When the Workforce Breaks: Developing a SEA-Based Early Warning Risk Assessment for Health Systems Saturation and Collapse

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Abstract

Health systems increasingly operate under sustained workforce pressures that may lead to saturation and eventual collapse. However, existing performance frameworks often fail to capture early warning signals related to workforce dynamics. This study aims to develop a SEA-based Early Warning Risk Index to assess health system vulnerability from a workforce perspective, with a particular focus on burnout and attrition as leading indicators of system degradation.

A qualitative approach was employed, integrating qualitative data from semi-structured interviews with 15 health system experts and a targeted synthesis of relevant studies. Interview questions were explicitly designed to elicit early warning signals of workforce-related stress. Thematic analysis identified key domains of workforce degradation, including workload escalation, workforce depletion, burnout, attrition, and adaptation failure. These themes were systematically translated into measurable indicators and mapped onto the SEA framework, encompassing Stability, Efficiency, and Adaptability.

The findings demonstrate that workforce-related stressors operate as early warning signals that precede observable system failure. While stability and efficiency are progressively weakened under pressure, the loss of adaptability primarily driven by burnout emerges as a critical tipping point toward system saturation.

Although the model assumes equal weighting across SEA dimensions, the results suggest that adaptability may exert a disproportionately greater influence on system resilience. Future research should refine the weighting structure to improve predictive accuracy. Overall, the proposed framework offers a practical and theory-driven tool for early detection of health system risk, supporting timely intervention before the onset of collapse.

Keywords: SEA Model, Workforce, Healthcare professional, health Workforce, Health systems, Early warning, Collapse, Saturation, Risk assessment

1. Introduction

Health systems globally are increasingly exposed to prolonged structural, financial, operational, and workforce pressures that challenge their long-term sustainability. Traditional health system performance frameworks have historically focused on dimensions such as service quality, efficiency, financial performance, and access, offering important governance tools but often failing to detect the progressive accumulation of internal stress that may move systems toward saturation and eventual collapse (Gutowski et al., 2026; Hojabri et al ,2026 a; Hojabri et al., 2013; World Health Organization [WHO], 2000). Although resilience-oriented approaches expanded this perspective by emphasizing crisis response and recovery, many

existing models remain primarily focused on episodic disruptions rather than gradual structural degradation (WHO, 2024; Hojabri & Manafi, 2026b). Consequently, conventional frameworks frequently underrepresent the mechanisms through which health systems progressively deteriorate under sustained pressure.

Recent theoretical developments in saturation and collapse research provide a broader lens for understanding these vulnerabilities. Manafi's Theory of Saturation conceptualizes collapse as a progressive, saturation-driven process in which increasing optimization, complexity, and efficiency eventually degrade systemic stability, meaning, and adaptability rather than improving performance (Manafi, 2025, 2026 a). Building on this foundation, the Stability–Efficiency–Adaptability (SEA) framework interprets health system sustainability as the result of dynamic balance among institutional stability, operational efficiency, and adaptive capacity (Hojabri & Manafi, 2026b). Within this model, collapse is not viewed as a sudden catastrophic event, but as the cumulative consequence of prolonged imbalance across these three dimensions, eventually leading to structural brittleness, service degradation, and loss of reversibility.

Among the major determinants of saturation and collapse identified in prior SEA-oriented research, workforce burnout and attrition have emerged as particularly significant. The Early Warning Framework for Healthcare System Collapse explicitly identifies workforce burnout and attrition as one of seven core determinants of progressive health system collapse (Hojabri & Manafi, 2026a). This framework emphasizes that workforce degradation directly affects all three SEA dimensions: it undermines stability by eroding institutional memory and service continuity, weakens efficiency through excessive workload and declining performance, and reduces adaptability by impairing recruitment, retention, and reorganization capacity under crisis conditions. In this sense, workforce-related pressures are not isolated human resource problems, but systemic destabilizers capable of accelerating broader structural failure. (Hojabri & Manafi, 2026 a, b).

The broader workforce literature strongly reinforces this collapse-oriented interpretation. Global workforce analyses have consistently demonstrated that inadequate staffing, poor retention, migration, burnout, absenteeism, and workforce shortages can significantly impair service continuity and threaten health system functionality. The WHO health workforce report identifies workforce insufficiency as a direct structural threat to service delivery and system performance, emphasizing that health systems cannot function effectively without adequate workforce capacity, planning, and support structures (WHO, 2010,2016,2020,2024).

More recent workforce-focused literature further demonstrates that burnout, moral injury, workload overload, and attrition are increasingly associated with declining care quality, workforce withdrawal, reduced patient safety, and broader organizational instability. Grumbach and colleagues' comprehensive review of health worker burnout highlights that burnout is not merely an occupational wellness issue, but a structural condition that can progressively undermine workforce sustainability and health system performance. Their synthesis further indicates that chronic overload and intent to leave are strongly associated with deteriorating workforce resilience, especially under sustained crisis conditions such as COVID-19. (Grumbach, K., & Willard-Grace, R. ,2025).

Despite this growing body of evidence, important gaps remain. First, much of the workforce literature examines burnout, staffing shortages, or attrition in isolation rather than as interconnected drivers of system-wide saturation and collapse. Second, while SEA and Early Warning frameworks identify workforce degradation conceptually, there remains limited operationalization of workforce-related collapse factors into measurable indicators for

continuous monitoring. Third, existing health system KPI structures frequently prioritize efficiency and output metrics while insufficiently integrating workforce-centered early warning indicators related to professional exhaustion, attrition, and adaptive erosion. As a result, policymakers often lack structured tools capable of identifying progressive workforce-related vulnerabilities before overt service disruption occurs.

