An Early Warning Framework for Healthcare System Collapse

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Abstract

Healthcare systems are increasingly exposed to sustained internal pressures that extend beyond episodic shocks. While resilience has been widely studied, the concept of healthcare system collapse remains weakly theorized and rarely operationalized, particularly in relation to saturation and adaptive capacity loss.

This study aims to explore healthcare system collapse as a saturation-driven process using the Stability–Efficiency–Adaptability (SEA) framework and to identify key determinants and early warning key performance indicators (KPIs).

A qualitative exploratory design was employed, integrating semi-structured interviews with 12 experts from health policy, academia, and health information systems, alongside a targeted review of international literature. A common interview guide covering seven thematic domains was used for all participants. Data were analyzed thematically and mapped onto the SEA framework to redefine collapse factors and develop SEA-aligned KPIs.

Result shows that Seven core determinants of healthcare system collapse were identified. Stability and efficiency related factors were found to create cumulative stress and saturation conditions, while loss of adaptability emerged as an integrative system-level outcome. Based on these findings, a structured set of KPIs was developed across the Stability, Efficiency, and Adaptability dimensions, with adaptability indicators capturing early warning signals of impending collapse. Healthcare system collapse is best understood as a progressive outcome of sustained imbalance within the SEA framework, driven by saturation and culminating in loss of adaptability. The proposed SEA-aligned KPIs provide a theoretically grounded approach for early detection of collapse-prone conditions and support anticipatory health system governance.

Keywords: HealthCare system collapse; SEA model; Saturation; System resilience; Key performance indicators; KPI; Qualitative study; Health systems governance

1. Introduction

Healthcare systems across the world are increasingly exposed to sustained and compounding pressures, including demographic ageing, epidemiological transitions, fiscal constraints, workforce shortages, technological complexity, and recurrent large-scale shocks. While these challenges have traditionally been examined through the lens of health system resilience, recent global experiences suggest that many healthcare systems are not merely under strain but are approaching, or have already entered, states of systemic collapse (Fridell et al., 2019; Fleming et al., 2022; World Health Organization [WHO], 2024).

Despite its growing prominence in policy discourse, healthcare system collapse remains weakly theorized and insufficiently operationalized in academic research. Much of the existing literature implicitly conceptualizes collapse as an abrupt and externally triggered event, such as a pandemic or economic crisis (Kruk et al., 2018; Fridell et al., 2019). However, systems-oriented scholarship increasingly emphasizes that collapse should be understood as a cumulative, endogenous, and non-linear process, driven by prolonged internal imbalances that erode system capacity over time, often well before overt failure becomes visible (Fleming et al., 2022; Zhao et al., 2023).

A critical but underexplored concept in this regard is saturation. Saturation describes a condition in which incremental reforms particularly those grounded in efficiency-oriented logic no longer generate proportional improvements in system performance. Under saturated conditions, marginal returns diminish, operational buffers are depleted, and the system's capacity to absorb stress and adapt progressively weakens. Rather than signaling success, continued efficiency optimization in such contexts may paradoxically accelerate systemic vulnerability and precipitate collapse (WHO, 2024; Chuang & Hu, 2025). Despite its explanatory relevance, saturation remains largely absent from mainstream health system theory and is rarely incorporated into empirical assessment frameworks.

The Stability–Efficiency–Adaptability (SEA) framework, articulated by Manafi (2025), provides a novel theoretical foundation for addressing these conceptual gaps. Within the SEA framework, healthcare systems are understood as dynamic and complex entities that must continuously balance three interdependent capacities. Stability refers to institutional coherence, legitimacy, and continuity of essential services. Efficiency captures the system's ability to transform resources into outputs with minimal waste. Adaptability reflects the system's capacity to learn, respond, and reorganize in the face of sustained stress and uncertainty. According to this framework, collapse emerges not from the failure of a single dimension, but from the prolonged imbalance among these capacities ,particularly when efficiency dominance undermines adaptability, leading to saturation and eventual systemic breakdown (Manafi, 2025).

Although prior research has produced a wide range of indicators to monitor health system performance and resilience, these efforts remain fragmented and largely detached from an explicit theory of collapse (Fleming et al., 2022; WHO, 2024). Existing indicator sets tend to prioritize service outputs, cost efficiency, or short-term crisis response, while paying limited attention to early warning signals associated with legitimacy erosion, learning failure, and adaptive capacity depletion key precursors of collapse identified in systems-based analyses (Emami et al., 2023; Zhao et al., 2023).

