Systemic Saturation: Conceptualizing the Core Dimensions of Interconnected Systems Under Pressure

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Abstract

The Theory of Saturation (Manafi, 2025, 2026) conceptualizes how systems operating under finite capacities respond to excessive complexity, interdependence, and resource demands. While prior work has examined saturation at emotional, cognitive, and institutional levels, the dynamics of systemic saturation remain insufficiently explored. Addressing this gap, the present study aims to conceptualize the dimensions of systemic saturation as a distinct yet structurally consistent form within the broader saturation framework.

Using an exploratory qualitative design, data were collected through semi-structured interviews with seven experts across domains including systems thinking, governance, and organizational complexity. The data were analyzed using qualitative content analysis, allowing patterns to emerge inductively. The findings reveal that systemic saturation unfolds as a progressive, multidimensional process comprising four core dimensions: systemic overload, systemic attenuation, systemic degradation, and systemic breakdown. Systemic overload reflects the accumulation of excessive interdependencies, complexity, and resource pressures; systemic attenuation captures the failure of regulatory mechanisms, including distorted feedback loops and coordination breakdowns; systemic degradation highlights the erosion of resilience and adaptive capacity; and systemic breakdown represents a tipping-point condition characterized by systemic fragility and heightened risk of nonlinear collapse or phase transition.

The study contributes to the literature by extending the Theory of Saturation to the macro level of interconnected systems and by integrating insights from complexity and resilience perspectives into a unified conceptual model. By identifying the underlying dimensions and process dynamics of systemic saturation, this research provides a foundation for future empirical measurement and cross-level theoretical integration. Practically, the findings offer a framework for diagnosing emerging systemic risks and understanding how complex systems transition from stability to fragility under sustained pressure.

Keywords: Theory of Saturation, Systemic Saturation, Complexity, Interdependence, Resilience, Phase Transition

1. Introduction

The Theory of Saturation (Manafi, 2025, 2026) provides a unifying framework for understanding how systems respond to excessive input, complexity, and accumulated pressures. The theory is grounded in the premise that all systems—ranging from individual psychological processes to large-scale societal structures—operate within finite processing and regulatory capacities. When these capacities are exceeded, systems enter a state of saturation in which their ability to function, adapt, and regulate progressively deteriorates. Rather than viewing dysfunction as a set of isolated problems, the theory conceptualizes saturation as a structured and dynamic process that unfolds across different levels of analysis.

Within this framework, saturation manifests in multiple forms depending on the nature of the system involved. Previous work has identified four analytically distinct yet structurally analogous types of saturation: emotional, cognitive, institutional, and systemic saturation. Emotional saturation reflects the overload of affective processes, leading to diminished responsiveness and regulatory failure. Cognitive saturation captures the limits of information processing, resulting in reduced clarity, impaired decision-making, and executive dysfunction. Institutional saturation extends the concept to organizational and governance structures, where accumulated policies, procedural rigidity, and coordination failures contribute to declining effectiveness and legitimacy. Building on these levels, systemic saturation represents the most comprehensive and complex form, occurring within large-scale, interconnected systems characterized by dense interdependencies and multi-layered interactions.

In contemporary contexts, systemic saturation has become increasingly relevant as global systems grow in scale, complexity, and interconnection. Economic networks, technological infrastructures, ecological systems, and governance frameworks are now tightly coupled, meaning that disruptions in one domain can rapidly propagate across others. While such interconnectedness can enhance efficiency and integration, it also increases vulnerability to cascading failures and amplifies the impact of localized shocks. At the same time, the accumulation of complexity—manifested in expanding networks, increasing data flows, and layered regulatory environments—has made prediction, control, and coordination more difficult. These conditions create a systemic environment in which feedback mechanisms may become distorted, resilience may erode, and the capacity for effective adaptation may decline.

Despite the growing importance of these challenges, the concept of systemic saturation has not been explicitly defined or systematically examined in the existing literature. Related research in complexity theory, resilience theory, and systems thinking has addressed issues such as interdependence, nonlinear dynamics, and system fragility; however, these perspectives are often fragmented and lack an integrated process model that explains how systems transition from stability to breakdown under sustained pressure. The Theory of Saturation offers a valuable lens for integrating these insights by framing systemic dysfunction as a progressive process driven by the interaction of overload, regulatory failure, and declining resilience.

