Constraint Analysis: A Causal Framework for Understanding and Influencing Complex Systems

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Abstract

This paper develops a framework for analysing complex systems based on the concept of constraint as a causal mechanism. Constraints are defined as processes involving the transfer of matter, energy, or information that enable or inhibit system behaviour. From this perspective, patterns of stability, instability, and change can be understood in terms of the configuration and alignment of constraints acting on a system.

Building on this foundation, the paper introduces constraint analysis as a structured method for examining system dynamics. The method integrates historical, current, and prospective perspectives within a single analytical process, allowing for the identification of stable attractors, the analysis of transitions between them, and the diagnosis of present system conditions. It also supports the identification of potential future configurations and the design of interventions through the reconfiguration of constraints.

The framework is applied to an illustrative case study of the English water industry, demonstrating how changes in material, structural, and cultural constraints have produced distinct attractor states and contributed to the emergence of a current condition characterised by constraint misalignment and instability. The analysis shows how the method can be used to provide causal explanations of system behaviour and to structure the exploration of alternative future trajectories.

The paper concludes by considering the broader implications of the framework, including its generalisation to physical systems, where agency-dependent elements are absent, and to epistemic systems, where constraints operate through information, interpretation, and reflexivity. In doing so, it positions constraint analysis as a domain-general approach grounded in general systems theory and a causal account of system behaviour, offering a practical tool for understanding and intervening in complex systems.

1. Introduction

This paper is the third in a series of papers on social systems theory. It builds on the theory presented in the first and second papers and also in an earlier series on general systems theory. Definitions of the terms used, some of which are from earlier papers are given in Appendix C.

Constraints may arise in two closely related forms: configurational constraints, which derive from the arrangement of system components and shape the set of possible interactions, and causal constraints, which operate directly through the transfer of matter, energy, or information to enable or inhibit system processes. While both forms are significant, the present paper focuses on causal constraints. Accordingly, unless otherwise stated, the term "constraint" will be used to refer to causal constraints.

Understanding how complex social systems behave, change, and can be influenced remains a central challenge across the social sciences and systems theory (Bertalanffy, 1968; Wiener, 1948). While many approaches describe patterns of behaviour or identify structural features, fewer provide a clear and consistent account of the causal mechanisms through which such patterns arise and are sustained (Meadows, 2008). In particular, there is often a gap between abstract systems concepts and practical methods that can be applied to real-world systems in a structured and interpretable way.

This paper addresses that gap by introducing constraint analysis as a general method for analysing complex systems. The framework builds directly on two foundations developed in earlier papers: a causal, physicalist account of systems grounded in the transfer of matter, energy, and information, and the Enhanced Morphogenetic Cycle (EMC), which describes how social systems evolve through the interaction of structure, culture, and agency. Constraint analysis may therefore be understood as the operational integration of these foundations, providing a practical means of applying general systems principles to the analysis of real-world social systems.

Within this framework, constraints are understood not as passive limitations, but as active causal mechanisms that enable or inhibit system processes. From this perspective, system behaviour can be explained in terms of the configuration of constraints acting upon it, and patterns of stability and change can be understood as arising from the alignment or misalignment of constraints across material, structural, and cultural domains, together with the internal biogenic and agentic constraints that shape agent behaviour.

It is useful to distinguish between constraints that operate at the level of the system and its environment, i.e., material, structural, and cultural constraints, and those that are internal to agents. The latter include biogenic constraints, which arise from the biological nature of agents, and agentic constraints, which govern decision-making processes. For the purposes of analysis in this paper, biogenic and agentic constraints may be treated pragmatically alongside material conditions insofar as they define the conditions under which agents can act. However, they are conceptually distinct and should not be understood as fixed or analytically negligible. Both may vary across agents and populations, and such variation can have significant effects on system behaviour. In this sense, they are best understood as relatively stable and slowly varying internal constraints, whose variation becomes analytically significant where it shapes system outcomes. Building on this foundation, the paper introduces constraint analysis as a structured method for examining system dynamics. The method integrates historical, current, and prospective perspectives within a single analytical process, allowing the analyst to move from causal explanation to system diagnosis and, where appropriate, to the design of interventions. In doing so, it provides a bridge between general systems theory and practical analysis, enabling abstract concepts such as causality, feedback, and attractors to be applied in a consistent and interpretable way.

The significance of this paper within the wider programme of work is twofold. First, it provides a practical analytical framework that can be applied directly to social systems. Second, it establishes the conceptual structure that subsequent papers will elaborate in greater detail. Later papers will therefore develop and extend specific aspects of the framework, including the role of needs and satisfiers, reflexivity and information processing, constraint dynamics, and the operation of power and institutions. In this sense, the present paper serves both as an introduction to constraint analysis and as a unifying reference point for the development of the broader social systems theory.

The paper proceeds in a series of stages. It begins by establishing the conceptual and causal basis of constraints, including their system-specific nature and their role in enabling and inhibiting behaviour. It then introduces the principal types of constraint, i.e., material, structural, cultural, and biogenic, and explains how these operate across different levels of system organisation. The concept of attractors and constraint alignment is then developed as a means of understanding stability and transition within systems.

Following this conceptual groundwork, the paper sets out the method of constraint analysis in a step-by-step form, explaining how it can be applied in practice. This is followed by an illustrative example drawn from the English water industry, demonstrating how the method can be used to analyse system evolution, diagnose current conditions, and identify possible future trajectories. The paper concludes with a discussion of the implications of the framework, including its potential generalisation beyond social systems to physical and epistemic domains.

The aim of the paper is therefore twofold: to provide a coherent theoretical account of constraints as causal mechanisms in complex systems, and to develop a practical analytical method that can be applied to understand and influence system behaviour. In doing so, it seeks to contribute to the development of a more integrated and operationally useful approach to general systems theory.

2. Causality

Causality is often misunderstood as a simple relationship between events or as a form of abstract influence. In a systems context, however, causality must be understood as a physical process involving the transfer of matter, energy, or information between systems (Wiener, 1948). A causal interaction occurs when something is transmitted across a boundary from one system to another, resulting in a change in the state or behaviour of the receiving system.

The boundary of a system is defined by the set of components and interactions selected for analysis, and determines which causal interactions are treated as internal or external.

Transfers may be continuous, as in the case of sustained flows of energy or material, or intermittent, as in the case of discrete signals or events. In all cases, causality is not a static linkage but an ongoing process that connects systems through real exchanges. This understanding is important because it grounds causal explanation in observable processes and provides a clear basis for analysing how systems influence one another.

3. Causal Mechanisms

A causal mechanism consists of one or more interacting transfers that shape system behaviour by enabling or inhibiting its processes.

Importantly, the effect of a causal mechanism does not necessarily arise from a single input acting alone. In many cases, multiple causal inputs are involved, and their relationship may vary. Some inputs may be necessary, meaning that without them the process cannot occur. Others may be sufficient, meaning that their presence alone is enough to produce the effect. In many real systems, however, outcomes depend on combinations of inputs, where no single factor is sufficient on its own, but several together enable or inhibit the process. Understanding causal mechanisms therefore requires attention not only to individual causal transfers, but also to how they combine to produce or prevent particular system behaviours.

4. Constraints

A constraint can be understood as a causal mechanism that operates on a system to influence its processes and behaviour. A constraint does not sit outside the system as an abstract limit, but functions through causal interaction, shaping what the system is able or unable to do. In this sense, constraints are not separate from causality but are specific causal mechanisms that determine which behaviours are possible and which are not.

In this framework, causality is understood as the transfer of matter, energy, or information. However, system behaviour depends not only on the presence of such transfers, but also on the conditions that enable or inhibit them. Constraints may therefore take the form of either active causal mechanisms or the absence of enabling conditions within a configuration. The absence of an enabling condition does not constitute a causal transfer in itself, but it functions as a constraint by preventing the occurrence of a process. In this sense, absences are treated as causally relevant conditions within a configuration of constraints, rather than as causes in their own right.

5. Constraints are System Specific

A constraint is always system-specific. Whether a causal mechanism enables or inhibits behaviour depends on the nature and capabilities of the system to which it is applied. The same mechanism may constrain one system but not another. For example, a cultural norm constrains only those systems capable of recognising and responding to shared meaning. Constraints are therefore relational, arising from the interaction between a causal mechanism, as defined above, and a particular system.

Any discussion of constraints requires, therefore, a clear definition of the system to which they apply. This definition must include not only the system as a whole, but also its relevant components and levels of organisation. A system such as a nation, for example, may be analysed in terms of interacting individuals, interacting institutions, or interactions between different organisational levels. Constraints that apply at one level may not apply, or may operate differently, at another.

6. The Universality of Constraints

Before distinguishing between different types of constraint, it is important to recognise that constraints operate at all levels of system organisation. From the assembly of subatomic particles and the formation of atoms and molecules, through biological systems and living organisms, to social and epistemic systems, behaviour is always shaped by causal mechanisms that enable or inhibit particular processes (Bertalanffy, 1968; Prigogine & Stengers, 1984). At each level, constraints arise from the interaction between a system and its environment, as well as from the internal organisation of the system itself. Although the specific form and complexity of constraints vary across these levels, the underlying principle remains the same: system behaviour is always the result of constrained causal processes. This universality is important because it shows that the concept of constraint is not limited to any particular domain, but provides a general basis for understanding organisation and behaviour across physical, biological, and social systems.

7. Types of Constraint: Physical or Agentic

Before distinguishing between different types of constraint, it is important to recognise a fundamental shift that occurs with the emergence of agency. At lower levels of system organisation, such as physical and chemical systems, constraints take the form of universal laws and fixed causal regularities. These constraints are not subject to choice; they operate uniformly and cannot be altered by the systems to which they apply. In social systems, these law-like conditions reappear in the form of biogenic needs, which operate as necessary conditions for the functioning of agents.

With the emergence of living and, more significantly, reflexive agents, a new dimension is introduced. Agents are capable of responding to, selecting among, and in some cases modifying the constraints under which they operate.

In this context, agentic constraints may be understood as constraints that arise through the presence and activity of agents, i.e., systems capable of perception, evaluation, and action. Unlike purely physical constraints, which operate independently of interpretation, agentic constraints depend on how agents recognise, interpret, and respond to conditions. They are therefore mediated by cognition, communication, and social interaction.

Agentic constraints therefore represent a distinct class of internal constraint, operating at the level of decision-making. They differ from biogenic constraints, which define underlying needs and capacities, and from cultural constraints, which shape interpretation through shared meaning. Instead, they mediate between these domains by governing how agents interpret conditions and select actions.

For example, a legal rule functions as a constraint only insofar as agents recognise it and adjust their behaviour accordingly. Similarly, social norms constrain behaviour through shared expectations, but may be followed, resisted, or reinterpreted by different agents. Economic incentives operate as constraints by shaping choices, but their effects depend on how agents perceive and respond to them. In each case, the constraint is not simply imposed, but operates through the agent's capacity to interpret and act.

This does not mean that constraints cease to exist or that universal constraints no longer apply, but rather that an additional layer of constraint becomes relevant; one in which behaviour is shaped not only by fixed causal conditions but also by shared, learned patterns. It is this emergence of agency that gives rise to the need to distinguish between different types of constraint on human social systems.

Variations in agentic constraints across agents may therefore contribute to differences in behaviour, coordination, and influence within social systems, and are an important source of system-level variation.

8. Types of Constraint: Human Social Systems

Having established that constraints are system-specific causal mechanisms that enable or inhibit processes, it is now useful to distinguish between them.

The different types of constraint on human social systems were addressed in earlier work on the Enhanced Morphogenetic Cycle (EMC). The EMC provides a general framework for understanding how such systems are shaped and transformed through interacting domains of constraint. Three broad types of constraint were identified: material, structural, and cultural. In addition to these domains, biogenic and agentic constraints operate within agents and may vary across them, influencing both individual behaviour and aggregate system dynamics.

Material constraints arise from the physical and informational conditions external to the system, including the availability of resources, energy, and environmental inputs. Structural constraints arise from the internal organisation of the system, including the arrangement and interaction of its components. Cultural constraints arise from shared meanings, norms, and knowledge that guide the behaviour of agents within the system. These three types of constraint operate together, influencing system behaviour by enabling or inhibiting processes at different levels. A full account of the EMC is provided elsewhere; here it serves as a useful basis for distinguishing the principal domains within which constraints operate.