This limitation is particularly evident in the use of KPIs in health system governance. While KPIs are widely employed to track performance, their selection is often driven by data availability or managerial convenience rather than theoretical relevance. As a result, many KPI frameworks inadvertently reinforce efficiency-centric monitoring while overlooking indicators capable of capturing saturation dynamics and the progressive loss of adaptive capacity (Langarizadeh et al., 2024; Chuang & Hu, 2025).

Against this background, the present study makes four primary contributions. First, it conceptualizes healthcare system collapse as a process shaped by saturation and adaptive capacity loss, rather than as a discrete failure event. Second, it applies the SEA framework to systematically identify the multi-domain factors that contribute to collapse across governance, financing, workforce, infrastructure, digital systems, and trust. Third, it develops a set of theoretically grounded KPIs aligned with the Stability, Efficiency, and Adaptability dimensions, explicitly designed to function as early warning indicators. Finally, by integrating qualitative expert interviews with international evidence, the study bridges the gap between collapse theory and practical system monitoring, offering a structured and transferable approach to anticipating healthcare system failure. The aim of this study is to explore healthcare system collapse as a saturation-driven process using the SEA framework and to identify key determinants and early warning KPIs that signal loss of adaptive capacity prior to system collapse.

2. Literature Review

a. Conceptualizing Healthcare System Collapse

The concept of healthcare system collapse has gained increasing attention in policy discourse; however, its treatment in academic literature remains fragmented and conceptually ambiguous. Most existing studies implicitly address collapse through the broader notion of health system resilience, focusing on the system's ability to absorb shocks and maintain functionality (Fridell et al., 2019; Fleming et al., 2022). While this body of work has contributed valuable insights into system preparedness and recovery, it often conceptualizes failure as a temporary deviation from equilibrium rather than as a structural and progressive breakdown.

Several scholars argue that collapse should not be understood as a singular catastrophic event but as the outcome of cumulative internal pressures that progressively undermine system capacity (Zhao et al., 2023). In this view, external shocks act primarily as catalysts that expose pre-existing weaknesses rather than as root causes of failure. Despite this recognition, the literature lacks a coherent framework capable of explaining how internal dynamics interact over time to produce collapse-like states.

b. Saturation and the Limits of Efficiency-Oriented Health Systems

A dominant theme in health system reform literature is the pursuit of efficiency through cost containment, performance management, and resource optimization. Efficiency-oriented reforms have been widely promoted as mechanisms to improve sustainability and control expenditure growth (World Health Organization [WHO], 2024). However, an emerging body of evidence suggests that excessive reliance on efficiency-driven logic may produce diminishing returns and unintended systemic risks.

The concept of **saturation** captures this phenomenon by describing a condition in which additional efficiency gains no longer yield proportional improvements in performance. Under saturated conditions, health systems experience declining marginal returns, erosion of operational buffers, workforce overload, and reduced flexibility (Chuang & Hu, 2025). Rather than enhancing resilience, persistent optimization may increase system fragility and accelerate failure. Despite its relevance, saturation remains weakly theorized in health system research and is rarely incorporated into analytical or measurement frameworks.

c. The Stability–Efficiency–Adaptability (SEA) Framework

The Stability–Efficiency–Adaptability (SEA) framework, proposed by Manafi (2025), offers a novel and integrative theoretical lens for understanding healthcare system dynamics under sustained stress. Unlike conventional resilience frameworks, the SEA model explicitly conceptualizes collapse as an emergent outcome of prolonged imbalance among three interdependent system capacities.

Within this framework, stability refers to institutional coherence, legitimacy, and continuity of essential services. Efficiency denotes the system's ability to transform inputs into outputs with minimal waste. Adaptability represents the system's capacity to learn, respond, and reorganize in the face of uncertainty and sustained pressure. Manafi (2025) argues that while each dimension is necessary for system functioning, excessive dominance of efficiency particularly when coupled with rigid forms of stability can undermine adaptability, leading to saturation and eventual collapse.

