

A Prospective Macroergonomic Framework to Mitigate Deskilling and Cognitive Load in Advanced-AI Services

Aldi Adi Pratama^{1*}

¹Department of Interdisciplinary Engineering, Faculty of Engineering, Universitas Indonesia

*Corresponding author: aldi.adi@ui.ac.id

ABSTRACT

Advanced artificial intelligence (AI) may reshape knowledge-intensive service work by increasing reliance on automated judgment and the demand to verify AI-generated outputs. This prospective conceptual study examines potential risks of cognitive deskilling and verification-related cognitive load without assuming that artificial superintelligence (ASI) currently exists. Using Macroergonomic Analysis and Design (MEAD), Sociotechnical Systems Theory, and a structured narrative synthesis of selected scholarly and policy documents from the International Labour Organization, the International Organization for Standardization, and the World Economic Forum, the study proposes a Macroergonomic Work System Design (MWSD) framework. The framework connects organizational governance (performance indicators and human accountability), interface design (calibrated friction and uncertainty cues), and operational practices (unassisted reasoning exercises and fatigue management). An intervention crosswalk identifies potential risk mechanisms, hypothesized outcomes, and candidate indicators for future evaluation. These interventions remain design propositions rather than empirically demonstrated solutions; suggested operating thresholds are illustrative and require context-specific calibration. Further studies should assess feasibility, unintended workload effects, and performance outcomes across knowledge-intensive service settings.

Keywords: Cognitive Deskilling; Friction by Design; Macroergonomic Work System Design (MWSD); Sociotechnical Systems; Advanced AI.

1. Introduction

Advances in artificial intelligence (AI) are extending automation beyond routine tasks into analytical and decision-support activities. These developments may reshape employment and, in some settings, contribute to social and economic tensions associated with unequal access to technological benefits (Jacobs, 2024). Knowledge-intensive service occupations increasingly encounter AI systems capable of rapidly synthesizing large volumes of information, although their performance varies by task and context. Artificial superintelligence (ASI) denotes a hypothetical class of AI whose capabilities would surpass human performance across a broad range of cognitive domains (Ueda et al., 2026). Fully realized ASI has not been empirically observed; existing large language models and other AI systems remain more limited and fallible. Accordingly, this article examines advanced AI using current deployment-related literature and treats ASI as a prospective scenario, not an observed workplace condition.

Two potential risks for professionals are cognitive deskilling and increased cognitive workload. Cognitive deskilling describes a possible decline in independent reasoning and analytical proficiency when problem-solving tasks are repeatedly delegated to automated systems. Prolonged reliance on external assistance without sustained cognitive practice may weaken some forms of task-specific judgment, although the effect depends on the system and work context (El Tarhouny & Farghaly, 2026). Cognitive workload refers to mental resources required to perform tasks, including the effort needed to assess uncertain or complex outputs. Fluctuations and sudden peaks in workload may be associated with performance deterioration, even where average workload is manageable (Knisely et al., 2021). These risks should not be assumed to arise universally: AI may also augment human capabilities under appropriate conditions.

Existing human-in-the-loop and human-centred AI approaches often emphasize governance, interface design, or individual work practices. This article considers how these dimensions can be organized within an integrated work-system perspective. Its guiding question is: How can macroergonomic and sociotechnical principles inform multi-level design interventions intended to mitigate cognitive deskilling and verification-related workload in knowledge-intensive services using advanced AI? The study proposes a conceptual Macroergonomic Work System Design (MWSD) framework informed by Sociotechnical Systems Theory and selected documents from the International Labour Organization (ILO), International Organization for Standardization (ISO), and World Economic Forum (WEF). The framework links organizational governance, technology interfaces, and personnel practices; its effectiveness remains a hypothesis for future testing.

2. Methods

This prospective conceptual study does not report field implementation or empirical effectiveness testing. It applies a descriptive-analytical qualitative approach using a structured narrative review of selected scholarly literature and policy documents. The synthesis is informed by Macroergonomic Analysis and Design (MEAD) and Sociotechnical Systems Theory. MEAD uses a systems-oriented, top-down perspective to examine relationships among people, technology, work organization, and work environments in designing interventions (Ma'ruf et al., 2026). The present review is not presented as an exhaustive systematic review or meta-analysis; the cited documents provide conceptual and policy context rather than a representative sample of workplace outcomes.

