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## System Shift and Stress Testing a Systems Reading Tool for Detecting Pre Shift Vulnerability in Complex Organizations

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Index

### ABSTRACT

Organizations invest significant resources in measuring how well they are performing. However, almost no investment is made in measuring how close they are to the conditions under which that performance collapses. This research argues that this gap is not accidental but rather a structural feature of measuring normal conditions, which is epistemologically blind to the dynamics that precede systemic transitions. Drawing on process ontology and the Systems Shift Framework, we develop a cross-domain stress testing methodology the Systems Shift Stress Testing Framework (SS-STF) oriented not so much on scenario simulation as on the interrogation of assumptions: identifying the structural conditions that hold a system in its current configuration, the thresholds at which those conditions fail, and the organization's current proximity to those thresholds. The framework was developed across three organizational domains manufacturing, finance, and human capital and integrated through a composite instrument, the Transition Proximity Index (TPI). Governance implications are outlined, including reframing stress testing as an epistemological obligation at the board level rather than a mere compliance exercise. This paper contributes to systems theory, the organizational resilience literature, and governance studies.

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## INTRODUCTION

There is a question that most organizations never ask about themselves: under what conditions does this system stop working? Not "how are we performing?" that question gets answered quarterly, annually, in dashboards and board reports and management reviews. The other question, the harder one, rarely appears on any agenda. It is the question of systemic position rather than systemic output: not what the system is producing, but what it is resting on.

The omission is not due to indifference. It reflects something more fundamental: the instruments organizations use to measure themselves are calibrated for normal operating conditions (Hollands et al., 2024). They measure throughput when demand is within forecast range, liquidity when counterparties are functioning, capability when key people are present (Sikiru et al., 2021). These instruments are precisely what they are designed to be accurate, informative, and practically useful. Their limitation is equally precise: they are silent about the conditions of their own validity. They tell you how the system performs given that its enabling assumptions hold. They tell you nothing about how close those assumptions are to not holding.

This is the epistemological gap that stress testing, properly conceived, is designed to close (Dunne, 2025, 2026). The phrase "properly conceived" is deliberate. Stress testing as it is currently practiced outside the financial sector, where regulatory requirements have forced a degree of rigor is largely reactive. It is triggered by visible symptoms of system stress, by post-crisis reviews, or by regulatory pressure. It takes the form of scenario analysis: what would happen *if* a specified adverse event occurred? This is a valuable form of inquiry, but it is not the most important one. It presupposes that the relevant stressor is known and can be specified in advance. The transitions that actually destabilize organizations usually do not announce themselves. They develop gradually, from the accumulation of stress in structural assumptions that no one has been monitoring because no one has thought to ask about them.

The novelty of the present research lies in three interconnected contributions. First, the SS-STF grounds stress testing in process ontology rather than scenario analysis, changing what stress testing is for: not preparing responses to specified adverse events, but reading the stability conditions of a system that is always in process. Second, the framework provides a cross-domain synthesis, offering a common theoretical architecture condition mapping, threshold identification, and proximity measurement that applies across manufacturing, finance, and human capital domains. Third, the SS-STF reframes stress testing as an epistemological obligation at the board level, connecting organizational governance to the ethical requirements of responsible complex system management (Ivanov, 2025).

The argument of this paper begins from a different ontological premise, drawn from process philosophy: organizations are not stable objects that occasionally undergo disruption (Diem et al., 2025; Dolgui et al., 2025). They are *stabilized processes* temporary achievements of coherence among interacting subsystems, maintained by enabling assumptions that have a finite range of validity. When those assumptions are stressed beyond their range, the system does not degrade gracefully (Ivanov & Dolgui, 2022). It shifts often rapidly, always irreversibly in the short term. The challenge is not to respond to the shift (Ivanov, 2026). The challenge is to read it before it completes (Ivanov, 2025).

The System Shift Framework, developed in prior work, formalizes this intuition as a theoretical account of organizational transition dynamics. This paper extends that framework into a stress testing methodology the System Shift Stress Testing Framework (SS-STF) and develops it across three organizational domains: manufacturing, finance, and human capital. Section II reviews the theoretical terrain. Section III develops the SS-STF architecture, including the Transition Proximity Index. Section IV addresses governance implications. Section V discusses contributions and limitations. Section VI concludes.