A key contribution of the SEA framework lies in its treatment of adaptability as an integrative system capacity rather than as a parallel or independent dimension. Loss of adaptability is conceptualized not as an isolated failure but as a cumulative outcome of prolonged efficiency saturation and hollow stability. This perspective addresses a major limitation in existing health system models, which often treat system dimensions as static and independent.

d. Determinants of Collapse Across Health System Domains

Empirical and conceptual studies identify multiple factors associated with health system failure, including governance fragmentation, financial fragility, workforce burnout, infrastructure limitations, weak information systems, and erosion of public trust (Emami et al., 2023; Zhao et al., 2023). Governance failures are commonly linked to policy incoherence and short-term crisis-driven decision-making, while financial analyses highlight the risks of underfunding and budget volatility. Workforce-related studies emphasize burnout and attrition as critical threats to system continuity, particularly under sustained efficiency pressures (Langarizadeh et al., 2024). Similarly, research on health information systems underscores the risks of compliance-oriented data infrastructures that prioritize reporting over learning and adaptive decision-making. Trust and legitimacy are increasingly recognized as central to system stability, yet remain poorly operationalized in empirical assessments. Despite extensive documentation of these factors, the literature typically examines them in isolation. Few studies situate these determinants within an integrated model capable of explaining how their interaction produces saturation and collapse over time.

e. Key Performance Indicators and Early Warning Signals

KPIs are widely used in health system governance to monitor performance and guide decision-making. International organizations and academic studies have proposed numerous indicators related to service delivery, financial efficiency, and crisis response (WHO, 2024; Fleming et al., 2022). However, most existing KPI frameworks are designed to assess outputs and short-term performance rather than to detect early warning signals of systemic failure.

Recent studies call for the development of system-level indicators capable of capturing adaptive capacity, feedback quality, and threshold dynamics (Chuang & Hu, 2025). Nevertheless, there is limited consensus on how such indicators should be theoretically grounded or interpreted. As a result, KPI selection is often driven by data availability rather than by relevance to collapse dynamics, reinforcing efficiency-centric monitoring while neglecting signals of saturation and adaptive exhaustion.

Taken together, the literature reveals several critical gaps. First, healthcare system collapse remains conceptually underdeveloped and is frequently subsumed under resilience without explicit theorization. Second, saturation is rarely incorporated into health system analysis despite its explanatory relevance. Third, determinants of collapse are examined in fragmented ways, with limited attention to their interaction and cumulative effects. Finally, existing KPI frameworks lack theoretical grounding in collapse dynamics and fail to provide actionable early warning signals.

Building on Manafi’s (2025) SEA framework, the present study addresses these gaps by conceptualizing collapse as an emergent outcome of sustained imbalance among stability, efficiency, and adaptability. By integrating qualitative expert insights with international evidence, the study identifies key determinants of collapse and develops theoretically grounded KPIs capable of signaling saturation and impending system failure.

Reference	Main Focus	Key Contribution to This Study	Strengths of the Study	Identified Gap Addressed by This Study
Fridell et al. (2019) – *Health system resilience: What are we talking about?*	Conceptualization of resilience	Provides foundational discussion on system stress and resilience	Clear conceptual clarification; system-level perspective	Does not address **collapse** explicitly; lacks saturation and early-warning logic
Fleming et al. (2022) – *Metrics and indicators to assess health system resilience*	Indicators for resilience	Demonstrates diversity of resilience indicators	Systematic review; strong methodological rigor	Indicators are fragmented; no unified framework or collapse thresholds
WHO (2024) – *Health System Resilience Indicators*	Monitoring and measurement	Provides globally accepted indicators	High legitimacy; operational readiness	Focuses on resilience, not collapse or saturation dynamics
Zhao et al. (2023) – *Evaluation of health system resilience in 60 countries*	Empirical resilience assessment	Shows cross-country measurement feasibility	Large sample; comparative approach	Lacks theoretical model explaining **why systems fail**
Chuang & Hu (2025) – *Resilience assessment using KPIs*	KPI-based system assessment	Demonstrates KPI aggregation across dimensions	Quantitative clarity; KPI logic	Does not integrate governance, trust, or collapse trajectories
Langarizadeh et al. (2024) – *KPIs of hospital supply chains*	Performance indicators	Provides practical KPI examples	Detailed KPI taxonomy	Limited to hospital level; not system-wide collapse
Emami et al. (2023) – *Systems framework for health systems*	Systems components	Supports multi-domain analysis	Systems thinking approach	No dynamic or saturation-based interpretation
Kruk et al. (2018) – *High-quality health systems*	Quality & resilience	Links quality to system failure	Strong normative framework	Focus on quality, not collapse thresholds
Manafi (2025) – *Saturation, collapse, and Rosetta Stone Model*	Saturation & collapse theory	Core theoretical foundation (SEA)	Introduces saturation and collapse as processes	Requires empirical operationalization (addressed in this study)
Hojabri et al. (2013) – *Evaluation of excellence models*	Organizational performance models	Provides background on performance/excellence logic	Comparative evaluation of models	Not focused on collapse or adaptive failure
Manafi et al. (2025) – *Leadership styles and organizational growth*	Governance & leadership	Informs governance and adaptability dimensions	Links leadership to system outcomes	Does not address health system collapse directly

