

Organizational Readiness for Quality 5.0: A Framework for Assessing Human-Centric Quality Transformation

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Abstract:

Quality 4.0 has advanced the digitalization of quality management through automation, analytics, and connected technologies. However, organizations consistently struggle with readiness factors including workforce capability, governance, and cross-functional integration, limiting realized value. Advances in artificial intelligence (AI) further amplify socio-technical complexity by increasing dependence on algorithmic decision-making and intensifying risks related to accountability, trust, and transparency. Quality 5.0 is an emerging paradigm that extends quality management beyond digital efficiency toward human-centricity, sustainability, and resilience—aligned with Industry 5.0 principles and the recognition that technology should augment, not replace, human judgment. This paper reframes Quality 5.0 adoption as an organizational readiness problem rather than a purely technological deployment challenge. Drawing on a structured synthesis of Quality 4.0 readiness literature and emerging Quality 5.0 studies, a five-dimensional conceptual organizational readiness model is proposed, encompassing: human-centric system integration, AI governance and accountability, workforce capability and change readiness, sustainability alignment, and organizational trust. A phased implementation roadmap with associated validation methodology is presented to support responsible sequencing of Quality 5.0 initiatives in AI-enabled industrial environments. The model is conceptual in nature and is intended as a diagnostic framework pending empirical validation through future research.

Keywords: Quality 4.0, Quality 5.0, organizational readiness, artificial intelligence, human-centric quality management, Industry 5.0, AI governance, sustainability, conceptual framework.

I. INTRODUCTION

Industrial organizations are increasingly digitalized, yet operational performance gains from Quality 4.0 remain inconsistent. Quality 4.0 integrates digital technologies—automation, analytics, and cyber-physical systems—into quality management to enhance planning, assurance, and control [1]. Despite increasing adoption, systematic reviews indicate that many organizations fail to achieve expected benefits due to organizational readiness deficiencies, including gaps in skills, leadership alignment, governance structures, and value chain integration [2]–[4].

Quality 5.0 represents an emerging paradigm shift that moves beyond the technology-centric focus of Quality 4.0. Where Quality 4.0 asked "how do we digitize quality processes?", Quality 5.0 asks "how do we ensure those digitized systems serve human values, sustainability goals, and organizational resilience?" It is grounded in Industry 5.0 principles—the European Commission's framework emphasizing that industry must become human-centric, sustainable, and resilient rather than solely efficient and automated [7]. In practice, this means quality professionals retain meaningful decision authority, AI systems are governed with accountability frameworks, workforce capabilities are developed alongside technology deployment, and sustainability objectives are embedded into quality key performance indicators (KPIs).

The rapid diffusion of AI into industrial quality contexts amplifies organizational challenges by increasing reliance on opaque, data-driven decision processes that traditional quality governance structures were not

designed to manage [5], [6]. This paper addresses the critical gap between technological capability and organizational preparedness for Quality 5.0 adoption. Our contributions include: (1) a five-dimensional conceptual readiness model grounded in Quality 4.0 empirical evidence and Industry 5.0 principles; (2) a phased implementation roadmap with actionable metrics; and (3) a structured validation methodology for assessing organizational preparedness.

II. PROBLEM STATEMENT

A. Quality 4.0 Readiness Barriers

Research on Quality 4.0 identifies multiple barrier categories constraining successful adoption. Systematic reviews and large-scale empirical studies highlight technological, organizational, workforce, data-related, and economic barriers, with organizational and workforce factors frequently outweighing technological limitations [1]–[4], [10].

Adoption studies demonstrate that quality professionals' self-efficacy, role clarity, and perceived organizational support significantly influence Quality 4.0 uptake, even in digitally mature environments [2]. A study of 192 decision-makers found that innovation capacity and attitudes toward change significantly predict Industry 5.0 readiness, with psychosocial safety climate indirectly influencing readiness through those attitudes [11].

B. Emerging Quality 5.0 Paradigm

Quality 5.0 literature frames a paradigm shift toward proactive, human-centric, and sustainability-oriented quality management, often proposing technical solutions such as predictive quality control and advanced analytics [8], [9]. However, this body of work remains largely conceptual or method-focused, providing limited guidance on assessing organizational readiness for transition.

