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Zuber Mujeeb Shaikh
Corporate Executive Director of Quality, Patient Safety, Risk, Accreditations & Compliance, Dr. Sulaiman Al Habib Medical Services Group Company, Riyadh, Saudi Arabia,
ORCID ID: 0000-0002-1491-8379; Email: drzuber5@yahoo.co.in

Area/Section: Quality Management in Healthcare.
Type of Paper: Model Development.
Number of Peer Reviews: Two.
Type of Review: Peer Reviewed as pe |C|O|P|E| guidance.
Indexed in: OpenAIRE.
DOI: https://doi.org/10.5281/zenodo.22756025
Google Scholar Citation: PIJMESS

How to Cite this Paper:
Shaikh, Z. M. (2026). Zuber's Cost of Quality Intelligence Framework (ZCoQ-IF): A Validated Model for Healthcare Quality Intelligence. *Poornaprajna International Journal of Management, Education & Social Science (PIJMESS), 3*(2), 334-345. DOI: https://doi.org/10.5281/zenodo.22756025

Poornaprajna International Journal of Management, Education & Social Science (PIJMESS)
A Refereed International Journal of Poornaprajna Publication, India.
ISSN: 3107-4626

Crossref DOI: https://doi.org/10.64818/PIJMESS.3107.4626.0068

Received on: 05/08/2026
Published on: 15/09/2026

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Zuber Mujeeb Shaikh
Corporate Executive Director of Quality, Patient Safety, Risk, Accreditations & Compliance, Dr. Sulaiman Al Habib Medical Services Group Company, Riyadh, Saudi Arabia,
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ABSTRACT

Purpose: *Healthcare organizations incur substantial costs to prevent poor quality, assure conformance, detect and correct internal failures, and manage failures that reach patients or external stakeholders. Conventional Cost of Quality (CoQ) accounting identifies where resources are spent or lost but does not by itself indicate how effectively the four quality-cost domains are being managed. This study develops and validates Zuber's Cost of Quality Intelligence Framework (ZCoQ-IF), a healthcare-specific model that preserves monetary CoQ while adding a separate 0–100 performance-intelligence index.*

Methodology/Approach: *A structured framework-development and validation design was used. Classical prevention–appraisal–failure theory, healthcare quality-cost literature, patient-safety economics, composite-index methodology, and the author's published healthcare quality and accreditation research were synthesized. Four domains were operationalized: Prevention, Appraisal/Assurance, Internal Failure Control, and External Failure Control. Internal mathematical verification was followed by a six-stage external validation and application process comprising multidisciplinary content/construct review, weight validation, normalization and aggregation robustness testing, multicenter retrospective application, criterion/convergent/predictive evaluation, and prospective implementation assessment in anonymized participating healthcare settings.*

Findings/Result: *ZCoQ-IF integrates Prevention (30%), Appraisal/Assurance (20%), Internal Failure Control (20%), and External Failure Control (30%) into a transparent 0–100 index. Internal analytical verification confirmed weight closure, boundedness, monotonicity, decomposability, and reproducibility of the scoring model. The completed six-stage validation process supported content and construct coherence, robustness of the scoring architecture, multicenter operational feasibility, alignment with independent quality and organizational performance domains, and prospective applicability. A central validated design principle is that monetary CoQ and ZCoQ-IF performance must be reported together but must not be mathematically conflated.*

Originality/Value: *ZCoQ-IF extends the established prevention–appraisal–failure model from a cost-classification approach into a healthcare quality-intelligence architecture. It links quality economics with patient safety, accreditation/compliance, organizational learning, digital performance management, and strategic resource allocation while preserving traceability to underlying measures and actual monetary costs.*

Paper Type: *Original framework-development and validation research paper.*

Keywords: Cost of quality, Cost of poor quality, Healthcare quality, Patient safety, Prevention, Appraisal, Internal failure, External failure.

1. INTRODUCTION :

Quality in healthcare consumes resources, and poor quality consumes resources as well. Healthcare organizations invest in safe process design, workforce competency, preventive maintenance, infection prevention, medication safety, quality measurement, audits, accreditation, incident investigation, remediation, and improvement. They also absorb the consequences of failure through rework, repeated

diagnostics, prolonged hospitalization, avoidable utilization, complaints, claims, regulatory action, loss of trust, and other direct and indirect effects.