Table1. Key References on Healthcare System Collapse, Saturation, and KPIs: Contributions, Strengths, and Research Gaps

3. Methodology

This study employed a qualitative, exploratory research design to identify the determinants of healthcare system collapse and to develop a set of KPIs for early warning and system monitoring. A qualitative approach was selected due to the complex, systemic, and context-dependent nature of healthcare system collapse, which cannot be adequately captured through predefined quantitative indicators alone. It was guided by the SEA framework, which was used as an initial analytical lens while allowing for iterative refinement based on empirical data. Two complementary data sources informed the analysis:

1. Semi-structured expert interviews, conducted to capture experiential and contextual knowledge on healthcare system collapse processes.
2. Documentary analysis, including peer-reviewed articles, international reports, and policy documents, used to inform the identification and operationalization of KPIs.

This triangulated approach enabled the integration of empirical insights from experts with established international evidence. Between November 2025 and January 2026, semi-structured interviews were conducted with 12 participants possessing expertise relevant to healthcare system functioning and systemic collapse. The interviewees were drawn from three professional groups:

- Health policymakers and senior health system managers
- Academic experts in health systems, health economics, and public health
- Specialists in health information systems and digital health

Table 2. Expert Group distribution

Expert Group	n	Share (%)	Typical Analytical Emphasis*
Health policymakers & senior health system managers	2	16.7%	System-level governance, policy dynamics, real-world collapse pathways, feasibility of reforms
Academic experts (health systems, health economics, public health)	7	58.3%	Conceptual framing (SEA), theoretical integration, determinant structure, KPI logic/validity
IT / HIS & digital health specialists	3	25.0%	KPI operationalization, data availability, measurement feasibility, HIS constraints
Total	**12**	**100%**	—

* All interviewees were asked the full set of interview questions; the table reflects areas where participants typically provided deeper or more detailed insights based on professional background.

The interview participants were drawn from multiple geographic contexts, including Asian, Middle Eastern, Arab, and European countries. This geographic diversity allowed the study to capture perspectives shaped by different health system structures, governance models, and stages of system development, thereby enriching the identification of collapse determinants and SEA-aligned indicators.

Interviews continued until theoretical saturation was achieved, defined as the point at which no substantively new themes or concepts emerged. Data were collected through semi-structured interviews conducted either in person or remotely. An interview guide was developed based on the study objectives and the SEA framework, with open-ended questions designed to elicit:

- Conceptualizations of healthcare system collapse as a process
- Identification of structural and systemic collapse factors
- Insights into stability, efficiency, and adaptability dynamics
- Expert perspectives on early warning signals and measurable indicators

The interview guide remained flexible, allowing participants to introduce unanticipated themes. Interview transcripts were analyzed using thematic analysis. The analytical process followed an iterative and reflexive procedure consisting of:

1. **Open coding**, to identify initial concepts and patterns emerging from the data
2. **Axial coding**, to group codes into higher-order themes related to governance, financing, workforce, infrastructure, digital systems, trust, and system capacity
3. **Selective coding**, to integrate themes within the SEA framework

During analysis, adaptability consistently emerged as an integrative system capacity reflecting the cumulative effects of instability and efficiency saturation. Consequently, indicators related to the loss of adaptability were analytically consolidated within the Adaptability domain, rather than being distributed across Stability and Efficiency. This refinement improved conceptual clarity and reduced analytical overlap. KPIs were developed through a multi-step process:

1. Identification of candidate indicators from international literature and policy reports
2. Mapping of qualitative themes to Stability, Efficiency, and Adaptability oriented domains
3. Refinement of KPIs through expert interpretation and consensus
4. Definition of operational characteristics, including calculation methods, data sources, measurement frequency, and indicative threshold ranges

Indicative ranges were defined to signal early warning, saturation, and collapse-prone states, rather than to establish normative benchmarks.

