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Propagatio: A Predictive Mathematical Framework for Organisational Health and Stress Propagation

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This is a working paper intended to stimulate scholarly discussion and empirical testing. The retrospective case studies are illustrative demonstrations, not empirical validation. Mathematical parameters are theoretical priors subject to calibration.

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Abstract

This paper introduces Propagatio, a predictive mathematical framework for modelling organisational health and stress propagation. Unlike existing diagnostic frameworks - which are predominantly static, qualitative, and retrospective - Propagatio provides a dynamic, quantitative, and forward-looking model of organisational behaviour.

The framework is built on three core innovations. First, every organisational system is characterised by three measurable variables - Capacity, Load, and Recovery - which are combined into a bounded Health Index (H) defined as $H = 40 + 0.4C - 0.4L + 0.2R$, yielding a 0–100 index that requires no post-hoc normalisation. Second, stress is modelled as a propagation phenomenon: stress entering one system (e.g., Commercial) transmits to others (e.g., Operations, Finance, People) with measurable coefficients, enabling prediction of systemic failure trajectories. Third, the Organisational Pulse - weekly tracking of health, change, acceleration, and 90-day forecast - provides early warning signals before stress manifests in financial or operational outcomes.

The framework is operationalised through a straightforward spreadsheet-based protocol requiring no specialised expertise. Retrospective applications to the Toyota recall crisis (2009–2010) and Nokia's smartphone collapse (2007–2010) illustrate the framework's diagnostic and predictive capabilities.

Important Note: *This is a working paper introducing a novel theoretical framework. It is intended to stimulate scholarly discussion and empirical testing. The retrospective case studies are illustrative demonstrations, not empirical validation. The mathematical parameters presented are theoretical priors subject to calibration using longitudinal organisational data.*

Keywords: organisational health, stress propagation, predictive analytics, systems theory, organisational resilience, management framework, Capacity-Load-Recovery model

JEL Classification: M10, M12, M14, L20

1. Introduction

The problem of organisational failure is both consequential and poorly understood. Despite decades of research and the proliferation of management frameworks, organisations continue to fail with alarming regularity - often with little warning and catastrophic consequences. The collapse of Nokia's smartphone business (2007–2013) and Toyota's recall crisis (2009–2010) exemplify a recurring pattern: organisations exhibit detectable signs of dysfunction long before these signs appear in financial statements, yet existing frameworks are ill-equipped to detect or interpret these signals.

This paper addresses a fundamental gap in the management literature: the absence of a quantitative, predictive, dynamic, and systemic framework for modelling organisational health. Existing frameworks - Porter's Five Forces (1979), McKinsey's 7S (Pascale & Athos, 1981; Peters & Waterman, 1982), the Balanced Scorecard (Kaplan & Norton, 1992), and McKinsey's Organisational Health Index - offer valuable diagnostic insights but are predominantly static, qualitative, or retrospective. They describe what is or was, but not what will be.

Propagatio addresses this deficit by treating organisations as dynamic systems governed by measurable state variables and lawful causal relationships. The framework draws upon systems theory (Forrester, 1961), resilience research (Holling, 1973; Gunderson & Holling, 2002), and operations management to create a predictive engine for organisational health.

The paper proceeds as follows. Section 2 reviews the relevant literature and identifies the theoretical gap. Section 3 introduces the Propagatio framework, including the mathematical formulation of the Health Index, the propagation model, and the Organisational Pulse. Section 4 presents the operationalisation protocol. Section 5 states the research hypotheses. Section 6 outlines the proposed validation methodology. Section 7 provides illustrative retrospective applications to Toyota and Nokia. Section 8 discusses limitations. Section 9 identifies directions for future research. Section 10 concludes.

2. Literature Review and Theoretical Gap

2.1 Existing Management Frameworks

The management literature offers a diverse array of diagnostic instruments. Porter's (1979) Five Forces framework provides a qualitative lens for understanding industry structure and competitive positioning. However, it is static - it assumes a fixed equilibrium and does not inherently model change over time. The McKinsey 7S framework (Pascale & Athos, 1981; Peters & Waterman, 1982) offers a structured heuristic for assessing internal alignment across seven dimensions: strategy, structure, systems, skills, staff, style, and shared values. While valuable for diagnosis, it is not predictive - it describes alignment but does not, as originally formulated, forecast future states. Gartner's evaluative methodologies serve as comparative benchmarks for vendor capability but do not engage with internal organisational dynamics.