Empirical evidence demonstrates potential benefits when organizational conditions adequately support advanced quality systems. Human-centric manufacturing implementations incorporating AI-powered execution systems, extended reality (XR) training, and collaborative robotics achieved a 22% reduction in downtime, a 14% improvement in scheduling accuracy, and a doubling of employee-driven innovations [7]. A clear research gap exists in operationalizing organizational preparedness for the socio-technical, governance, and trust challenges introduced by AI-enabled Quality 5.0 systems.

TABLE I. COMPARISON OF QUALITY 4.0 AND QUALITY 5.0 PARADIGMS

Dimension	Quality 4.0	Quality 5.0
Primary Focus	Technology-driven digitalization of quality processes	Human-centric, sustainable quality transformation
Decision-Making	Automated, algorithm-driven decisions	Human-in-the-loop with AI augmentation
Key Enablers	IoT, Big Data, Cloud computing, Advanced Analytics	AI + Human collaboration, resilience systems, socio-technical design
Workforce Role	Operator and monitor of digital quality tools	Co-designer, decision authority, and oversight provider
Sustainability	Incidental benefit of efficiency gains	Core strategic objective integrated into quality KPIs
Governance Model	Traditional QMS and ISO-based structures	AI accountability frameworks (RACI, NIST AI RMF, OECD Principles)
Trust Mechanism	Implied by system reliability and certification	Actively managed via explainability, TEVV protocols, and feedback loops
Readiness Req.	Technical infrastructure and data integration	Organizational, governance, workforce, and human readiness

Source: Author synthesis from Quality 4.0 readiness literature and Industry 5.0 principles [1]–[9]

III. SOLUTION: QUALITY 5.0 ORGANIZATIONAL READINESS MODEL

A. Model Development

To address the identified gaps, a conceptual organizational readiness model for Quality 5.0 is proposed. The model synthesizes: (i) Quality 4.0 readiness and critical success factor research; (ii) Industry 5.0 principles of human-centricity, sustainability, and resilience; and (iii) emerging insights on AI governance and trustworthiness [1]–[9]. This model is explicitly conceptual in nature, functioning as a diagnostic assessment framework pending empirical validation through future studies.

Rather than prescribing specific technologies, the model identifies the organizational conditions that must be established to support responsible transition. The model's five dimensions are interdependent: weakness in any single dimension constrains overall readiness regardless of strength in others. Figure 1 illustrates the model and the relationships between dimensions.



Fig. 1. *Quality 5.0 Organizational Readiness Model: Five interdependent dimensions supporting successful Quality 5.0 implementation. The dashed outer ring indicates that all five dimensions are mutually reinforcing.*

B. Five Readiness Dimensions

The five dimensions are summarized in Table II, followed by detailed descriptions of each.

TABLE II. QUALITY 5.0 READINESS DIMENSIONS, DESCRIPTIONS, AND ASSESSMENT METRICS

Dimension	Description	Assessment Metrics
Human-Centric System Integration	Ensures meaningful human authority over AI-assisted quality decisions, with defined oversight and escalation mechanisms	% critical decisions with human-in-the-loop; operator intervention rate; human override frequency
AI Governance & Accountability	Explicit ownership, RACI documentation, model cards, and audit trails aligned with NIST AI RMF and OECD Principles	% AI models with governance artifacts; audit nonconformance rate; governance board meeting cadence
Workforce Capability & Change Readiness	Skills, training, self-efficacy, and role clarity enabling responsible adoption of advanced quality technologies	% staff meeting competency targets; employee resilience index; training completion rate
Sustainability Alignment	Integration of UNSDG-linked KPIs and lifecycle thinking into quality priorities and trade-off decisions	Energy per unit output; % projects addressing UNSDGs; eco-efficiency improvement rate
Organizational Trust & Transparency	Explainability summaries, TEVV protocols, and feedback mechanisms sustaining confidence in AI-supported quality outcomes	TEVV coverage rate; transparency satisfaction scores; incident/rollback rate

Source: Author synthesis

1) Human-Centric System Integration: This dimension establishes clear human authority, oversight, and escalation mechanisms in AI-assisted quality decisions. Critical decisions require human-in-the-loop configurations that ensure meaningful human control over automated quality processes. This operationalizes the fundamental Industry 5.0 principle that technology should augment—rather than replace—human judgment in complex quality scenarios.