This study addresses these gaps by extending prior SEA and Early Warning research into the specific domain of workforce-centered collapse assessment. Building directly on prior studies of saturation, collapse, and SEA-based health system vulnerability (Manafi, 2025, 2026; Hojabri & Manafi, 2026a, 2026b), this research develops a structured SEA-Based Early Warning Risk Index focused specifically on workforce-related determinants of health system saturation and collapse. By integrating qualitative expert interviews, synthesis of reviewed workforce-related literature, and structured indicator development, this study seeks to identify early warning signals of workforce-related system stress, categorize them systematically within the SEA framework, and operationalize them into a continuous monitoring tool. More specifically, this study is guided by three central research questions:

1. What workforce-related conditions function as early warning signals of health system saturation and collapse?
2. How can these workforce-related signals be systematically categorized within the SEA framework?
3. Can workforce-related indicators be operationalized into a structured checklist and composite risk index for continuous assessment of collapse risk?

By addressing these questions, this study contributes both theoretically and practically. Theoretically, it advances collapse-oriented health systems research by operationalizing workforce degradation as a measurable systemic driver of saturation and collapse. Practically, it provides policymakers, health system leaders, and researchers with a structured early warning framework capable of identifying hidden vulnerabilities before overt system failure occurs.

Ultimately, this study argues that when workforce systems begin to deteriorate through sustained burnout, attrition, overload, and declining adaptability, health systems may already be entering progressive stages of saturation. Therefore, systematic workforce-centered monitoring is essential not only for workforce management but also for preserving system resilience, safeguarding institutional continuity, and preventing progressive health system collapse.

2. Literature Review

Across the reviewed literature, workforce and human capital degradation consistently emerge as among the most significant structural threats to health system functionality, resilience, and sustainability (World Health Organization [WHO], 2006; WHO, 2016; Dal Poz et al., 2006; U.S. Department of Health and Human Services [HHS], 2024; Amini Rarani, 2026). Health systems depend fundamentally on workforce availability, competency, retention, psychological well-being, governance, and adaptive capacity, and disruptions in these domains progressively undermine service continuity, institutional resilience, and broader system performance (Beaglehole, 2004; WHO, 2006; Schady et al., 2023). Rather than functioning solely as isolated labor market concerns, workforce pressures increasingly operate as systemic destabilizers capable of accelerating health system saturation and eventual collapse (Hojabri & Manafi, 2026a; Hojabri & Manafi, 2026b).

Early global evidence established that workforce crises predate contemporary shocks such as COVID-19. WHO's foundational workforce analyses identified chronic shortages, weak workforce planning, migration, maldistribution, governance deficits, and underinvestment as major barriers to sustainable health system performance, particularly in low-resource and fragile settings (WHO, 2020,2024). Similarly, Beaglehole (2004) argued that inadequate public health workforce development substantially constrained national and global responses to evolving health challenges. Dal Poz et al. (2006) further framed workforce crisis as a global systemic issue requiring coordinated policy solutions rather than fragmented local interventions. These studies collectively demonstrate that workforce fragility has long functioned as a foundational determinant of system vulnerability.

During the Sustainable Development Goals(SDG) and post-2015 strategic period, workforce challenges increasingly expanded beyond shortages alone to include training deficits, aging populations, workforce distribution mismatches, retention failures, and inadequate adaptability to demographic and epidemiological transitions (WHO, 2016; Kuhlmann, E. (2025).; Al Qadiri et al., 2025). WHO's Workforce 2030 strategy explicitly linked universal health coverage and long-term health system sustainability to substantial workforce investment, education, retention, and governance reforms (WHO, 2016). European analyses similarly revealed that even advanced systems faced severe long-term threats through retirement waves, insufficient workforce replacement, and dependence on migrant labor (Kuhlmann, E. (2025).).

Country-level studies further demonstrate that workforce-related vulnerabilities transcend geography, political systems, and income levels. In Nigeria, workforce crises were linked to weak financing, salary instability, governance failures, and policy denial, directly impairing service delivery (Adeloye et al.; Nwankwo et al.). Zimbabwean evidence demonstrated that prolonged shortages of skilled health workers significantly constrained maternal and child health service quality over more than a decade (Haley, C. A.,et al, 2017). In conflict settings such as Syria, infrastructure destruction and large-scale healthcare worker displacement produced severe long-term workforce depletion and service disruption (Alhaffar & Janos, 2021). These studies indicate that workforce collapse can emerge through chronic governance failures, prolonged underinvestment, or acute geopolitical crises.

Advanced health systems similarly demonstrate substantial workforce vulnerabilities. In the United States, persistent shortages, direct care instability, burnout, turnover, moral injury, and administrative burden have increasingly threatened workforce sustainability even outside acute crisis periods (HHS, 2024; Grumbach & Willard-Grace, 2025). Digital systems, regulatory burdens, and efficiency-oriented redesign have often exacerbated rather than alleviated workforce strain (Grumbach & Willard-Grace, 2025). In the United Kingdom, doctor training bottlenecks and insufficient workforce absorption have created structural mismatches between workforce production and service demand. Comparative studies across the UAE, Saudi Arabia, Singapore, Canada, the UK, and the USA similarly identified shortages, burnout, educational gaps, and preparedness deficits despite differing system structures (Al Qadiri et al., 2025).