The Cost of Quality (CoQ) concept provides a disciplined way to organize these resources. The established prevention–appraisal–failure (PAF) model separates costs incurred to prevent nonconformance, costs incurred to appraise or assure conformance, costs arising from failures detected internally, and costs arising after a failure reaches an external customer or stakeholder (Broyles & Al-Assaf, 1999; Crosby, 1979; Feigenbaum, 1991; Juran & Godfrey, 1999). The American Society for Quality similarly defines CoQ through prevention, appraisal, internal failure, and external failure categories.

Healthcare studies demonstrate that both quality infrastructure and quality failure have measurable economic consequences. Blanchfield et al. (2018) quantified substantial annual expenditure on quality and patient-safety infrastructure in an academic health center. Saraswathula et al. (2023) demonstrated the considerable personnel and vendor resources required for quality-metric reporting. Zahar et al. (2016) operationalized the PAF model in a clinical laboratory, while Donnelly et al. (2018) described quality and safety costs in radiology. These studies reinforce the managerial importance of understanding not only how much quality costs, but whether quality-related resources are positioned effectively.

A conceptual problem remains, however. Monetary CoQ answers an accounting question: how much is spent or lost in each quality-cost category? It does not automatically answer a performance question: how effectively is the organization managing prevention, assurance, and failure control? The ZCoQ-IF was developed to connect these two managerial perspectives without confusing them. It therefore produces two complementary outputs: monetary CoQ and a separate normalized performance-intelligence index.

2. RELATED WORKS / LITERATURE REVIEW :

2.1 Cost of Quality and the PAF model:

Traditional CoQ theory classifies quality-related expenditure into prevention, appraisal, internal failure, and external failure. Prevention costs are incurred before defects or failures occur; appraisal costs arise from measurement, inspection, testing, audit, and assurance; internal failure costs arise when nonconformance is detected before external consequence; and external failure costs arise after the failure reaches the customer or another external stakeholder. In healthcare, the external stakeholder concept must be broader than the commercial customer because patients, families, regulators, payers, accreditation bodies, communities, and clinicians may all experience consequences.

Broyles and Al-Assaf (1999) modeled interactions among prevention, appraisal, and failure costs in health services. Jarlier and Charvet-Protat (2000) examined whether improving quality could decrease hospital costs. Zahar et al. (2016) demonstrated practical allocation of clinical-laboratory costs across PAF categories. Walsh and Antony (2009) linked quality costs with electronic adverse-incident reporting, while laboratory literature has emphasized that hidden error and rework costs can be reduced by designing quality into processes.

2.2 Quality, patient safety, and economic consequences:

The economic case for quality must remain subordinate to the ethical obligation to prevent harm, but economic analysis can improve resource stewardship. The Institute of Medicine (2000, 2001) established the systemic nature of patient-safety and quality problems, while Donabedian (1988) provided the enduring structure–process–outcome logic for quality assessment. Slawomirski et al. (2017) highlighted the economic burden of patient harm, and Nuckols et al. (2013) described mechanisms through which quality can influence healthcare and health-status-related costs. Berwick et al. (2008) and Porter (2010) further connected quality, outcomes, experience, and cost within broader value-oriented healthcare thinking.

2.3 Composite-index methodology and quality intelligence:

A performance-intelligence index introduces methodological requirements beyond traditional cost accounting. Composite indicators require explicit construct definitions, normalization, weighting, aggregation, missing-data rules, sensitivity analysis, and transparent interpretation (OECD/European Union/EC-JRC, 2008). Saisana et al. (2005) emphasized uncertainty and sensitivity analysis as tools for assessing composite-indicator robustness, while Dobbie and Dail (2013) showed that weighting and aggregation choices can materially influence composite indices. ZCoQ-IF therefore treats its weighting architecture as an explicit, auditable design rather than an implicit scoring convention.

2.4 Author's prior research informing ZCoQ-IF:

The author's prior research provides healthcare-specific empirical and conceptual grounding for the domains consolidated by ZCoQ-IF. Prevention and proactive quality management are reflected in work on patient and family education, international patient-safety goals, workforce qualification standards, smoking-related health education and promotion, and accreditation requirements (Khan et al., 2016; Shaikh et al., 2016a, 2016b, 2016c; Shaikh, 2017a). Appraisal and assurance are represented by studies of personnel-file completeness, laboratory and blood-bank quality indicators, and national health-system indicators (Shaikh, 2017b; Shaikh, 2018a, 2018b, 2018c, 2018d).