Sociotechnical Systems Theory emphasizes joint consideration of the social subsystem (people, capabilities, and organizational values) and the technical subsystem (tools, technologies, and work processes). It supports coordinated redesign rather than optimizing technical performance independently of human work (Ang et al., 2025). For clarity, this manuscript organizes its conceptual synthesis in three steps: identifying plausible risks discussed in the cited literature; mapping them to macro-, meso-, and micro-level design interventions; and proposing candidate indicators that could be examined in future empirical studies. These steps describe the analytical organization of the proposed framework, not a validated causal model or a formal systematic-search protocol.

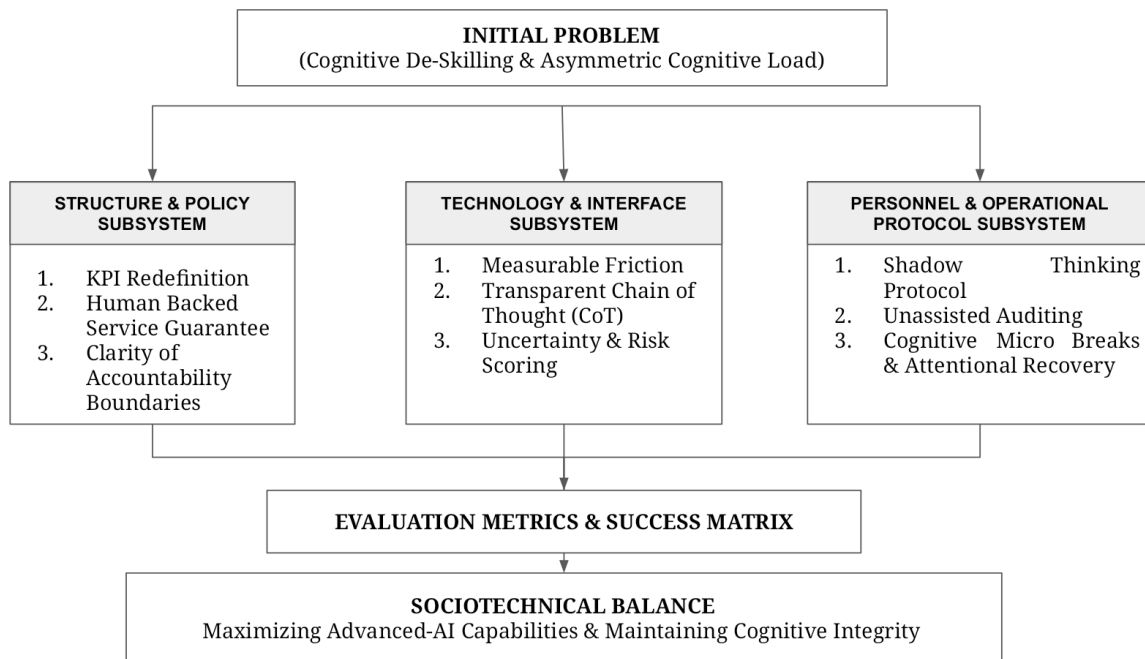


Figure 1. Conceptual architecture of the proposed framework: from problem identification to sociotechnical balance.

The proposed conceptual framework is organized around the following components:

a. Problem Statement & Point of Departure

The research originates from a plausible risk scenario, extrapolated from current AI literature, in which increasingly capable systems may erode the critical thinking acuity of professional staff while also imposing a substantial verification burden.

b. Solution Pillars (The Three Key Subsystems)

- Structure and Policy (Macro Level) : Restructuring organizational performance evaluation frameworks and explicitly delimiting the boundaries of human professional accountability within the work system.
- Technology and Interface (Meso Level) : Designing digital systems to preclude passive human over-reliance, instead actively stimulating cognitive engagement prior to decision execution.
- Personnel and Operations (Micro Level) : Sustaining staff mental acuity through periodic independent reasoning exercises and enforcing disciplined cognitive recovery intervals.

c. Ultimate Goal (Sociotechnical Equilibrium). In future applications, candidate indicators could be used to evaluate whether these interventions support a balanced human–AI work system while preserving human cognitive autonomy. Logical reasoning and critical thinking remain important for identifying misleading information, assessing potential bias, and exercising professional judgment (Bolang et al., 2026).