To enhance methodological rigor, several strategies were employed:

- **Triangulation** of data sources (interviews and documents)
- **Peer debriefing** during the analytical process
- **Transparent audit trail**, documenting analytical decisions and refinements
- **Theoretical saturation** to ensure completeness of thematic coverage

These measures strengthened the credibility, dependability, and confirmability of the findings.

Participation was voluntary, and informed consent was obtained from all participants. Interviews were anonymized to protect confidentiality. The study was conducted in accordance with applicable ethical guidelines for qualitative research.

The semi-structured interview guide presented in Table 3 was developed to explore expert perspectives on healthcare system collapse through the integrated lenses of saturation and the SEA framework. The guide comprised seven thematic question domains covering governance, financing, workforce, infrastructure, digital systems, trust, and adaptability. All interviewees were asked the same set of questions to ensure methodological consistency and comparability across expert groups.

While a common interview structure was applied, participants' responses varied in depth and emphasis according to their professional background and experiential knowledge. Policymakers and senior managers tended to elaborate on governance dynamics, policy coherence, and system-level decision-making, whereas academic experts provided deeper conceptual interpretations of collapse, saturation, and SEA interactions. Specialists in health information systems and digital health contributed detailed insights into data limitations, measurement feasibility, and the operationalization of KPIs. These variations reflect differential emphasis rather than differentiated questioning and were analytically leveraged to enrich the identification of collapse determinants and the development of SEA-aligned key performance indicators.

Interview Section	Analytical Focus	Open-Ended Interview Questions	Primary Analytical Output
Conceptualization of Collapse	Collapse as a systemic and threshold process	How would you describe healthcare system collapse? Do you consider collapse a sudden event or a gradual process? What distinguishes a resilient system from one that collapses?	Collapse defined as cumulative, non-linear, threshold phenomenon
Identification of Collapse Factors	Structural drivers of collapse	What systemic factors contribute most to healthcare system collapse? Which domains (governance, finance, workforce, infrastructure, digital systems, trust) are most critical, and why? Which factors are typically underestimated?	Identification of core collapse factors
Stability	Loss of legitimacy, continuity, and coherence	How does loss of stability manifest before collapse? How do policy coherence and service continuity change under prolonged stress? What role does trust play in maintaining system stability?	Stability-related determinants and KPIs
Efficiency and Saturation	Efficiency dominance and saturation effects	How do efficiency-driven reforms affect system performance over time? When do efficiency gains begin to generate risks? Can you describe examples of efficiency saturation?	Efficiency saturation and over-optimization
Adaptability (Integrative Capacity)	Learning, response, and system reconfiguration	How do you define adaptability in healthcare systems? Is adaptability an independent feature or an integrative system capacity? Why? What happens when adaptability is lost despite apparent stability?	Adaptability as an emergent, integrative capacity
Indicators and Early Warning Signals	Translation of qualitative insights into KPIs	What indicators would you monitor to detect early warning signs of collapse? Which indicators are misleading, and which reveal deeper problems? How can qualitative signals be operationalized into KPIs?	KPI identification and validation
Thresholds and Decision-Making	False stability and delayed transformation	How do systems behave near critical thresholds? Have you observed false stability preceding collapse? What prevents timely structural reform?	Threshold dynamics and false stability

Table 3. Semi-Structured Interview Guide and Thematic Question Domains

4. Results

Analysis of interview data, supported by international literature, indicates that healthcare system collapse is consistently understood as a progressive, saturation-driven process rather than a sudden failure event. Across interviews, participants emphasized that collapse emerges when prolonged efficiency pressures and institutional constraints erode system capacity, ultimately resulting in the loss of adaptability. The results are presented in alignment with the four analytical tables developed in this study.

a. Healthcare System Collapse Factors within the SEA Framework

A total of seven core factors contributing to healthcare system collapse were identified through qualitative analysis and literature synthesis. These factors span governance, financing, workforce, infrastructure, digital systems, trust, and systemic capacity. As summarized in Table 4 (Healthcare System Collapse Factors Categorized by the SEA Model), the identified factors are not isolated drivers but interact dynamically across the Stability, Efficiency, and Adaptability dimensions.