The COVID-19 pandemic acted as a major accelerant rather than sole origin of workforce collapse pressures. Across Iran, Peru, South Korea, Lebanon, and global comparative studies, COVID-19 dramatically intensified pre-existing shortages, burnout, psychosocial distress, infection risk, absenteeism, and attrition (Shoja et al., 2020; Moazzami et al., 2020; Neyra-León et al., 2021; Yeo et al., 2021). WHO's pandemic workforce policy framework explicitly recognized burnout prevention, redeployment management, workforce protection, and absenteeism as critical to maintaining health system continuity (WHO, 2020). Thus, pandemic conditions exposed and amplified pre-existing structural workforce weaknesses rather than creating them de novo.

Recent literature increasingly conceptualizes workforce degradation not merely as an HR issue, but as a resilience and collapse determinant. Amini Rarani (2026) describes the global nursing workforce as approaching structural collapse due to burnout, migration, moral injury, shortages, and systemic neglect. Grumbach and Willard-Grace (2025) similarly interpret burnout and moral injury as manifestations of system design failures rather than solely individual resilience deficits. Manafi's SEA-based frameworks further position workforce burnout and attrition as one of the central pathways through which systems transition from stress toward saturation and collapse (Hojabri & Manafi, 2026a; Hojabri & Manafi, 2026b).

Geographic synthesis demonstrates that workforce pressures are globally pervasive, affecting advanced, transitional, fragile, conflict-affected, and low-resource systems alike. Across diverse settings, recurring workforce sub-factors include shortages, burnout, migration, governance failures, educational deficits, aging workforce populations, administrative overload, preparedness limitations, and moral injury (WHO, 2006; HHS, 2024; Amini Rarani, 2026; Al Qadiri et al., 2025). Table 1. shows Geographic Synthesis of Workforce-Related Health System Saturation and Collapse Literature.

Temporal synthesis demonstrates that workforce-related pressures represent a progressive and historically persistent phenomenon. Early structural shortages evolved into governance crises, burnout recognition, adaptive deficits, and eventually acute crisis amplification under COVID-19, followed by persistent post-pandemic fragility and future workforce collapse projections (WHO, 2006; WHO, 2016; HHS, 2024; Mikkelsen, 2026). Table 2. shows Temporal Synthesis of Workforce-Related Health System Saturation and Collapse Literature Grouped by Time Periods .

Table 1. Geographic Synthesis of Workforce-Related Health System Saturation and Collapse Literature (Grouped by Country/Region)

Country / Region	Workforce-Related Issues	Dominant Themes	References
United States	Burnout, turnover, administrative burden, direct care instability, preparedness deficits, moral injury,	Governance Burnout, digital burden, retention, system design failures; retention, financing	U.S. Department of Health and Human Services (2024); Grumbach & Willard-Grace (2025); Morrison & Rudolph (2011); ; Bostick, D. (2025). ; ; Franco, C. et al, (2006) ; Van Slyke, A. (2020) ; Bostick, D. (2025). ; Michaeli, D. Tet al (2024) ; Veenema et al(2022) ; Reinhart, E. (2023).; Kim, S.,et al (2023) ; Pittman, P., & Meeker, S. (2025). ; Baptiste, M., & Talley, R. (2022). ; Wallace, R., & Wallace, D. (1990). ;
United Kingdom	Burnout, NHS strain, doctor training bottlenecks, attrition	Retention, policy mismatch, overload	Al Qadiri et al. (2025); Xames, M. D. (2025).
Canada	Public health adaptation gaps, workforce sustainability deficits	Preparedness, adaptability, sustainability	Al Qadiri et al. (2025) ; Kuhlmann, E et al (2023)
European Union	Aging workforce, graduate deficits, migration imbalance, retirement waves	Aging, migration, future shortages	Kuhlmann, E. (2025).; Michaeli, D. Tet al (2024) ; Buchan, J., & Campbell, J. (2013). ; Kwaku Agyeman-Manu (2023) ; Kuhlmann, E et al (2023) ; Sipos, D., et al (2024) ; Azzopardi-Muscat et al (2023) ; Almeida-Meza, P (2025) ;
Australia	Organizational compliance capacity, EHR downtime staffing, workforce adaptability	Governance, preparedness, adaptability	Hackman (2009); Lyon et al. (2023)
Saudi Arabia	Public health education deficits, preparedness limitations	Training, preparedness	Al Qadiri et al. (2025) ; Siraj, R. A., & Almulhem, M. M. (2026)
UAE	Public health workforce development gaps	Infrastructure, preparedness	Al Qadiri et al. (2025)
Singapore	Chronic disease demand pressures, health workforce adaptation gaps	Capacity, adaptation	Al Qadiri et al. (2025)
Brazil	Shortage of health professionals; Burnout, COVID overload, loss of capacity; psychological distress, provider well-being erosion	critical overload, mental health, crisis burden , trust crisis	Lemos, D. R. Q., et al. (2020). ; Alcoforado, F. (2020) ; de Carvalho et al.(2023) ; Silva, S. J. R., & Pena, L. (2021). ; Kwaku Agyeman-Manu (2023) ; Kuhlmann, E et al (2023) ;
Romania	Low wages for health professionals Aging workforce, graduate deficits, migration imbalance, retirement waves ; infrastructure destruction, long-term workforce depletion	Governance, retention, financing	Casey, Q. (2010). ; Kwaku Agyeman-Manu (2023)
Nigeria	Salary delays, poor remuneration, governance failures, weak workforce financing	Governance, retention, financing	Adeloye et al.; Nwankwo et al.; ; O.A. Chukwu and B. Essue (2024) ; Adeloye, D., et al. (2017).