9. Environment

In discussing material constraints, it is necessary to clarify what is meant by the environment of a system. The environment should be understood as the set of external systems with which the system of interest is capable of causal interaction. Since causality consists of transfers, the environment comprises those systems that can exchange such transfers with the system under consideration. This definition applies across all levels of organisation. In physical and biological contexts, the environment includes surrounding physical conditions and neighbouring systems. In social systems, however, the environment is not limited to the natural world but also includes other social systems, such as institutions, organisations, and societies, with which the system interacts or of which it may form a part. The environment is therefore relationally defined: it consists of those external systems that can affect, or be affected by, the system through causal interaction.

10. Material Constraints

Material constraints primarily arise from the causal conditions external to a system, that is, from its environment as specified in the previous section. They comprise the availability and distribution of matter, energy, and information flowing between the system and its environment. Material constraints thus define the external conditions under which a system operates and determine whether particular processes are possible. They do so by affecting the flow of matter energy or information between sub-systems within a system. For example, a positive feedback loop will consume ever-increasing amounts of matter or energy until a constraint on their availability is reached. Similarly, many processes depend on threshold environmental conditions: a chemical reaction may proceed only within a specific temperature range, or a biological organism may function only within certain limits of oxygen availability. When these material conditions fall outside the required range, the process is inhibited or ceases altogether, regardless of the internal organisation of the system.

Here, information refers to the availability of signals or data flowing between the system and its environment, rather than their shared interpretation, which is addressed under cultural constraints.

In physical and biological systems, material constraints are often immediately apparent. The availability of energy limits the processes an organism can sustain; the presence or absence of particular chemical substances determines which reactions can occur; environmental conditions such as temperature or pressure enable or inhibit specific forms of activity. In many physical contexts, these constraints operate independently of internal organisation or interpretation: they are imposed through the causal structure of the environment itself.

In social systems, material constraints continue to play a fundamental role, although they may be less immediately visible. The availability of food, water, and raw materials constrains economic activity; the distribution of energy resources influences patterns of production and development; and physical infrastructure enables or limits movement, communication, and exchange. Informational inputs from the environment also function as material constraints in this sense, as they provide or withhold the conditions necessary for particular responses. For example, access to timely and accurate information can enable coordinated action, while its absence can inhibit effective decision-making.

Material constraints are therefore foundational: they define the basic conditions under which a system must operate. While other types of constraint may shape how a system responds, material constraints determine whether certain processes are possible at all. They operate across all levels of organisation and are not subject to direct alteration by the system. However, systems may, through their behaviour, modify their material environment over time.

For analytical purposes, internal constraints within agents, particularly biogenic and agentic constraints, may be treated alongside material conditions insofar as they define the conditions under which action can occur. However, they are conceptually distinct in that they arise from the internal characteristics of system components rather than from the external environment. Moreover, unlike many external material constraints, they may vary across agents and populations, and such variation can play a significant role in shaping system behaviour.

11. Structural Constraints

Structural constraints arise from the internal organisation of a social system, that is, from the arrangement of its component sub-systems (components, each of which may itself be treated as a system) and the causal interactions between them. Whereas material constraints derive from the environment, structural constraints derive from the system's own configuration. They operate through the patterns of interaction that are possible, required, or excluded by the way the system is structured. As with all constraints, they are realised through causal transfers, but in this case those transfers occur within the system itself.

The identification of structural constraints depends on how the system is defined, particularly on the selection of its components. Different levels of analysis may reveal different structural constraints. A system defined in terms of interacting individuals will exhibit different patterns of constraint from one defined in terms of interacting institutions. For this reason, it is essential that the components of the system be specified clearly, as structural constraints arise from the relationships between them.

In the case of social systems, an additional consideration arises. Although the components, typically agents or organisations, are capable of choice, they are not unconstrained. In order to function, they must satisfy certain needs. These needs operate as necessary conditions for continued participation in the system and can therefore be understood as a form of constraint. Interactions between components are thus not arbitrary, but are structured around the exchange of satisfiers for these needs. Individuals exchange goods, services, information, and recognition; organisations exchange resources, authority, and compliance. These exchanges enable the continued functioning of the components and, through them, the system as a whole.

Structural constraints in social systems therefore arise from the patterned exchanges required to sustain component functioning. The roles that components occupy, the relationships they maintain, and the dependencies that exist between them all shape what actions are possible and which are not. For example, hierarchical structures constrain decision-making by channelling authority through specific pathways; market structures constrain behaviour through patterns of exchange and competition; and organisational structures constrain action through defined roles and responsibilities. In each case, the structure of the system determines the causal interactions available to its components, thereby enabling or inhibiting particular processes.

Structural constraints may propagate across levels, with patterns at one level influencing and being influenced by those at others.

12. Summary of Social Constraints

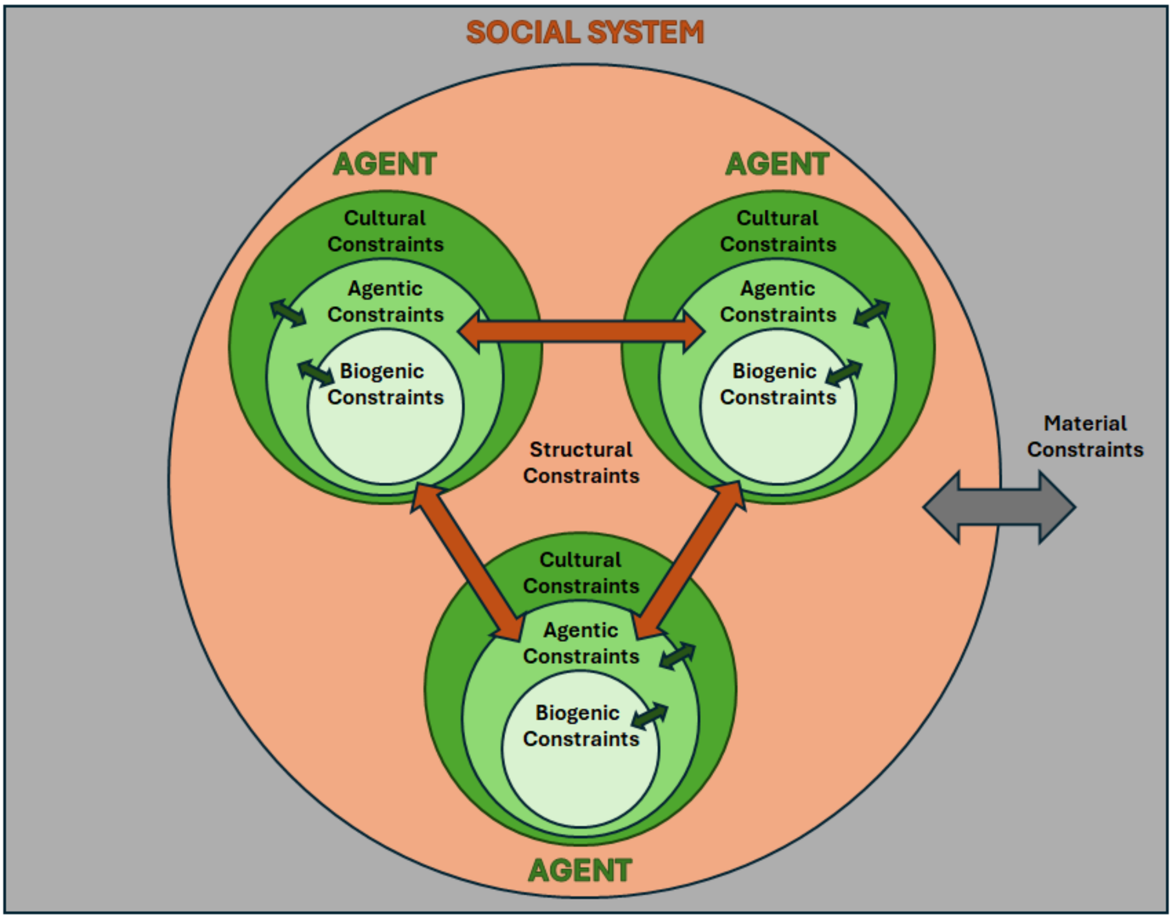

Figure 1. Summary of Social Constraints

Figure 1. represents the multi-level structure of constraints within a social system and the way in which they interact to shape behaviour.

At the centre of the diagram are individual agents, each of which is characterised by three nested layers of constraint. At the innermost level are biogenic constraints, arising from the biological nature of the agent and defining its fundamental needs and capacities. Surrounding these are agentic constraints, which govern decision-making processes, i.e., how the agent perceives, evaluates, and selects actions. At the outer layer are cultural constraints, comprising shared meanings, norms, values, and knowledge that shape interpretation and expectations.

These layers are not independent. Agentic constraints are influenced by both biogenic and cultural constraints: biological needs generate pressures for action, while cultural frameworks shape how situations are interpreted and what responses are considered appropriate. In this way, agentic constraints mediate between underlying drives and socially constructed expectations. At the same time, agentic constraints shape structural constraints, as patterns of interaction arise from the decisions and actions of agents operating under these influences.

These internal constraints are not uniform across agents. Differences in biogenic and agentic constraints may influence how agents interpret conditions, participate in interactions, and exert influence within the system. Structural constraints, in turn, affect cultural constraints by shaping the pathways through which information is exchanged, thereby influencing how shared meanings, norms, and expectations are transmitted and maintained.

Biogenic and agentic constraints therefore operate as internal constraints within agents, while material, structural, and cultural constraints operate at the level of the system and its environment. For analytical purposes, these internal constraints may be treated alongside material constraints, but they are conceptually distinct in their origin and operation.

Structural constraints arise from the interactions between agents. In the diagram, these are represented by the connections between the agentic layers of different agents. This reflects the fact that social interactions are primarily the result of decisions made by agents under constraint. Although these interactions occur at the level of decision-making, they are indirectly shaped by the biogenic and cultural constraints that influence those decisions. Structural constraints therefore emerge as stabilised patterns of interaction between agents.

The social system as a whole is embedded within a wider environment, from which material constraints arise. These consist of the availability and distribution of matter, energy, and information, and define the external conditions under which the system operates. Material constraints influence the system as a whole, but are not themselves generated within it.

Overall, the diagram illustrates a nested and interactive structure in which biogenic and cultural constraints shape agentic decision-making, agentic interactions give rise to structural constraints, and material constraints define the broader conditions of possibility. System behaviour emerges from the interaction of constraints across all of these levels.

13. Cooperation and Conflict

Within social systems, interactions between components take the form of exchanges through which the needs of those components are either satisfied or frustrated. These exchanges can be understood in terms of their causal effects. Where interactions involve the provision of satisfiers, i.e., causal inputs that enable the processes required for continued functioning, they give rise to co-operation. Co-operation can therefore be understood as a pattern of interaction in which components engage in the relatively equitable exchange of causal enablers, allowing each to maintain or enhance its functioning within the system. By contrast, where interactions involve the imposition or exchange of contra-satisfiers, i.e., causal inputs that inhibit or disrupt necessary processes, conflict arises. Conflict may involve the withholding of required enablers, the imposition of inhibitory constraints, or both. In this way, co-operation and conflict are not abstract social categories, but can be understood directly in terms of causal mechanisms: as patterns of interaction that either support or undermine the processes through which system components sustain themselves.

14. Cultural Constraints

Cultural constraints differ from structural constraints in that they shape behaviour through shared meaning rather than through the organisation of interactions themselves. However, cultural constraints are transmitted and reproduced through the structured interactions between system components. In this sense, while culture shapes interpretation, its propagation depends on the underlying structural pathways through which information is exchanged.

Cultural constraints arise from the shared meanings, norms, values, and bodies of knowledge that shape the behaviour of components within a social system. Unlike material constraints, which derive from the environment, and structural constraints, which arise from the organisation of interactions, cultural constraints operate through the interpretation of information. They are therefore realised through causal transfers of information that are widely shared across the components of the system, giving rise to common expectations about appropriate behaviour.

