Boundary Stability Index (BSI):

A Responsive Security Framework for Migration Governance in the European Union

Eiji Kodama
Independent Researcher / CoSpira Project
ORCID:0009-0005-2589-9475
https://cospira-arch.github.io/
cospira2025@gmail.com
Date: December 2025

Abstract

The European Union represents one of the most advanced experiments in supranational governance, characterized by the free movement of people, capital, and information across historically rigid borders. This openness has generated immense economic, cultural, and political value. At the same time, it has exposed structural vulnerabilities—most visibly in the governance of migration, where rapid demographic flows, narrative polarization, and institutional overload interact across multiple layers of society.

This paper proposes the **Boundary Stability Index (BSI)** as a novel analytical and operational framework for managing migration-related stress without resorting to border closure or coercive securitization. Grounded in the **Boundary Operating System (Boundary OS)** theory, BSI conceptualizes borders not as static barriers but as **dynamic, multi-layered membranes** whose stability depends on their capacity to sense, absorb, and repair stress across material, physiological, affective, narrative, and institutional layers.

By integrating real-time data, affective signal analysis, and institutional response metrics—while maintaining strict human primacy in decision-making—BSI enables early detection of "boundary tremors" and supports calibrated, non-dominant interventions. The framework is designed to enhance responsiveness rather than exclusion, preserving democratic legitimacy and social cohesion.

Using migration governance in the EU as a primary application domain, this paper demonstrates how BSI can be deployed from **micro-level human interactions**, through **meso-level institutional coordination**, to **macro-level policy resilience**, offering a scalable pathway toward sustainable, humane, and resilient migration governance.

---

1. Introduction

1.1 The European Union as a Boundary Innovation

The European Union is often described as a political and economic union, but at a deeper level, it is a **boundary innovation**. By transforming borders from hard lines into zones of regulated permeability, the EU has enabled unprecedented levels of mobility, integration, and shared sovereignty. Few political entities have attempted—and sustained—such an ambitious reconfiguration of borders.

Migration, however, has become the most visible stress test of this model. The issue is not migration per se, but the **misalignment between the speed and intensity of cross-border human movement and the adaptive capacity of existing governance systems**. When institutional responses lag behind material realities, pressure

accumulates—not only at physical borders, but within societies themselves.

Importantly, the European migration challenge should not be framed as a failure of openness. Rather, it reveals a **need for more sophisticated boundary management mechanisms**—ones capable of operating across emotional, narrative, and institutional dimensions, not solely legal or physical controls.

1.2 From Border Control to Boundary Stability

Traditional migration governance tends to oscillate between two extremes: unrestricted openness and rigid closure. Both approaches misunderstand the nature of modern borders. In complex, interdependent systems, borders function less as walls and more as **interfaces**—points of continuous exchange, negotiation, and adjustment.

This paper argues that what is currently missing is not stronger borders, but **stable boundaries**.

Boundary stability is defined here as the capacity of a socio-political system to:

- detect early signs of stress,
- prevent escalation into rupture,
- and repair relational, institutional, and narrative breakdowns when disruption occurs.

The **Boundary Operating System (Boundary OS)** provides a conceptual foundation for this approach. Building upon it, the **Boundary Stability Index (BSI)** operationalizes boundary health as a measurable, actionable construct.

1.3 Migration as a Multi-Layered Boundary Phenomenon

Migration pressures manifest simultaneously at multiple scales:

- **Micro level:** physiological stress, fear, empathy fatigue, and interpersonal encounters between migrants, officials, and residents.
- **Meso level:** overload of municipal services, fragmentation between agencies, and misaligned national policies.
- **Macro level:** polarized narratives, erosion of trust in institutions, and geopolitical instrumentalization of migration flows.

Current policy instruments tend to address these layers separately—if at all. As a result, interventions often resolve tension in one layer while amplifying instability in another.

This paper proposes BSI as a **unifying metric and governance tool** capable of integrating signals across layers, enabling proportionate and timely responses without undermining democratic values or human dignity.

Section 2. Problem Statement: Migration as a Boundary Failure

Contemporary migration challenges in Europe are often framed as issues of border control, labor supply, or humanitarian capacity. However, these framings obscure a deeper structural problem: migration crises represent **boundary failures across multiple layers of society**, not merely physical or legal breaches.

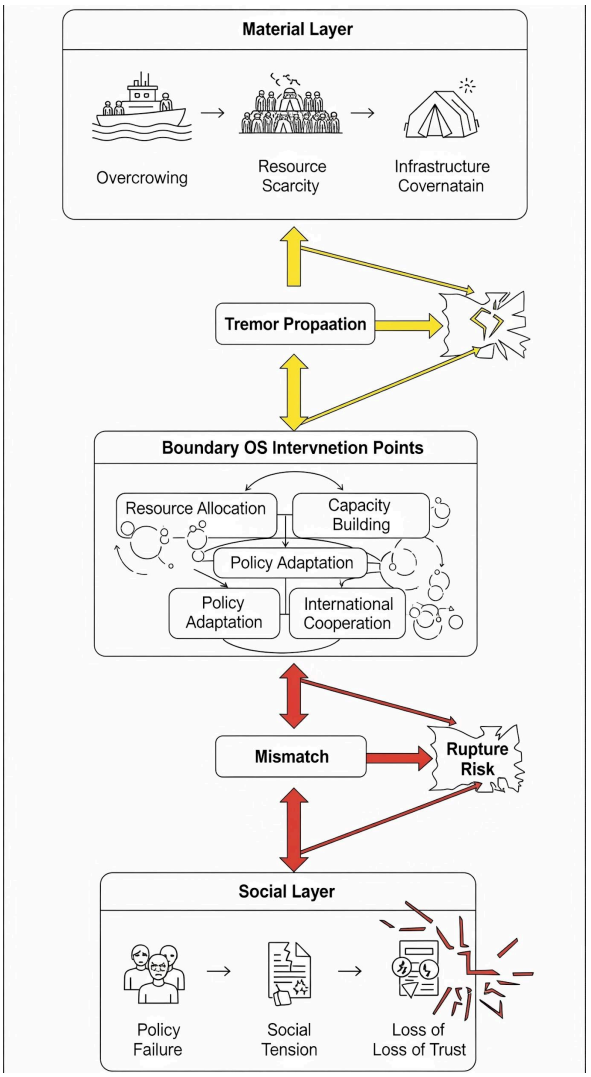
At the **micro level**, migrants experience physiological stress, trauma, and affective instability during displacement and settlement. Host communities simultaneously exhibit anxiety, threat perception, and loss of social trust. These reactions occur prior to any formal policy response and often escalate faster than institutional mechanisms can respond.

At the **meso level**, local governments, municipalities, and service providers face coordination breakdowns. Information flows between welfare systems, policing, healthcare, and housing authorities become fragmented,

producing policy lag and contradictory signals. This mismatch amplifies public frustration and fuels narrative polarization.

At the **macro level**, migration becomes politicized as a symbolic struggle over sovereignty, identity, and values. Competing narratives—humanitarian obligation versus national security—harden into rigid positions, reducing the system's capacity for adaptive response. Once this stage is reached, policy debates tend toward rupture rather than repair.

Crucially, these failures are not independent. They propagate **diagonally across layers**, creating cascading instability. Migration, therefore, should be understood not as a single policy problem, but as a **systemic boundary stress phenomenon**.