Internal and external failure-control concepts are supported by the author's work on occurrence-variance/incident reporting and critical-care outcome measures (Shaikh, 2018e; Shaikh et al., 2018). The downstream stakeholder consequences of quality are further represented by accreditation-related patient-satisfaction studies across ambulance, dietary, emergency, haemodialysis, inpatient, laboratory, outpatient, radiology, pharmacy, and physiotherapy services (Shaikh, 2016; Shaikh, 2017c–2017k). Collectively, these studies support the need for an enterprise model that links prevention, assurance, failure control, outcomes, and resource stewardship rather than treating them as isolated quality activities.

2.5 Research Gap:

Healthcare lacks a widely adopted performance-intelligence architecture that preserves the established monetary PAF taxonomy while separately quantifying how effectively the four quality-cost domains are being managed. Existing literature demonstrates the economic relevance of prevention, appraisal, failure, quality infrastructure, patient harm, and reporting burden, but cost accounting and quality-performance dashboards are commonly separated. ZCoQ-IF addresses this gap by integrating the four domains into a transparent performance index while maintaining monetary CoQ as a distinct construct.

3. OBJECTIVES :

(1) To adapt the prevention–appraisal–internal failure–external failure model to healthcare quality management.
(2) To operationalize a transparent 0–100 ZCoQ-IF performance-intelligence index while preserving monetary CoQ as a separate construct.
(3) To define and validate the relative weighting and scoring direction of the four ZCoQ-IF domains.
(4) To specify data-governance, normalization, aggregation, and interpretation rules for reproducible application.
(5) To evaluate the framework through content/construct validation, robustness testing, multicenter retrospective application, criterion/convergent/predictive evaluation, and prospective implementation.

4. METHODOLOGY :

This study used a structured framework-development and validation design. Classical CoQ theory, healthcare quality-cost research, patient-safety economics, composite-index methodology, and the author's prior healthcare quality and accreditation research were synthesized to construct the ZCoQ-IF. The framework was then subjected to internal mathematical verification and a six-stage external validation and application process in anonymized participating healthcare settings. Institutional identities are intentionally not reported.

Framework development followed seven steps: (1) preserve the established PAF taxonomy; (2) translate each domain into healthcare-specific constructs; (3) distinguish monetary costs from normalized performance scores; (4) standardize score direction so that higher values consistently indicate better management performance; (5) define explicit domain weights and linear aggregation; (6) specify data-quality, missing-data, traceability, and interpretation rules; and (7) evaluate the framework through external validation and prospective application.

The four domain weights were prespecified as strategic design weights: Prevention 30%, Appraisal/Assurance 20%, Internal Failure Control 20%, and External Failure Control 30%. The weighting gives greater emphasis to prevention and to control of failures with external consequences while maintaining substantial weight for assurance and internal failure control. These are performance-index weights, not recommendations for allocating 30–20–20–30 of the monetary quality budget.

For every component indicator, polarity must be defined before normalization. Higher normalized scores must always indicate better performance. Consequently, failure-domain scores represent effectiveness of failure prevention, containment, correction, or achievement against an approved target; raw counts of failures cannot be entered directly as positive performance values.

5. PROPOSED ZCOQ-IF MODEL :

Table 1: ZCoQ-IF Domains, Weights, and Healthcare Interpretation

Domain	Weight	Healthcare interpretation
Prevention (P)	30%	Proactive measures that prevent errors, harm, noncompliance, defects, process failure, and avoidable quality loss.
Appraisal / Assurance (A)	20%	Measurement, audit, surveillance, assessment, testing, validation, and assurance activities used to evaluate conformance and performance.
Internal Failure Control (IF)	20%	Detection, containment, correction, learning, and control of defects or failures before significant external consequence.
External Failure Control (EF)	30%	Prevention, containment, remediation, and learning related to failures affecting patients, outcomes, compliance, accreditation, reputation, or other external stakeholders.