McKinsey's Organisational Health Index (OHI) represents a significant advance, measuring health across nine dimensions of organisational effectiveness. OHI research has consistently shown that organisational health is the best predictor of long-term performance. However, the OHI remains predominantly diagnostic and retrospective - it measures current health (and can track change through repeated applications) but does not model how stress propagates across systems or generate dynamic future trajectories in a mathematical sense.

Propagatio is conceptually distinct from McKinsey's Organizational Health Index (OHI). Whereas OHI is a survey-based diagnostic of organisational outcomes and management practices, Propagatio defines organisational health as a mathematical function of capacity, load and recovery and extends this construct through dynamic stress-propagation modelling.

2.2 Systems Theory and Organisational Resilience

Systems theory provides the foundational ontology for Propagatio. Forrester's (1961) industrial dynamics demonstrated that organisations could be modelled as systems of stocks and flows, with feedback loops governing behaviour. Holling's (1973) resilience theory introduced the adaptive cycle, explaining phases of growth, conservation, release, and reorganisation. Gunderson and Holling (2002) extended this into panarchy theory, showing how stress at one level of a system can cascade upward or downward, influencing resilience options across scales.

At the organisational level, resilience research has explored how organisations withstand, adapt to, and recover from stress. However, most resilience frameworks remain qualitative or survey-based. Quantitative approaches, such as the Resilience Analysis Grid (RAG) and the Resilience Quotient, have emerged but focus on static measurement rather than dynamic prediction.

2.3 The Theoretical Gap

What remains absent from the extant literature is a unifying theoretical framework that is simultaneously:

1. **Quantitative** - expressed in measurable variables, not qualitative adjectives
2. **Predictive** - capable of forecasting future states, not merely diagnosing current conditions
3. **Dynamic** - continuously updated, not static
4. **Systemic** - modelling interdependence and propagation across systems, not treating departments as silos
5. **Actionable** - directly informing intervention priorities

Propagatio is designed to fill this gap.

3. The Propagatio Framework

3.1 Fundamental Premise

Every organisational system - whether Commercial, Operations, Finance, People, or Leadership - can be characterised by three measurable variables:

Variable	Definition	Operational Definition
Capacity (C)	The maximum sustainable output the system can deliver	Current output ÷ Best historical output × 100
Load (L)	The demand currently placed upon the system	Current demand ÷ Maximum sustainable capacity × 100
Recovery (R)	The speed at which the system restores itself after stress	Domain-specific (see Section 3.4)

Table 1. Core variables of the Propagatio framework

These variables are ratios derived from existing operational data: production volumes, order books, cycle times, cash conversion cycles, and employee turnover rates.

3.2 The Health Index

Let Capacity (C), Load (L), and Recovery (R) each be measured on a bounded scale of 0 to 100, where higher values indicate greater capacity, greater load, and faster recovery respectively.

The Propagatio Health Index (H) is defined as:

$$H = 40 + (0.4 \times C) - (0.4 \times L) + (0.2 \times R)$$

Structural Rationale for the Weights

The weights reflect the theorised contribution of each variable to organisational health:

6. **Capacity and Load (0.4 each):** These variables are accorded equal weight because they represent the fundamental supply–demand tension governing every organisational system. When Load exceeds Capacity, stress is inevitable; when Capacity exceeds Load, slack exists. Their opposing effects are symmetric and of first-order importance.
7. **Recovery (0.2):** Recovery receives half the weight of Capacity or Load because it functions as a moderating factor rather than a primary determinant. A system with high Recovery can withstand temporary overload and restore equilibrium; a system with low Recovery will accumulate stress even under moderate load. Recovery cannot substitute for a chronic structural deficit in Capacity or a persistent excess of Load.

Boundedness ($0 \leq H \leq 100$)

The index is inherently bounded without post-hoc normalisation:

- **Maximum (H = 100):** $C = 100, L = 0, R = 100 \rightarrow H = 40 + 40 - 0 + 20 = 100$
- **Minimum (H = 0):** $C = 0, L = 100, R = 0 \rightarrow H = 40 + 0 - 40 + 0 = 0$

For all admissible values of C, L, and R within [0, 100], H is strictly bounded between 0 and 100 inclusive.

Calibration of Weights

The weights are theoretical priors - initial estimates derived from structural logic. They are not asserted as universal constants. Organisations with sufficient longitudinal data may estimate organisation-specific weights through multivariate regression, with the dependent variable being an independently validated measure of organisational performance (e.g., operating margin, employee retention) and the independent variables being historical C, L, and R values.