Section 3. Conceptual Framework: Boundary OS and the Five-Layer Model

To address migration as a boundary stress phenomenon, this paper applies the **Boundary Operating System (Boundary OS)** framework. Boundary OS conceptualizes society as a dynamic system composed of five interdependent layers:

1. **Material Layer** – physical infrastructure, borders, housing, transportation
2. **Physio-Sensory Layer** – biological responses, stress indicators, sensor data
3. **Affective Layer** – emotions such as fear, empathy, anger, and relief
4. **Narrative Layer** – public discourse, media framing, collective meaning-making
5. **Social/Institutional Layer** – laws, norms, governance structures

Unlike traditional security models that prioritize control and exclusion, Boundary OS aims to maintain **responsive permeability**, described as a *"breathing membrane."* The objective is not to prevent movement or disagreement, but to **detect tremors early**, adjust boundary rigidity through tuning, and enable repair before rupture occurs.

Within this framework, **AI is positioned as a Boundary Medium**, not an autonomous decision-maker. Its role is restricted to sensing, visualization, and pattern detection—particularly in the lower layers—while final judgment and normative decisions remain under human authority.

This architecture is particularly suited to migration governance, where premature hardening of boundaries often exacerbates instability rather than resolving it.

Section 4. Boundary Stability Index (BSI): A New Measurement Paradigm

A core contribution of this paper is the introduction of the **Boundary Stability Index (BSI)**—a composite indicator designed to quantify the resilience of societal boundaries under stress.

4.1 Definition of BSI

The Boundary Stability Index measures the system's capacity to:

- Absorb boundary-related shocks
- Prevent layer-to-layer escalation
- Restore functional connectivity after disruption

Rather than measuring threat levels, BSI evaluates **responsiveness without collapse**.

4.2 BSI Components

BSI aggregates metrics across the five layers:

- **Material Stability Score**
  Infrastructure load, housing capacity variance, transit congestion
- **Physio-Sensory Stability Score**
  Stress indicators, healthcare access latency, biometric anomaly rates
- **Affective Stability Score**
  Anxiety diffusion, sentiment volatility, emotional polarization indices
- **Narrative Stability Score**
  Semantic divergence, misinformation velocity, framing inconsistency
- **Institutional Stability Score**
  Policy coherence, response time, inter-agency synchronization

Each component is normalized and weighted based on contextual relevance. Importantly, **no single layer dominates the index**, preventing over-optimization in security or narrative control.

4.3 Why BSI Matters for Migration

Migration debates often rely on static indicators (arrival numbers, asylum approvals). BSI instead captures **dynamic stress trajectories**, enabling policymakers to intervene during the tremor phase—before political or social rupture occurs.

Section 5. Application to EU Migration Governance: From Control to Responsiveness

The European Union provides a uniquely fertile environment for applying Boundary OS and BSI. Its multi-level governance structure, legal integration, and commitment to ethical AI establish a foundation for **non-dominant, coordinated boundary management**.

5.1 Micro-Level Intervention: Human-Centered Sensing

At the local level, BSI-informed dashboards can visualize stress indicators in reception centers, schools, and healthcare systems. AI-assisted sensing detects physiological and affective overload without profiling individuals or assigning intent.

This enables **early tuning measures**, such as resource reallocation or communication adjustments, reducing escalation risk.

5.2 Meso-Level Coordination: Institutional Tuning

At the municipal and national levels, BSI reveals synchronization gaps between agencies. Rather than imposing uniform policies, Boundary OS supports **context-sensitive tuning**, allowing

regions to adjust boundary permeability according to real-time stability signals.

5.3 Macro-Level Governance: EU as a Stability Amplifier

At the macro level, BSI offers the EU a shared, non-punitive language for migration governance. Instead of framing compliance as obligation, BSI frames cooperation as **collective boundary stability enhancement**.

This reframing aligns with the EU's normative identity while increasing operational effectiveness—demonstrating that ethical governance and resilience are not competing objectives.

Section 6. Boundary OS Application to Migration Governance

6.1 Reframing Migration as a Boundary Phenomenon

Conventional migration policy has primarily treated migration as a problem of **control**—border enforcement, quota management, or legal classification. This approach implicitly assumes that borders function as static walls. However, migration crises reveal a different reality: borders behave as **dynamic membranes**, continuously stressed by economic disparity, conflict, climate change, and narrative polarization.

Boundary OS reframes migration not as a threat to be excluded, but as a **boundary stress process** unfolding simultaneously across multiple layers:

- **Material Layer:** Physical movement of people, housing, transportation, border facilities
- **Physio-Sensory Layer:** Fatigue, trauma, stress responses of migrants and frontline officials
- **Affective Layer:** Fear, resentment, empathy, and anxiety among host populations and migrants
- **Narrative Layer:** Competing stories of "invasion," "humanitarian duty," or "economic burden"
- **Social/Institutional Layer:** Laws, asylum systems, labor markets, and international agreements

Migration crises escalate when tremors detected in lower layers are misinterpreted or ignored until they rupture at the narrative or institutional level. Boundary OS is designed precisely to intervene **before rupture**, maintaining system responsiveness without collapse.

6.2 Micro-Level: Individual and Community Interfaces

At the micro level, Boundary OS operates where migrants, local communities, and frontline institutions intersect.

Key interventions include:

- **Physio-Sensory Monitoring (Non-Intrusive):** Aggregated indicators of stress and overload in reception centers, healthcare facilities, and municipal services.
- **Affective Layer Mapping:** Detecting anxiety and hostility spikes in local communities through anonymized sentiment and behavioral signals.
- **Narrative Drift Detection:** Early identification of semantic shifts (e.g., humanitarian discourse turning into securitized rhetoric).

AI mediation at this level remains **strictly non-dominant**:

- AI may *detect and visualize* boundary stress.
- AI may *not* assess intent, moral value, or political legitimacy.

The objective is not behavioral control, but **early tuning**—adjusting service capacity, communication tone, and policy timing before escalation.

6.3 Meso-Level: Institutional Coordination and Policy Tuning

At the meso level, Boundary OS coordinates between municipalities, national agencies, NGOs, and supranational bodies such as the EU.

This level addresses a core failure of migration governance: **institutional desynchronization**.

Boundary OS enables:

- Cross-agency boundary dashboards showing stress propagation across layers.
- Scenario-based tuning recommendations (e.g., adjusting asylum processing speed to reduce affective overload).
- Narrative coherence checks between national and EU-level communications.

Importantly, this architecture aligns with the EU's foundational principles:

- Shared responsibility
- Legal pluralism
- Human dignity as a systemic constraint

Rather than undermining sovereignty, Boundary OS **preserves sovereign decision-making** by improving situational awareness and reducing reactive policy swings.

6.4 Macro-Level: EU as a Boundary Stabilization Actor

At the macro level, the European Union emerges not as a monolithic authority, but as a **boundary stabilizer**.

The EU's value lies in:

- Providing institutional buffers between national affective surges and long-term policy commitments.
- Maintaining narrative continuity across electoral cycles.
- Supporting shared sensing and visualization infrastructures without enforcing uniform outcomes.

Boundary OS complements existing EU frameworks (e.g., CEAS, Frontex reform, Digital Europe) by adding a missing layer: **boundary-state intelligence without command authority**.

This approach positions the EU as a **breathing membrane**—absorbing pressure, redistributing load, and preventing rupture between member states.

Section 7. Boundary Stability Index (BSI) as an Evaluation Framework

7.1 Conceptual Definition of BSI

The **Boundary Stability Index (BSI)** is introduced as a composite indicator designed to measure the **health of boundary systems** under stress.