2) AI Governance and Accountability: This dimension requires explicit ownership, governance routines, and accountability mechanisms for AI-enabled quality processes, including RACI documentation, model cards, and audit trail templates aligned with the NIST AI Risk Management Framework and OECD AI Principles [5], [6]. Without clear governance, AI systems become organizational black boxes that erode quality assurance credibility.

3) Workforce Capability and Change Readiness: This dimension addresses skills, training, self-efficacy, and role clarity enabling responsible adoption of advanced quality technologies. A structural equation modeling (SEM) study (n = 301) demonstrated that employee resilience and system integration positively affect data quality and digital transformation success, with resilience mediating integration effects [13]. Technology adoption consistently fails when workforce capabilities and psychological readiness lag behind technical deployment.

4) Sustainability Alignment: This dimension integrates environmental and societal objectives into quality priorities and trade-off decisions. Cross-industry analyses report that Six Sigma, Lean, PDCA, and Root Cause Analysis most frequently advance UN Sustainable Development Goals—particularly Goals 9, 12, and 13—with demonstrated improvements in defect reduction, energy efficiency, and cost management [14]. Quality

5.0 requires that quality excellence and sustainability be pursued as integrated rather than competing objectives.

5) Organizational Trust and Transparency: This dimension operationalizes explainability, stakeholder confidence, and feedback mechanisms supporting trust in AI-supported quality outcomes. It includes Test, Evaluation, Verification, and Validation (TEVV) protocols that ensure algorithmic transparency. Without robust trust mechanisms, quality professionals may circumvent or resist AI-enabled systems regardless of technical performance.

IV. USES: IMPLEMENTATION ROADMAP AND ASSESSMENT METHODOLOGY

A. Phased Implementation Roadmap

Operationalizing the five readiness dimensions requires a phased, evidence-based approach. Table III presents a seven-phase implementation roadmap aligned with the NIST AI Risk Management Framework and OECD AI Principles [5], [6]. Phases are designed with intentional overlap to enable parallel workstreams while maintaining logical dependencies. Organizations should adapt phase sequencing to their specific context, existing maturity levels, and resource constraints.

TABLE III. QUALITY 5.0 IMPLEMENTATION PHASES, ACTIVITIES, AND METRICS

Phase	Timeline	Key Activities	Deliverables & Metrics
Phase 0	Weeks 0–4	Catalogue AI use cases, map stakeholders, assess current controls	Readiness heatmap, AI system inventory, risk register. Metric: % AI cases with documented owner
Phase 1	Weeks 5–10	Establish AI Quality Oversight Board, codify governance policies	RACI charts, model cards, audit trail templates. Metric: % models with governance artifacts
Phase 2	Weeks 8–16	Redesign workflows for meaningful human control, pilot human-robot collaboration	Updated SOPs, revised risk controls. Metric: % critical decisions with human-in-the-loop
Phase 3	Weeks 8–20	Create skills framework, deploy reskilling programs, embed communities of practice	Competency matrices, change readiness dashboard. Metric: % staff meeting competency targets
Phase 4	Weeks 10–22	Embed UNSDG-linked KPIs, apply Lean/Six Sigma for eco-efficiency, integrate lifecycle thinking	Sustainability quality scorecard, LCA templates. Metric: Energy per unit output
Phase 5	Weeks 12–26	Implement predictive quality pipelines, AI-assisted FMEA	Real-time dashboards, data quality SLAs. Metric: Defect ppm, time-to-root-cause
Phase 6	Weeks 14–28	Operationalize TEVV, publish explainability summaries, create feedback loops	TEVV protocol library, quarterly trust reports. Metric: TEVV coverage, transparency satisfaction scores
Phase 7	Weeks 20–36	Integrate with enterprise excellence frameworks, institutionalize continuous improvement	EFQM-aligned maturity model, annual stakeholder value report. Metric: Maturity level gains

Source: Author synthesis aligned with NIST AI RMF [5] and OECD AI Principles [6]

Phase 0 (Diagnostic Baseline) establishes the foundation by cataloguing AI use cases and documenting existing governance status. Phases 1 through 3 address governance, human-centric integration, and workforce capability in parallel, as these are foundational preconditions for responsible AI deployment. Phase 4 embeds sustainability alignment before Phase 5 deploys predictive quality pipelines, ensuring environmental objectives are built into quality systems from inception. Phase 6 operationalizes trust through TEVV protocols, and Phase 7 integrates all dimensions into enterprise excellence framework for sustained continuous improvement.