A key feature of cultural constraints is that they are collective in nature. For them to function effectively, they must be broadly shared among system components, such that individuals or organisations recognise and respond to similar patterns of meaning. This shared character means that cultural constraints can exert a powerful influence on behaviour, often guiding action without the need for continuous explicit enforcement. However, this influence is not automatic. Cultural constraints are typically socialised from an early age, through processes of learning, imitation, and reinforcement, by which components acquire the norms and expectations of the system.

Despite this, cultural constraints are not universally or uniformly accepted. Components may resist, reinterpret, or ignore them, particularly where they conflict with other needs or incentives. For this reason, cultural constraints generally require ongoing reinforcement or policing to remain effective. This may take formal forms, such as laws and regulations, or informal forms, such as social approval, disapproval, and reputational effects. Through these mechanisms, deviations from shared norms are discouraged and conformity is maintained.

It is also important to recognise that not all components have equal influence over the formation and evolution of cultural constraints. Some actors, such as institutions, leaders, or influential groups, may have a disproportionate capacity to shape shared meanings and norms. Through control of communication channels, authority structures, or symbolic resources, such components can influence which cultural constraints become dominant and how they are interpreted within the system.

Cultural constraints therefore operate as a distinct but interacting domain of constraint within social systems. They shape behaviour by establishing shared expectations, guiding interpretation, and reinforcing patterns of action, while remaining subject to variation, contestation, and change over time.

15. Biogenic Constraints within Social Systems

Although structural and cultural constraints in social systems are often associated with agency, choice, and interpretation, not all constraints operate in this way. Some arise from the biological nature of human beings and function as relatively stable conditions on behaviour. These may be referred to as biogenic constraints.

Biogenic constraints derive from the biological requirements and capacities of human agents. They include the need to secure resources necessary for survival, such as food, water, and shelter, as well as the need for social interaction, reproduction, and development. These needs function as necessary conditions for continued functioning and are therefore not subject to variation in the same way as many cultural or institutional arrangements. While the means by which such needs are satisfied may vary across systems, the underlying requirements remain relatively constant.

Biogenic constraints also extend to patterns of interaction required for reproduction and social continuity. For example, biological reproduction imposes constraints on the relationships and behaviours necessary for the continuation of a population. Cultural systems may shape and interpret these relationships in different ways, but they do so within the limits set by these underlying biological conditions.

In analytical terms, biogenic constraints can be treated as relatively stable over the timescales of social analysis. While often stable over the timescales of social analysis, biogenic constraints may vary across individuals and populations, and such variation can have important consequences for system behaviour, particularly in relation to health, capability, and participation. Because they change only over long timescales, they typically do not act as drivers of short-term system change. Their primary role is to define the needs and capacities of system components, thereby shaping the range of possible structural and cultural arrangements. As such, they provide a foundational constraint framework within which both stable conditions and variations in agent capacities shape the range of possible structural and cultural arrangements.

While biogenic constraints are treated analytically as relatively stable over the timescales of social analysis, they are conceptually distinct in that they arise from the internal biological nature of system components rather than from external environmental conditions.

16. Temporal Dynamics of Constraints

Constraints within social systems do not all change at the same rate. Different types of constraint, i.e., material, structural, cultural, and biogenic, operate on different timescales, reflecting the nature of the processes through which they are formed and maintained. This variation in the pace of change is a fundamental feature of social systems and has important consequences for system behaviour.

At one extreme, biogenic constraints are relatively stable over the timescales typically considered in social analysis. They arise from the biological nature of human agents and change only over evolutionary timescales. As such, they provide a relatively stable foundation upon which other constraints operate. Material constraints may change more rapidly, particularly where they involve flows of resources or information, but are still often limited by physical and environmental conditions.

Structural constraints typically change at an intermediate pace. They are shaped by the organisation of interactions between system components and may evolve over time through processes such as institutional development, technological change, or shifts in patterns of exchange. While they can be deliberately altered, such changes often require coordinated action and therefore tend to occur over extended periods.

Cultural constraints can, in some cases, change more rapidly, particularly in response to new information or shifting patterns of communication. However, deeply embedded cultural norms and values may be highly resistant to change and may persist over long periods. Cultural change is therefore variable, with some elements adapting quickly while others remain stable.

The coexistence of constraints operating on different timescales means that social systems are rarely fully aligned. Faster-changing constraints may shift in response to new conditions, while slower-changing constraints lag behind. This can result in temporary or persistent misalignment, as different parts of the system respond at different rates. Such misalignment is often associated with instability and conflict, particularly where established patterns of co-operation are disrupted before new ones have become stabilised.

17. Landscapes and Attractors

The behaviour of a system is not random but is shaped by the constraints under which it operates. One useful way of understanding this is to think of system behaviour as taking place within a landscape defined by those constraints (Prigogine & Stengers, 1984; Haken, 1983). In this landscape, different configurations of the system correspond to different positions, while the constraints acting upon the system shape the form of the landscape itself.

More precisely, the landscape represents a constraint-defined state space in which each position reflects both the configuration of the system and the causal processes that sustain it. The span of the landscape is determined by the variables that characterise these configurations and processes, including structural arrangements, patterns of interaction, and the intensities of relevant constraints.

The elevation of the landscape represents the relative cost of maintaining system behaviour. Regions of higher elevation correspond to configurations that require greater energy or effort to sustain, typically due to misaligned or conflicting constraints. By contrast, troughs or attractor basins correspond to lower-cost configurations in which constraints are aligned and mutually reinforcing, allowing system processes to be maintained with less effort. In this sense, attractors represent energetically favourable states under the prevailing configuration of constraints (Prigogine & Stengers, 1984).

An attractor is a state, or set of states, toward which a system tends to move and within which, given its current constraints, it tends to remain. Although the system may fluctuate within this region, the combined effect of the constraints acting upon it tends to keep it within a limited range of behaviours.

Where constraints are strong and mutually reinforcing, they give rise to deeper attractors. These correspond to configurations in which constraints are aligned and interdependent, so that system behaviour is relatively consistent. Such configurations tend to require less effort to maintain, as processes are enabled rather than resisted. In social systems, this is typically associated with higher levels of co-operation, as components exchange satisfiers in ways that sustain both their own functioning and that of the wider system. Co-operative interaction therefore reduces the overall cost of maintaining system behaviour, contributing to the formation of stable attractor basins.

By contrast, peaks or ridges are regions of the landscape where constraints are weaker, less aligned, or in tension. These correspond to configurations in which system processes are not consistently supported, and greater effort is required to sustain behaviour. In such conditions, interactions are more likely to involve the exchange of contra-satisfiers, leading to conflict and instability. Conflictual interaction increases the cost of maintaining system behaviour, making such regions inherently less stable.

The landscape can therefore be understood as varying both in stability and in the relative cost of maintaining different patterns of behaviour. Deep attractors correspond to low-cost, co-operative configurations in which constraints are aligned, while peaks correspond to higher-cost, conflict-prone configurations in which constraints are misaligned.

18. Attractor Transitions in a Stable Environment, and thus, a Stable Landscape

In a stable environment, the landscape of system behaviour can be treated as relatively fixed, with a set of existing attractors defined by the prevailing constraints. Changes in constraints within such a landscape do not create entirely new structures. Rather, a system may move from one attractor to another, shifting from one stable pattern of behaviour to a different one.

However, such movement is not typically direct. To transition from one attractor to another, the system must pass through less stable regions of the landscape, i.e., over peaks or ridges between attractors. In these regions, constraints are weaker, less aligned, or in tension, and the stabilising effects that characterise attractors are reduced. System behaviour therefore becomes more variable and less predictable.

In social systems, these transitional regions are often associated with increased conflict. As the system moves away from one stable configuration, established patterns of co-operation are disrupted, while alternative patterns have not yet become stabilised. Interactions may therefore increasingly involve the exchange of contra-satisfiers, reflecting the temporary breakdown of co-ordinated behaviour. Once the system settles into a new attractor, a different pattern of co-operation and constraint alignment may emerge.

19. Constraint Alignment and Misalignment

Constraint alignment refers to a condition in which the material, structural, cultural, and biogenic constraints acting on a system operate in a mutually supportive manner. In such a condition, the causal mechanisms that enable or inhibit system processes are consistent with one another, allowing the system to sustain coherent patterns of behaviour. Alignment does not imply the absence of constraint, but rather that constraints combine in ways that reinforce stable and co-ordinated interaction.

In social systems, constraint alignment is closely associated with co-operation. Where constraints are aligned, the exchange of satisfiers between system components can be sustained, as the conditions required for their functioning are mutually supported. Structural arrangements facilitate interaction, cultural norms guide behaviour in compatible ways, and material conditions provide the necessary resources. This alignment gives rise to stable attractors, within which system behaviour is relatively predictable and co-operative patterns are maintained. The degree of constraint alignment is reflected in the depth of attractors within the system's landscape.

Constraint misalignment, by contrast, occurs when different constraints operate in tension or contradiction. This may arise, for example, when material conditions change more rapidly than structural or cultural arrangements, or when cultural expectations are inconsistent with structural opportunities. In such cases, the causal mechanisms acting on the system no longer support a coherent pattern of behaviour. Processes that are enabled in one domain may be inhibited in another, leading to disruption.

In social systems, misalignment is often associated with conflict and instability. As previously aligned patterns of exchange break down, interactions may increasingly involve the exchange of contra-satisfiers, reflecting the inability of components to secure the conditions required for their functioning. Established norms and structures may lose their effectiveness, while alternative arrangements have not yet become stabilised. This corresponds to movement away from a stable attractor and into less stable regions of the landscape.

Alignment is therefore a key condition for stability within an attractor, while misalignment is a primary driver of instability and transition. Because constraints operate on different timescales and are influenced by both internal organisation and external conditions, perfect alignment is rarely achieved. Instead, social systems are characterised by ongoing processes of alignment and misalignment, which shape their stability, adaptability, and overall viability.

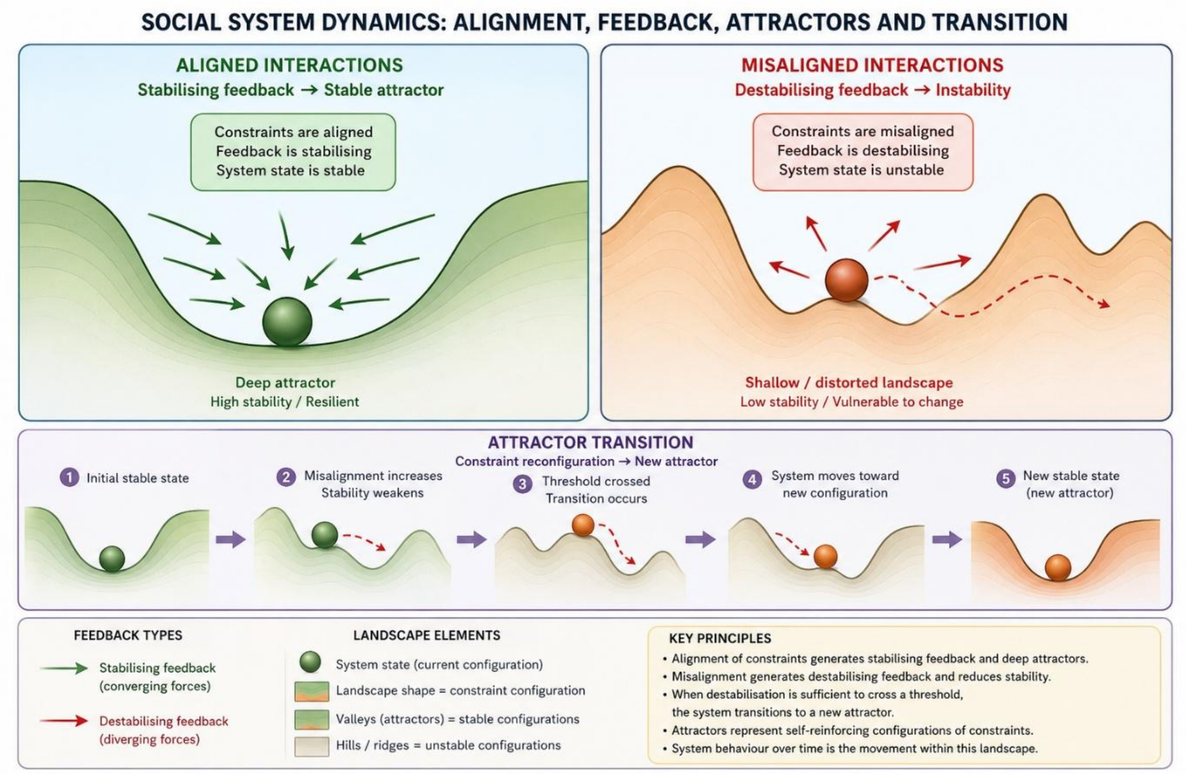

Figure 2 – The Relationship between Systems Alignment/Misalignment and Landscapes.