5.1 Two-level Scoring Architecture:

Where multiple KPIs contribute to a ZCoQ-IF domain, each KPI is first normalized to a 0–100 performance score (s_{ij}). Within-domain weights (v_{ij}) must sum to 1.00. The domain score D_j is calculated as:

$$\mathbf{D_j = \Sigma\ (v_{ij} \times s_{ij})}$$

The enterprise ZCoQ-IF score is then calculated as:

$$\mathbf{ZCoQ\text{-}IF = (P \times 0.30) + (A \times 0.20) + (IF \times 0.20) + (EF \times 0.30)}$$

P, A, IF, and EF are normalized 0–100 domain-performance scores. Because the four domain weights sum to 1.00, the composite remains on a 0–100 scale when all domain scores are bounded to that interval.

5.2 Monetary CoQ and the Performance Index:

Monetary Cost of Quality is calculated separately:

$$\mathbf{Monetary\ CoQ = C(P) + C(A) + C(IF) + C(EF)}$$

C(P), C(A), C(IF), and C(EF) are actual monetary costs attributable to the four domains over a defined period. Monetary CoQ may be reported as an absolute amount and relative to an appropriate denominator such as operating expense, revenue, patient-days, encounters, or activity volume. ZCoQ-IF must never be interpreted as a monetary percentage or substituted for actual costing.

5.3 Data Quality and Comparability Requirements:

Valid use requires a governed KPI dictionary, explicit numerator and denominator definitions, target and benchmark rules, score polarity, data-source ownership, refresh frequency, missing-data rules, auditability, and version control. Comparisons across facilities require semantic equivalence of measures and consistent normalization. A composite score must always remain drillable to its domains and underlying KPIs.

Cost assignment requires a separate cost dictionary defining inclusion/exclusion rules, cost owner, source system, period, direct versus indirect cost, and controls against double counting. Where one event generates costs in several domains, allocation rules must be documented before aggregation.

5.4 Illustrative Calculation:

Table 2: Illustrative ZCoQ-IF Calculation

Domain	Illustrative score	Weight	Weighted contribution
Prevention	90	30%	27.00
Appraisal / Assurance	87	20%	17.40
Internal Failure Control	80	20%	16.00
External Failure Control	82	30%	24.60
ZCoQ-IF	—	100%	85.00

The illustrative values yield 27.00 + 17.40 + 16.00 + 24.60 = 85.00. This example demonstrates the calculation mechanics and is not presented as facility-specific validation data.

5.5 Analytical Verification:

Internal analytical verification confirmed five properties. First, weight closure is satisfied because 0.30 + 0.20 + 0.20 + 0.30 = 1.00. Second, boundedness is preserved because a weighted average of domain scores constrained to 0–100 remains within 0–100. Third, monotonicity is preserved: increasing any domain score while holding the others constant cannot reduce the composite score. Fourth, decomposability is retained because every composite value can be traced to domain and KPI contributions. Fifth, the illustrative calculation is exactly reproducible at 85.00.

5.6 Performance Classification:

Table 3: ZCoQ-IF Performance Classification

ZCoQ-IF score	Classification	Interpretation
<60	Critical	Material weakness across one or more quality-cost domains; immediate prioritized improvement is required.
60–69.9	Developing	Basic controls are present but substantial gaps remain in prevention, assurance, or failure control.
70–79.9	Effective	Generally effective management with identifiable opportunities for stronger prevention, assurance, and learning.
80–89.9	High Performing	Strong performance across the assessed quality-cost domains, supported by domain-level review.
≥90	Optimized	Very strong integrated performance across prevention, assurance, and failure-control domains, subject to confirmation by underlying KPI and trend review.

Classification is interpreted together with domain scores, trends, material events, and monetary CoQ. A favorable composite score must not conceal a critical safety, regulatory, or ethical issue.

5.7 Non-compensatory Safety and Regulatory Override:

Because weighted arithmetic aggregation is compensatory, strong performance in one domain can mathematically offset weakness in another. Healthcare governance therefore requires an override rule. A predefined sentinel-level safety condition, critical regulatory breach, severe compliance failure, or other high-consequence event may trigger an override classification or mandatory escalation

irrespective of the aggregate ZCoQ-IF score. This protects the framework from implying that serious harm can be 'balanced' by favorable performance elsewhere.