BSI does not evaluate moral correctness or policy success. Instead, it measures:

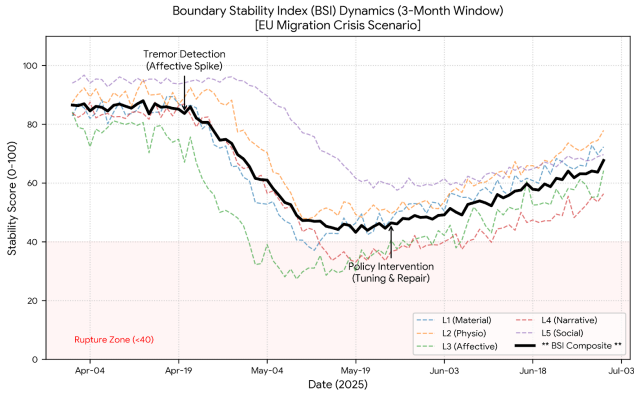
> *How well a system maintains responsiveness, coherence, and repair capacity under sustained boundary pressure.*

BSI integrates signals across all five layers, weighted by rupture risk rather than political priority.

7.2 BSI Components (Migration Context)

Layer	BSI Indicators (Examples)
Material	Shelter capacity utilization, transit congestion
Physio-Sensory	Healthcare overload index, frontline burnout
Affective	Anxiety volatility, hostility amplification rate
Narrative	Semantic polarization score, misinformation velocity
Social/Institutional	Processing backlog, inter-agency delay

A stable system is not one with zero tension, but one where **tension remains recoverable**.



7.3 BSI as a Policy Feedback Mechanism

BSI functions as:

- A **diagnostic instrument**, not a target
- A **feedback loop**, not a ranking system
- A **shared reference**, not a control mechanism

Policy actions are evaluated based on whether they:

- Reduce rupture probability
- Improve repair speed
- Maintain narrative coherence

This avoids the common trap of KPI-driven policy distortions.

7.4 Ethical and Political Safeguards

To prevent technocratic overreach:

- BSI outputs are advisory only.
- All interpretations require human judgment.
- BSI cannot trigger automated enforcement.

This design ensures compliance with EU ethical AI standards and preserves democratic legitimacy.

7.5 Implications for EU Migration Governance

Integrating BSI into EU migration governance enables:

- Earlier intervention with lower political cost
- Reduced oscillation between securitization and humanitarian overload
- Evidence-based solidarity mechanisms grounded in shared boundary conditions

Rather than asking *"Who should take responsibility?"*, BSI reframes the question to:

> *"Where is the boundary under stress, and how do we repair it together?"*

Section 8: Policy Implications & Global Replicability

8.1 Policy Implications for the European Union

The Boundary Operating System (Boundary OS) offers a reframing of migration governance beyond conventional securitization or humanitarian dichotomies. Rather than treating migration as a binary issue of inclusion or exclusion, Boundary OS conceptualizes migration as a **dynamic boundary phenomenon**, requiring continuous sensing, tuning, and repair across multiple layers.

For the European Union, this approach aligns with its foundational principles of proportionality, subsidiarity, and human dignity. Boundary OS does not replace existing legal frameworks such as the Common European Asylum System (CEAS); instead, it functions as an **operational meta-layer**, enhancing responsiveness without necessitating legal overhaul.

Key policy implications include:

- **Early Intervention without Coercion:** By detecting tremors at the physio-sensory and affective layers (e.g., stress indicators, public anxiety signals), authorities can intervene before escalation into social or institutional rupture.

- **Narrative Load Balancing:** Boundary OS enables real-time monitoring of narrative saturation, allowing policymakers to reduce over-amplification of threat narratives while preserving democratic discourse.

- **Human Primacy Preservation:** AI remains strictly non-dominant, ensuring that migration policy remains a human judgment informed by data, not replaced by it.

This model allows the EU to strengthen resilience without compromising normative commitments.

8.2 Implications for Migration Governance

Migration governance has historically suffered from **layer collapse**, where material pressures (border crossings, housing capacity) are directly translated into narrative or political crises. Boundary OS explicitly prevents such collapse by enforcing **layer-specific safeguards**.

In practice, this means:

- Material congestion does not automatically justify narrative securitization.
- Affective fear spikes do not trigger institutional overreaction.
- Policy responses are staged, reversible, and auditable.

This staged approach is particularly suited to pluralistic societies where migration debates are politically sensitive and ethically charged.

8.3 Global Replicability Framework

Boundary OS is designed for **contextual replication**, not uniform deployment. Its modularity enables adaptation across different governance cultures:

Region	Replication Mode
EU	Rights-preserving resilience enhancement
ASEAN	Crisis coordination & narrative harmonization
City-states	High-resolution sensing & rapid tuning
Fragile states	Early warning & rupture prevention

Replication requires only three prerequisites:

1. Minimal data-sharing agreements
2. Human-in-the-loop governance
3. Commitment to non-dominant AI mediation

8.4 Boundary OS as a Global Public Good

When deployed across migration corridors, Boundary OS creates interoperability between national systems, enabling what this paper terms **"breathing borders"**—boundaries that adapt under pressure without collapse.

This positions Boundary OS as a candidate for:

- UN AI for Good initiatives
- EU EquiTech 2.0 frameworks
- Cross-regional migration resilience networks

Conclusion

This paper introduced the Boundary Operating System as a new paradigm for responsive security in the age of AI, with a focused application to migration governance. By decomposing migration-related stress into five interacting layers and applying non-dominant AI mediation, Boundary OS demonstrates that security, ethics, and adaptability are not mutually exclusive.

The proposed Boundary Stability Index (BSI) operationalizes this paradigm by transforming abstract resilience into a measurable, auditable construct. Together, Boundary OS and BSI enable governance systems to respond without rupture, decide without domination, and adapt without losing legitimacy.

Rather than offering a universal solution, Boundary OS provides a **grammar of response**—one that can be locally articulated, globally shared, and ethically bounded.

References

(Boundary Stability Index: Measuring Responsive Security in Migration Governance)

A. Migration, EU Policy, and Forced Displacement

European Commission. (2020). *New Pact on Migration and Asylum*. COM(2020) 609 final. Brussels: European Commission.

Eurostat. (2024). *Asylum statistics*. Luxembourg: Publications Office of the European Union.

UNHCR. (2023). *Global Trends: Forced Displacement in 2023*. Geneva: United Nations High Commissioner for Refugees.

Castles, S., de Haas, H., & Miller, M. J. (2020). *The Age of Migration: International Population Movements in the Modern World* (6th ed.). New York: Guilford Press.

Triandafyllidou, A. (2018). A “refugee crisis” unfolding: “Real” events and their interpretation in media and political debates. *Journal of Immigrant & Refugee Studies*, 16(1–2), 198–216. https://doi.org/10.1080/15562948.2017.1309089

Crawley, H., & Skleparis, D. (2018). Refugees, migrants, neither, both: Categorical fetishism and the politics of bounding in Europe’s “migration crisis”. *Journal of Ethnic and Migration Studies*, 44(1), 48–64. https://doi.org/10.1080/1369183X.2017.1348224

Huysmans, J. (2006). *The Politics of Insecurity: Fear, Migration and Asylum in the EU*. London: Routledge.

B. Security, Securitization, and Responsive Governance

Buzan, B., Wæver, O., & de Wilde, J. (1998). *Security: A New Framework for Analysis*. Boulder, CO: Lynne Rienner.

Balzacq, T. (2011). *Securitization Theory: How Security Problems Emerge and Dissolve*. London: Routledge.