The shape of the landscape represents the configuration of constraints. Feedback arises when the outcomes of interactions between agents, shaped by constraints across material, structural, and cultural domains, act back upon those constraints to reinforce or destabilise system behaviour. Feedback therefore operates through the modification, reinforcement, or disruption of constraint configurations.

Stabilising feedback occurs when the outcomes of constrained interactions reinforce the constraints that produced them, increasing the likelihood that similar interactions and behaviours will be repeated. Destabilising feedback occurs when the outcomes of constrained interactions undermine or disrupt the constraints that produced them, reducing the likelihood of their continued reproduction and increasing the potential for change.

20. Open Systems and Embedded Landscapes

Social systems do not exist in isolation but are open systems, continuously interacting with external systems through the exchange of matter, energy, and information. As a result, the behaviour of a social system is influenced not only by its internal constraints but also by the constraints arising from its environment. In many cases, this environment includes larger or more encompassing systems of which the system of interest forms a part. These may be understood as parent systems, within which the social system is embedded.

For example, a national economy operates within the global economic system, where international trade conditions, capital flows, and geopolitical developments act as external constraints. Similarly, an organisation operates within a regulatory and legal framework defined by the state, while also being influenced by broader cultural expectations within society.

The concept of landscapes can therefore be extended to reflect this embeddedness. The landscape of a social system, defined by the constraints that shape its possible behaviours, is influenced by the landscape of the parent system. Changes in the parent system, whether material, structural, or cultural, can alter the constraints acting on the embedded system and thereby reshape its landscape. While parent systems shape the constraints acting on embedded systems, the latter may also respond and adapt in ways that partially modify these effects.

This has important consequences for system behaviour. Attractors that were previously deep and stable within the social system of interest may become less stable as external conditions change. In extreme cases, what was once a strong attractor may become a relatively shallow feature of the landscape, making it easier for the system to move away from previously stable patterns of behaviour. Conversely, new attractors may emerge or existing ones may deepen as constraints imposed by the broader environment change.

For example, an industry that was previously stable under a particular regulatory regime may become unstable following policy reform or technological disruption. Similarly, organisations that operated effectively under one set of cultural expectations may experience increasing instability as those expectations shift, requiring adaptation to new norms or practices.

In this way, the dynamics of social systems cannot be fully understood in isolation. Their stability, instability, and transitions between patterns of behaviour are influenced by the wider systems within which they are embedded, and by the changing constraints that arise from those systems.

21. Viability: The Roles of Stability and Adaptability

The concept of viability refers to the capacity of a system to continue functioning over time under the constraints within which it operates. A viable system is one that is able to sustain the processes necessary for its continued existence, despite the presence of internal and external pressures. Viability is therefore not simply a matter of stability, nor of change, but of maintaining an appropriate balance between the two.

Viability ultimately depends on the system's ability to sustain the satisfaction of the needs of its components over time.

Stability is essential to viability because it allows the system to maintain coherent patterns of behaviour. Where constraints are sufficiently aligned, they give rise to stable attractors in which co-operative interactions can be sustained and the processes required for system functioning are reliably reproduced. In such conditions, stability supports predictability, co-ordination, and the efficient satisfaction of the needs of system components.

However, stability alone is not sufficient. Systems exist within environments that may change, sometimes gradually and sometimes abruptly. Adaptability is therefore also essential to viability. Adaptability refers to the capacity of a system to adjust its behaviour in response to changes in constraints, whether arising internally or from the environment. This may involve movement within an attractor, or transitions between attractors, as the system responds to new conditions.

The relative importance of stability and adaptability depends on the context in which the system operates. In relatively stable environments, where constraints change slowly or predictably, stability plays a dominant role in maintaining viability. In more dynamic or uncertain environments, adaptability becomes more important, as the system must be able to respond to changing conditions in order to continue functioning. In practice, viable systems require both: stability to sustain coherent behaviour in the short term, and adaptability to ensure continued functioning in the longer term.

A failure to maintain this balance can undermine viability. Excessive stability may result in rigidity, preventing the system from adapting to new conditions. Excessive emphasis on change may lead to instability, disrupting the co-operative patterns required for system functioning. Viability therefore depends on the capacity of the system to maintain alignment between its constraints in a way that supports both stability and adaptability across different timescales.

22. Quantification and the Need for Constraint Analysis

In principle, the landscape of a social system could be described and analysed in a similar way to that of a physical system. Since both are shaped by constraints that influence the transfer of matter, energy, and information, it is possible to conceive of a formal representation in which the relative stability of different states is quantified and the transitions between them modelled. In physical systems, such approaches are well established (Prigogine & Stengers, 1984; Haken, 1983), with landscapes defined in terms of measurable variables and governed by known relationships.

However, in the case of social systems, the practical application of such an approach is prohibitively difficult. This is due to several factors. First, social systems involve a very large number of interacting components, often operating across multiple levels of organisation. Second, many of the relevant variables, particularly those associated with cultural constraints, are difficult to measure precisely or consistently. Third, the relationships between variables are often non-linear, context-dependent, and subject to change over time. Fourth, the presence of agency introduces reflexivity: components of the system can respond to, reinterpret, and alter the conditions under which they operate, making the system inherently dynamic and adaptive. Finally, social systems are embedded within other systems, meaning that their landscapes are influenced by external factors that may themselves be complex and changing.

As a result, while the concept of a landscape remains a useful way of understanding system behaviour, direct quantification is rarely feasible in practice. An alternative approach is therefore required, one that retains the causal grounding of the concept while allowing for meaningful analysis without full formalisation. Constraint analysis provides such an approach. Rather than attempting to measure the entire landscape directly, it focuses on identifying and understanding the key constraints that shape system behaviour, and how these constraints interact to produce stability, instability, and transitions between different patterns of behaviour.

23. Constraint Analysis: Definition and Scope

Constraint analysis is a method for understanding the behaviour of a social system by identifying and examining the causal mechanisms that enable or inhibit its processes (cf. Meadows, 2008). Rather than attempting to fully quantify the landscape within which a system operates, constraint analysis focuses on the key constraints, material, structural, and cultural, that shape the system's possible behaviours. This analysis also recognises the role of internal constraints within agents, particularly biogenic and agentic constraints, which shape motivation and decision-making respectively. Variation in biogenic and agentic constraints across agents may also be relevant, particularly where differences in needs or decision-making processes influence system behaviour.

By analysing how these constraints interact, align, or come into tension, it becomes possible to explain patterns of stability, instability, and transition between different modes of behaviour.

The strength of constraint analysis lies in its ability to provide a causally grounded and system-specific account of behaviour without requiring complete formalisation. It allows the analyst to identify which factors are most influential in enabling or inhibiting particular processes, to understand how different domains of constraint combine, and to trace how changes in constraints may alter system dynamics. In social systems, it is particularly useful for analysing co-operation and conflict, as these can be understood in terms of the exchange of satisfiers and contra-satisfiers within structurally and culturally mediated interactions.

However, constraint analysis also has limitations. It does not provide precise quantitative predictions, nor does it yield a complete or exhaustive representation of the system. The selection of relevant constraints depends on the definition of the system and the level of analysis, and therefore involves a degree of judgement. In addition, because social systems are open and dynamic, the set of relevant constraints may change over time, and external influences may alter the system in ways that are difficult to anticipate. Constraint analysis therefore provides a structured and insightful framework for understanding system behaviour, but it should be understood as an interpretive and diagnostic method rather than a predictive or fully formal model.

24. Generality of Constraint Analysis

The methods of constraint analysis outlined here are intended to apply to social systems in general. This is because they are based on features that are common to all such systems, rather than on the specific characteristics of any particular case. All social systems consist of interacting components, whether individuals, groups, or organisations, that are capable of agency but must satisfy certain needs in order to function. These components engage in interactions that involve the exchange of satisfiers and, in some cases, contra-satisfiers. As a result, patterns of co-operation and conflict arise as general features of social interaction.

In addition, all social systems operate under constraints that can be broadly classified as material, structural, and cultural, together with internal biogenic and agentic constraints that shape the behaviour of system components. Material constraints arise from the environment, structural constraints from the organisation of interactions between components, and cultural constraints from shared meanings and norms. While the specific form of these constraints varies between systems, the underlying categories and their causal roles remain consistent. Furthermore, social systems are open and embedded within larger systems, meaning that their behaviour is influenced by both internal and external constraints across multiple levels.

Because constraint analysis is grounded in these general features, i.e., causal mechanisms, needs-based interactions, and the three domains of constraint, it can be applied across a wide range of social systems. The method does not depend on detailed quantification or on system-specific assumptions, but instead provides a structured way of identifying and interpreting the constraints that shape behaviour. Its applicability therefore extends to systems of different scales and types, including small organisations, institutions, economies, and societies.

25. Temporal Perspectives on Constraint Analysis

Constraint analysis is a unified method that can be applied from different temporal perspectives depending on the purpose of the enquiry. These perspectives, i.e., historical, current, and prospective, do not represent separate methods, but rather different applications of the same analytical framework. Each focuses on a different temporal aspect of system behaviour, and together they provide a more complete understanding of system dynamics.

Current constraint analysis focuses on the present configuration of constraints acting on a system. It involves identifying the key enabling and inhibiting conditions across material, structural, and cultural domains, and assessing the degree of alignment between them. This perspective provides a diagnostic view of the system's current condition, indicating whether it is stable, unstable, or in transition between attractors.

Historical constraint analysis examines how a system has evolved over time through changes in its constraints. It identifies past attractors, the configurations of material, structural, and cultural constraints (with consideration of biogenic and agentic constraints where relevant) that sustained them, and the changes that led to transitions between them. This perspective is particularly useful for explaining how the current state of a system has emerged and for identifying persistent constraints that continue to shape behaviour.

Prospective constraint analysis considers how potential changes in constraints may influence the future behaviour of a system. It involves identifying possible shifts in material, structural, or cultural conditions and assessing how these might influence transitions between attractors. This perspective supports the exploration of possible future states and the design of interventions aimed at improving system viability.

These three perspectives are complementary and are typically applied together within the overall constraint analysis process. However, depending on the purpose of the analysis, one or more perspectives may be emphasised or omitted. For example, a purely explanatory study may focus on historical analysis, while a diagnostic study may emphasise the current configuration of constraints. In all cases, the underlying method remains the same: the identification and analysis of the causal constraints that shape system behaviour.

26. The Constraint Analysis Process

26.1. Purpose

Constraint Analysis is a method for analysing social systems in terms of the causal conditions that shape their behaviour. It is used to:

- identify the constraints that enable or inhibit system behaviour;
- explain how systems remain stable or become unstable;
- analyse transitions between different stable system states (attractors);
- diagnose current system conditions; and
- inform potential strategies for stabilisation or change.

The method integrates causal analysis, system dynamics, and practical intervention within a single framework.

26.2. Core Concepts

The method is based on the following key concepts:

- **Constraint**: Anything that limits or shapes what a system can do by acting as a causal condition.
- **Enabling condition**: A condition that makes behaviour possible.
- **Inhibiting constraint**: A condition that prevents or restricts behaviour.
- **Presence and absence**: Behaviour is shaped both by what is present (inhibitors or enablers) and what is absent (missing enablers or missing inhibitors).
- **Attractor**: A relatively stable pattern of system behaviour maintained by a configuration of constraints.
- **Primary constraint domains (analytical):**
    - **Material** (physical, energetic, and informational conditions, including internal biogenic and agentic conditions where relevant)
    - **Structural** (organisation and interactions within the system)
    - **Cultural** (shared meanings, norms, and control mechanisms)

Biogenic constraints arise from the biological nature of system components and define the needs and capacities required for their continued functioning. They are relatively stable over the timescales of social analysis. In analytical terms, they can be understood as functions of the components that must be satisfied for the system to operate. These include requirements such as access to energy, resources, social interaction, and reproduction. While the specific means by which these requirements are met may vary, the underlying constraints remain relatively stable over the timescales relevant to most social analysis.