Understanding the dimensions of systemic saturation is therefore both theoretically and practically significant. From a theoretical standpoint, it extends the scope of saturation theory to the macro level, contributing to a unified, multi-level framework that links individual, organizational, and systemic phenomena. From a practical perspective, identifying the key dimensions of systemic saturation enables researchers and practitioners to better diagnose emerging risks within complex systems, anticipate potential tipping points, and design interventions aimed at preserving resilience and adaptive capacity. Without such a framework, systemic failures may appear sudden or unpredictable, when in fact they are the outcome of gradual and identifiable processes.

Accordingly, the primary aim of this study is to explore and conceptualize the core dimensions of systemic saturation through an exploratory qualitative approach. Drawing on expert insights, the study seeks to identify the underlying mechanisms and patterns through which systemic saturation manifests in interconnected systems. By developing a structured, multidimensional framework, this research provides a foundation for future empirical investigation, measurement development, and theoretical integration within the broader context of complex systems and governance research.

2. Literature Review

The concept of systemic saturation intersects with several established streams of research that examine how complex systems respond to increasing levels of interdependence, complexity, and pressure. Although the term "systemic saturation" has not been explicitly developed in prior literature, its underlying logic is consistent with foundational work in systems theory, complexity science, and resilience research. The Theory of Saturation (Manafi, 2025, 2026) builds on these traditions by proposing a unified framework in which systems across different levels exhibit similar patterns of overload, adaptation, degradation, and potential breakdown. Recently, several studies have applied the Theory of Saturation across diverse fields such as psychology, mathematics, political science, economics, and urban studies (e.g., Hojabri & Manafi, 2026; Manafi & Ojaqi, 2026; Manafi et al., 2026; Marefatnia & Manafi, 2026; Klein & Manafi, 2026; Samoylenko & Mazurkevich, 2026). These works highlight the theory's versatility and suggest promising directions for further research.

Early contributions in general systems theory emphasized that systems are composed of interconnected elements whose interactions determine overall behavior (Bertalanffy, 1972). This perspective was further developed in systems thinking, where scholars highlighted the importance of feedback loops, nonlinearity, and dynamic interactions in shaping system outcomes (Meadows, 2008). Within this tradition, feedback mechanisms play a central role in maintaining system stability; however, when feedback becomes delayed, amplified, or distorted, systems may exhibit instability and unintended consequences. These insights align closely with the notion of systemic attenuation, where regulatory processes fail to maintain equilibrium under increasing pressure.

Complexity theory provides additional foundations for understanding systemic saturation. Research in this domain has demonstrated that as systems grow in size and interconnectedness, they become increasingly difficult to predict and control, often exhibiting emergent behavior and nonlinear dynamics (Mitchell, 2009). The concept of tightly coupled systems, introduced by Perrow (1984), suggests that high levels of interdependence can increase the likelihood of cascading failures, as disruptions propagate rapidly across system components. Similarly, studies on networked systems have shown that interconnected structures can amplify both efficiency and vulnerability, creating conditions in which localized disturbances trigger widespread systemic effects (Helbing, 2013). These findings correspond to the dimension of systemic overload, where excessive interdependence and complexity exceed the system's capacity for effective management.

The literature on resilience further contributes to understanding how systems cope with stress and disruption. Resilience is typically defined as the capacity of a system to absorb shocks, adapt, and maintain function (Holling, 1973). However, research has also shown that highly optimized systems, while efficient under stable conditions, often lack redundancy and buffering capacity, making them more vulnerable to unexpected disturbances (Taleb, 2012). The erosion of resilience, characterized by reduced diversity, redundancy, and adaptive flexibility, can transform systems from robust to fragile. This perspective aligns with the concept of systemic degradation, where the gradual loss of resilience increases susceptibility to failure.