Bigo, D. (2002). Security and immigration: Toward a critique of the governmentality of unease. *Alternatives*, 27(S1), 63–92. https://doi.org/10.1177/03043754020270S105

Aradau, C., & Van Munster, R. (2011). *Politics of Catastrophe: Genealogies of the Unknown*. London: Routledge.

C. Boundary Theory, Social Systems, and Multi-Layer Analysis

Lamont, M., & Molnár, V. (2002). The study of boundaries in the social sciences. *Annual Review of Sociology*, 28, 167–195.

https://doi.org/10.1146/annurev.soc.28.110601.141107

Star, S. L., & Griesemer, J. R. (1989). Institutional ecology, “translations,” and boundary objects. *Social Studies of Science*, 19(3), 387–420. https://doi.org/10.1177/030631289019003001

Latour, B. (2005). *Reassembling the Social: An Introduction to Actor-Network-Theory*. Oxford: Oxford University Press.

Luhmann, N. (1995). *Social Systems*. Stanford, CA: Stanford University Press.

D. AI Governance, Ethics, and Algorithmic Mediation

European Commission. (2021). *Proposal for a Regulation Laying Down Harmonised Rules on Artificial Intelligence (Artificial Intelligence Act)*. COM(2021) 206 final. Brussels: European Commission.

Dignum, V. (2019). *Responsible Artificial Intelligence: How to Develop and Use AI in a Responsible Way*. Cham: Springer. https://doi.org/10.1007/978-3-030-30371-6

Floridi, L., Cowls, J., Beltrametti, M., Chatila, R., Chazerand, P., Dignum, V., … Vayena, E. (2018). AI4People—An ethical framework for a good AI society. *Minds and Machines*, 28(4), 689–707. https://doi.org/10.1007/s11023-018-9482-5

Veale, M., & Brass, I. (2019). Administration by algorithm? Public management meets public sector machine learning. In K. Yeung & M. Lodge (Eds.), *Algorithmic Regulation* (pp. 121–149). Oxford: Oxford University Press.

E. Measurement Theory, Index Construction, and Policy Evaluation

DeVellis, R. F. (2017). *Scale Development: Theory and Applications* (4th ed.). Thousand Oaks, CA: Sage.

Nunnally, J. C., & Bernstein, I. H. (1994). *Psychometric Theory* (3rd ed.). New York: McGraw-Hill.

Cronbach, L. J., & Meehl, P. E. (1955). Construct validity in psychological tests. *Psychological Bulletin*, 52(4), 281–302. https://doi.org/10.1037/h0040957

Campbell, D. T., & Fiske, D. W. (1959). Convergent and discriminant validation by the multitrait–multimethod matrix. *Psychological Bulletin*, 56(2), 81–105. https://doi.org/10.1037/h0046016

Moynihan, D. P. (2008). *The Dynamics of Performance Management*. Washington, DC: Georgetown University Press.

F. Computational Social Science & Data Methodology

Salganik, M. J. (2018). *Bit by Bit: Social Research in the Digital Age*. Princeton, NJ: Princeton University Press.

Grimmer, J., Roberts, M. E., & Stewart, B. M. (2022). *Text as Data: A New Framework for Machine Learning and the Social Sciences*. Princeton, NJ: Princeton University Press.

Lazer, D., Pentland, A., Adamic, L., et al. (2009). Computational social science. *Science*, 323(5915), 721–723. https://doi.org/10.1126/science.1167742

G. Boundary Stability Index (BSI): Conceptual Lineage

Prigogine, I., & Stengers, I. (1984). *Order Out of Chaos: Man's New Dialogue with Nature*. New York: Bantam Books.

Damasio, A. R. (1994). *Descartes' Error: Emotion, Reason, and the Human Brain*. New York: Putnam.

Reference Count (BSI Paper)

- Migration & EU policy: 7
- Security & IR: 4
- Boundary & systems theory: 4

- AI governance: 4
- Measurement & evaluation: 5
- Computational methods: 3
- Foundational theory: 2

Total: 29 references

Glossary of Terms: BSI

Boundary Stability Index (BSI)

A composite analytical index designed to measure the stability and resilience of socio-political boundaries by integrating indicators across five interdependent layers: material, physio-sensory, affective, narrative, and social/institutional.
BSI evaluates *boundary conditions* rather than outcomes, emphasizing responsiveness over control.

Boundary

A dynamic, multi-layered interface that regulates interaction, flow, and separation between actors, systems, or populations.
In the Boundary OS framework, boundaries are not fixed lines but adaptive membranes.

Boundary OS (Operating System)

A conceptual and operational framework that models, monitors, and tunes boundary states across multiple layers using non-dominant AI mediation.
BSI functions as a quantitative module within Boundary OS.

Five-Layer Model

An analytical decomposition of boundary phenomena into five interacting layers:

- **Material Layer (L1):** Physical infrastructure, bodies, spatial configurations.
- **Physio-Sensory Layer (L2):** Biological responses, stress signals, sensory data.
- **Affective Layer (L3):** Emotions, collective mood, anxiety, trust.
- **Narrative Layer (L4):** Meaning-making, discourse, media framing.
- **Social/Institutional Layer (L5):** Laws, norms, governance structures.

Layer Score (Li)

A normalized quantitative value (0–1) representing the stability of a specific layer within the Five-Layer Model.
Each Li is calculated using domain-specific indicators and validation methods.

Weight (wi)

A configurable coefficient representing the relative importance of each layer in the overall BSI calculation.
Weights may vary by policy domain, region, or scenario but must sum to 1.

Composite Index

A single numerical score derived from the weighted aggregation of multiple component measures.
BSI is a composite index designed to preserve interpretability at the layer level.

Tremor

An early-stage signal of boundary stress or instability, detectable before overt crisis or rupture occurs.
Tremors may originate in any layer and propagate across others.

Boundary Rupture

A condition in which a boundary loses its regulatory function, leading to uncontrolled escalation, breakdown of trust, or institutional failure.

Responsive Security

A security paradigm focused on adaptive response, early detection, and boundary tuning rather than exclusion, deterrence, or static control.

Breathing Boundary

A metaphor describing a boundary that dynamically adjusts its permeability—neither sealed nor collapsed—according to contextual conditions.

Non-Dominant AI Mediation

A governance principle in which AI systems assist by sensing, classifying, and visualizing boundary conditions but do not autonomously decide, judge, or enforce actions.

Boundary State Machine

A formal representation of boundary conditions as discrete but transitionable states (e.g., stable, stressed, ruptured), enabling scenario simulation and policy testing.

Ethical Safeguard

Procedural and institutional constraints ensuring that BSI measurement and AI mediation remain transparent, accountable, and subject to human override.

Synthetic Dataset

An artificially generated dataset designed to simulate plausible boundary conditions for testing, validation, and demonstration purposes when real data is unavailable or sensitive.

Policy Intervention Simulation

A structured “if–then” modeling process that estimates how changes in policy inputs affect layer scores and overall BSI outcomes.

Cross-Layer Propagation

The process by which changes or disturbances in one layer influence other layers, often non-linearly (e.g., narrative escalation triggering affective stress).

Validation (Construct Validity)

The degree to which BSI accurately measures the theoretical concept of boundary stability rather than proxy variables or outcomes alone.

Interpretability

The ability of policymakers and stakeholders to understand how BSI scores are generated, decomposed, and affected by interventions.

Boundary Stability Threshold

A defined BSI value or range used to classify boundary states (e.g., stable, fragile, critical), subject to contextual calibration.