## **METHOD**

### **Architecture and Core Logic**

The SS-STF was built around a single reorientation: from asking how the system is performing to asking what the system is resting on. That reorientation generates a three-layer analytical structure (Nasrazadani et al., 2025).

The first layer is condition mapping: the identification of the enabling assumptions that currently hold the system in its functioning configuration. This is not a description of current performance. It is an inventory of the structural conditions operational, financial, relational, institutional that make current performance possible. Some of these conditions are explicit and

well-documented. Most are tacit: things the organization has never had to articulate because they have never been challenged.

The second layer is threshold identification: the determination of the boundary conditions for each enabling assumption the value at which the assumption fails and the system can no longer maintain its current configuration. Thresholds may be hard (regulatory minima, physical capacity limits, covenant triggers) or soft (relational trust levels, tacit coordination norms, informal authority structures). The soft thresholds are typically more dangerous, because they are invisible until they are breached.

The third layer is proximity measurement: the computation, for each enabling assumption, of the current distance between actual state and failure threshold. The Transition Proximity Index (TPI) aggregates these distances into a composite measure of systemic pre-shift vulnerability. Formally, for domain  $d$  and enabling assumption  $i$ :

$$\text{TPI}(d,i) = (\text{Current State} - \text{Safe State}) / (\text{Threshold} - \text{Safe State})$$

A  $\text{TPI}(d,i)$  of 0 indicates that the assumption is operating well within its valid range. A score of 1.0 means it is at the failure threshold. The aggregate organizational TPI is a weighted function of domain-level scores, with weights reflecting the degree of coupling between domains because the most dangerous condition is not high TPI in a single domain, but simultaneous TPI elevation across coupled domains.

### **Manufacturing: What Holds Throughput Together**

Manufacturing systems appear, to their own management, to be among the better-monitored organizational systems. Output rates, defect rates, equipment availability, supplier lead times all of these are measured continuously in most modern production environments. The problem is that what is being measured is the output of the system under the conditions that currently hold, not the integrity of those conditions themselves.

Three clusters of enabling assumptions are particularly important for manufacturing stress testing. The first concerns throughput capacity. There is a well-documented non-linearity in production systems: quality degradation does not increase proportionally with utilization but accelerates sharply above approximately 85–90% of rated capacity. A system reporting acceptable quality at 80% utilization and excellent throughput metrics may be two percentage points of demand increase away from a quality crisis. The relevant TPI component is not current utilization but the ratio of current utilization to the inflection threshold a number that most production monitoring systems do not compute.

The second cluster concerns input reliability. Single-source supply dependencies represent concentrated structural vulnerability. The enabling assumption that the supplier will perform within acceptable parameters is valid until it is not, and its invalidity tends to arrive suddenly and at high cost. The TPI component for input reliability is a function of source concentration, substitution readiness, and the recency and thoroughness of the last supply stress event. Organizations that have not tested their supply substitution capacity within the past two years should assume their TPI component in this dimension is significantly elevated.

The third cluster concerns process redundancy. Lean manufacturing optimization, pursued aggressively, tends to eliminate buffer capacity as waste. From a process efficiency perspective, this is correct. From a systems stress testing perspective, it means that the organization's manufacturing resilience has been systematically reduced in the pursuit of

normal-condition performance gains. The TPI component for process redundancy is at its maximum in a fully optimized lean system with no alternative process pathways a condition that is indistinguishable from excellent performance on standard manufacturing KPIs.

The cross-domain point, which will recur, is this: the enabling assumptions most critical to manufacturing stability are precisely those that manufacturing metrics are not designed to monitor. Stress testing in manufacturing is not an extension of quality management or operations management. It requires a different category of question.

### **Finance: The Load-Bearing Assumptions Inside Models**

Financial models are not descriptions of reality. They are instruments for managing uncertainty by transforming it into risk a category of uncertainty that can be quantified, priced, and hedged. That transformation depends on assumptions that are embedded in model structure and rarely made explicit. The assumptions are not wrong; they are valid within a range. The question is whether the organization knows what that range is and how close current conditions are to its boundary.