Participants consistently noted that governance failure, financial fragility, workforce burnout, infrastructure vulnerability, digital system failure, and erosion of trust function as **structural stressors**, while the loss of adaptability represents a **system-level outcome** reflecting the cumulative impact of these stressors. Table 4 provides the foundational structure upon which subsequent SEA-oriented redefinitions are built.

Table 4. Healthcare System Collapse Factors Categorized by the SEA Model

System Domain	Identified Collapse Factor	Interpretation within SEA Framework	Dominant SEA Dimension
Governance	Governance failure	Preservation of apparent stability through control mechanisms while suppressing learning and feedback	Stability ↓ / Adaptability ↓
Financing	Financial fragility	Short-term efficiency gains achieved by eliminating buffers and fiscal flexibility	Efficiency ↑ / Stability ↓
Workforce	Workforce burnout and attrition	Human resources treated as efficiency inputs rather than adaptive assets	Efficiency ↑ / Adaptability ↓
Infrastructure	Infrastructure and supply chain vulnerability	Systems optimized for normal conditions without redundancy or shock absorption	Efficiency ↑ / Adaptability ↓
Digital systems	Digital and information system failure	Data used for reporting and control rather than learning and adaptation	Symbolic Efficiency ↑
Trust	Erosion of trust and social capital	Loss of legitimacy and social cohesion undermining systemic stability	Stability ↓
Systemic capacity	Loss of adaptability	Inability to lean, respond, and redesign under stress	Adaptability ↓ (core driver)

b. Stability-Oriented Redefinition of Collapse Factors

From a stability perspective, collapse-related factors were primarily associated with declining institutional coherence, weakened legitimacy, and disruption of service continuity. As shown in Table 5 (Stability-Oriented Redefinition of Healthcare System Collapse Factors and KPIs), governance failure was frequently linked to policy inconsistency, short-term crisis management, and reduced predictability of decision-making.

Financial fragility was described as undermining stability by introducing budget volatility that compromises the continuity of essential services. Workforce burnout and attrition were perceived as destabilizing forces due to the loss of institutional memory and professional continuity. Infrastructure and digital system failures further weakened stability by increasing the frequency of service interruptions and reducing coordination reliability. Erosion of trust emerged as a central stability-related factor, affecting both public confidence and professional legitimacy.

The KPIs presented in Table 5 operationalize these stability-related dynamics by capturing early signs of institutional erosion and service discontinuity, without conflating stability with adaptive capacity.

Table 5. Stability-Oriented Redefinition of Healthcare System Collapse Factors and KPIs

Collapse Factor	Redefinition from a Stability Perspective	Stability KPI	Stable Range	At-Risk Range	Collapse-Prone Range
Governance failure	Loss of institutional legitimacy, policy coherence, and predictable governance	Policy coherence index	High	Moderate	Low
Financial fragility	Inability to sustain core services due to budget volatility	Budget predictability score	High	Moderate	Low
Workforce burnout & attrition	Disruption of professional continuity and institutional memory	Annual workforce attrition rate	<5%	5–10%	>10%
Infrastructure vulnerability	Recurrent service interruptions and operational brittleness	Service continuity rate	>95%	85–95%	<85%
Digital systems failure	Declining reliability of information for coordination	Data reliability index	High	Moderate	Low
Erosion of trust	Breakdown of social and professional legitimacy	Public/professional trust index	>70%	40–70%	<40%

c. Efficiency-Oriented Redefinition and Saturation Dynamics

Efficiency-oriented findings highlighted the role of saturation and over-optimization in driving collapse-related dynamics. As summarized in Table 6 (Efficiency-Oriented Redefinition of Healthcare System Collapse Factors and KPIs), participants described how sustained cost containment, workforce intensification, and just-in-time resource management initially improved performance indicators but gradually reduced system flexibility and safety margins.

Once efficiency saturation was reached, additional optimization efforts were perceived as counterproductive, contributing to increased error rates, workforce exhaustion, and erosion of redundancy. Infrastructure and digital systems optimized for compliance and throughput were seen as particularly vulnerable under stress. Importantly, efficiency-related findings did not directly describe loss of adaptability but rather identified the conditions under which adaptive capacity becomes compromised. The KPIs in Table 6 capture these saturation dynamics by distinguishing between optimal, saturated, and destructive efficiency states.