B. Readiness Assessment Methodology

Consistent with prior readiness and maturity assessment methodologies [2], [3], the proposed model functions as a diagnostic tool rather than a predictive performance measure. A structured assessment methodology combining quantitative metrics and qualitative evaluation is proposed, built around the following protocol:

1. Multi-stakeholder panel formation: Assemble 5–8 cross-functional experts representing quality management, IT/data science, operations, HR/training, and sustainability functions.
2. Evidence-based scoring: Each dimension is evaluated on a 5-point maturity scale (1=Ad hoc, 2=Developing, 3=Defined, 4=Managed, 5=Optimizing) using structured prompts and documentary evidence requirements.
3. Artifact documentation: Assessors provide documentary evidence (policies, training records, governance charters, audit reports) supporting each score.
4. Gap analysis workshop: The panel convenes to review scores, resolve discrepancies, and identify critical gaps requiring immediate attention.
5. Risk prioritization: Identified gaps are mapped to implementation phases and prioritized by their potential impact on Quality 5.0 adoption success.

Assessment outputs include: a readiness heatmap identifying dimension-specific strengths and gaps; an AI system inventory with ownership and governance documentation status; a risk register for high-priority transition risks with mitigation recommendations; and a customized action roadmap sequencing phases based on organizational context.

C. Validation Strategy

The readiness model requires multi-stage validation to establish reliability, validity, and practical utility. The proposed validation roadmap encompasses four types of validity assessment:

Content Validity: Expert panel review by 10–15 quality management academics and industry practitioners to evaluate dimension comprehensiveness, clarity, and relevance. Refinement is based on qualitative feedback and Content Validity Index (CVI) calculation, targeting $CVI > 0.80$ for each dimension.

Construct Validity: Pilot assessment in 8–12 organizations across diverse sectors (automotive, aerospace, electronics, pharmaceuticals) to examine dimensional independence through factor analysis and correlation analysis. Expected moderate positive correlations ($r = 0.3–0.6$) would indicate interdependence without redundancy.

Criterion Validity: Longitudinal tracking of 15–20 organizations implementing Quality 5.0 initiatives to examine whether baseline readiness scores predict adoption outcomes at 6, 12, and 18 months. Success metrics include percentage of planned AI quality use cases deployed, stakeholder satisfaction scores, realized quality performance improvements, and incident/rollback rates.

Inter-rater Reliability: Multiple assessors independently score the same organization to calculate Cohen's kappa or intraclass correlation coefficient (ICC), targeting $ICC > 0.75$, indicating substantial agreement.

This validation roadmap will require 18–24 months to complete and will be reported in subsequent publications as empirical data becomes available.

V. IMPACT: THEORETICAL CONTRIBUTIONS AND PERFORMANCE EVIDENCE

A. Theoretical Contributions

This work extends Quality 4.0 readiness research by explicitly addressing AI governance, human-centricity, and sustainability dimensions required for Quality 5.0 transition. Unlike technology-centric Quality 5.0 proposals, the proposed model emphasizes organizational preconditions for responsible adoption. The model bridges Industry 5.0 conceptual frameworks and operational quality management practice, providing an actionable translation of broad principles into assessable organizational capabilities.

The five-dimensional model addresses a distinctive gap in existing literature: whereas Quality 4.0 research primarily examines barriers to technology adoption, and Quality 5.0 literature proposes new technical architectures, neither body of work provides a structured organizational readiness framework that integrates governance, human oversight, and sustainability into a unified assessment instrument. This paper addresses that gap directly.

B. Practical Implications

The phased roadmap provides actionable guidance for quality managers and organizational leaders planning Quality 5.0 initiatives. By identifying readiness gaps prior to technology deployment, organizations can mitigate common adoption failures and align investments with organizational capacity. Specifically, the model supports: (1) pre-investment feasibility assessment; (2) identification of capability development priorities; (3) vendor selection by matching solution requirements to organizational readiness; and (4) change management planning anchored in specific readiness gaps.