3.3 Interpretation of the Health Index

Score Range	State	Description
≥ 80	Optimal	Sustainable performance. Capacity exceeds Load; Recovery is robust.
65–79	Stable	Healthy with minor stress. Capacity and Load are broadly balanced.
50–64	Strained	Performance beginning to degrade. Load approaching or exceeding Capacity.
35–49	Critical	Failure propagation accelerating. Multiple systems affected.
< 35	Failing	Systemic dysfunction. Structural intervention required.

Table 2. Health Index interpretation bands

Neutral Reference Point: When $C = 50, L = 50, R = 50 \rightarrow H = 40 + 20 - 20 + 10 = 50$. This corresponds to a system in neutral equilibrium, neither flourishing nor failing.

3.4 Domain-Specific Recovery Metrics

Recovery is defined as domain-specific to eliminate vagueness:

Domain	Recovery Metric	Operational Definition
Operational Recovery	Time to resolve bottlenecks	Average time from stress detection to resolution

Financial Recovery	Cash replenishment speed	Days to convert receivables to cash
Human Recovery	Employee burnout recovery	Average time to restore performance after peak stress
Innovation Recovery	R&D cycle restoration	Time to restore innovation velocity after disruption
Leadership Recovery	Decision response speed	Time from decision request to decision output

Table 3. Domain-specific recovery metrics

The Health function becomes system-specific. Illustrative formulations include:

$$Health(Commercial) = 0.4C - 0.4L + 0.2(Financial\ Recovery + Operational\ Recovery)$$
$$Health(Operations) = 0.4C - 0.4L + 0.2(Operational\ Recovery + Human\ Recovery)$$
$$Health(Leadership) = 0.4C - 0.4L + 0.2(Leadership\ Recovery + Financial\ Recovery)$$

3.5 Stress Propagation

The Core Innovation

The health score tells you where you are. But the defining innovation of Propagatio is stress propagation.

Current management systems assume independence. Propagatio assumes dependency. Stress does not stay where it originates. It spreads - like a wave, like a contagion, like the propagation of failure through a complex system.

The Propagation Network

Propagatio models the organisation as a directed graph:

- **Nodes** represent organisational systems
- **Edges** represent propagation pathways
- **Coefficients (0.0–1.0)** represent the strength of propagation

Propagation coefficients represent empirical priors derived from historical organisational observations. In the absence of organisation-specific data, coefficients are initially estimated using industry baselines. These coefficients are not fixed - they are continuously recalibrated as new evidence accumulates. In software implementation, coefficients are learned through Bayesian updating or machine learning regression.

Example propagation map (illustrative priors):

Commercial stress ──(0.72)──→ Operations stress
Operations stress ──(0.81)──→ Finance stress
Finance stress ──(0.46)──→ Leadership stress
Leadership stress ──(0.63)──→ People stress
People stress ──(0.50)──→ Operations stress

These coefficients are illustrative, not universal. Actual coefficients must be empirically calibrated.

3.6 The Predictive Equation

The framework's predictive core is:

Future Performance = Current Health − Accumulating Stress + Recovery Capacity − Propagation Risk ± External Conditions

Every term is measurable:

- **Current Health:** Derived from the Health function
- **Accumulating Stress:** Sum of stress inputs from all propagation pathways
- **Recovery Capacity:** The system's ability to heal
- **Propagation Risk:** Expected stress transmission based on coefficients
- **External Conditions:** Market, regulatory, or competitive factors (exogenous)

4. Operationalisation Protocol

4.1 System Identification

Organisations identify 5–8 core systems. A default mapping includes:

- Commercial (sales, marketing, revenue)
- Operations (production, delivery, fulfilment)
- Finance (cash, margins, cost control)
- People (talent, engagement, capability)
- Product/Innovation (R&D, development, quality)
- Leadership (decision quality, strategic clarity)

4.2 Variable Measurement

For each system:

Variable	Calculation
Capacity	(Current output / Best historical output) × 100
Load	(Current demand / Maximum sustainable capacity) × 100
Recovery	(Best cycle time / Current cycle time) × 100

Table 4. Variable measurement formulas

4.3 The Organisational Pulse

Every week, organisations measure health, change, acceleration, and prediction:

Week	Health	Change	Acceleration
1	82	—	—
2	80	−2	—
3	76	−4	−2
4	68	−8	−4

Table 5. Illustrative Organisational Pulse tracker

Acceleration - the rate of change of change - becomes the first predictive signal. When acceleration is negative for two consecutive weeks, the framework issues a warning.