Table 6. Efficiency-Oriented Redefinition of Healthcare System Collapse Factors and KPIs

Collapse Factor	Redefinition from an Efficiency Perspective	Efficiency KPI	Optimal Range	Saturation Range	Destructive Range
Governance failure	Short-term crisis control replacing effective system performance	Crisis-driven policy ratio	<20%	20–50%	>50%
Financial fragility	Cost containment achieved through buffer elimination	Cost-cutting intensity (%)	<15%	15–30%	>30%
Workforce burnout & attrition	Over-utilization of human resources to maximize output	Workforce utilization rate	70–85%	85–95%	>95%
Infrastructure vulnerability	Just-in-time optimization without redundancy	Redundancy ratio	≥1.3	1.0–1.3	<1.0
Digital systems failure	Data systems optimized for reporting and compliance	Reporting compliance focus (%)	<40%	40–70%	>70%
Erosion of trust	Efficiency measures losing effectiveness due to low compliance	Compliance effectiveness	High	Declining	Ineffective

d. Adaptability-Oriented Redefinition and Loss of Adaptability

Adaptability emerged as a central and integrative finding of the study. As presented in Table 7 (Adaptability-Oriented Redefinition of Healthcare System Collapse Factors and KPIs), adaptability was consistently described by participants as a system-wide capacity reflecting the combined effects of governance quality, financial flexibility, workforce conditions, data systems, and trust.

Based on this analytical insight, indicators related to the loss of adaptability were consolidated exclusively within the Adaptability domain. Participants emphasized that once adaptive capacity was compromised, healthcare systems were unable to learn from stress, revise policies effectively, or reorganize services, even when stability and efficiency indicators appeared acceptable. This loss was often preceded by false stability and efficiency saturation, but it represented a distinct system-level outcome.

The adaptability-oriented KPIs in Table 7 focus on learning, feedback integration, system reconfiguration, stakeholder participation, and adaptive response capacity, providing a structured means of detecting when systems cross from saturation into collapse-prone states.

Table 7. Adaptability-Oriented Redefinition of Healthcare System Collapse Factors and KPIs

Collapse Factor	Redefinition from an Adaptability Perspective	Adaptability KPI	High Adaptability	Moderate	Low Adaptability (High Risk)

Governance failure	Suppression of feedback, learning, and policy revision	Feedback-based policy revision (%)	>60%	30–60%	<30%
Financial fragility	Limited fiscal flexibility under shock	Financial buffer ratio	≥1.3	1.0–1.3	<1.0
Workforce burnout & attrition	Reduced learning, innovation, and adaptive capacity	Training & learning investment (%)	>5%	2–5%	<2%
Infrastructure vulnerability	Inability to reconfigure logistics during disruption	System reconfiguration time	<14 days	14–30 days	>30 days
Digital system failure	Absence of data-driven learning and decision support	Data-informed decision rate (%)	>60%	30–60%	<30%
Erosion of trust	Weak stakeholder participation and collective adaptation	Stakeholder participation (%)	>60%	30–60%	<30%
Loss of adaptability	Structural inability to respond, learn, or transform	Adaptive response capacity	High	Moderate	Low
	Over-optimization dominating system logic	Over-optimization index	Low	Moderate	High
	False stability maintained through inertia and denial	False stability indicators	Absent	Emerging	Dominant

Taken together, the results demonstrate that healthcare system collapse arises from sustained imbalance across the SEA dimensions, driven by stability erosion and efficiency saturation and culminating in the loss of adaptability. **Tables 1–4** collectively show how qualitative insights can be systematically translated into a coherent analytical framework and a set of early warning KPIs capable of capturing collapse dynamics before irreversible failure occurs.

5. Discussion

This study set out to examine healthcare system collapse through the dual lenses of **saturation** and the SEA framework, with the aim of identifying key determinants of collapse and translating them into actionable early warning indicators. The findings extend existing health systems literature by reframing collapse as a processual and emergent phenomenon, rather than a sudden or externally driven event.

a. Collapse as a Saturation-Driven Process

This finding aligns with prior resilience literature that highlights internal fragility but goes beyond it by explicitly conceptualizing saturation as a precursor **to** collapse. While earlier studies emphasize shock absorption and recovery, they often overlook the conditions under which systems lose the ability to respond meaningfully to stress. By foregrounding saturation, this study clarifies why systems may appear functional or efficient, while simultaneously approaching collapse.