In addition, studies of critical transitions and tipping points highlight how systems may undergo sudden and nonlinear changes when key thresholds are crossed (Scheffer et al., 2009). These transitions often occur after prolonged periods of stress, during which the system appears stable but is in fact losing its capacity to recover from perturbations. Early warning signals, such as increased volatility and slower recovery rates, have been identified as indicators of approaching tipping points. This body of work directly relates to the dimension of systemic breakdown, where systems reach a phase in which small disturbances can trigger large-scale collapse or reorganization.

Despite these significant contributions, existing research tends to address specific aspects of systemic behavior—such as interdependence, feedback, or resilience—in isolation. There remains a lack of an integrated framework that explains how these elements interact over time to produce systemic dysfunction. The Theory of Saturation addresses this gap by conceptualizing systemic failure as a progressive and multidimensional process driven by the accumulation of pressures and the gradual weakening of regulatory and adaptive capacities. By synthesizing insights from systems theory, complexity science, and resilience research, the concept of systemic saturation offers a comprehensive lens for understanding how interconnected systems transition from stability to fragility and, ultimately, to breakdown or transformation.

3. Method and Results

A qualitative research approach was employed in this study between December 2025 and May 2026. Data were collected through semi-structured interviews with 12 experts and academics from the European Union who possessed extensive professional and research experience in system theories and the human sciences across different regions of the world. Depending on participants' availability and geographical location, interviews were conducted both online and face-to-face.

The interview protocol was designed to examine institutional functioning under conditions of increasing complexity and demand. Although the interview questions did not explicitly address the concept of saturation, recurring themes across participants' narratives revealed a consistent pattern of progression from overload to institutional decline and dysfunction. These findings provided empirical support for the theoretical framework of institutional saturation. In total, six main questions were asked, as presented below:

Q1. How would you describe the level of complexity and interconnectedness in today's systems (e.g., economic, technological, governance, or global systems)?

Q2. To what extent do you think current systems can sustain the level of demand placed on their resources, flows, and operations?

Q3. How effectively do current systems regulate themselves through feedback mechanisms such as markets, policies, or social responses?

Q4. How well do different parts of the system (e.g., institutions, sectors, or countries) coordinate and align their actions and goals?

Q5. How resilient do you think current systems are when facing shocks or crises? What happens when disruptions occur?

Q6. What do you think happens when these pressures continue over time? Do systems stabilize, adapt, or face deeper risks?

Table 1. Emergent Dimensions of Systemic Saturation from Expert Interviews

Dimension	Subdimensions	Description (Derived from Expert Narratives)	Illustrative Expert Insights	Example Measurement Items
Systemic Overload	Interdependency Overload; Complexity Accumulation; Resource & Throughput Saturation	Systems experience excessive interconnectedness, growing complexity, and unsustainable resource demands that exceed their capacity to manage effectively	Experts described systems as “too interconnected to isolate failures,” “increasingly complex and unpredictable,” and “constantly hitting resource limits and bottlenecks”	“Failures in one part of the system quickly spread to others.”“The system has become too complex to manage effectively.”“The system is operating close to its resource limits.”
Systemic Attenuation	Feedback Loop Distortion; Coordination & Synchronization Failure	Systems lose their ability to self-regulate effectively as feedback mechanisms become delayed, amplified, or distorted, and coordination across actors weakens	Experts noted “feedback arriving too late or in exaggerated forms,” “vicious cycles instead of correction,” and “lack of alignment across institutions and scales”	“Feedback mechanisms in the system do not function properly.”“Different parts of the system fail to coordinate effectively.”
Systemic Degradation	Resilience Erosion	Systems progressively lose their buffering capacity, redundancy, and ability to absorb shocks, becoming increasingly fragile	Experts emphasized “lack of slack,” “over-optimization,” and “systems that break easily under stress”	“The system lacks the capacity to absorb shocks.”“There is little redundancy to handle unexpected disruptions.”
Systemic Breakdown / Phase Transition	Systemic Fragility; Phase Transition Risk	Systems reach a tipping point where small disruptions can trigger large-scale breakdowns or forced reorganization into new states	Experts highlighted “increasing volatility,” “risk of sudden collapse,” and “possibility of radical system transformation rather than gradual change”	“Small disruptions can trigger major system failures.”“The system is at risk of sudden breakdown or transformation.”