5.8 Healthcare Cost Taxonomy:

Table 4: Illustrative Healthcare Cost-of-Quality Taxonomy

Domain	Illustrative activities / costs
Prevention	Competency development; preventive maintenance; infection-prevention design; medication-safety engineering; FMEA; policy standardization; simulation; safety-by-design; digital decision support.
Appraisal / Assurance	Audits; accreditation assessments; surveillance; quality-control testing; tracer activity; KPI validation; peer review; compliance monitoring; environmental rounds.
Internal Failure	Rework; repeat testing due to internal error; rejected specimens; corrected records; intercepted medication errors; internal nonconformity correction; avoidable process downtime.
External Failure	Preventable patient harm; remedial care; avoidable readmission attributable to failure; complaints and claims; regulatory penalties; accreditation consequences; recalls; reputational loss.

6. ANALYSIS / RESULTS / DISCUSSION :

ZCoQ-IF changes the managerial question from 'How much does the quality function cost?' to two linked questions: 'Where are quality-related resources being consumed?' and 'How effectively are prevention, assurance, and failure-control systems performing?' This distinction is essential because a low quality budget is not necessarily efficient if hidden failure costs are high, while substantial prevention expenditure may represent rational investment when it reduces downstream harm and rework.

The framework also separates cost of conformance from cost of nonconformance without assuming that all prevention or appraisal activity is automatically valuable. Excessive manual auditing, duplicate reporting, or low-value measurement can themselves create opportunity cost. The objective is therefore intelligent allocation and effectiveness, not indiscriminate maximization of prevention or appraisal.

Digital implementation can strengthen ZCoQ-IF by connecting incident reporting, risk registers, complaints, audit findings, accreditation nonconformities, infection surveillance, medication safety, claims, laboratory quality, workforce competency, and financial systems. Automation should remain governed by explicit classification rules, audit trails, and human review because a single event may create clinical, operational, regulatory, and financial consequences simultaneously.

Longitudinal interpretation is particularly important. Prevention and assurance are predominantly proactive or control-oriented, whereas internal and external failure domains capture the effectiveness of detecting, containing, correcting, and learning from nonconformance. A mature implementation should examine whether sustained prevention and assurance performance is accompanied by declining failure burden and improved outcomes over time rather than relying only on a static composite score.

External failure has special importance in healthcare because consequences may extend beyond directly monetizable loss to patient harm, family burden, staff impact, regulatory scrutiny, and loss of trust. ZCoQ-IF does not place a financial value on human harm; monetary analysis remains a management tool, while clinical, ethical, and regulatory obligations remain primary.

7. FINDINGS :

(1) The PAF taxonomy is operationally transferable to healthcare when prevention, assurance, and failure concepts are defined in clinical, regulatory, and stakeholder terms.
(2) Monetary CoQ and ZCoQ-IF performance are complementary but distinct constructs and should be displayed together rather than collapsed into one measure.

(3) The 30–20–20–30 architecture is mathematically coherent, transparent, and bounded on a 0–100 scale.
(4) Failure-domain scoring must represent control effectiveness or target achievement; raw failure counts cannot be treated as positive performance scores.
(5) Data governance, normalization, cost-allocation rules, drill-down, and non-compensatory safety/regulatory overrides are necessary for responsible interpretation.
(6) External validation and prospective application supported the framework's content/construct coherence, methodological robustness, multicenter operational feasibility, relationship with independent performance domains, and practical applicability in participating healthcare settings.

8. EXTERNAL VALIDATION AND APPLICATION :

Following framework development and internal analytical verification, ZCoQ-IF underwent a structured six-stage external validation and application process in participating healthcare settings. Institutional identities are intentionally not reported. The process addressed content and construct validity, weighting, methodological robustness, multicenter application, criterion/convergent/predictive evaluation, and prospective implementation.

Stage 1 – Content Validity and Construct Refinement

A multidisciplinary expert panel representing quality, patient safety, clinical operations, finance/cost accounting, patient experience, human resources, digital health, risk management, accreditation/compliance, and executive leadership reviewed the framework. A modified Delphi process was used to evaluate relevance, clarity, completeness, construct distinctiveness, non-overlap, operational definitions, cost-domain boundaries, and scoring direction, consistent with established Delphi and content-validity methodology (Hasson et al., 2000; Polit & Beck, 2006). Feedback was incorporated iteratively into the framework specification.

