocation appears relatively balanced. Fifth, the incidence of delay, reversibility, and switching costs should be evaluated position by position rather than assigned globally to a policy or system.

Justice analysis can require the same historical depth. Presently equal treatment can interact with unequal temporal positions, inherited constraints, and differently accessible futures. A policy that offers an identical formal opportunity can have unequal generative effects where some positions can wait, travel, document, finance entry, or survive failure while others cannot. A repair can restore resources without recreating lost time, dissolved relations, missed education, damaged health, or foreclosed institutional trajectories. These questions exceed the scope of Chapter 15 because they require explicit normative criteria, yet generative spacetime identifies why a purely synchronic evaluation can be incomplete.

Governance can also operate on the architecture of possibility. Rules can change access conditions; institutions can shorten or lengthen delay; infrastructure can

widen reach; interoperability and portability can reduce switching costs; procedural protections can preserve contestability; sunset clauses and staged commitments can preserve reversibility; public records can increase future recognizability; long-term investment can create capabilities that expand later options. Governance can therefore affect both realized outcomes and the spacetime through which later outcomes become possible.

A final restraint is necessary. The ability to shape future options is sometimes indispensable to collective coordination. Education systems structure learning pathways; safety regulation excludes dangerous options; environmental rules constrain extractive activity; public infrastructure channels mobility; contracts stabilize expectations by limiting unilateral revision. The relevant analytical problem concerns the relational organization, justification, distribution, contestability, and revisability of structures that shape effective possibility. Those questions belong to the next chapter's explicit treatment of power and justice.

Proposition 15.34 (Spacetime–power interface). *A generative-spacetime asymmetry becomes power-relevant when differences in temporal position, reach, delay capacity, exit capacity, or influence over admissible futures materially condition the feasible action or future trajectories of another position through identifiable relational, institutional, or infrastructural mechanisms. Such a finding establishes an interface for power analysis; it does not by itself determine whether the relation constitutes power, whether it is unjust, or which governance response is appropriate. Those conclusions require additional analysis of dependence, control, constraint, justification, participation, distribution, historical formation, and revisability.*

Proposition 15.34 closes the chapter's substantive sequence. Generative spacetime has provided a grammar for events, trajectories, heterogeneous presents, relational distance, accessibility, sequence, path dependence, delayed generation, spatial propagation, structural transformation, multiple scales, value processes, intervention, historical re-epistemization, and the unequal distribution of effective possibility. The resulting framework does not supply a complete theory of economic power. It identifies temporal, spatial, relational, and historical conditions within which such a theory can be developed. Chapter 16 can therefore begin with the more demanding question of how asymmetry becomes power and then develop the associated problems of justice and governance without treating them as synonyms for the spacetime inequalities identified here.

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