The findings of the interviews (See Table 1) indicate that systemic saturation emerges as a complex and progressive condition in which the overall architecture of interconnected systems reaches a state of overload and fragility. In this state, dense interdependencies amplify localized stresses, feedback mechanisms become destabilized, and the system's resilience and adaptive capacity gradually collapse under the weight of accumulated complexity and pressures. Rather than a sudden event, systemic saturation unfolds through a sequence of interrelated stages that reflect the evolving condition of the system under sustained strain.

The first dimension identified is systemic overload, which represents the stage of core pressure accumulation. At this stage, systems become excessively interconnected, increasingly complex, and constrained by limited resource flows. Experts described environments in which subsystems are so tightly coupled that disturbances in one domain rapidly propagate across others, creating cascading effects. This interdependency overload is compounded by continuous complexity accumulation, as the number of interacting components, variables, and rules grows beyond manageable levels. At the same time, systems begin to experience resource and throughput saturation, where the flow of critical inputs such as energy, materials, capital, or attention approaches or exceeds sustainable limits. Together, these conditions mark the initial saturation of the system's input and structural capacity.

As these pressures intensify, systems enter a second stage referred to as systemic attenuation, which reflects an adaptive but ultimately destabilizing response. In this phase, the system attempts to regulate itself; however, its control mechanisms begin to malfunction. Feedback loop distortion becomes evident as corrective signals are delayed, amplified, or even inverted, transforming stabilizing processes into sources of volatility. Simultaneously, coordination and synchronization across different parts of the system begin to break down. Misalignment between actors, scales, and timelines reduces the system's ability to respond coherently to emerging challenges. Unlike attenuation in emotional or institutional contexts, which often manifests as withdrawal or rigidity, systemic attenuation reflects a deeper failure of control architecture, where the very mechanisms designed to maintain balance contribute to instability.

The third dimension, systemic degradation, captures the weakening of the system's core functional capacity. At this stage, resilience erosion becomes the defining feature. Systems lose their buffering capacity, redundancy, and diversity, which are essential for absorbing shocks and maintaining stability. Experts highlighted how highly optimized systems, designed for efficiency, often lack the slack necessary to adapt under stress. As redundancy diminishes and alternative pathways disappear, the system becomes increasingly brittle. The transition from adaptability to fragility is gradual but consequential, as even minor disruptions begin to produce disproportionately large effects.

If these dynamics persist, the system ultimately reaches the stage of systemic breakdown or phase transition. This final dimension represents a tipping point at which the system becomes highly vulnerable to sudden, nonlinear change. Systemic fragility intensifies to the extent that small perturbations can trigger widespread disruption. At this stage, the system faces not only the risk of collapse but also the possibility of forced reorganization into a new structural configuration. Rather than a simple failure, this phase may involve a transition to an alternative state, reflecting the reconfiguration of underlying relationships and dynamics. This distinguishes systemic saturation from other forms, as the outcome is not limited to breakdown but may include transformation through nonlinear shifts.

Taken together, these findings demonstrate that systemic saturation follows a coherent process structure that aligns with other forms of saturation identified in the broader theory. Across emotional, cognitive, institutional, and systemic levels, a consistent pattern emerges in which systems move from overload to adaptive response, followed by functional degradation and eventual breakdown. However, systemic saturation is unique in that its terminal stage involves the potential for phase transitions, where systems may collapse or reorganize into new forms. This insight situates systemic saturation within a broader theoretical landscape that intersects with complexity theory, resilience theory, and systems thinking, while maintaining its distinct contribution as part of a unified, multi-level theory of saturation. See Figure 1.