4.4 Decision Rules

Signal	Threshold	Action
Health Alert	$H < 65$	Investigate root causes; monitor weekly
Critical Alert	$H < 50$	Immediate intervention required
Failing Alert	$H < 35$	Emergency structural intervention
Change Alert	$\Delta H < -5$ in one week	Investigate immediate cause
Acceleration Alert	Acceleration < 0 for 2 weeks	Proactive intervention required

Table 6. Decision rules and alert thresholds

5. Research Hypotheses

Based on the theoretical framework, the following hypotheses are proposed for empirical testing:

H1: The Health Index (H) is negatively associated with future organisational failure events (operational disruptions, financial restatements, leadership turnover) within a 90-day horizon.

H2: The acceleration of health decline (negative acceleration for two consecutive weeks) predicts organisational stress events with greater accuracy than absolute health scores alone.

H3: Stress propagation coefficients are stable within industries but vary significantly across industries, reflecting different systemic dependencies.

H4: Organisations with higher Recovery scores exhibit faster restoration of health following stress events, controlling for initial health and stress magnitude.

H5: Interventions targeting propagation pathways (rather than individual systems) produce greater improvement in overall organisational health than interventions targeting isolated systems.

6. Proposed Validation Methodology

6.1 Prospective Study Design

Formal validation of Propagatio requires a prospective longitudinal study with the following design:

- **Sample:** Minimum 50 organisations across 3–5 industries
- **Duration:** Minimum 24 months
- **Data Collection:** Weekly measurement of C, L, and R for each system; independent validation of outcomes (operational metrics, financial performance, employee retention)
- **Analysis:** Multilevel modelling to test hypotheses H1–H5; time-series analysis to validate predictive accuracy

6.2 Retrospective Validation

Prior to prospective testing, retrospective validation can be conducted using publicly available data from organisations that experienced well-documented crises. The Toyota and Nokia cases presented in Section 7 are illustrative examples of this approach.

6.3 Calibration Methodology

The theoretical priors (weights and coefficients) should be calibrated using:

- **Cross-sectional calibration:** Regression analysis on historical data from a diverse sample of organisations
- **Longitudinal calibration:** Time-series analysis tracking coefficient stability and variation
- **Bayesian updating:** Continuous refinement as new evidence accumulates

7. Illustrative Retrospective Applications

Important Note: *The following case studies are illustrative retrospective applications of the Propagatio framework. They demonstrate that Propagatio would have detected early warning signals in well-documented corporate crises. They are not empirical validation - they are existence proofs intended to illustrate the framework's plausibility and generate hypotheses for prospective testing.*

7.1 Toyota Recall Crisis (2009–2010)

Background: In September 2009, Toyota announced its largest-ever U.S. recall - 3.8 million vehicles - due to accelerator pedal defects. By January 2010, the recall had expanded to 7.5 million vehicles. The U.S. government later concluded that recalls should have been initiated at least one year earlier.

Propagatio Analysis (Pre-Crisis, Early 2009):

System	C	L	R	H	State
Commercial	90	85	75	57	Strained
Operations (Quality)	95	90	40	50	Strained
Finance	85	60	80	66	Stable
Leadership	70	75	30	44	Critical
People	80	70	50	54	Strained

Table 7. Toyota pre-crisis Health Index scores (illustrative)

Interpretation: Leadership was already in Critical territory (H = 44) with dangerously weak Recovery (R = 30). Operations was on the cusp of Critical (H = 50). Propagation simulation predicted that Operations stress would propagate to Commercial (0.81), then Finance (0.72), Leadership (0.46), and People (0.63). Propagatio would have flagged the leadership dysfunction and propagation risk 12+ months before the public recall.

7.2 Nokia Smartphone Collapse (2007–2010)

Background: In 2007, Nokia dominated the global mobile phone market with over 50% of the smartphone market. That year, Apple introduced the iPhone. By 2010, Nokia's market share had fallen to approximately 38%.

Propagatio Analysis (2007, iPhone Launch):

System	C	L	R	H	State
Commercial	95	80	90	64	Strained
Product/Innovation	0	85	30	12	Failing
Finance	90	50	85	73	Stable
Leadership	65	80	20	38	Critical
People	75	70	40	50	Strained

Table 8. Nokia 2007 Health Index scores (illustrative)

Interpretation: Product/Innovation was profoundly Failing (H = 12) with zero capacity in the emerging touchscreen segment. Leadership was Critical (H = 38) with nearly non-existent Recovery (R = 20). Propagation simulation predicted systemic collapse within 90 days. Propagatio would have shown that Nokia's product system was already Failing in 2007 - the year the iPhone launched.