In addition to biogenic constraints, agentic constraints operate at the level of decision-making. They govern how agents interpret and respond to conditions and therefore mediate between biogenic needs, cultural expectations, and structural interactions. Agentic constraints are not treated as a separate domain alongside material, structural, and cultural constraints, but are analytically essential in mediating their effects.

For the purposes of constraint analysis, biogenic constraints are often treated as relatively stable conditions rather than rapidly changing drivers. However, variation across agents may be analytically significant in many contexts, as differences in biogenic and agentic constraints can directly influence patterns of interaction, participation, and influence within the system. These constraints define the conditions required for system viability and typically do not change rapidly enough to account for short-term transitions. Instead, they provide a relatively stable reference against which the alignment or misalignment of structural and cultural constraints can be assessed.

26.3. Constraint Interaction and Stability

Constraint analysis is concerned not only with the identification of individual constraints, but also with how different types of constraint interact to shape system behaviour. These interactions can be understood in terms of simple causal relationships between constraint domains.

For example:

- **Biogenic + Cultural → Agentic**
- **Agentic + Material → Structural**
- **Structural + Agentic → Cultural**
- **Structural + Cultural → Agentic**

A full list of constraint interaction relationships and more common feedback loops are given in Appendix B.

These interaction relationships provide a causal articulation of the interaction between structure, culture, and agency described in the Enhanced Morphogenetic Cycle. They indicate that the behaviour of any one domain is influenced by the combined effects of others. They do not represent precise mathematical relationships, but rather a simplified way of expressing causal influence within the system.

The significance of these interactions lies in their role in producing stability or instability. Where the effects of interacting constraints are mutually reinforcing, they contribute to coherent patterns of behaviour and the formation of stable attractors. Where they are in tension or contradiction, they give rise to disruption, conflict, and potential transitions between attractors.

For example, when biogenic needs and cultural expectations are aligned, agent behaviour tends to be coherent and stable. When they are misaligned, agents may experience conflicting pressures, leading to inconsistent or destabilising behaviour. Similarly, where agentic behaviour is well matched to material conditions, structural arrangements are likely to be viable and stable. Where such alignment is absent, structural instability may arise.

These interaction relationships can therefore be used as a diagnostic tool within constraint analysis. By examining whether key interactions are aligned or misaligned, the analyst can identify sources of stability, instability, and potential system transition. This provides a dynamic complement to the classification of constraints as enabling or inhibiting conditions, allowing the analysis to move beyond static description to a more process-oriented understanding of system behaviour.

Illustrative Example: The Emergence of Hierarchy

The emergence of hierarchical structures in social systems provides a useful example of how interacting constraints can produce stable patterns of behaviour. Variation in biogenic and agentic constraints across agents gives rise to differences in capacity, behaviour, and decision-making. This may be expressed as:

- **Biogenic + Cultural → Agentic**

Under material and organisational conditions, these differences contribute to the formation of differentiated roles and patterns of interaction:

- **Agentic + Material → Structural**

Over time, these patterns stabilise into hierarchical structures, which are then reinforced and legitimised through shared meanings, norms, and expectations:

- **Structural + Agentic → Cultural**

These cultural constraints feed back into agent behaviour, shaping expectations of authority, responsibility, and compliance:

- **Structural + Cultural → Agentic**

Where these interactions are aligned, hierarchy can provide an efficient mechanism for coordinating action, allocating resources, and maintaining system stability. However, where misalignment occurs, for example between underlying capacities, structural positions, and cultural expectations, hierarchical arrangements may become unstable, giving rise to conflict and potential reconfiguration.

26.4. Analytical Structure

The full method proceeds through the following steps:

Step 1: System Definition

Steps 2 to 6: Current Constraint Mapping

Steps 7 to 10: Historical Constraint Analysis

Steps 11 to 14: Diagnosis and Intervention

It is recommended that all steps are carried out to obtain a complete picture of the systems dynamics but diagnosis and intervention can be omitted if only an explanation of the current state of the system is needed. The current constraint stage can also be omitted if only a historical analysis is required.

26.5. Step-by-Step Procedure

The analysis focuses on those constraints that have a significant enabling or inhibiting effect on system behaviour.

Step 1: Define the System

The first step is to clearly define the system to be analysed. This involves specifying what is included within the system, what lies outside it, and the level at which the system will be examined. The analyst must identify the relevant components, such as individuals, organisations, or institutions, and determine the key behaviours or outcomes of interest. Some iteration in the selection of system components may be necessary as the procedure progresses and familiarity with the system develops.

This step is essential because constraints are system-specific: a causal mechanism only functions as a constraint in relation to a particular system and level of analysis. Without a clear definition, it is not possible to identify which constraints are relevant or how they operate. A well-defined system allows constraints to be identified consistently and avoids confusion between different levels of organisation. Poor system definition typically leads to inconsistent or contradictory conclusions, as constraints that apply at one level are mistakenly applied at another.

For example, in analysing the English water industry, the system may be defined as the sector comprising firms, regulators, employees, and consumers. The key behaviour of interest might be the provision of reliable, affordable, and environmentally sustainable water services. This definition determines which constraints, such as regulatory structures, financial incentives, and environmental conditions, are relevant to the analysis.

Step 2: Map Current Constraints

The second step is to identify and map the current configuration of constraints acting on the system. This involves examining the present state of the system across the three main domains, i.e., material, structural, and cultural, and identifying the key conditions that enable or inhibit its behaviour. The analyst should focus on constraints that have a significant effect on system outcomes, using available data such as reports, observations, performance indicators, or structured tools such as SWOT analyses.

In doing so, it is also important to consider whether the current configuration satisfies the biogenic constraints of system components or, in the case of organisations, their equivalent functional constraints. These constraints define the conditions for component and, thus, system viability. Consideration should also be given to how agentic constraints influence decision-making, particularly where behaviour depends on interpretation, perception, or strategic choice.

Where cultural, biogenic/functional or agentic constraints vary significantly across system components this can affect system behaviour and should therefore be reflected in the components selected.

This step is important because it provides a diagnostic snapshot of the system as it currently operates. While historical analysis, explained in later steps, will describe how the system arrived at its present state, this stage identifies the actual conditions under which it is now functioning. It allows the analyst to move from explanation to diagnosis by identifying the constraints that are actively shaping behaviour.

The results should be interpreted in terms of presence and absence. It is not sufficient to identify only what is present; missing enabling conditions are often just as important as existing constraints. The analyst should therefore distinguish between present enablers, present inhibitors, missing enablers, and missing inhibitors, as each has a different causal implication. Missing inhibitors, for example, may permit behaviours that undermine system viability by allowing processes that would otherwise be constrained. Particular attention should be paid to whether key processes are being supported, constrained, or undermined.

For example, in the English water industry, material constraints include ageing infrastructure and increasing environmental pressures. Structural constraints include regulatory frameworks and financial arrangements, while cultural constraints include public expectations regarding service quality and environmental performance. The absence of sufficient long-term investment may be identified as a missing enabling condition, while financial pressures may act as inhibiting constraints on such investment.

Step 3: Classify Constraints Using the Logic Table

The third step is to classify identified constraints according to their causal role using the following constraint logic table. For each key factor, the analyst determines whether it functions as an enabling condition or an inhibiting constraint, and whether it is present or absent. This classification ensures that each factor is interpreted in terms of its actual causal effect on system behaviour.

Causal Role	Present	Absent
Inhibiting constraint	Behaviour is prevented or restricted	Behaviour is allowed (not blocked)
Enabling condition	Behaviour is possible or facilitated	Behaviour is not possible (cannot occur)

Table 1 *– Constraint Logic Table*

This step is important because it removes ambiguity and forces analytical discipline. Many factors that appear similar in descriptive terms may have very different causal roles. For example, the absence of an enabling condition is not the same as the presence of an inhibiting constraint, and the two require different responses. The logic table provides a simple but rigorous way of distinguishing these cases.

The results should be interpreted in terms of causal clarity. A well-classified set of constraints will reveal patterns that may not be immediately visible in descriptive analysis, such as clusters of missing enablers or the accumulation of inhibitors. These patterns provide important diagnostic signals regarding system condition.

For example, in the English water industry, regulatory oversight may function as an inhibiting constraint on undesirable behaviours, such as underinvestment or non-compliance, while also enabling coordinated service provision.

Financial extraction mechanisms may function as enabling conditions for the transfer of resources to investors, while simultaneously acting as inhibiting constraints on reinvestment in infrastructure and service quality by reducing the resources available. At the same time, the absence of strong environmental enforcement mechanisms may be understood as a missing inhibitor, permitting behaviours that lead to environmental degradation.

Thus, a single constraint may function as an enabler in relation to one process and as an inhibitor in relation to another, depending on the behaviour under consideration.

Step 4: Assess Constraint Intensity (Amplitude)

The fourth step is to assess the intensity, or amplitude, of key constraints. This involves evaluating the relative strength of different constraints and identifying which ones are dominant in shaping system behaviour. Not all constraints have equal influence, and understanding their relative weight is essential for accurate diagnosis.

This step is important because it introduces a sense of scale and prioritisation into the analysis. Without assessing intensity, all constraints may appear equally important, leading to an unfocused or misleading interpretation. By identifying dominant constraints, the analyst can determine which factors are most influential in enabling or inhibiting system behaviour.

The results should be interpreted in terms of dominance and weakness. Strong constraints are those that consistently shape behaviour across the system, while weak or failing constraints have limited effect or are inconsistently applied. Particular attention should be paid to cases where constraints that should be strong, such as regulatory or cultural constraints, are weak, as this often indicates underlying instability.

For example, in the English water industry, financial constraints associated with investor returns may be assessed as strong and dominant, while environmental regulatory constraints may be assessed as comparatively weaker in practice. This imbalance contributes to the observed misalignment between financial priorities and environmental expectations.

Step 5: Assess Constraint Rate and Frequency of Change

The fifth step is to assess the rate at which different constraints change and the frequency with which they are altered. This involves identifying how quickly constraints evolve and how often significant changes occur within each domain. Different types of constraint operate on different timescales, and understanding these temporal dynamics is essential for diagnosing system behaviour.

This step is important because differences in the rate and frequency of change are a primary source of constraint misalignment. When some constraints change rapidly while others change slowly, the system may become temporarily or persistently misaligned. This can lead to instability or conflict.

The results should be interpreted in terms of temporal alignment or lag. Rapidly changing constraints, such as cultural expectations or financial conditions, may outpace slower-changing structural or regulatory arrangements. Conversely, slow-changing constraints may act as stabilising anchors but may also prevent timely adaptation. The key question is whether the rates of change across domains are broadly compatible or whether they generate misalignment.

For example, in the English water industry, financial constraints have evolved rapidly following structural changes such as the removal of ownership restrictions, while regulatory and cultural constraints have adapted more slowly. This difference in rates of change has contributed to increasing misalignment within the system and has played a significant role in its current instability.

Step 6: Assess Alignment Across Domains

The sixth step is to assess the degree of alignment between constraints across the material, structural, and cultural domains. This involves determining whether feedback between constraints reinforces or destabilises existing constraint configurations. Alignment occurs when constraints are mutually supportive and enable coherent system behaviour, while misalignment occurs when they conflict or undermine one another. This assessment should also consider the extent to which these constraints are aligned with biogenic constraints, as these define the underlying conditions for system viability.

This step is important because alignment is the primary condition for stability within an attractor. Without alignment, the system cannot sustain coherent patterns of behaviour, and instability is likely to emerge. Assessing alignment therefore provides a direct indication of the system's integrity.

The results should be interpreted in terms of coherence and tension. High alignment indicates that the system is likely to be stable and capable of sustaining co-operative interactions. Misalignment, particularly when persistent or increasing, indicates instability and a higher likelihood of transition. It is also important to identify where misalignment occurs, whether between domains or within them, as this affects how it may be addressed.