Zimbabwe	Skilled workforce depletion, service limitations	HR depletion, long-term shortages	Haley, C. A et al (2017) ;
Iran	Burnout, COVID overload, psychological distress, provider well-being erosion persistent workforce shortages, and moral injury, and systemic neglect contributing to attrition.	Acute overload, mental health, crisis burden	Shoja et al. (2020); Moazzami et al. (2020); Manafi et al. (2012) ; Rarani, S. A. (2026).
India	Shortage of healthcare professionals; Workforce flight ; lace of training programs ; Burnout during overlapping ; shortage in supply chain ; shortage in equipment and facilities	Compound crisis burnout	Christopher N. Rocha et al.(2021)
Lebanon	Burnout during overlapping political, economic, War and COVID crises	Compound crisis burnout	Clinton et al.(2022) ; Bou Sanayeh et al. (2023)
Libia	fragmented governance, limited financial resources, deficient human resources humanitarian crisis , restricted movements of doctors and healthcare services, restricted access to health facilities, shortages of Healthcare professionals, low wages , immigration	Acute emergency saturation	Rowan Al-ghfafi (2020)
Gaza (Palestine)	humanitarian crisis , Lack of security, Workforce flight, infrastructure destruction, long-term workforce depletion	Acute emergency saturation	; Abuzerr, S., et al. (2025). Dağdeviren et al (2024) ; Manduca, P et al (2024) ; Kooli, C., & Kooli, Y. (2023)
Peru	Workforce maldistribution, PPE shortages, ICU shortages	Geographic maldistribution, protection deficits	Neyra-León et al. (2021)
Sudan	humanitarian crisis , restricted movements of doctors and healthcare services, restricted access to health facilities, shortages of doctors,	Acute emergency saturation	AbdulRahman A Saied. (2023). ; Ahmed et al (2024) ; ; Irfan et al. (2026) ; ; El-Sadig, S. M et al (2023) ;
Venezuela	Lack of security; shortage of health professionals ,immigration; psychosocial stress ; governance failures, weak workforce financing	Acute emergency saturation	Pierce, J. M. (2017). ; Fhabián S et al (2025) ; Page, K. R.,et al (2019)
South Korea	Emergency department overload, shortage of health professionals; psychosocial stress ; weak training	Governance , retention , training , mental health issues	Yeo et al. (2021) ; Kim Y and Che S. (2025).
Syria / conflict settings	Shortage of healthcare professionals Workforce flight, infrastructure destruction, long-term workforce depletion	Conflict collapse, migration Acute emergency saturation	Alhaffar & Janos (2021)

Afghanistan	Shortage of healthcare professionals, the negative impacts of disaster, and the lack of international aid contributed to the collapse of the healthcare system in Afghanistan	Acute emergency saturation	Tao, N. et al (2023)
Pakistan	Shortage of healthcare professionals; Workforce flight ; lace of training programs ; Burnout during overlapping ; shortage in supply chain ; shortage in equipment and facilities	Burnout, Human Resources system strain	Waqar et al.(2023)
South Africa	poor performance and outcomes ; deteriorating conditions ; witnesses to poor practices and suboptimal treatment.; A feeling of futility ; burden of moral injury	Governance, retention, Acute emergency saturation	De Maayer, T., & Coovadia, A. (2024). ; Venter, S. (2020).
Sub-Saharan Africa / LMICs	Migration, shortages, weak governance, poor training capacity	Chronic shortages, workforce outflow	WHO (2006); WHO (2016); Amini Rarani (2026) ; ; Kwaku Agyeman-Manu (2023) ; O.A. Chukwu and B. Essue (2024)
Myanmar	humanitarian crisis , restricted movements of doctors and healthcare services, restricted access to health facilities, shortages of doctors,	Acute emergency saturation	Rocha, I. C. N et al (2023),
Yemen	Shortage of healthcare professionals; Workforce flight, infrastructure destruction, long-term workforce depletion	Conflict collapse, migration	Looi, M.-K. (2020). ; Cole et al (2021)

Table 2. Temporal Synthesis of Workforce-Related Health System Saturation and Collapse Literature (Grouped by Time Period)