Volatility assumptions are load-bearing in virtually every financial model. Historical volatility parameters calibrated to a specific period become structurally embedded in how losses are estimated, capital is allocated, and positions are hedged. The 2007–2008 financial crisis was, in part, a large-scale demonstration of what happens when models calibrated to a decade of housing market stability encountered conditions outside their calibration envelope.<sup>16</sup> The TPI component for volatility assumptions is not simply current volatility relative to historical average it is current volatility relative to the calibration envelope of the models in use. These are different numbers, and the latter is rarely reported.

Covenant and leverage assumptions present a more discrete risk. Debt covenant triggers financial ratio thresholds below which creditors gain contractual rights are hard thresholds with non-linear consequences: the system is compliant until, suddenly, it is in breach. The TPI component for covenant proximity is simple to compute but frequently not computed: the distance between current ratios and trigger levels, expressed as a percentage of the available buffer. An organization with a 2% buffer on a leverage covenant is materially more vulnerable than one with a 15% buffer, regardless of whether either organization is in breach.

Liquidity concentration assumptions are perhaps the most under monitored. Organizations with concentrated funding structures reliance on a small number of counterparties, narrow instrument types, or correlated maturity profiles have enabled assumptions that can fail simultaneously rather than sequentially. Under stress conditions, correlations that appear low in normal times tend to increase: counterparties face the same market pressures, instruments become illiquid at the same time, and maturity walls that seemed manageable individually become simultaneous demands. The TPI component for liquidity concentration reflects this correlation risk, not merely the current funding volume.

### **Human Capital: The Invisible Architecture of Organizational Capability**

Human capital stress testing is, in many respects, the most neglected of the three domains developed here. This is partly because human capital is the domain most resistant to quantification and partly because organizations tend to confuse capability with headcount a confusion that standard HR metrics actively reinforce (Duchek, 2020).

The most critical enabling assumption in human capital systems is the distribution of knowledge and coordination capacity across organizational members. Key person dependency the condition in which critical processes depend on the continued presence of a small number of individuals is widely recognized as a risk, but rarely measured with the precision that its importance warrants. The relevant TPI component is not the number of key persons but the ratio of critical process knowledge held by individuals to that held in documented, transferable systems. Organizations that have grown rapidly through periods of strong performance typically exhibit severe key person concentration, because the urgency of operational execution has prevented the documentation of the processes that drive it.

A related but distinct vulnerability is capability cliff risk the condition in which workforce age structure and succession pipeline create predictable near-term capability gaps. A capability cliff is different from a vacancy: a vacancy is a discrete event, visible and actionable. A capability cliff is a trajectory, developing across years, and largely invisible to organizations that measure current headcount and current performance rather than future capability availability. The TPI component for capability cliff is the proportion of critical capability held by cohorts within five years of expected departure, discounted by succession readiness a number that is computable from existing HR data in most organizations, but almost never computed.

Perhaps the most undertheorized human capital vulnerability is coordination network fragility. Formal organization charts measure authority. They do not measure where knowledge actually flows, which relationships sustain coordination across organizational boundaries, and which informal network nodes people who are not formally senior but who hold the relational architecture together are the genuine load-bearing elements of the organization's human system. When these informal network nodes depart, the organization's effective capability may decline far more severely than formal headcount metrics suggest. The TPI component for coordination network fragility requires organizational network analysis a methodology available and well-validated, but rarely deployed in governance contexts.

### **Compounding Vulnerability: Why the Cross-Domain Synthesis Matters**

Isolated TPI elevation in a single domain is typically manageable. An organization that detects elevated manufacturing TPI can address supply chain concentration; an organization that detects elevated covenant proximity can refinance; an organization that detects key person dependency can accelerate succession planning. The danger lies elsewhere.

Under stress conditions, enabling assumptions across domains tend to deteriorate simultaneously and in correlated fashion. A financially stressed organization one with elevated Finance TPI is more likely to defer maintenance investment, elevating Manufacturing TPI. It is also more likely to lose key personnel who prefer the stability of less stressed organizations, elevating Human Capital TPI. The compounding effect creates a trajectory toward systemic shift that no single-domain metric would detect, because each domain, observed in isolation, may still appear within acceptable ranges.

The aggregate organizational TPI the weighted cross-domain composite is designed to detect this compounding. Its weighting function must reflect coupling strength between domains, because the degree to which financial stress propagates into manufacturing and human capital stress varies by organizational structure and sector. The determination of

coupling weights requires organizational knowledge that cannot be fully generalized; it must be calibrated to the specific organization.