For example, in the English water industry, financial and regulatory structures may be aligned with one another, but misaligned with cultural expectations regarding environmental performance. This cross-domain misalignment contributes to conflict and reduces the stability of the system.

Step 7: Identify Historical Attractors

The seventh step is to identify the major historical phases of the system and treat each as a distinct attractor. This involves examining the system's history and identifying periods in which behaviour was relatively stable and patterned. Each such period is characterised by a configuration of constraints that maintained a consistent mode of operation.

This step is important because it establishes the baseline structure of the system's dynamics. By identifying attractors, the analyst moves beyond a simple chronological narrative and instead focuses on stable configurations of behaviour. These attractors provide the reference points for understanding change: transitions between them reflect changes in constraint alignment.

The results should be interpreted as identifying periods of relative stability rather than exact or sharply bounded phases. Attractors are not fixed states but regions of stability, and their boundaries may be gradual or overlapping. The key question is whether a recognisable pattern of behaviour is sustained over time.

For example, in the English water industry, two clear attractors can be identified: the state-owned system prior to privatisation, and the early regulated private system following privatisation. Each of these periods exhibits a relatively stable pattern of behaviour supported by a particular configuration of constraints.

Step 8: Analyse Constraint Changes Between Attractors

The eighth step is to analyse the changes in constraints that occurred between attractors. For each transition, the analyst identifies which constraints were introduced, removed, strengthened, or weakened. These changes are then classified according to constraint domain, i.e., material, structural, or cultural, and according to their causal role as enabling conditions or inhibiting constraints.

This step is central to the method because it provides the causal explanation for system change. Rather than attributing transitions to events alone, the analysis focuses on how those events altered the underlying constraint configuration. This allows the analyst to identify the mechanisms through which stability was disrupted and a new attractor emerged.

An important diagnostic feature of this analysis is the asymmetry in the types of constraint change observed. In principle, systems may experience four kinds of change: the addition of enabling conditions, the loss of enabling conditions, the introduction of inhibiting constraints, and the removal of inhibiting constraints. In practice, however, the relative prominence of these categories provides a strong indication of system condition. Stable or developing systems tend to exhibit a balance of changes, often characterised by the addition of enablers and the selective removal of inhibitors, which together expand the range of viable behaviours and reinforce a coherent attractor. By contrast, systems in stress or transition are more likely to show a dominant pattern of lost enablers and accumulating inhibitors. This asymmetry reflects a contraction in the system's range of viable options and a weakening of the conditions required for coordinated action. The relative absence of newly established enablers or the removal of existing inhibitors is therefore not merely an omission in analysis, but a meaningful signal that a system has not yet stabilised into a new attractor configuration.

The results should therefore be interpreted in terms of causal asymmetry. Particular attention should be paid to whether transitions are associated with the loss of enabling conditions, the accumulation of inhibiting constraints, or a balanced restructuring of both. Transitions characterised by the loss of enablers and accumulation of inhibitors are typically associated with instability and stress, while more balanced changes are associated with successful adaptation.

For example, the transition from state ownership to privatisation in the English water industry involved the introduction of new structural constraints related to private ownership and financial performance, alongside the weakening of constraints associated with centralised planning. These changes altered the balance of enabling and inhibiting conditions, leading to a shift in system behaviour and the emergence of a new attractor.

Step 9: Identify Recurring Transition Patterns

The ninth step is to identify recurring patterns in the transitions between attractors. This involves examining whether similar types of constraint change occur repeatedly, and whether certain kinds of events or conditions tend to produce similar effects on the system. These may include economic shocks, technological changes, regulatory reforms, cultural shifts, or disruptions to the conditions required for system viability, such as resource shortages or environmental shocks.

This step is important because it allows the analyst to move from case-specific explanation to more general insight. By identifying recurring patterns, it becomes possible to understand the typical drivers of change within the system and to anticipate how similar conditions may affect it in the future.

The results should be interpreted cautiously, as patterns may not be exact or deterministic. The aim is not to identify rigid laws, but to recognise recurring tendencies in how constraints evolve and interact. These patterns can then inform both diagnosis and prospective analysis.

For example, in many infrastructure sectors, major structural changes are associated with periods of economic or political reform, often leading to shifts in ownership models and regulatory frameworks. In the English water industry, the transition to privatisation reflected a broader pattern of structural change associated with economic policy shifts in the late twentieth century.

Step 10: Identify Agency in Constraint Changes

The tenth step is to identify the role of agency in the formation and modification of constraints. This involves distinguishing between constraints that arise primarily through deliberate action by specific actors, such as governments, regulators, or corporate leadership, and those that emerge more diffusely through collective behaviour, cultural change, or broader system dynamics. These may be described, respectively, as elite-driven and population-driven constraint changes.

This step is important because it clarifies how constraints come into being and how they may be altered. Not all constraints are equally malleable: some can be changed relatively quickly through policy or decision-making, while others evolve more gradually through shifts in behaviour or shared understanding. Identifying the sources of constraint change helps to determine the feasible pathways for system adaptation or intervention.

The results should be interpreted in terms of alignment or conflict between different sources of agency. Where elite-driven and population-driven changes are aligned, constraint changes are more likely to be coherent and effective. Where they are in tension, constraint configurations may become unstable, as different parts of the system move in different directions.

For example, in the English water industry, financial and structural changes have largely been driven by elite actors, including policymakers and investors, while shifts in cultural expectations, particularly regarding environmental performance, have emerged more from the wider population. The lack of alignment between these sources of change has contributed to the current misalignment of constraints.

Differences in agentic constraints may also influence the capacity of actors to initiate or shape constraint changes, contributing to asymmetries in influence and control within the system.

Step 11: Identify the Current Attractor State

The eleventh step is to identify the system's current attractor state based on the configuration and alignment of constraints. This involves determining whether the system is operating within a stable attractor, an unstable configuration, or a transitional state between attractors.

This step is important because it provides an overall characterisation of the system's condition. By integrating the results of previous steps, the analyst can assess whether the system's constraints are sufficiently aligned to sustain stable behaviour, or whether instability and transition are more likely.

The results should be interpreted in terms of stability, instability, or transition. A stable attractor is indicated by strong and coherent constraint alignment. An unstable state is indicated by weak or conflicting constraints. A transitional state is indicated by the breakdown of an existing alignment without the establishment of a new one.

For example, the English water industry appears to be in a transitional state, with increasing misalignment between financial, regulatory, and cultural constraints. This indicates movement away from a previously stable attractor without yet reaching a new stable configuration.

Step 12: Diagnose System Condition

The twelfth step is to synthesise the findings of the analysis into an overall diagnosis of the system's condition. This involves identifying the key inhibiting constraints, missing enabling conditions, and the degree of alignment across constraint domains, as well as assessing the likely trajectory of the system.

In addition, the analysis should explicitly consider the extent to which the current configuration satisfies biogenic constraints. Because these define the fundamental needs and capacities of system components, persistent misalignment with biogenic constraints provides a direct indication of threats to system viability. Such misalignment may arise through insufficient resources, excessive demands, or structural and cultural conditions that prevent the satisfaction of basic requirements.

This step is important because it translates detailed analysis into a clear and actionable understanding of system behaviour. It allows the analyst to summarise complex interactions in a way that highlights the most significant issues affecting system stability and viability.

The results should therefore be interpreted not only in terms of stability or instability, but also in terms of viability. A system may exhibit short-term stability while failing to meet underlying biogenic constraints, indicating a risk of longer-term decline or collapse. Conversely, improving alignment with biogenic constraints may signal a strengthening of system viability, even where other forms of instability are present.

For example, the English water industry may be diagnosed as experiencing increasing instability due to the divergence between financial, regulatory, and cultural constraints, combined with the absence of sufficient enabling conditions for long-term infrastructure investment and environmental performance.

Step 13: Identify Emerging Attractors

The thirteenth step is to identify potential emerging attractors by examining alternative configurations of constraints that could give rise to new stable states. This involves considering how existing constraints might be reconfigured, and what new alignments could emerge under different conditions.

This step is important because it shifts the analysis from diagnosis to structured anticipation. Rather than attempting to predict a single outcome, the analyst identifies a set of plausible future states, each defined by a distinct configuration of constraints. This provides a basis for understanding the range of possible system trajectories.

The results should be interpreted as scenarios rather than predictions. Each potential attractor represents a coherent configuration of constraints that could stabilise the system under certain conditions. The analyst should focus on the internal consistency of each configuration and its compatibility with material, structural, and cultural conditions.

For example, in the English water industry, potential emerging attractors might include a re-aligned regulatory model, a continued financially dominant regime, or a more fundamental restructuring of ownership and governance. Each of these corresponds to a different pattern of constraint alignment.

Step 14: Design Constraint Reconfiguration

The final step is to design potential interventions by identifying how constraints might be reconfigured to improve system stability and viability. This involves determining which inhibiting constraints should be removed or weakened, which enabling conditions should be introduced or strengthened, which inhibiting constraints should be introduced, and which enabling conditions should be removed. It also requires consideration of how changes in one domain will affect others.

This step is important because it connects analysis to action. By understanding the causal role of constraints, the analyst can identify targeted interventions that are more likely to produce coherent and sustainable outcomes. This avoids ad hoc or piecemeal changes that fail to address underlying misalignment.

The results should be interpreted in terms of feasibility and coherence. Proposed changes must be compatible with material conditions, structurally implementable, culturally legitimate, and biogenically feasible. Interventions that fail in any of these respects are unlikely to produce lasting stability. The goal is not simply to change constraints, but to restore alignment across domains in a way that supports both stability and adaptability.

For example, in the English water industry, potential reconfigurations might include strengthening environmental regulatory constraints, adjusting financial incentives to support long-term investment, and aligning governance structures more closely with public expectations. The effectiveness of such measures would depend on their ability to produce a coherent alignment across domains.

26.6. Outputs

Constraint analysis can produce a set of structured outputs that translate the analytical process into forms that can be interpreted, communicated, and applied. Examples are given in Appendix A.

One of the primary outputs is a set of constraint diagnostic tables, in which key factors are classified according to their causal role as enabling conditions or inhibiting constraints, and whether they are present or absent. These tables provide a clear and systematic overview of the conditions shaping system behaviour, making it possible to identify, for example, dominant constraints, missing enablers, and patterns of imbalance across domains.

A second output is a historical transition analysis, which traces the evolution of the system through successive attractors by identifying changes in constraint configurations over time. This allows the analyst to move beyond descriptive history and provide a causal explanation of system change, showing how the introduction, removal, or modification of constraints has led to shifts in system behaviour.

A third output is the development of attractor maps, which represent the system in terms of relatively stable configurations and the transitions between them. These may be expressed conceptually or diagrammatically, showing how different combinations of constraints correspond to different modes of system behaviour. Attractor maps help to clarify the structure of the system's landscape, highlighting regions of stability, instability, and potential transition pathways.

Finally, the method supports the formulation of stabilisation or intervention strategies, based on the identification of key inhibiting constraints and enabling conditions that are present or absent. By linking proposed actions directly to the underlying constraint configuration, these strategies provide a more coherent and targeted approach to system change. Rather than addressing symptoms in isolation, they aim to restore or establish alignment across material, structural, cultural, and biogenic domains in a way that supports long-term viability.

Taken together, these outputs enable the analyst to move from description to explanation, from explanation to diagnosis, and from diagnosis to informed intervention. They provide both a conceptual understanding of system behaviour and a practical basis for decision-making.

26.7. Application

Constraint analysis identifies conditions of possibility rather than providing precise predictions. The method establishes which configurations of constraints are likely to enable or inhibit particular system behaviours, but does not determine exact outcomes, as these depend on complex and often contingent interactions.

Cultural constraints require particularly careful interpretation. Unlike material and many structural constraints, they are not directly observable and must be inferred from patterns of behaviour, communication, and shared understanding. As such, cultural analysis involves a degree of interpretation and should be approached with appropriate caution.

The definition of system boundaries is also critical. Constraints are system-specific, and different boundary choices may lead to different interpretations. It is therefore essential that boundaries are clearly defined and consistently applied throughout the analysis.