Time Period	Dominant Workforce Pressures	Collapse / Saturation Dynamics	References
Pre-2005	Public health workforce neglect, chronic shortages, weak planning	Foundational structural vulnerabilities	Beaglehole (2004); WHO (2006); Haley, C. A et al (2017) ; Wallace, R., & Wallace, D. (1990). ; Chen, L., Evans, T., Anand, S., et al. (2004).
2005–2010	Global workforce crisis recognition, migration, workforce governance concerns	Early systemic recognition of workforce crisis	World Health Organization (2006 , 2010); Dal Poz et al. (2006); Hackman (2009) ; Franco, C. et al, (2006) ; Casey, Q. (2010).; Haley, C. A et al (2017)
2011–2015	Governance failures, salary instability, skilled worker shortages, service delivery limitations	Progressive structural strain	Morrison & Rudolph (2011); Manafi et al. (2012) ; O'Brien, P., & Gostin, L. O. (2011). ; Aluttis, C., Bishaw, T., & Frank, M. W. (2014). Al-ghfafi, R. (2020) ; Buchan, J., & Campbell, J. (2013). ; Haley, C. A et al (2017)
2016–2019	Workforce strategy expansion, burnout recognition, aging workforce, retention concerns	Broadening workforce vulnerability	World Health Organization (2016); EU workforce crisis studies ; Frezza, E. E. (2019) ; Pierce, J. M. (2017).; Adeloye, D., et al. (2017).; Lacy, B. E., & Chan, J. L. (2018). ; Brindley et al.(2019) ; Kim, S.,et al (2023) ; Fridell et al (2020) ; Page, K. R.,et al (2019)
2020–2022 (COVID era)	Burnout, overload, PPE shortages, moral injury, redeployment, psychosocial stress	Acute crisis amplification of pre-existing workforce fragility	Shoja et al. (2020); Moazzami et al. (2020); Yeo et al. (2021); Neyra-León et al. (2021); WHO (2020) ; Wemos. (2020) ; ; Džakula, A., Relić, D., & Michelutti, P. (2022). ; Lemos, D. R. Q., et al. (2020). ; Alcoforado, F. (2020) ; Van Slyke, A. (2020) ; Christopher N. Rocha et al.(2021) ; Looi, M.-K. (2020). ; Silva, S. J. R., & Pena, L. (2021).; Cole et al (2021) ; Venter, S. (2020).; VEENEMA ET AL(2022) ; Baptiste, M., & Talley, R. (2022). ; Bou Sanayeh et al. (2023)
2023–2026 (post-COVID / future projections)	Persistent shortages, direct care instability, nursing collapse, adaptation deficits, physician moral injury, retirement waves	Long-term structural fragility and projected future collapse risks	HHS (2024); Grumbach & Willard-Grace (2025); Al Qadiri et al. (2025); Mikkelsen (2026) WHO (2024) Ellen Kuhlmann (2025); U.S. Department of Health and Human Services. (2024). ; Abuzerr, S., et al. (2025). ; Bostick, D. (2025). ; Shaale, M.,et al (2025) ; Dağdeviren et al (2024) ; Tao, N. et al (2023) ; Rarani, S. A. (2026). ; Manduca, P et al (2024) ; Bostick, D. (2025). ; De Maayer, T., & Coovadia, A. (2024). ; AbdulRahman A Saied. (2023). ; Kooli, C., & Kooli, Y. (2023) ; Fhabián S et al (2025) ; de Carvalho et al.(2023) ; Ahmed et al (2024) ; Irfan et al. (2026) ; Rocha, I. C. N et al (2023) ; El-Sadig, S. M et al (2023) ; Michaeli, D. Tet al (2024) ; Kwaku ;Agyeman-Manu (2023) ; O.A. Chukwu and B. Essue (2024) ; Kuhlmann, E et al (2023); Sipos, D., et al (2024) ; Siraj, R. A., & Almulhem, M. M. (2026) ; Azzopardi-Muscat et al (2023) ; Xames, M. D. (2025).; Antonia Kolokythas. (2025).; Clinton et al.(2022) ; Almeida-Meza, P (2025) ; Reinhart, E. (2023).; Pittman, P., & Meeker, S. (2025). ; Waqar et al.(2023) ; ; Kim Y and Che S. (2025).

Collectively, the literature strongly supports workforce and human capital failure as a universal, historically persistent, and structurally embedded determinant of health system vulnerability. However, despite broad empirical evidence, much of the existing literature remains fragmented, often focusing on isolated dimensions such as burnout, shortages, migration, or preparedness without integrating them into unified collapse-oriented assessment frameworks.

a. Major Workforce Sub-Factors Driving Saturation and Collapse

Across the reviewed literature, several recurring sub-factors consistently emerge as major contributors to workforce-related health system stress. Burnout is one of the most frequently documented drivers, characterized by emotional exhaustion, depersonalization, cognitive overload, and reduced professional efficacy (Grumbach & Willard-Grace, 2025; Shoja et al., 2020; Lebanon nursing burnout study). Burnout is closely linked to attrition, absenteeism, reduced productivity, and declining patient safety.

Attrition and intention to leave are similarly critical. Studies in Iran, nursing systems globally, and direct care sectors demonstrate that workforce dissatisfaction, burnout, and poor organizational fit substantially increase exit risk (Manafi et al., 2012; Amini Rarani, 2026; HHS, 2024). Migration further intensifies these pressures by redistributing health professionals from lower-resource to higher-resource settings, thereby worsening shortages in already vulnerable systems (WHO, 2006).

Governance failures including delayed salaries, weak welfare systems, poor financing, and policy denial are especially prominent in lower-resource settings such as Nigeria and Zimbabwe (Adeloye et al.; Nwankwo et al.; Haley, C. A.,et al, 2017). Administrative and digital burdens are more prominent in advanced systems, where EHR complexity, regulatory demands, and productivity pressures increase cognitive load and moral injury (Grumbach & Willard-Grace, 2025; Lyon et al., 2023).

Preparedness deficits, educational gaps, and surge-capacity limitations further weaken workforce adaptability, particularly during emergencies (WHO, 2020; Al Qadiri et al., 2025). Aging workforce populations and retirement waves represent major future threats in Europe and North America (Kuhlmann, E. ,2025).

These sub-factors rarely operate independently. Instead, shortages intensify workload; workload accelerates burnout; burnout drives attrition; attrition further worsens shortages; governance failures impair retention; and preparedness deficits reduce adaptability. This cumulative interaction strongly aligns with saturation theory, wherein progressive pressure accumulation gradually erodes system resilience until tipping points emerge.

b. Limitations of Traditional Health System Performance and Excellence Models

Traditional health system performance and excellence models have historically focused on efficiency, quality improvement, productivity, and organizational outputs (Gutowski et al., 2026; Hojabri et al., 2013). While such models may improve service efficiency and measurable operational outcomes, they often insufficiently capture deeper structural vulnerabilities related to workforce degradation, burnout, adaptive exhaustion, and collapse risk (Gutowski et al., 2026).