What can be generalized is the structural logic: a system is most vulnerable not when any single assumption is stressed, but when multiple assumptions are simultaneously approaching their thresholds. This is the condition the System Shift Framework identifies as the pre-shift state. The SS-STF provides the instruments to detect it.

## **RESULTS AND DISCUSSION**

### **The Rhythm of Structural Stress Testing**

If the SS-STF is taken seriously as a governance instrument, it changes what boards of directors are required to know and therefore what management is required to produce. Current governance practice in most non-financial sectors either lacks stress testing entirely or treats it as a periodic, event-triggered exercise: something done in response to visible stress, not as a standing monitoring practice.

Structural stress testing, as the SS-STF proposes it, requires a different temporal logic. Enabling assumptions change at different rates. Financial model calibration envelopes may deteriorate over months; supply chain concentration may develop over years; human capital capability cliffs may be visible five years in advance. The testing frequency for each TPI component should be calibrated to the rate at which the underlying assumption changes not to fiscal years or audit cycles.

More fundamentally, TPI-based escalation protocols should be triggered by proximity to threshold rather than by performance deterioration. This is the governance implication that most directly challenges current practice. In most organizations, the signal for action is a performance metric moving outside acceptable range but by that point, the enabling assumption has already failed. Governance that responds to performance deterioration is, structurally, governance that responds to the aftermath of a transition rather than to its approach.

### **Regulatory Dimensions**

The Basel III experience demonstrates that regulatory pressure can institutionalize stress testing practices that would not emerge spontaneously from organizational self-interest.<sup>19</sup> Banks that stress-tested prior to 2008 were in the minority; after Basel III, stress testing became a mandatory and increasingly sophisticated governance practice across the sector. The logic of that regulatory intervention that organizations operating systems that affect multiple stakeholders have an obligation to know their systemic vulnerability, not only their current performance is transferable beyond banking.

What the Basel framework also demonstrates is the risk of domain-specific stress testing frameworks that are not designed to detect cross-domain compounding. Banking stress tests are calibrated to financial system scenarios; they do not, by design, detect the human capital and operational vulnerabilities that may accompany financial stress (Ebner, 2018; Karakostas et al., 2023). A governance framework built on the SS-STF's cross-domain architecture would require regulators to develop sector-specific enabling assumption taxonomies and threshold parameters a more demanding exercise than scenario specification, but one that reflects the actual structure of systemic risk (Abbondanza et al., 2025; Grassi et al., 2025).

## **Epistemic Responsibility as a Governance Norm**

There is a normative dimension to the argument that deserves explicit statement. Organizations that operate systems affecting multiple stakeholders' employees, customers, suppliers, communities have an obligation that extends beyond maximizing performance under favorable conditions. That obligation includes knowing, to the extent it is knowable, how close the system is to a condition of failure (Koj, 2025; Schwenkenbecher, 2022).

Systemic blindness the failure to interrogate enabling assumptions is not merely a strategic error. Where it results in preventable harm to stakeholders who had reasonable expectations of system reliability, it constitutes a governance failure. The legal framework governing directors and officers has developed, over several decades, a duty of care that requires informed decision-making (Hill & Conaglen, 2018). The epistemic correlate of that duty the obligation to deploy monitoring instruments capable of detecting pre-transition vulnerability, not only current performance has not been fully articulated in governance law or practice. The SS-STF provides a framework for articulating it.

This connects the stress testing methodology to a broader question in systems governance: the normative status of predictable but undetected transitions. When an organization could have detected its approach to a systemic threshold using available instruments and chose not to deploy those instruments, the moral and legal quality of the subsequent harm is different from harm caused by genuinely unforeseeable events. Assumption stress testing, by making proximity to threshold knowable, changes the moral landscape of organizational governance (Klein et al., 2019; Lund & Pollman, 2021).

## **What This Framework Adds**

Three contributions deserve explicit statement. The first is ontological: by grounding stress testing in process philosophy rather than in scenario analysis, the SS-STF changes what stress testing is for. It is not an instrument for preparing responses to specified adverse events. It is an instrument for reading the stability conditions of a system that is, by its nature, always in process always moving, always resting on assumptions that have a finite range of validity. That ontological reframing has methodological consequences throughout the framework.