The framework is applicable across manufacturing and industrial sectors and adaptable to adjacent domains including healthcare quality management, financial services compliance, and supply chain quality assurance—wherever AI-assisted decision systems require structured human oversight and accountability.

C. Documented Performance Evidence from Quality 5.0-Aligned Implementations

Available empirical evidence demonstrates meaningful performance improvements when organizational conditions align with Quality 5.0 principles. Table IV summarizes documented outcomes from implementations exhibiting characteristics consistent with the proposed readiness dimensions [7], [12]. These outcomes span quality, efficiency, and sustainability metrics, confirming that human-centric, AI-governed approaches deliver multi-dimensional value.

TABLE IV. DOCUMENTED PERFORMANCE OUTCOMES FROM QUALITY 5.0-ALIGNED IMPLEMENTATIONS

Implementation Context	Performance Metric	Baseline	Outcome	Ref.
Human-centric manufacturing with AI-MES, XR training, and collaborative robotics	Unplanned downtime	Baseline	22% reduction	[7]
Human-centric manufacturing with AI-MES, XR training, and collaborative robotics	Scheduling accuracy	Baseline	14% improvement	[7]
Human-centric manufacturing with AI-MES, XR training, and collaborative robotics	Employee-driven innovations	Baseline	2× increase	[7]
EFQM model pathway to net zero — European automotive plant	CO ₂ emissions	Baseline	17% reduction	[12]

EFQM model pathway to net zero — European automotive plant	Water usage	Baseline	9.3% decrease	[12]
EFQM model pathway to net zero — European automotive plant	Recycling rate	93.3%	98.1%	[12]

Source: Compiled from empirical studies cited in this paper [7] and [12]

VI. SCOPE: LIMITATIONS, BOUNDARY CONDITIONS, AND FUTURE RESEARCH

A. Limitations and Boundary Conditions

Several important limitations constrain interpretation and application of this work. The proposed model is conceptual and synthesized from literature; it has not yet been empirically validated through systematic assessment across organizations. Dimensions may require refinement, additional sub-factors, or sector-specific adaptations based on validation studies.

Cross-sectoral generalizability remains unknown. The model assumes reasonable applicability across manufacturing and industrial sectors; however, regulatory environments (e.g., FDA-regulated pharmaceuticals versus commercial electronics), technological maturity levels, and organizational cultures vary substantially. Sector-specific weighting or additional dimensions may be necessary.

Additionally, the seven-phase roadmap presents an idealized sequence. Real-world implementations face resource constraints, competing priorities, and organizational disruptions that may necessitate iterative cycles or phase replanning. Small and medium enterprises may lack resources for comprehensive phased implementation, requiring scaled-down adaptations.

B. Future Research Directions

- Empirical validation across diverse sectors to refine dimensions and establish psychometric properties
- Development of quantitative measurement instruments for each readiness dimension
- Longitudinal studies examining readiness-outcome relationships at 6, 12, and 18 months
- Sector-specific adaptations (automotive, aerospace, pharmaceuticals, food safety)
- Integration with existing maturity models (CMMI, EFQM, ISO 9004)
- Investigation of readiness evolution dynamics during active Quality 5.0 transitions
- Comparative analysis of assessment-driven versus technology-driven implementation approaches

VII. CONCLUSION

As AI increasingly shapes quality decision-making, the transition from Quality 4.0 to Quality 5.0 cannot be treated as purely technological progression. The literature consistently indicates that organizational readiness, particularly in governance, workforce capability, and trust—plays a decisive role in determining whether advanced quality systems enhance or undermine operational performance.

The proposed five-dimensional conceptual readiness model provides a structured basis for assessing organizational preparedness and mitigating transition risks. By addressing human-centric integration, AI governance, workforce capability, sustainability alignment, and organizational trust before scaling AI-enabled quality systems, organizations can pursue Quality 5.0 transformation more responsibly and effectively. Future empirical validation will further refine the model's dimensions, measurement instruments, and predictive validity.

This research contributes to the emerging Quality 5.0 discourse by shifting focus from "what technologies to deploy" to "what organizational conditions must exist" for responsible, AI-enabled quality transformation.

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