Efficiency-driven redesigns may paradoxically intensify workforce strain by increasing throughput expectations, administrative burden, and cognitive overload without adequately protecting workforce sustainability (Grumbach & Willard-Grace, 2025). Consequently, traditional performance systems may mask early warning signs of workforce saturation while preserving short-term productivity metrics. This creates major blind spots in identifying progressive collapse trajectories.

The literature therefore suggests that while performance models remain useful for operational benchmarking, they require augmentation through frameworks capable of incorporating saturation, collapse vulnerability, and workforce-centered early warning indicators.

c. Saturation Theory and the SEA Framework as an Integrative Lens

Saturation theory conceptualizes collapse as the progressive accumulation of structural pressures beyond adaptive system thresholds (Hojabri & Manafi, 2026a). Within this framework, workforce degradation is not a peripheral symptom but a central mechanism through which Stability, Efficiency, and Adaptability are progressively compromised.

The SEA framework provides a particularly useful lens because it integrates:

- Stability: workforce continuity, retention, governance, and staffing sufficiency
- Efficiency: productivity under sustainable workforce conditions
- Adaptability: surge capacity, retraining, preparedness, and workforce flexibility

This approach allows workforce pressures to be interpreted not merely as staffing shortages, but as multidimensional structural signals that may progressively indicate movement toward saturation or collapse (Hojabri & Manafi, 2026b).

d. Early Warning Systems and the Need for a Workforce-Specific Collapse Risk Index

Although numerous studies document workforce pressures, few offer unified operational frameworks for continuous early warning assessment. Existing literature often examines burnout, shortages, or governance failures independently, limiting proactive intervention capacity (Amini Rarani, 2026; HHS, 2024). Recent conceptual work increasingly emphasizes the need for structured KPI systems capable of integrating workforce indicators into broader collapse monitoring systems (Hojabri & Manafi, 2026a). Such systems would allow repeated measurement of workforce vulnerability across SEA domains, transforming fragmented evidence into actionable early warning intelligence. This gap directly motivates the present study's objective: developing a workforce-centered SEA-based early warning risk index capable of assessing health system saturation and collapse risks through integrated checklist and indicator architecture.

The literature overwhelmingly demonstrates that workforce and human capital degradation represent globally pervasive, historically persistent, and structurally embedded drivers of health system vulnerability. Across diverse geographies and time periods, workforce pressures repeatedly emerge through recurring sub-factors including shortages, burnout, attrition, migration, governance failures, educational deficits, and preparedness limitations. Traditional performance models inadequately capture these pressures, necessitating more collapse-sensitive frameworks. Saturation theory and the SEA model provide a robust conceptual foundation for integrating workforce vulnerability into broader health system collapse assessment. However, a major operational gap remains in translating these insights into practical early warning systems an unmet need this study directly addresses.

3. Methodology

This study was conducted with the aim of developing a structured, assessment tool to evaluate the level of health system saturation and the risk of collapse from a workforce perspective. To achieve this objective, a mixed-methods approach was adopted, integrating qualitative exploration, evidence synthesis, and expert validation within a unified analytical framework. The study was conceptually grounded in the Early Warning Framework for Health System Collapse and further structured through the SEA model, encompassing Stability, Efficiency, and Adaptability as the core dimensions of system performance.

The research design followed a sequential process. In the initial phase, qualitative data were collected through semi-structured interviews to identify key workforce-related factors contributing to system stress, degradation, and eventual collapse. Participants were selected using purposive sampling to ensure representation across critical stakeholder groups within the health system. A total of 15 participants were included, comprising policy makers and senior managers, academic experts, human resource and system specialists, and frontline healthcare providers. The distribution of participants is presented in Table 3.

Table 3. Distribution of Interview Participants

Group	Description	Number of Participants
Policy-makers and senior managers	Health system leaders and decision-makers	3
Academic experts	Researchers in health systems, public health, and health economics	5
HR and system specialists	Experts in workforce management and system operations	3
Frontline providers	Physicians and nurses	4
Total		**15**

The interview guide was designed using open-ended questions to capture in-depth insights into workforce-related challenges, including workload pressure, burnout, attrition, and their systemic consequences. The structure of the questions was explicitly aligned with the SEA model and early warning concepts to ensure theoretical coherence. In addition, a set of integrative questions was included to capture cross-cutting themes such as burnout, workforce attrition, and early warning signals of system collapse. The full set of interview questions and their analytical purposes are presented in Table 4.

Table 4. Semi-Structured Interview Guide

Code	Question	Analytical Objective
Q1	From your experience, what are the earliest signs indicating that a health system is moving from a stable condition toward stress due to workforce-related factors?	Identify early warning signals of system stress
Q2	How do workload, staffing levels, and workforce pressures evolve before the system reaches a saturated or critical state?	Understand progression toward saturation (Stability & Efficiency)
Q3	In your view, how do burnout and workforce attrition develop, and how do they contribute to weakening system performance?	Capture core collapse mechanisms (Burnout & Attrition)
Q4	How does the health system respond to increasing pressure, and what are the signs that it is losing its ability to adapt or recover?	Identify loss of adaptability (Adaptability dimension)

Q5	Based on your experience, what key indicators would you use to assess whether a health system is approaching saturation or collapse?	Extract measurable indicators for checklist development
Q6	From your perspective, are there any additional workforce-related factors, dynamics, or emerging issues that we have not covered in the previous questions but are important for understanding health system stress, saturation, or risk of collapse?	Identifying new perspectives