Governance Readiness

The institutional capacity to respond to detected tremors and adjust boundary conditions using legal, diplomatic, or administrative tools.

Scenario-Based Evaluation

An assessment method that tests BSI behavior under simulated stress conditions rather than relying solely on historical data.

Notes for Publication Use

- All terms are **operationally defined** to support quantitative modeling.
- Definitions avoid normative claims and preserve compatibility with EU, UN, and OECD policy language.
- The glossary is designed to scale across domains (migration, AI governance, diplomacy).

Data Appendix: Boundary Stability Index (BSI) Dataset Proposal

A. Purpose

The BSI Dataset is proposed as an **open, modular dataset** enabling comparative analysis of boundary stability across migration contexts. Its goal is to support evidence-based policy tuning while preserving human decision authority.

B. Dataset Structure (Layered)

Layer	Data Category	Examples
Material	Infrastructure load	Border throughput, housing capacity
Physio-Sensory	Biological stress proxies	Health service spikes, biometric aggregates
Affective	Emotional signals	Sentiment indices, anxiety indicators
Narrative	Semantic patterns	Media framing drift, misinformation velocity
Social/Institutional	Governance response	Policy latency, inter-agency coherence

---

C. Temporal Resolution

- **Real-time:** Physio-sensory, affective signals
- **Weekly:** Narrative drift analysis
- **Quarterly:** Institutional response metrics

D. Governance & Ethics

- No individual-level identification
- Mandatory anonymization
- AI outputs limited to visualization and alerts
- All thresholds adjustable by human operators

E. Intended Outputs

- Boundary Stability Index (BSI) score (0–100)
- Layer-specific stress heatmaps
- Trend-based rupture risk forecasts

Proposed Figures & Tables (for BSI Dataset Section)

Figure D-1

BSI Five-Layer Data Architecture

Diagram showing data flows from sensors/media/governance logs into layer-specific indices, converging into BSI.