Stage 2 – Weight Validation

The 30–20–20–30 domain weights were evaluated against alternative weighting assumptions, including equal weighting and structured expert-derived alternatives. The assessment examined strategic coherence, interpretability, and consistency of the weighting architecture and considered structured multicriteria weighting principles, including the Best-Worst Method (Rezaei, 2015). The final weighting structure was retained as the specified ZCoQ-IF architecture following comparative validation.

Stage 3 – Normalization and Aggregation Robustness

Robustness testing examined plausible normalization approaches, missing-data rules, within-domain weighting assumptions, and alternative aggregation choices. Uncertainty and sensitivity principles were applied to determine whether reasonable methodological alternatives materially altered composite interpretation or organizational comparisons (Saisana et al., 2005; OECD/European Union/EC-JRC, 2008; Dobbie & Dail, 2013). This stage also informed requirements for polarity, denominator governance, cost attribution, traceability, and version control.

Stage 4 – Multicenter Retrospective Validation

ZCoQ-IF was retrospectively applied to standardized historical performance information from multiple participating healthcare facilities. Validation examined score behavior, data completeness, stability, repeatability of calculations, interfacility discrimination, traceability to underlying measures, and the effect of alternative methodological assumptions. Participating organizations were anonymized to preserve institutional confidentiality. The multicenter application supported operational feasibility of the composite index and its linked monetary-cost taxonomy.

Stage 5 – Criterion, Convergent, and Predictive Evaluation

Composite and domain-level ZCoQ-IF scores were evaluated in relation to independently measured performance domains, including patient experience, selected clinical and patient-safety outcomes, accreditation/compliance performance, workforce measures, operational productivity, and financial sustainability. The evaluation examined whether the index behaved coherently in relation to the constructs it was designed to represent and whether the integrated view added decision value beyond isolated KPI reporting.

Stage 6 – Prospective Implementation Evaluation

The framework was prospectively applied and evaluated in participating healthcare settings. Implementation assessment considered usability, managerial interpretation, decision timeliness, action

follow-up, reporting burden, drill-down behavior, governance of indicator and costing-rule changes, and potential unintended consequences such as gaming or overreliance on the composite score. Governance rules were applied to indicators, weights, targets, normalization logic, cost classification, and safety/regulatory override criteria. This stage supported the practical applicability of ZCoQ-IF as an enterprise quality-economics and performance-intelligence framework.

Validation Synthesis

Taken together, the six-stage process provided complementary evidence across content, construct, methodological, operational, and implementation dimensions. The validation supported the scientific coherence and practical applicability of ZCoQ-IF while preserving three non-negotiable governance principles: monetary CoQ remains analytically separate from the performance index; every composite result remains auditable to underlying domains and measures; and critical safety or regulatory conditions cannot be concealed by favorable performance elsewhere. Institutional identities and facility-level results are not disclosed in this manuscript.

9. CONCLUSION :

Healthcare organizations need to understand both the economics of quality and the effectiveness of the systems used to manage it. Zuber's Cost of Quality Intelligence Framework (ZCoQ-IF) integrates these perspectives without conflating them. It preserves the established prevention–appraisal–internal failure–external failure logic, adds a transparent two-level 0–100 performance-intelligence index, and maintains monetary CoQ as a separate accounting construct. Internal mathematical verification established the coherence and reproducibility of the scoring architecture, and a six-stage external validation and application process supported content/construct coherence, weighting and methodological robustness, multicenter operational feasibility, alignment with independent performance domains, and prospective applicability. ZCoQ-IF therefore provides an auditable framework for linking quality economics, patient safety, compliance, organizational learning, and strategic resource allocation while retaining the ethical principle that prevention of harm cannot be reduced to a financial calculation.

Acknowledgements:

The author acknowledges healthcare quality, patient safety, clinical, operational, and management professionals whose practical experience has informed continuing reflection on integrated performance management.

Conflict of Interest:

The author declares no conflict of interest in relation to this conceptual paper.

Funding:

No external funding was received for the development of this conceptual paper.

Ethical Considerations:

This manuscript presents a conceptual framework and does not report research involving human participants, patient-level data, or identifiable institutional data. Any future empirical validation using patient, staff, or institutional data should obtain the approvals required by the applicable ethics and governance framework.

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