The interviews were conducted until theoretical saturation was reached. The collected data were analyzed using thematic analysis, involving open coding, identification of recurring patterns, and abstraction of higher-level themes. These themes were interpreted as workforce-related drivers of system stress and mapped onto the SEA dimensions as well as early warning indicators of system failure. To complement and strengthen the qualitative findings, a targeted synthesis sources was conducted, including peer-reviewed articles, policy reports, and empirical case studies addressing workforce related stress and system level consequences. The inclusion criteria focused on studies that explicitly linked workforce dynamics such as burnout, attrition, and workforce shortages to disruptions in health system performance, including reduced service capacity, delays in care, and systemic fragility. The integration of literature and interview findings enabled the identification of consistent and recurring patterns that connect workforce degradation to system saturation and eventual collapse. Based on the combined findings, an initial assessment was developed and structured according to the SEA framework.

In this assessment framework, higher values indicate greater vulnerability and closer proximity to system saturation and collapse. The indicators was subsequently reviewed by experts to ensure content validity, clarity, and relevance. Based on expert feedback, items were refined, redundant elements were removed, and the final structure was optimized. Through this integrated methodological approach combining qualitative insights, empirical evidence, and theoretical grounding the study developed a structured and operational tool capable of capturing workforce-related early warning signals and assessing the risk of health system saturation and collapse within the SEA framework.

4. Results

The analysis of semi-structured interviews, guided by early warning-oriented questions, revealed a coherent and progressive pattern of workforce-related system degradation. Participants consistently described a transition from initial stress signals to advanced stages of saturation and, ultimately, conditions indicative of imminent system collapse. Rather than isolated factors, findings highlighted an interconnected set of workforce dynamics, with burnout, attrition, and workload escalation emerging as central drivers. Across all participants, early warning signals were identifiable prior to visible system breakdown. These signals included increasing workload pressure, growing staff shortages, rising psychological exhaustion, and early signs of workforce withdrawal. Importantly, these indicators appeared before large-scale service disruption, confirming their role as leading indicators of system saturation. Thematic analysis resulted in the identification of five core domains representing workforce-related early warning signals. These domains reflect both the progression of system stress and its manifestation across the SEA dimensions. Table 6 shows extracted themes and early warning signals.

Table 6. Extracted Themes and Early Warning Signals

Theme	Key Early Warning Signals	Frequency
Workload Escalation	Increased workload, overtime dependency, high patient-to-staff ratio	14
Workforce Depletion	Staff shortages, unfilled positions, reduced workforce availability	13
Burnout	Emotional exhaustion, psychological fatigue, reduced motivation	13
Attrition	Leaving jobs, migration, intention to quit	11
Adaptation Failure	Inability to respond, lack of flexibility, delayed reactions	12

The extracted themes were then mapped onto the SEA framework to examine their structural implications. The results demonstrate that each workforce-related factor contributes differently but simultaneously to system degradation. Table 7 shows Mapping of Themes to SEA Dimensions.

Table 7. Mapping of Themes to SEA Dimensions

Theme	SEA Dimension	System-Level Impact
Workforce Depletion	Stability	Reduced service continuity and capacity
Attrition	Stability	Loss of critical workforce and disruption
Workload Escalation	Efficiency	Overutilization and performance decline
Burnout	Adaptability	Reduced response capacity and resilience
Adaptation Failure	Adaptability	Inability to adjust to system stress

Findings indicate that adaptability degradation acts as a tipping point. While systems may temporarily maintain stability and efficiency under pressure, the loss of adaptability primarily driven by burnout and workforce exhaustion marks the transition toward saturation. The analysis of interview data and evidence synthesis led to the identification of a structured set of workforce-related indicators that function as early warning signals of health system stress, saturation, and potential collapse. These indicators were not treated as isolated metrics but were systematically organized within the SEA framework (Stability, Efficiency, Adaptability) to capture the multidimensional nature of system performance. The findings demonstrate that workforce-related risks manifest differently across the three SEA dimensions. Indicators related to workforce availability and continuity were associated with Stability, those reflecting workload pressure and resource utilization were linked to Efficiency, and indicators capturing system responsiveness and recovery capacity were mapped to Adaptability. Table 8 shows Classification of Workforce Indicators within the SEA Framework.

Table 8. Classification of Workforce Indicators within the SEA Framework

SEA Dimension	Key Indicators	System Function Captured
Stability	Turnover rate, vacancy rate, absenteeism rate, service continuity	Workforce availability and continuity of care
Efficiency	Patient-to-staff ratio, workload intensity, overtime rate, waiting time, error rate	System pressure and workforce utilization
Adaptability	Burnout prevalence, recruitment time, surge capacity, workforce flexibility	System responsiveness and recovery capacity

To enable operational assessment, each indicator was defined using a measurable formula and standardized for continuous monitoring.

Table 9. Key Workforce Indicators and Measurement Methods

Indicator	Formula	Data Source	Frequency
Turnover Rate	Employees leaving / Average staff ×100	HR records	Quarterly
Vacancy Rate	Vacant positions / Total positions ×100	HR records	Monthly
Absenteeism Rate	Absent days / Total working days ×100	HR records	Monthly
Patient-to-Staff Ratio	Number of patients / Staff	HIS	Monthly
Overtime Rate	Overtime hours / Total hours ×100	HR records	Monthly
Workload Intensity	Service volume / Staff hours	Administrative data	Monthly
Error Rate	Errors / Total cases ×100	Clinical reports	Monthly
Burnout Prevalence	Staff with high burnout / Total staff ×100	Survey	Quarterly
Recruitment Time	Hiring date – Vacancy date	HR records	Continuous
Workforce Flexibility	Reassignable staff / Total staff ×100	HR/Admin	Periodic
Surge Capacity	Expandable capacity / Normal capacity ×100	System reports	Periodic

To facilitate interpretation, each indicator was associated with threshold ranges representing different levels of system risk. These thresholds were derived from literature, empirical

observations, and expert-informed judgment, and are presented as proposed operational benchmarks. Table 10 shows Proposed Risk Thresholds for Workforce Indicators.