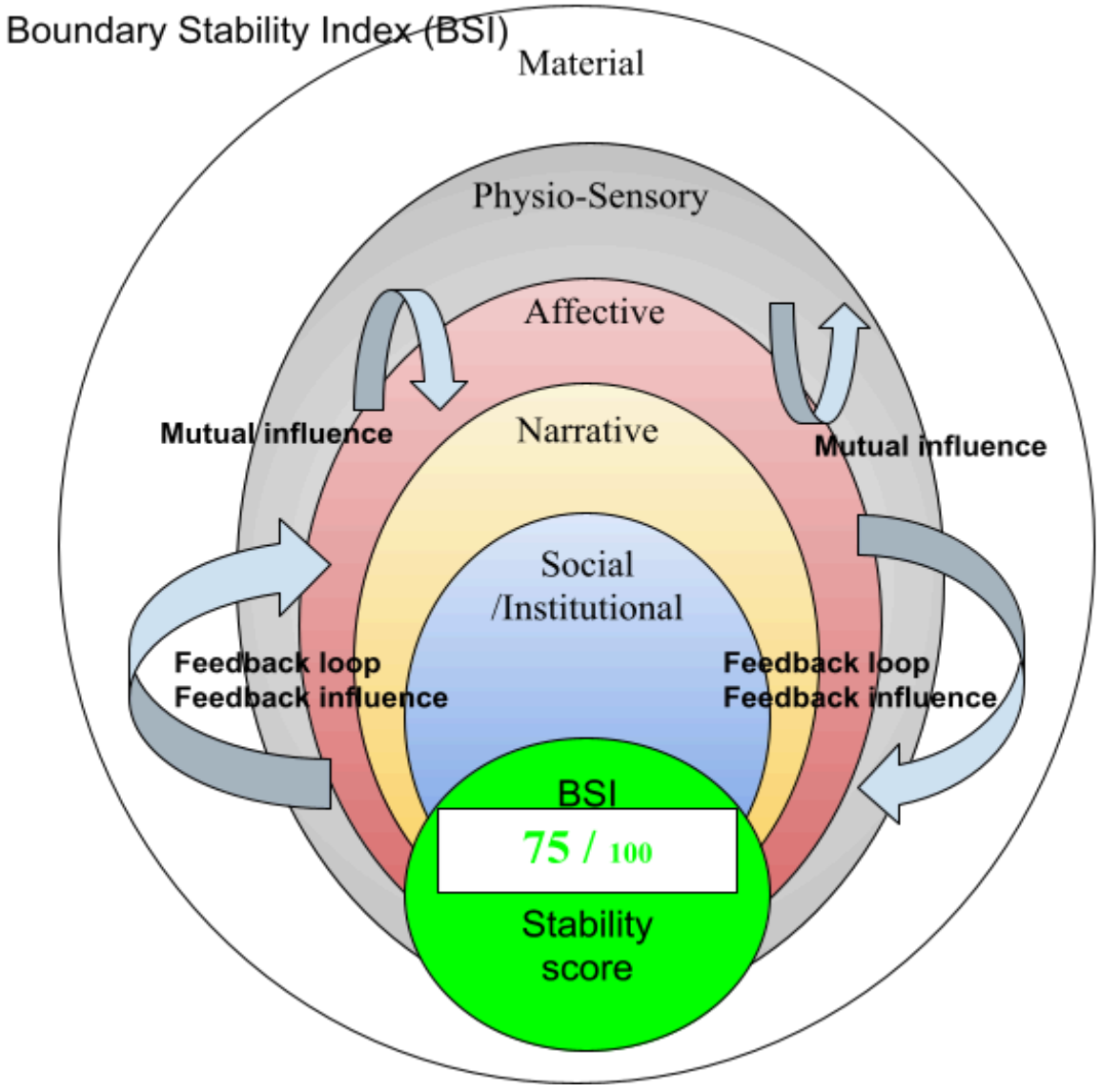


Table D-1

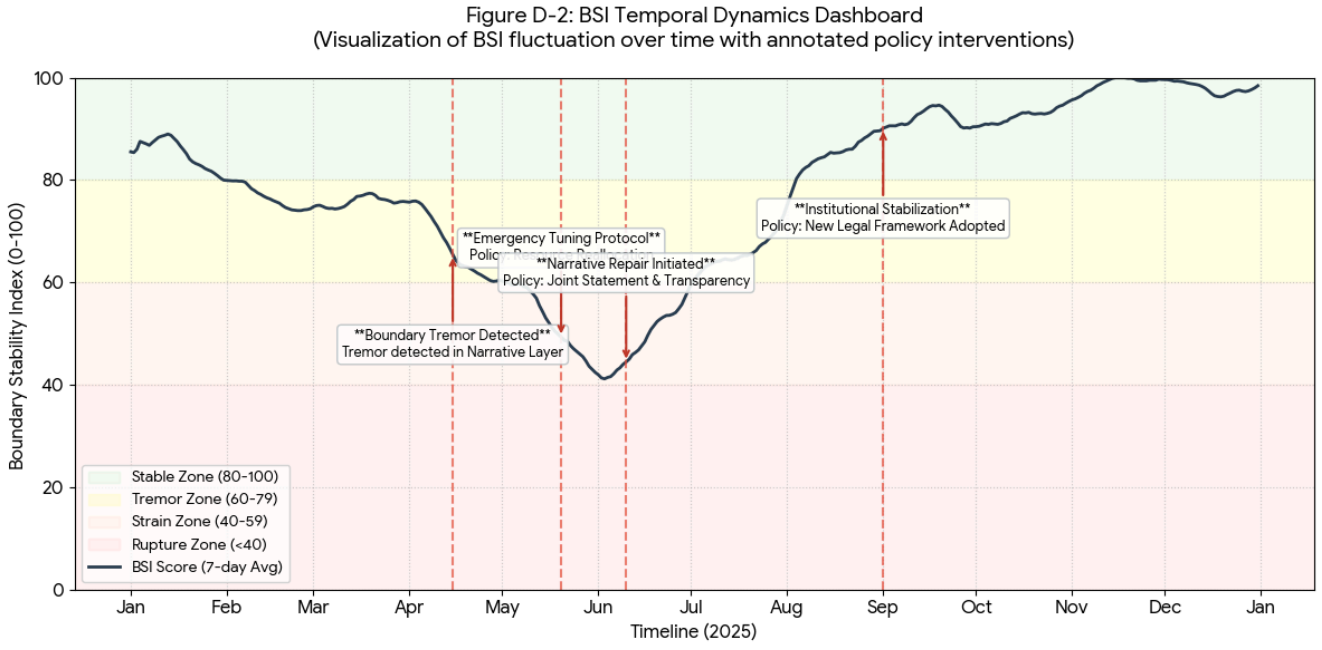
BSI Indicators & Data Sources

Indicator	Layer	Source
Border Load Ratio	Material	National statistics
Stress Spike Index	Physio	Health aggregates
Affective Volatility	Affective	Survey + NLP
Narrative Drift Score	Narrative	Media NLP
Institutional Lag	Social	Policy logs

Figure D-2

BSI Temporal Dynamics Dashboard

Visualization of BSI fluctuation over time with annotated policy interventions.



What Fundamentally Differentiates BSI from Conventional Immigration Policy Evaluation

Core Argument

The Boundary Stability Index (BSI) fundamentally differs from conventional immigration policy evaluation by measuring the state of boundaries, not policy outcomes alone.

---

1. Limitations of Conventional Immigration Policy Metrics

Traditional immigration policy evaluation focuses on outcome-based indicators:

- **Number of migrants and asylum seekers**
- **Irregular migration statistics**
- **Employment and welfare dependency rates**
- **Crime statistics**
- **Fiscal burden**
- **Public opinion polls**

Structural Limitations

1. **Post-hoc evaluation**
2. **Single-layer analysis**
3. **Inability to capture affective escalation**
4. **Binary policy framing (open vs. closed)**

As a result, conventional metrics explain *what happened*, but not *why societal cohesion failed*.

---

2. The Core Innovation of BSI

2.1 Boundaries as Breathing Membranes

BSI conceptualizes borders and social boundaries as dynamic membranes, not static lines.

- **Over-permeability → social backlash**
- **Over-rigidity → humanitarian and economic failure**
- **The key variable is tuning, not closure**

2.2 Five-Layer Integrated Assessment

BSI evaluates migration stress across five interacting layers:

Layer	Conventional Focus	BSI Focus
Material (L1)	**Numbers**	**Spatial pressure**
Physio-Sensory (L2)	**Ignored**	**Stress & fatigue**
Affective (L3)	**Polls**	**Emotional amplification**
Narrative (L4)	**Messaging**	**Competing meaning systems**
Social/Institutional (L5)	**Legal compliance**	**Institutional trust elasticity**

This allows policymakers to identify which layer is failing first.

2.3 Early Tremor Detection

BSI captures:

- **Boundary tremors**
- **Pre-rupture instability**
- **Repairability margins**

This shifts policy from reactive crisis management to anticipatory governance.

2.4 AI as a Boundary Instrument, Not a Decision-Maker

Unlike conventional AI-driven policy tools, BSI enforces strict non-dominant AI mediation:

- **AI detects, maps, and visualizes**
- **AI does not judge, decide, or enforce**
- **Human agency remains primary**

---

3. The Decisive Shift in Policy Evaluation Logic

Conventional question:

> **“Are there too many migrants?”**

BSI question:

> **“Is the boundary still responsive and breathable?”**

---

4. Relevance to the EU Migration Crises (2015 / 2023)

In both crises:

- **Legal frameworks existed**
- **Economic absorption capacity remained**
- **But affective (L3) and narrative (L4) layers collapsed first**

BSI would have enabled:

- **Early detection of narrative rupture**
- **Affective overheating alerts**
- **Layer-specific tuning interventions**

---

5. One-Sentence Summary

BSI does not measure migration volume.
It measures a society’s capacity to respond without rupture.

Boundary Stability Index (BSI)

Synthetic Score Calculation Example

EU Migration Crisis: 2015 vs 2023

1. Basic Assumptions of BSI (Simplified Version)

1.1 Layer Structure (L1–L5)

Layer	Name	Main Observation Targets
L1	Material Layer	Physical accommodation, movement, infrastructure
L2	Physio-Sensory Layer	Physiological load, immediate reactions
L3	Affective Layer	Anxiety, anger, fear
L4	Narrative Layer	Stories, meaning-making, discourse
L5	Social/Institutional Layer	Institutions, laws, coordination structures

1.2 Score Design

- **Each layer: 0–100**
- **Higher score indicates "boundary stability (Breathing Membrane state)"**
- **BSI = Weighted average**

$$BSI = \sum_{i=1}^{5} w_i \cdot L_i$$

Weights (v0.1 Provisional Setting)

Layer	Weight
L1 Material	0.15
L2 Physio	0.20
L3 Affective	0.25
L4 Narrative	0.20
L5 Social	0.20

(Note: Slightly emphasizing affective and narrative layers)

2. EU Migration Crisis: Provisional Scores

2.1 EU 2015 Migration Crisis (Provisional)

Layer	Indicator Example	Score
L1 Material	Overcrowding in accommodation facilities, physical border blockades	45
L2 Physio	Overload on administration, police, residents	40
L3 Affective	Fear, anger, divisive emotions	30
L4 Narrative	Dominance of "invasion" and "crisis" frames	25
L5 Social	Institutional divisions within EU, lack of consensus	35

▸ **BSI 2015 Calculation**

$$\begin{aligned} \mathrm{BSI}_{2015} &= (45 \times 0.15) + (40 \times 0.20) + (30 \times 0.25) \\ &\quad + (25 \times 0.20) + (35 \times 0.20) \\ &= 6.75 + 8 + 7.5 + 5 + 7 \\ &= \mathbf{34.25} \end{aligned}$$

👉 **BSI ≈ 34 (Severe Boundary Rupture Zone)**

2.2 EU 2023 Migration Pressure (Provisional)

Layer	Indicator Example	Score
L1 Material	Improved accommodation capacity, distributed placement	60
L2 Physio	High administrative load but manageable	55
L3 Affective	Continuing anxiety but trending toward control	50
L4 Narrative	Increase in discourse on "manageability" and "solidarity"	55
L5 Social	Progress in EU Pact negotiations	60

▸ **BSI 2023 Calculation**

$$\begin{aligned} \mathrm{BSI}_{2023} &= (60 \times 0.15) + (55 \times 0.20) + (50 \times 0.25) \\ &\quad + (55 \times 0.20) + (60 \times 0.20) \\ &= 9 + 11 + 12.5 + 11 + 12 \\ &= \mathbf{55.5} \end{aligned}$$