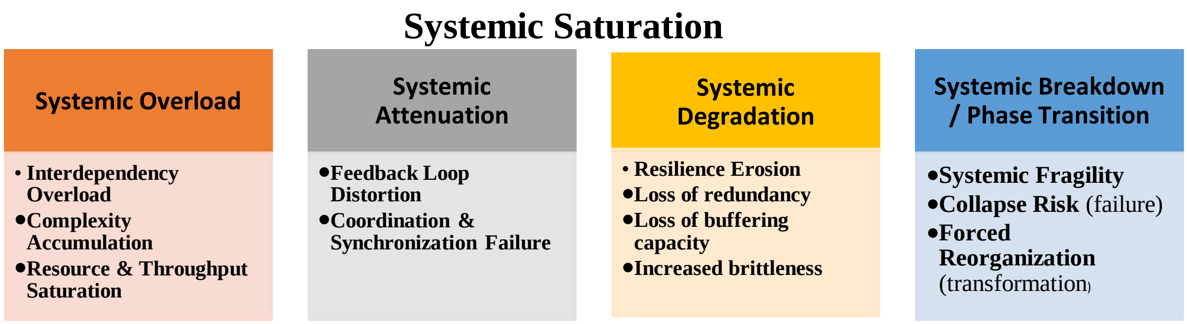

Figure 1. Systemic Saturation's Dimension

4. Conclusion

This study set out to explore and conceptualize the dimensions of systemic saturation within the broader framework of the Theory of Saturation (Manafi, 2025, 2026). Drawing on an exploratory qualitative approach and expert insights, the findings demonstrate that systemic saturation is not a sudden or isolated phenomenon, but a progressive and multidimensional process through which interconnected systems respond to increasing complexity, interdependence, and accumulated pressures. In doing so, the study extends the application of saturation theory to the macro level and contributes to a more integrated understanding of how large-scale systems evolve under conditions of sustained strain.

The results identify four core dimensions of systemic saturation: systemic overload, systemic attenuation, systemic degradation, and systemic breakdown. These dimensions reflect a coherent process structure. Systemic overload captures the accumulation of excessive interdependencies, growing complexity, and unsustainable resource demands that exceed the system's capacity. In response, systems enter a phase of attenuation in which regulatory mechanisms begin to malfunction, leading to distorted feedback loops and weakened coordination across actors and scales. As these conditions persist, systemic degradation emerges through the erosion of resilience, including the loss of redundancy, buffering capacity, and adaptive flexibility. Ultimately, prolonged saturation culminates in systemic breakdown, characterized by heightened fragility and the risk of nonlinear transitions, including collapse or forced reorganization into new system configurations.

By organizing these dynamics into a unified framework, this study provides a structured lens for understanding systemic dysfunction as an evolving condition rather than a series of disconnected failures. A key theoretical contribution lies in demonstrating that systemic saturation follows the same underlying logic observed in emotional, cognitive, and institutional saturation, while also exhibiting a distinctive feature: the potential for phase transitions. Unlike other forms of saturation that primarily result in functional breakdown, systemic saturation may lead to nonlinear transformations, where systems shift into qualitatively different states. This insight positions systemic saturation at the intersection of complexity theory, resilience theory, and systems thinking, while maintaining its coherence within a broader, multi-level theory of saturation.

The findings have important implications for both research and practice. From a theoretical perspective, they advance the development of a generalizable framework that links micro-, meso-, and macro-level processes under a common saturation logic. From a practical standpoint, identifying the dimensions of systemic saturation provides a basis for diagnosing emerging risks in complex systems, enabling earlier recognition of fragility and potential tipping points. Such a framework is particularly relevant in contemporary contexts characterized by global interdependence, rapid technological change, and increasing systemic complexity.

This study is not without limitations. The exploratory nature of the research and the relatively small sample of expert participants limit the generalizability of the findings. Future research should focus on developing and validating quantitative measures of systemic saturation, testing the proposed framework across different types of systems, and examining the dynamic interactions between the identified dimensions over time. Comparative studies across the four types of saturation may also further strengthen the theoretical integration and explanatory power of the model.

In conclusion, systemic saturation represents a critical lens for understanding the vulnerabilities and transformation dynamics of complex, interconnected systems. As global systems continue to grow in scale and complexity, the ability to identify, measure, and manage saturation will become increasingly essential for sustaining resilience, stability, and adaptive capacity.

Declaration: *Artificial intelligence (ChatGPT) was utilized solely for English language refinement and reference assistance during the preparation of this article. All concepts, interpretations, analyses, and conclusions presented in this work are entirely the author's own.*

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