b. Reinterpreting Collapse Factors through the SEA Framework

A key contribution of this study lies in the systematic redefinition of collapse factors within the SEA framework. Table 4 establishes that commonly cited determinants such as governance failure, financial fragility, workforce burnout, and infrastructure vulnerability do not operate independently. Rather, they interact dynamically across the Stability, Efficiency, and Adaptability dimensions. From a stability perspective (Table 5), collapse is associated with erosion of institutional coherence, legitimacy, and service continuity. Notably, participants described conditions of *false stability*, in which systems maintain outward continuity while internal capacity deteriorates. This challenges conventional interpretations of stability as an inherently positive state and underscores the need to distinguish between genuine and hollow forms of stability. From an **efficiency perspective** (Table 6), the findings highlight the phenomenon of efficiency saturation. While efficiency gains are often framed as unequivocally beneficial, the results indicate that sustained optimization, particularly in workforce utilization, cost containment, and just-in-time systems can erode buffers and amplify fragility. Once saturation is reached, additional efficiency gains become destructive, accelerating pathways toward collapse.

c. Adaptability as an Integrative System Capacity

Perhaps the most important theoretical insight of this study concerns the role of **adaptability**. Rather than functioning as a parallel dimension alongside stability and efficiency, adaptability emerged as an integrative system capacity reflecting the cumulative effects of both. This insight motivated the analytical refinement whereby loss of adaptability was consolidated exclusively within the Adaptability domain (Table 7), avoiding conceptual overlap and circular reasoning.

Loss of adaptability was consistently described as the point at which systems can no longer learn from stress, revise policies, or reorganize services even when some stability and efficiency indicators remain within acceptable ranges. In this sense, adaptability functions as the final common pathway through which prolonged imbalance in the SEA system manifests as collapse. This finding directly supports the theoretical propositions advanced by Manafi (2025) and provides empirical grounding for the SEA framework.

d. Implications for KPI Development and System Monitoring

The development of SEA-aligned KPIs represents a practical contribution of this study. Existing KPI frameworks tend to prioritize efficiency and output metrics, often reinforcing the very dynamics that drive saturation. By contrast, the KPIs proposed in Tables 5–7 are explicitly grounded in collapse dynamics and designed to function as early warning signals, rather than retrospective performance measures.

Importantly, the findings suggest that KPI interpretation should emphasize patterns, trends, and interactions across dimensions, rather than absolute thresholds alone. A system exhibiting moderate efficiency decline but severe adaptability erosion may be far closer to collapse than one experiencing short-term instability. This perspective has significant implications for health system governance, monitoring, and reform.

6. Limitations

This study has several limitations. First, the qualitative sample size was intentionally limited and exploratory, which constrains generalizability. Second, while international literature was used to triangulate findings, empirical validation of the proposed KPIs was beyond the scope of this study. Finally, contextual variation across health systems may affect the applicability of specific indicators.

Nevertheless, the study's strength lies in its theoretical integration, methodological transparency, and focus on early warning rather than post hoc explanation.

7. Conclusion

This study advances the understanding of healthcare system collapse by conceptualizing it as a saturation-driven, systemic process rooted in prolonged imbalance across stability, efficiency, and adaptability. Drawing on the SEA framework and expert insights, the study identifies key determinants of collapse and translates them into a coherent set of theoretically grounded KPIs.

By treating loss of adaptability as an integrative system outcome rather than an isolated factor, the study resolves a key conceptual ambiguity in the literature and provides a clearer pathway for operationalizing collapse dynamics. The proposed KPI framework offers policymakers and system leaders a structured approach to detecting early warning signals and intervening before irreversible failure occurs.

Ultimately, this study shifts the focus from resilience rhetoric toward anticipatory system governance, emphasizing the need to monitor saturation, protect adaptive capacity, and rebalance the SEA system before collapse becomes inevitable. Future research should empirically validate the proposed indicators and examine their applicability across diverse health system contexts.

AI Disclosure: *The authors declare that generative artificial intelligence tools (ChatGPT and Grok) were used solely for the purpose of improving the clarity, grammar, and academic English of the manuscript. These tools were not used for data analysis, interpretation of results, theory development, or the generation of original scientific content. All conceptual contributions, analyses, and conclusions presented in this article are entirely the responsibility of the authors.*

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