👉 **BSI ≈ 56 (Fragile but Recovering Zone)**

3. Comparison Summary (Table for Paper)

Year	BSI	Boundary State
EU 2015	34	Rupture Dominant
EU 2023	56	Partial Recovery

Appendix F.x

BSI Policy Simulation Interface

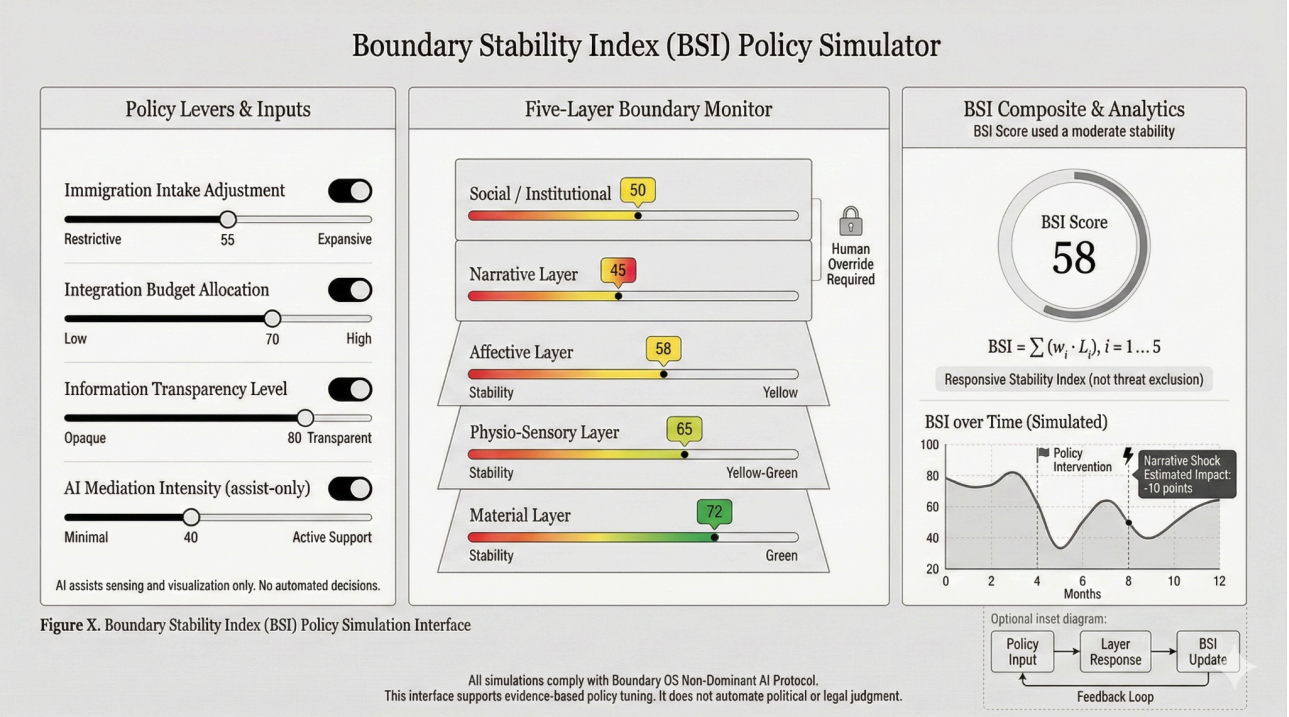


Figure X. Boundary Stability Index (BSI) Policy Simulation Interface

(Functional Specification for Policy and Research Use)
This appendix specifies the functional design of the Boundary Stability Index (BSI) Policy Simulation Interface, a decision-support tool intended for policymakers, researchers, and multilateral coordination bodies.

The interface operationalizes the Boundary OS framework by enabling controlled simulation of policy interventions across multiple boundary layers, without delegating judgment or authority to AI systems.

F.x.1 Purpose and Scope

The BSI Policy Simulation Interface is designed to:

- **Translate complex, multi-layer boundary conditions into an interpretable policy workspace**
- **Support *if–then* policy experimentation without normative automation**
- **Visualize stability dynamics across material, physiological, affective, narrative, and social/institutional layers**

The interface is explicitly non-prescriptive: it assists human decision-makers by exposing structural relationships, not by recommending actions.

F.x.2 Interface Architecture Overview

The interface consists of three functional domains:

1. **Policy Input Layer**
2. **BSI Computation & Layer Interaction Engine**
3. **Visualization & Comparative Output Layer**

(See *Figure F.x* for a conceptual layout.)

F.x.3 Policy Input Layer

This section allows users to define hypothetical or observed policy conditions.

Inputs include:

- **Policy Levers**
    - **Migration intake thresholds**
    - **Processing speed of asylum systems**
    - **Public communication intensity**
    - **Resource allocation ratios**
- **Temporal Parameters**
    - **Short-term (weeks–months)**
    - **Mid-term (1–3 years)**
    - **Long-term (structural)**

- **Geographical Scope**
    - **National**
    - **Regional**
    - **Cross-border / supranational**

All inputs are explicitly declared as *human-defined parameters*.
AI systems do not generate policy options.

F.x.4 BSI Computation & Layer Interaction

The core computation module translates inputs into layer-specific stability values (L1–L5) and aggregates them into a composite BSI score.

Key characteristics:

- **Layer weights *(w_1 … w_5)* are transparent and adjustable**
- **Cross-layer amplification effects (e.g., Narrative → Affective escalation) are explicitly modeled**
- **No automated optimization or decision logic is applied**

The system enforces the Boundary OS Negative Protocol:

> **AI may calculate and visualize, but may not decide, rank, or enforce.**

F.x.5 Visualization & Output Layer

Outputs are presented through synchronized visual instruments:

- **BSI Composite Gauge**
    - **Displays overall boundary stability state**

- **Layer Radar Chart (L1–L5)**
    - **Reveals imbalance or layer hijacking**

- **Temporal Stability Graph**
    - **Shows projected trajectories under simulated conditions**

- **Scenario Comparison Panel**
    - **Enables side-by-side evaluation of multiple policy paths**

Visualizations are descriptive rather than evaluative.

F.x.6 Policy Simulation Logic (If–Then Use)

The interface supports structured simulation logic:

- ***If*** **intake capacity increases without narrative coordination**
- ***Then*** **affective volatility may rise despite material improvement**

Such relations are presented as structural tendencies, not predictions.

F.x.7 Governance and Ethical Safeguards

To preserve human agency:

- **Human confirmation is required for all simulation runs**
- **All assumptions are logged and auditable**
- **No recommendation scores or rankings are produced**

This ensures compatibility with democratic accountability and international governance norms.

F.x.8 Intended Use Cases

The interface is intended for:

- **National migration policy stress-testing**
- **EU / ASEAN multilateral coordination**
- **Academic comparative research**
- **Early-warning analysis for boundary destabilization**

Figure Reference

Figure F.x — ***Conceptual Layout of the BSI Policy Simulation Interface***
(Visualization of input controls, layer computation core, and output dashboards)

Appendix F.2: Score Normalization Protocol (Scoring Rubric)

F.2 Score Normalization Protocol (Example: Material Layer)

The Boundary Stability Index (BSI) normalizes diverse raw data into a standardized Stability Score (0-100). The following rubric illustrates the conversion logic for the **Material Layer**, specifically focusing on "Shelter Capacity Utilization" as a proxy for infrastructure stress.

Conversion Logic:
The score is derived using a non-linear inverse mapping where 100 represents optimal redundancy and 0 represents functional collapse.