8. Limitations

The Propagatio framework, in its current form, has several limitations that must be acknowledged:

1. **Absence of Empirical Validation:** The framework has not yet been tested prospectively. The retrospective applications are illustrative, not confirmatory.
2. **Theoretical Priors:** The weights (0.4, 0.4, 0.2) and propagation coefficients are theoretical priors requiring empirical calibration.
3. **Data Availability:** The framework assumes that organisations can measure Capacity, Load, and Recovery for each system. Smaller organisations may lack the data infrastructure for full implementation.
4. **Simplification:** The framework reduces organisational complexity to three variables per system. This is a deliberate simplification for tractability, but it necessarily omits some contextual factors.
5. **Causality:** The framework identifies correlations and propagation patterns but does not establish causality. External factors (market shocks, regulatory changes) are treated as exogenous.
6. **Generalizability:** The framework has been illustrated on two large manufacturing/technology organisations. Its applicability to other industries, sizes, and contexts requires further testing.

9. Future Research

The following research directions are proposed:

1. **Prospective Validation:** Conduct a longitudinal study of 50+ organisations over 24 months to test hypotheses H1–H5.
2. **Calibration Studies:** Estimate organisation-specific weights and coefficients through multivariate regression and Bayesian updating.
3. **Industry Comparisons:** Test whether propagation coefficients vary systematically across industries.
4. **Intervention Effectiveness:** Compare the effectiveness of interventions targeting propagation pathways versus isolated systems.
5. **Software Development:** Build a prototype implementation to automate data collection, health calculation, and propagation simulation.
6. **Integration with Existing Frameworks:** Explore how Propagatio complements Porter's Five Forces, McKinsey's 7S, and the Balanced Scorecard.

10. Conclusion

This paper has introduced Propagatio, a predictive mathematical framework for organisational health and stress propagation. The framework addresses a fundamental gap in the management literature: the absence of a quantitative, predictive, dynamic, and systemic model of organisational behaviour.

Propagatio offers three core innovations:

1. A bounded Health Index ($H = 40 + 0.4C - 0.4L + 0.2R$) that is transparent, measurable, and inherently bounded between 0 and 100.
2. A stress propagation model that formalises how stress flows between organisational systems with measurable coefficients, enabling prediction of systemic failure trajectories.
3. An Organisational Pulse that provides early warning signals through weekly tracking of health, change, acceleration, and 90-day forecast.

The framework has been operationalised through a spreadsheet-based protocol requiring no specialised expertise. Retrospective applications to Toyota and Nokia illustrate its diagnostic and predictive capabilities.

This is a working paper intended to stimulate scholarly discussion and empirical testing. The framework is offered as a theoretical contribution, not as a validated instrument. The author invites replication, critique, and refinement.

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Appendix A: Operationalisation Templates

System Health Scorecard

System: _____
Date: _____
Capacity (0–100): _____
Load (0–100): _____
Recovery (0–100): _____
Health = 40 + (0.4 × C) − (0.4 × L) + (0.2 × R) = _____
State: [ ] Optimal [ ] Stable [ ] Strained [ ] Critical [ ] Failing

Weekly Pulse Tracker

Week	Comm.	Ops	Fin.	People	Lead.	Overall	Δ	Accel.
1							—	—
2								—
3								
4								

Table A1. Weekly Pulse Tracker template

Appendix B: Propagation Coefficient Estimation

Propagation coefficients are estimated through:

8. Historical data analysis: Regression of stress indicators across systems
9. Expert calibration: Structured team deliberation
10. Industry baselines: Averaged coefficients from comparable organisations
11. Machine learning: Continuous refinement through Bayesian updating

Recommended initial estimation protocol:

Step	Action
1	Identify all propagation pathways between systems
2	For each pathway, estimate coefficient using historical data (if available) or expert judgment

3	Validate coefficients through sensitivity analysis
4	Recalibrate quarterly as new evidence accumulates

Table B1. Propagation coefficient estimation protocol

This working paper is a preliminary draft. Comments and critiques are welcome. Please direct correspondence to: fabio.g@gasbarro-ai-consulting.com.

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