The second contribution is cross-domain synthesis. The stress testing literature has developed sophisticated domain-specific methodologies financial, supply chain, infrastructure but has not provided a common theoretical architecture that permits cross-domain TPI computation and the detection of compounding vulnerability. The SS-STF provides that architecture. Its three-layer structure (condition mapping, threshold identification, proximity measurement) applies to any organizational domain; the TPI provides a common metric across domains. This is not a technical convenience. It reflects the empirical reality that organizational transitions typically involve simultaneous stress across multiple domains, and that single-domain monitoring systems are structurally blind to the compounding effect.

The third contribution is the reframing of governance responsibility. The SS-STF's argument that assumption stress testing is an epistemological obligation not an optional management practice connects organizational governance to the deeper question of what responsible decision-making requires when one is operating complex systems. It places the SS-STF in conversation with the governance ethics literature and with the emerging legal literature on organizational duties in complex system management.

## **Limitations and What Remains to Be Done**

Several limitations are worth acknowledgment. The SS-STF as developed here is theoretical; the TPI is formally specified but not empirically validated. Future research should develop domain-specific TPI instruments and test their predictive validity against documented instances of organizational system shift. Retrospective reconstruction of TPI trajectories from archival data in cases of known organizational failures would provide the most direct test of the framework's predictive claims (Conz & Magnani, 2020).

The weighting function for cross-domain TPI aggregation is not specified in this paper. Coupling strength between domains varies by organizational type and sector, and its empirical determination requires case-study and simulation research beyond this theoretical development. Until domain-specific calibration studies are available, organizations implementing the SS-STF should treat the aggregate TPI as indicative rather than precise.

There is also a practical implementation challenge that the framework does not fully address. The identification of enabling assumptions and their thresholds requires a combination of domain expertise and organizational self-knowledge that is not uniformly available. Organizations with limited analytical capacity may find the full SS-STF difficult to operationalize. Research should develop simplified TPI instruments appropriate to different organizational scales.

## **Connections and Future Directions**

The most promising theoretical extension is toward ecological resilience theory, specifically the adaptive cycle framework developed by Holling and colleagues.<sup>21</sup> The adaptive cycle identifies four phases of system trajectory growth, conservation, release, and reorganization and argues that systems in the conservation phase (high connectivity, high potential, low resilience) are most vulnerable to catastrophic release. This maps closely to the pre-shift condition identified by the System Shift Framework: a system that appears highly functional and optimized is often, for exactly that reason, close to a transition threshold (Munoz, 2018). The SS-STF's TPI provides a prospective instrument for detecting the conservation-to-release transition before it occurs, which the adaptive cycle framework describes but does not operationalize at the organizational level.

Future empirical work should also examine how TPI-based information changes organizational decision-making behavior relative to standard performance reporting. There is reason to expect that proximity-to-threshold framing generates different decision responses than current-performance framing and that this difference has governance significance. Organizations that know they are at TPI 0.85 in their human capital domain may make succession investment decisions that organizations tracking only current headcount and attrition would not.

## **CONCLUSION**

Systems do not fail. They shift. The transition is preceded by a period in which the enabling assumptions that hold the system in its current configuration come under increasing pressure a period that is, in principle, detectable with the right instruments and invisible without them. The argument of this paper has been that existing organizational monitoring is, for

structural reasons, poorly equipped to detect this period. Normal-condition metrics are calibrated to conditions that, by definition, they will not detect departing. Scenario-based stress tests are valuable but presuppose knowledge of the relevant stressor. What is needed is a prior form of inquiry: assumption stress testing, oriented toward reading the integrity of the structural conditions that make normal performance possible. The System Shift Stress Testing Framework developed here provides that prior form of inquiry. Its three-layer architecture condition mapping, threshold identification, Transition Proximity Index applies across organizational domains and provides instruments for detecting the compounding cross-domain vulnerability that precedes most significant organizational transitions. Its governance implications extend beyond risk management into the domain of epistemic responsibility: the obligation of organizations operating complex systems to know, to the extent knowable, how close those systems are to their own configuration limits. The question that the SS-STF places on the governance agenda is one that most organizations have never formally asked: under what conditions does this system stop working, and how far are we from those conditions right now? It is, in the end, a question about organizational self-knowledge about whether an organization knows what it is resting on, and whether the foundations are holding.

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