Finally, causality within social systems is often recursive, involving feedback loops in which system behaviour influences the constraints that shape it. This means that constraint configurations may evolve dynamically over time, and analysis should take into account the possibility of reinforcing or balancing feedback processes.

26.8. Section Summary

Constraint analysis provides a structured way of understanding how social systems behave, change, and stabilise. By focusing on the causal role of constraints, both inhibiting and enabling, it allows the analyst to move from description to explanation, and from explanation to practical intervention.

27. Example of Constraint Analysis – The English Water Industry

This example is a summary of a more formal analysis in line with the process steps described above. The historical analysis of the English water industry suggests the presence of two relatively stable attractors, followed by a period of increasing instability associated with a shift in constraints.

The first attractor, corresponding to the post-war period up to privatisation, was characterised by state ownership and centralised control. Material, structural, and cultural constraints were broadly aligned around the provision of water as a public service, supporting long-term investment, universal access, and system stability.

The second attractor emerged following privatisation and the establishment of a regulated private model. During its early phase, structural constraints, defined by private shareholder ownership combined with regulatory oversight, remained sufficiently aligned with material requirements and prevailing cultural expectations to produce a stable configuration. Investment, service provision, and regulatory control were coordinated in a way that maintained a workable balance between financial performance and public service obligations.

A significant structural shift occurred with the expiry of the government's golden share, which had previously acted as a constraint on ownership and control within the industry. Its removal enabled takeovers and facilitated the entry of new financial actors, including private equity investors. This change altered the structural constraint environment by allowing greater flexibility in ownership structures and financial strategies.

Following this shift, financial constraints evolved rapidly, placing increased emphasis on returns to investors, financial efficiency, and capital structuring. In contrast, regulatory and cultural constraints adapted more slowly. Cultural expectations, particularly in relation to environmental standards, service quality, and public accountability, continued to evolve in a direction that was not fully aligned with emerging financial priorities. Regulatory structures, while maintaining oversight, remained more focused on financial performance and customer interaction metrics than on underlying service quality and environmental outcomes.

This divergence between constraint domains has resulted in increasing misalignment within the system. As a consequence, the previously stable regulated private model has become destabilised. The system is now best understood as occupying an unstable transitional phase, rather than representing a fully formed third attractor. Patterns of co-operation have weakened, conflict has increased, and the system exhibits characteristics of movement away from a stable attractor and into a less stable region of the landscape.

In summary, the evolution of the English water industry can be understood as a transition from a state-owned attractor to an early regulated private attractor, followed by destabilisation associated with the removal of ownership constraints and the increasing misalignment of service, environmental and financial constraints. The current configuration reflects an unstable transitional state, the future trajectory of which will depend on the extent to which material, structural, and cultural constraints can be brought back into alignment.

The prospective application of constraint analysis to the English water industry involves identifying potential future configurations of constraints and assessing how these may give rise to alternative attractor states. Given the current condition of misalignment between material, structural, and cultural constraints, the system appears to be in a transitional phase. Its future trajectory will depend on how these constraints evolve and whether a new alignment can be achieved.

Several potential attractor configurations can be identified.

One possible trajectory is the emergence of a re-aligned regulated model, in which structural and regulatory constraints are modified to better reflect evolving cultural expectations and material conditions. This could involve strengthening environmental regulation, rebalancing financial incentives towards long-term infrastructure investment, and increasing accountability mechanisms. In this configuration, financial, regulatory, and cultural constraints would be brought back into closer alignment, supporting a stable attractor characterised by improved co-operation between system components and enhanced system viability.

A second possible trajectory is the continuation of the current trend towards financially dominant structuring, in which financial constraints remain primary and other constraint domains continue to lag. In this case, misalignment would persist or increase, particularly between financial and cultural constraints. The system would likely remain unstable, with ongoing conflict between stakeholders, declining trust, and periodic interventions aimed at correcting specific failures without achieving overall alignment. This would correspond to a shallow or unstable attractor.

A third potential trajectory is a more significant structural shift towards reconfigured ownership or governance, potentially involving increased public or hybrid forms of ownership. Such a change would alter structural constraints more fundamentally, potentially enabling a new alignment with cultural expectations regarding public accountability and environmental responsibility. If accompanied by appropriate regulatory and material adjustments, this could give rise to a new, more stable attractor. However, the transition to such a configuration would likely involve significant disruption as existing constraints are dismantled and replaced.

Across all scenarios, material constraints, particularly those associated with environmental pressures and infrastructure requirements, are likely to become more demanding. This increases the importance of achieving alignment between structural and cultural constraints, as failure to do so may further reduce system viability.

The analysis therefore suggests that the long-term stability of the English water industry will depend on the extent to which financial, regulatory, and cultural constraints can be brought into alignment in a way that supports both effective service provision and environmental sustainability. Without such realignment, the system is likely to remain in a state of instability or undergo further transitions.

28. Discussion and Conclusions

This paper has set out a framework for understanding social systems in terms of the causal constraints that shape their behaviour. By grounding the analysis in a physicalist account of causality, understood as the transfer of matter, energy, and information, it has been possible to define constraints not as abstract limits, but as concrete causal mechanisms that enable or inhibit system processes. This provides a consistent ontological basis for analysing systems across domains, from physical and biological systems to complex social and institutional arrangements.

A key contribution of the framework is the integration of material, structural, and cultural constraints, together with internal biogenic and agentic constraints, into a unified account of social system behaviour. Rather than treating these as separate explanatory domains, the analysis shows how they interact to produce patterns of stability, instability, and transition. The concept of constraint alignment provides a clear basis for understanding stability within attractors, while misalignment explains the emergence of conflict and the conditions under which systems move away from established patterns of behaviour.

The introduction of constraint-based attractor analysis as a method extends this conceptual framework into a practical analytical tool. By structuring analysis around the identification of constraints, their causal roles, their intensity, and their rates of change, the method enables a systematic examination of how systems evolve and how they may be influenced. The use of historical, current, and prospective perspectives within a single analytical process allows the method to link explanation, diagnosis, and intervention in a coherent way.

The example of the English water industry illustrates how this approach can be applied in practice. By analysing the evolution of constraint configurations over time, it becomes possible to identify the emergence of stable attractors, the mechanisms through which they were destabilised, and the current condition of the system as a transitional state characterised by misalignment. The analysis also demonstrates how potential future attractors can be identified in terms of alternative configurations of constraints, providing a structured basis for considering possible trajectories without relying on deterministic prediction.

More generally, the framework highlights the importance of temporal dynamics in constraint systems. Because different types of constraint change over different timescales, perfect alignment is rarely achieved. Instead, social systems are characterised by ongoing processes of alignment and misalignment, which give rise to both stability and change. This perspective helps to explain why systems may appear stable for extended periods before undergoing relatively rapid transitions, and why interventions that address only one domain of constraint often fail to produce lasting change.

An important implication of the framework is that it can be generalised beyond social systems. In the case of physical systems, the same analytical logic applies, but elements that depend on agency, such as cultural constraints and deliberate intervention, are absent. What remains is the analysis of material and structural constraints operating through causal transfers of matter and energy. Physical systems can therefore be understood in terms of constraint-defined attractors and transitions between them, with stability and change arising from the configuration of causal conditions rather than from deliberate action (Prigogine & Stengers, 1984).

A further extension applies to the epistemic domain. Epistemic systems, concerned with the formation, organisation, and transmission of knowledge, can also be understood in terms of constraints, although these operate primarily through information and interpretation. In such systems, attractors correspond to stable configurations of understanding (Kuhn, 1962), such as shared frameworks or paradigms, while transitions occur when informational, structural, or cultural constraints change. A distinctive feature of epistemic systems is reflexivity: the capacity of agents to reflect on and modify the constraints that shape their own knowledge. This introduces recursive dynamics in which changes in understanding alter the conditions under which further knowledge is produced.

Constraint analysis therefore offers a practical tool for understanding and intervening in complex social systems that is firmly grounded in general systems theory (Bertalanffy, 1968) and a causal account of system behaviour. Its strength lies in its ability to provide a structured yet flexible framework that can be applied across different systems and levels of analysis, without requiring full quantification or highly specialised modelling techniques. By focusing on the conditions that enable or inhibit behaviour, it allows analysts and practitioners to move beyond descriptive accounts towards causal explanation and targeted intervention.

At the same time, the method has limitations. It does not provide precise predictions, and its application depends on the appropriate selection and interpretation of constraints. Cultural constraints require careful analysis, as they are not directly observable and may vary across different components of the system. In addition, because social systems are open and embedded within wider systems, external influences may alter constraint configurations in ways that are difficult to anticipate.

Despite these limitations, the framework provides a coherent basis for analysing systems across physical, social, and epistemic domains. It bridges the gap between abstract systems theory and real-world analysis by linking causal mechanisms to observable patterns of behaviour and to potential strategies for intervention. As such, it offers a useful foundation for further development, including more formal modelling approaches, empirical applications across different domains, and integration with related frameworks in systems science and social theory.

The framework also accommodates variation in the internal constraints of agents, including differences in biological capacities and decision-making processes. Such variation may be significant in many real-world systems, influencing patterns of participation, coordination, and influence. While the present paper does not explore these aspects in detail, they provide an important basis for further analysis, particularly in relation to the operation of power and the distribution of capabilities within social systems.

In conclusion, constraint analysis provides a systematic way of understanding how systems behave, how they change, and how they may be influenced. By focusing on the causal role of constraints and their alignment across domains, it enables a deeper understanding of both stability and transformation, and supports the design of more coherent and effective interventions in complex systems.

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Appendix A- Illustration of Outputs from Constraint Analysis

The following examples are from an analysis of the English water industry, comprising its suppliers, consumers, investors, and regulators.

A1. A Simplified Constraint Diagnostic Table

Domain	Factor	Type	Status	Effect
Material	Water availability	Enabler	Present	Supports service provision
Material	Infrastructure condition	Enabler	Weak	Limits reliability
Structural	Regulatory oversight	Inhibitor	Present	Constrains non-compliant behaviour
Structural	Investment incentives	Enabler	Absent	Reduces long-term reinvestment
Cultural	Environmental norms	Inhibitor	Weak	Allows environmentally damaging behaviour

Domain	Factor	Type	Status	Effect
Cultural	Public trust	Enabler	Declining	Reduces co-operation and compliance
Biogenic	Workforce capacity	Constraint	Stressed	Limits sustainable operation

A2. Historical Transition Summary

- **State 1 (Stable Public Model)**
  High regulatory alignment; moderate investment; stable service delivery
- **State 2 (Privatisation Transition)**
  Structural changes; increased financial incentives; emerging misalignment
- **State 3 (Current Transitional State)**
  Financial extraction dominant; declining trust; environmental misalignment

Pattern: Increasing divergence between structural and cultural constraints, with emerging stress on material and biogenic conditions

A3. Attractor Map (Conceptual Description)

- **Attractor A:** Stable, co-operative system with aligned constraints
- **Attractor B:** Financially optimised but socially misaligned system
- **Current Position:** Transitional region between A and B
- **Key Feature:** Increasing elevation (cost) due to misalignment

A4. Diagnostic Summary

- **Key inhibitors:** financial extraction mechanisms, weak enforcement
- **Missing enablers:** investment incentives, trust, regulatory coherence
- **Alignment:** low across domains
- **Biogenic alignment:** weakening (workforce stress, capacity limits)
- **Trajectory:** unstable, with risk of further decline

A5. Intervention Outline

- Introduce stronger environmental enforcement (add inhibitor)
- Reform financial incentives (remove harmful enabler)
- Strengthen investment frameworks (add enabler)
- Support workforce sustainability (restore biogenic alignment)

Appendix B: Constraint Interaction Relationships and Feedback Loops

B1. Introduction

Constraint analysis involves not only the identification of individual constraints, but also an understanding of how different constraint domains interact to shape system behaviour. The relationships set out below provide a simplified representation of these interactions using directional expressions of the form:

Constraint Domain + Constraint Domain → Constraint Domain

These expressions are not formal equations, but indicate the combined causal influence of different domains. They are intended as an interpretive tool to support analysis, particularly in identifying patterns of stability, instability, and feedback within social systems.

B2. Core Constraint Interaction Relationships

1. Biogenic + Cultural → Agentic

Biological needs and capacities, interpreted through cultural frameworks, shape how agents perceive situations, evaluate options, and select actions.