Raw Metric (Shelter Occupancy Rate)	Stability Score (0-100)	Boundary State Definition	Operational Implication
< 80%	**80 - 100**	**Stable (Green)**	**Healthy Metabolism.** System has sufficient buffer to absorb sudden shocks. No intervention needed.
80% - 100%	**60 - 79**	**Tremor (Yellow)**	**Pre-Symptomatic Stress.** Buffer is depleting. Monitoring frequency should be increased.
101% - 120%	**40 - 59**	**Strain (Orange)**	**Functional Strain.** Capacity exceeded. Immediate resource reallocation (Tuning) is required to prevent rupture.
> 120%	**0 - 39**	**Rupture (Red)**	**System Collapse.** Boundary function fails. Emergency protocols (Repair) and external support are mandatory.

Note: Similar logic is applied to Physio-Sensory (e.g., ER wait times), Affective (e.g., Sentiment Polarity), Narrative (e.g., Polarization Index), and Social (e.g., Processing Backlog) layers.

Appendix F.3: Dataset Structure Sample (Synthetic Data)

F.3 BSI Dataset Structure Sample (CSV Format)

The following represents the schema of the "BSI_Daily_Log.csv" exported by the system. This standardized format ensures interoperability across EU member states.

Material_Score, Physio_Score, Affective_Score, Narrative_Score, Social_Score

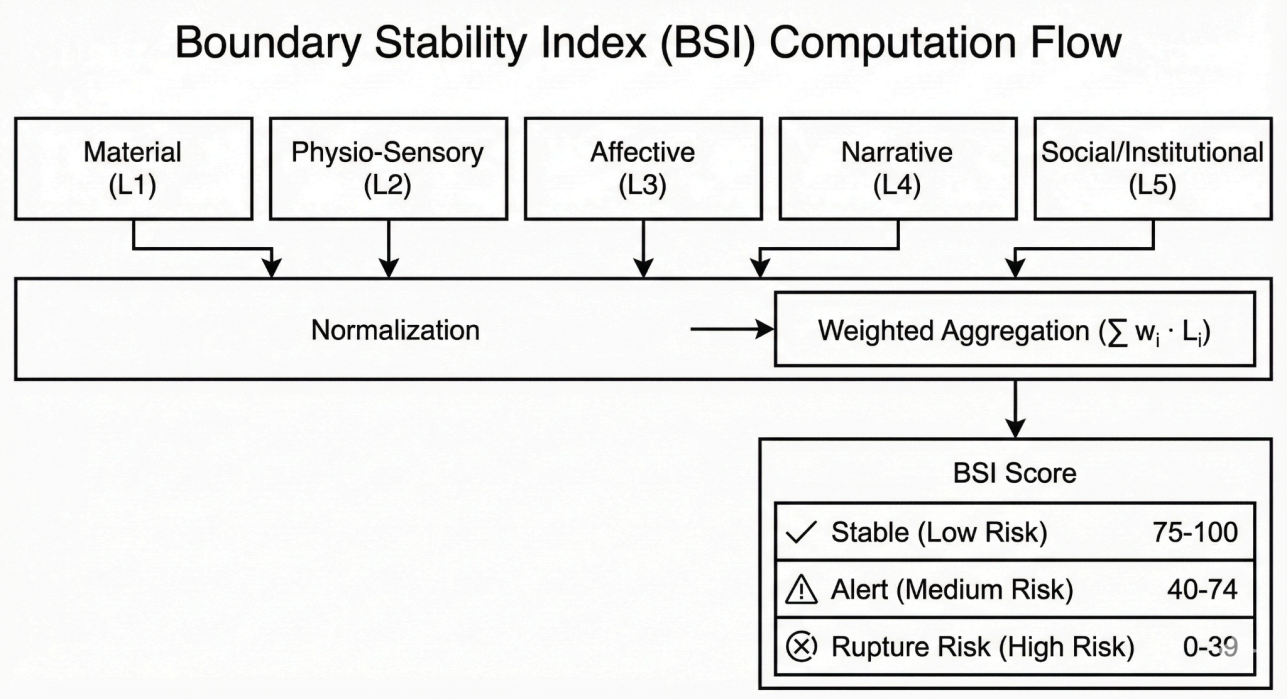
Timestamp, Region_ID, L1, L2, L3, L4, L5, BSI_Composite, Risk_Level
2025-10-01, EU_ITA_LAMP, 45.0, 60.5, 32.0, 25.0, 50.0, 42.5, WARNING
2025-10-02, EU_ITA_LAMP, 42.0, 58.0, 30.5, 22.0, 48.0, 40.1, WARNING
2025-10-03, EU_ITA_LAMP, 38.0, 55.0, 28.0, 18.0, 45.0, 36.8, CRITICAL
2025-10-04, EU_ITA_LAMP, 60.0, 62.0, 35.0, 25.0, 55.0, 47.4, RECOVERY

Data Dictionary:

- **L1_Material_Score:** Normalized score based on infrastructure load (0-100).
- **L3_Affective_Score:** AI-derived sentiment score from aggregated public discourse (anonymized).
- **BSI_Composite:** Weighted average of L1-L5 scores.
- **Risk_Level:** Automated classification based on BSI thresholds (Stable > 75, Warning 40-75, Critical < 40).

Closing Note

With the inclusion of the BSI Dataset, Boundary OS transitions from a conceptual framework to a **research-operational hybrid**, suitable for academic publication, policy pilots, and international benchmarking.



Appendix F.x — Mathematical Specification of the Boundary Stability Index (BSI)

F.x.1 Definition of the Boundary Stability Index (BSI)

Boundary Stability Index (BSI) is defined as a weighted composite index integrating five boundary layers:

$$BSI = \sum_{i=1}^{5} w_i \cdot L_i$$

where:

- Li denotes the normalized stability score of layer i
- wi denotes the weight assigned to layer i
- $$\sum_{i=1}^{5} w_i = 1$$

F.x.2 Layer Definitions

Layer Index iii	Layer Name	Description
1	Material Layer	Physical infrastructure, spatial pressure, border capacity
2	Physio-Sensory Layer	Biometric stress, crowd density, sensor-based strain
3	Affective Layer	Emotional tension, fear, hostility indicators
4	Narrative Layer	Discourse polarization, misinformation spread
5	Social/Institutional Layer	Legal capacity, policy coherence, institutional trust

$EachL_i \in [0,1]Li$, where:

- 1 = full boundary stability
- 0 = boundary collapse

F.x.3 Layer Score Normalization

Raw indicators Xij for each layer are normalized using min–max scaling:

$$Li = \frac{1}{n_i} \sum_{j=1}^{n_i} \frac{X_{ij} - X_{ij}^{\min}}{X_{ij}^{\max} - X_{ij}^{\min}}$$

where:

- ni = number of indicators in layer i

F.x.4 Weighting Scheme

Default equal-weight configuration:

$$wi = 0.2 \quad \forall i$$

Optional policy-adjusted weighting:

$$w_i^* = f(policypriority, riskexposure)$$

subject to:

$$\sum_{i=1}^{5} w_i^* = 1$$

F.x.5 Thresholds and Interpretation

BSI Range	Interpretation
0.80 – 1.00	Stable / Resilient
0.60 – 0.79	Latent Instability (Tremor Zone)
0.40 – 0.59	High Risk (Pre-Rupture)
< 0.40	Boundary Collapse

F.x.6 Temporal Dynamics (Optional)

For time-series evaluation:

$$\Delta \mathrm{BSI}_t = \mathrm{BSI}_t - \mathrm{BSI}_{t-1}$$

Early warning condition:

$$\Delta \mathrm{BSI}_t < -\theta$$

where θ is a policy-defined alert threshold.

F.x.7 Figure Reference

Figure F.x-1. BSI Computation Flow

- Indicator Collection → Layer Normalization → Weighting → Composite Index
- (See Appendix F.x Figure F.x-1)