Table 10. Proposed Risk Thresholds for Workforce Indicators

domain	Indicator	Normal	Moderate Risk	High Risk	Critical Risk
Stability	Turnover Rate	<5%	5–10%	10–20%	>20%
	Vacancy Rate	<5%	5–10%	10–20%	>20%
	Absenteeism Rate	<3%	3–5%	5–8%	>8%
Efficiency	Overtime Rate	<5%	5–10%	10–20%	>20%
	Workload Intensity	≤100%	Over load up to 15%	Over load up to 30%	Over load more than 30%
	Patient-to-Staff Ratio	≤Standard	20% over capacity	20% to 50% over capacity	50% over capacity
Adoptability	Burnout Prevalence	<20%	20–35%	35–50%	>50%
	Recruitment Time	≤Standard	10 to 25 days for Operational positions	25 to 40 days for Operational positions	Over 40 days for Operational positions
	Workforce Flexibility	>30%	20–30%	10–20%	<10%
	Surge Capacity	>25%	15–25%	5–15%	<5%

These composite indexes provide a single, interpretable measure of system risk, the results demonstrate that workforce-related indicators can be systematically transformed into a multi-dimensional SEA-based risk assessment model, enabling both:

- Early detection of system stress (Early Warning Signals)
- Quantitative assessment of proximity to system collapse

Importantly, while the final indexes provide an overall system status, the disaggregated SEA scores reveal whether the primary driver of risk lies in loss of stability (workforce depletion), efficiency breakdown (overload), or adaptability failure (burnout and system rigidity).

5. Discussion

This study developed a structured, workforce-centered framework for assessing health system saturation and collapse risk by gathering early warning indicators within the SEA model. The findings provide strong evidence that workforce-related dynamics are not merely operational challenges but constitute core structural drivers of system instability. A central contribution of this study is the identification of burnout and attrition as leading indicators of system degradation, rather than lagging outcomes. The results suggest that workforce deterioration begins long before

observable system failure and follows a progressive pathway characterized by increasing workload pressure, psychological exhaustion, and eventual workforce depletion. This aligns with the concept of early warning systems, where subtle but persistent changes in system behavior signal impending disruption.

By embedding workforce indicators within the SEA framework, this study demonstrates that system collapse is a multi-dimensional phenomenon. The findings indicate that workforce-related stress simultaneously undermines stability, efficiency, and adaptability, although through different mechanisms. Workforce depletion directly affects system stability by reducing service continuity, excessive workload compromises efficiency through overutilization and declining performance, and burnout critically weakens adaptability by eroding the system's capacity to respond, reorganize, and recover. Among these dimensions, adaptability appears to play a particularly critical role. The results suggest that while systems may temporarily sustain high levels of pressure in terms of stability and efficiency, the loss of adaptive capacity often marks the transition from stress to saturation. This finding reinforces the importance of monitoring not only resource levels but also the system's ability to adjust to changing demands, which is frequently overlooked in traditional performance measurement models.

Another key contribution of this study is the operationalization of workforce-related risks into a quantitative SEA-based risk index, enabling continuous monitoring and cross-system comparison. By translating qualitative insights and empirical indicators into a standardized scoring framework, the study bridges the gap between conceptual understanding and practical application. This allows policymakers and health system managers to identify early warning signals and intervene before the system reaches critical thresholds. However, an important methodological consideration emerges from the current formulation of the model. In the proposed SEA Workforce framework, the three dimensions Stability, Efficiency, and Adaptability are assigned equal weights. While this assumption provides a clear and interpretable baseline, it may not fully reflect the relative importance of each dimension in real-world settings. The findings of this study, along with existing literature, suggest that certain dimensions particularly adaptability may have a disproportionately larger influence on system resilience and collapse dynamics.

Therefore, the equal-weight structure should be interpreted as a starting point rather than a definitive representation of system behavior. Future research should aim to refine the model by introducing dimension-specific weighting schemes, potentially derived from empirical data, expert elicitation, or advanced modeling approaches such as regression analysis, machine learning, or system dynamics simulations. Such refinements would enhance the sensitivity and predictive accuracy of the model. In addition, the proposed threshold values for indicators and the composite risk index should be considered context-sensitive. Health systems differ in structure, capacity, and baseline performance, and therefore fixed thresholds may not universally apply. Future studies should validate and calibrate these thresholds across different settings to improve generalizability.

Despite these limitations, the study offers a novel and practical contribution by providing a structured early warning framework grounded in workforce dynamics. Unlike traditional performance models that focus on outputs or efficiency alone, this approach captures the underlying human factors that drive system behavior. By integrating indicators, checklist-based assessment, and a composite scoring model within the SEA framework, the study presents a comprehensive tool for assessing system vulnerability.

Declaration of AI Assistance: *We hereby declare that artificial intelligence tools (ChatGPT by OpenAI) were used solely for language editing and refinement of this article. The content, ideas, and analysis were developed by the author, while AI assistance was limited to improving clarity, grammar, and style.*

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