2. Biogenic + Material → Agentic

Material conditions affect the satisfaction of biological needs, influencing motivation, capability, and decision-making.

3. Cultural + Structural → Agentic

Cultural meanings shape interpretation, while structural arrangements define available roles and pathways for action.

4. Agentic + Material → Structural

Agents acting under material conditions generate patterns of interaction, roles, institutions, and organisational arrangements.

5. Agentic + Cultural → Structural

Culturally shaped behaviour contributes to the formation and reproduction of structured patterns of interaction.

6. Structural + Agentic → Cultural

Interactions between agents transmit, reinforce, or modify shared meanings, norms, and expectations.

7. Material + Structural → Cultural

Material conditions and structural arrangements influence which cultural meanings are sustained, adapted, or contested.

8. Structural + Cultural → Agentic

Existing structures and shared meanings shape expectations, behaviour, and decision-making in agents.

B3. Feedback Loops

1. Core Social Reproduction Loop

Biogenic + Cultural → Agentic → Structural → Cultural

Biological needs and cultural meanings shape agent behaviour; agent behaviour produces structured interactions; these interactions transmit and reproduce cultural meanings. When constraints are aligned this results in a stable attractor; when they are misaligned this leads to instability or transition.

2. Material–Structure Loop

Agentic + Material → Structural → Cultural → Agentic

Agent behaviour under material conditions produces structure; structure transmits culture; culture feeds back into future decision-making. This links the environment to behaviour and the reproduction of culture.

3. Role and Institution Loop

Structural + Cultural → Agentic → Structural

Existing roles and norms shape behaviour, which in turn reproduces or modifies those roles and structures. This explains institutional persistence and gradual change.

4. Stability–Destability Loop

Aligned Constraints → Reinforced Behaviour → Constraint Reproduction

Aligned constraints produce behaviour that reinforces those same constraints. The system remains within the current attractor.

Misaligned Constraints → Disrupted Behaviour → Constraint Breakdown

Conflicting constraints produce behaviour that weakens existing structures and meanings. The system transitions between attractors.

5. Power Formation and Feedback Loop

Agentic + Structural + Cultural → Power

Differences in capability, position, and legitimacy generate asymmetries in influence and control.

Power → Structural + Cultural + Material

Power then acts as constraint-shaping capacity, influencing:

- institutional arrangements
- cultural meanings
- resource distribution

Powerr can stabilise or destabilise the system depending on alignment.

B4. How to Use These Relationships

These interaction relationships may be used within constraint analysis as a diagnostic tool.

The analyst may:

- identify key constraint domains
- examine how they interact using the relationships above
- assess whether interactions are:
    - **aligned (mutually reinforcing)**
    - **misaligned (in tension or contradiction)**

Patterns of alignment are associated with stability and the formation of attractors, while patterns of misalignment are associated with instability, conflict, and transition.

These relationships therefore provide a conceptual bridge between the identification of constraints and the analysis of system dynamics.

Appendix C – Definitions

Refer to the Master List of Definitions and Propositions at https://rational-understanding.com/SST/ for updates.

D3.1 – Constraint Presence and Absence

Constraint effects arise both from presence (existing enablers or inhibitors) and absence (missing enablers or missing inhibitors), each of which has distinct causal implications.

D3.2 – System-Specific Constraint

A constraint is system-specific, meaning that its enabling or inhibiting effect depends on the nature, structure, and level of organisation of the system to which it is applied.

D3.3 – Constraint Domain

Constraint domains are analytical categories of constraint within social systems comprising:

- material (environmental and resource conditions),
- structural (organisational and interactional arrangements),
- cultural (shared meanings, norms, and knowledge).

Biogenic constraints, which arise from the biological nature of system components and define their fundamental needs and capacities, are treated as a subset of material constraints.

In addition, agentic constraints operate within agents at the level of decision-making, shaping how conditions are interpreted and actions selected. While not treated as a separate analytical domain, they are conceptually distinct and mediate between biogenic and cultural constraints in shaping behaviour.

D3.4 – Biogenic Constraint

Biogenic constraints are internal constraints arising from the biological nature of system components, defining the needs, capacities, and limits required for their continued functioning. They are typically relatively stable over the timescales of social analysis, although variation across agents or populations may be significant in shaping system behaviour.

D3.5 – Biogenic Constraint Variation

Biogenic constraint variation refers to differences in biological needs, capacities, or limitations across individuals or populations that influence their ability to participate in, respond to, or sustain system processes.

D3.6 – Agentic Constraint

Agentic constraints are internal constraints governing the processes of perception, interpretation, evaluation, decision-making, and action selection within agents. They mediate between biogenic needs, cultural meanings, and structural conditions, shaping how agents respond to the constraints acting upon them.

D3.7 – Agentic Constraint Variation

Agentic constraint variation refers to differences in cognitive capacity, reflexivity, interpretive frameworks, or decision-making processes across agents that influence how they respond to constraints and engage in system interactions.

D3.8 – Epistemic Constraint

An epistemic constraint is a constraint that operates through information and its interpretation, enabling or inhibiting the formation, organisation, or transmission of knowledge.

D3.9 – Internal Constraint Profile

The internal constraint profile of an agent is the combined configuration of its biogenic and agentic constraints, which together shape its capabilities, needs, and patterns of action within a system.

D3.10 – Constraint Intensity (Amplitude)

Constraint intensity is the relative strength of a constraint in shaping system behaviour.

D3.11 – Constraint Rate of Change

Constraint rate of change refers to the speed at which a constraint evolves over time.

D3.12 – Constraint Frequency of Change

Constraint frequency of change refers to how often a constraint is altered.

D3.13 – Attractor (Constraint-Based Interpretation)
In social systems, an attractor may be understood as a relatively stable pattern of system behaviour sustained by a coherent configuration of constraints.

D3.14 – Constraint Analysis

Constraint analysis is a method for understanding system behaviour by identifying and analysing the causal constraints, both external and internal, that enable or inhibit its processes.

D3.15 – Emerging Attractor

An emerging attractor is a potential future stable configuration defined by a coherent arrangement of constraints.

D3.16 – Constraint Reconfiguration

Constraint reconfiguration is the deliberate modification of constraints to alter system behaviour and improve alignment and viability.

Constraint regulation and constraint reconfiguration represent different modes of system adaptation: regulation involves ongoing adjustment within an existing structure, whereas reconfiguration involves deliberate restructuring of the constraint landscape.

D3.17 – Reflexive Constraint Modification

Reflexive constraint modification is the process by which agents identify, interpret, and deliberately alter the constraints that shape their own knowledge or behaviour.

Reflexive constraint modification is the operational expression of reflexive agency, through which agents analyse and deliberately alter the constraints shaping their behaviour.

Appendix D – Propositions

Refer to the Master List of Definitions and Propositions at https://rational-understanding.com/SST/ for updates.

P3.1 – Causality-Constraint Equivalence

Constraints are causally effective conditions that enable or inhibit system processes, either through direct causal transfers of matter, energy, or information, or through configurations that shape the possibility and structure of such transfers.

P3.2 – Enabler-Inhibitor Duality

All system behaviours depend on a combination of enabling conditions and inhibiting constraints.

P3.3 – Presence-Absence Proposition

The absence of enabling conditions is causally distinct from the presence of inhibiting constraints and must be analysed separately.

P3.4 – System Specificity Proposition

A constraint only exists as such in relation to a defined system and level of organisation.

P3.5 – Domain Interaction Proposition

Constraint domains (material, structural, cultural, biogenic, and agentic) interact to shape system behaviour and cannot be analysed in isolation.

P3.6 – Alignment-Stability Proposition

Constraint alignment across domains, together with compatible internal constraints within agents, produces stable attractors characterised by coherent and co-operative system behaviour.

P3.7 – Misalignment-Instability Proposition

Constraint misalignment across domains, or between external and internal constraints, produces instability, conflict, and increased likelihood of transition between attractors.

P3.8 – Temporal Misalignment Proposition

Differences in the rate and frequency of constraint change are a primary source of constraint misalignment.

P3.9 – Asymmetry Diagnostic Proposition

A predominance of lost enabling conditions and accumulating inhibiting constraints is indicative of system stress or transition.

P3.10 – Attractor Transition Proposition

Transitions between attractors occur when changes in constraint configurations disrupt existing alignment and establish new configurations.

P3.11 – Agency Constraint and Alignment Proposition
Constraint changes in social systems may arise from both elite-driven processes, such as institutional decisions or policy interventions, and population-driven processes, such as distributed behavioural or cultural change. Alignment between these sources supports coherent system adaptation, while misalignment contributes to instability and contested outcomes.

P3.12 – Constraint Dominance Proposition

Constraints differ in intensity, and dominant constraints disproportionately shape system behaviour.

P3.13 – Landscape Interpretation Proposition

System behaviour can be understood as movement within a constraint-defined landscape comprising attractors and transitional regions.

P3.14 – Cooperation-Constraint Proposition

Co-operation arises from the exchange of enabling conditions (satisfiers), while conflict arises from the exchange of inhibiting constraints (contra-satisfiers), as agents, through their agentic constraints, seek to satisfy their needs under constraint.

P3.15 – Viability Proposition

System viability depends on maintaining sufficient constraint alignment, through interactions with the environment, to support both stability and adaptability over time.

P3.16 – Open System Proposition

Social systems are open and embedded within larger systems, and their constraints are influenced by external conditions.

P3.17 – Non-Predictive Proposition

Constraint analysis identifies conditions of possibility rather than precise outcomes.

P3.18 – Intervention Proposition

Effective intervention requires the reconfiguration of constraints to restore alignment across material, structural, and cultural domains, taking into account the internal biogenic and agentic constraints that shape behaviour.

P3.19 – Epistemic Attractor Proposition

Epistemic systems exhibit attractors corresponding to stable configurations of knowledge, belief, or interpretation sustained by aligned constraints.

P3.20 – Reflexivity Proposition

In epistemic systems, agents can reflect on and deliberately modify constraints, introducing recursive dynamics in which knowledge influences the conditions of its own formation.

P3.21 – Biogenic Viability and Misalignment Proposition

Biogenic constraints define the fundamental requirements for system viability. Misalignment between these internal constraints and material, structural, or cultural conditions constitutes a direct threat to system stability, as it reflects a failure to sustain the processes necessary for the continued functioning of system components.

P3.22 – Cross-Domain Applicability Proposition

Constraint analysis applies across physical, social, and epistemic systems, with domain-specific constraints emerging from the organisation of each system type.

P3.23 – Internal–External Constraint Proposition

System behaviour arises from the interaction between external constraints operating at the level of the system and internal constraints operating within agents.

P3.24 – Internal Constraint Influence Proposition

Variation in the internal constraint profiles of agents, including both biogenic and agentic constraints, contributes to variation in behaviour, participation, and interaction within social systems.

P3.25 – Biogenic Variation Proposition

Differences in biogenic constraints across agents influence their capacity to satisfy needs and sustain participation in system processes.

P3.26 – Agentic Variation Proposition

Differences in agentic constraints influence how conditions are perceived, interpreted, and acted upon.

P3.27 – Participation Asymmetry Proposition

Variation in internal constraint profiles leads to asymmetries in participation and engagement within system processes.

P3.28 – Constraint Sensitivity Proposition

Agents with different internal constraint profiles respond differently to the same external constraints.

P3.29 – Internal Constraint Relevance Proposition

Variation in internal constraint profiles becomes analytically significant where it affects access to satisfiers, system participation, or overall system behaviour and stability.

P3.30 – Aggregation Proposition

System-level patterns emerge from aggregation of differing internal constraint profiles

P3.31 – Influence and Power Proposition

Variation in agentic constraints contributes to asymmetries in influence and control within social systems, forming a micro-level basis for differences in power.

P3.32 – Interaction Mediation Proposition

Agentic constraints mediate the effects of biogenic, cultural, and structural constraints by shaping how agents interpret and respond to them.

P3.33 – Cultural Transmission Proposition

Cultural constraints are transmitted and reproduced through the structured interactions between system components, as the exchange of information between agents provides the causal mechanism by which shared meanings, norms, and expectations are maintained and propagated.