Comparative analysis draws upon working documents from the International Labour Organization (ILO), particularly the report *Generative AI and Jobs: A Global Analysis of Potential Effects on Job Quantity and Quality* (Gmyrek et al., 2023). Read alongside international ergonomics standards for work system design (ISO, 2016), these documents suggest that the cognitive disruption anticipated from advanced AI may differ markedly from previous waves of automation.

- a. International Labour Organization (ILO)
ILO working paper on generative AI and jobs (Gmyrek et al., 2023)
- b. International standards and professional guidance
Standards on ergonomic principles for work systems and human-centred design published by the International Organization for Standardization (ISO, 2016, 2019)
- c. World Economic Forum (WEF)
The Future of Jobs Report regarding skill reprioritization dynamics (reskilling) across global industries (World Economic Forum, 2025).

These documents subsequently serve as foundational references for formulating macroergonomic interventions in service work systems with advanced AI to mitigate staff deskilling and cognitive load. Macroergonomics is a subdiscipline of ergonomics utilizing a sociotechnical approach that views work systems comprehensively and holistically, encompassing the interactions among humans, technology, organizational structures, and social environments. Developed to transcend the limitations of microergonomics which focuses predominantly on physical interactions between individual workers and tools, this approach aims to cultivate work systems that are adaptive, efficient, and supportive of both collective and organizational well-being (Nurrohkayati et al., 2026). The emergence of advanced technologies establishes new cognitive standards within organizations, requiring personnel to master modern skills to operate intelligent devices. To remain relevant and competitive in the digital era, workers may need to reinforce their cognitive capacities, including analytical thinking, creativity, and complex problem-solving, while fostering synergistic collaboration with sophisticated algorithmic systems (Aprilianti et al., 2025).

3. Results and Discussion

3.1. Prospective Analysis of Deskilling and Cognitive Load

Drawing on the ILO discussion of generative AI and work and on ergonomics standards, this section interprets potential differences between earlier mechanical automation and increasingly capable AI systems. The comparison is conceptual rather than empirically measured; statements about an ASI scenario are projections from existing literature, not observed outcomes (Gmyrek et al., 2023; ISO, 2016).

Table 1. Conceptual comparison of mechanical automation and an advanced-AI scenario.

Analytical Dimensions	Mechanical Automation	Advanced AI (Projected ASI Scenario)
Primary Focus of Disruption	Repetitive physical, manual, and administrative tasks.	High-level cognitive synthesis, legal/financial reasoning, and strategic formulation.
Impact on Personnel Behavior	Redefinition of physical workload and operational time efficiency gains.	Susceptibility to automation bias, passive approval (rubber-stamping), and erosion of first-principles thinking.
Nature of Cognitive Risk	Operational monotony and diminished motor activity.	Core expertise atrophy, degradation of critical thinking, and takeover failure.

Analytical Dimensions	Mechanical Automation	Advanced AI (Projected ASI Scenario)
Workload Characteristics	General cognitive workload reduction across routine task lines.	Asymmetric verification workload spikes (alert fatigue and cognitive exhaustion from evaluating complex drafts).
Work Quality Perspective (ILO & ISO)	Optimization of physical ergonomic safety and reduction of repetitive strain injuries (Decent Work).	Preservation of cognitive autonomy, prevention of psychological deskilling, and assurance of human-centered AI governance (Cognitive Ergonomics & Future of Work).

Source: Author-developed conceptual comparison based on Gmyrek et al. (2023) and ISO (2016).

Deskilling may occur when personnel approve AI-generated recommendations without independent assessment. Over time, reduced practice could affect core expertise and compromise the ability to take over when a system fails or encounters an unusual case. Studies of AI use in medicine discuss both potential deskilling and opportunities for upskilling, depending on how systems are deployed and how professionals maintain hands-on competencies (Oetl et al., 2026). Therefore, the proposed pathway is a context-dependent possibility rather than an inevitable consequence of AI adoption.

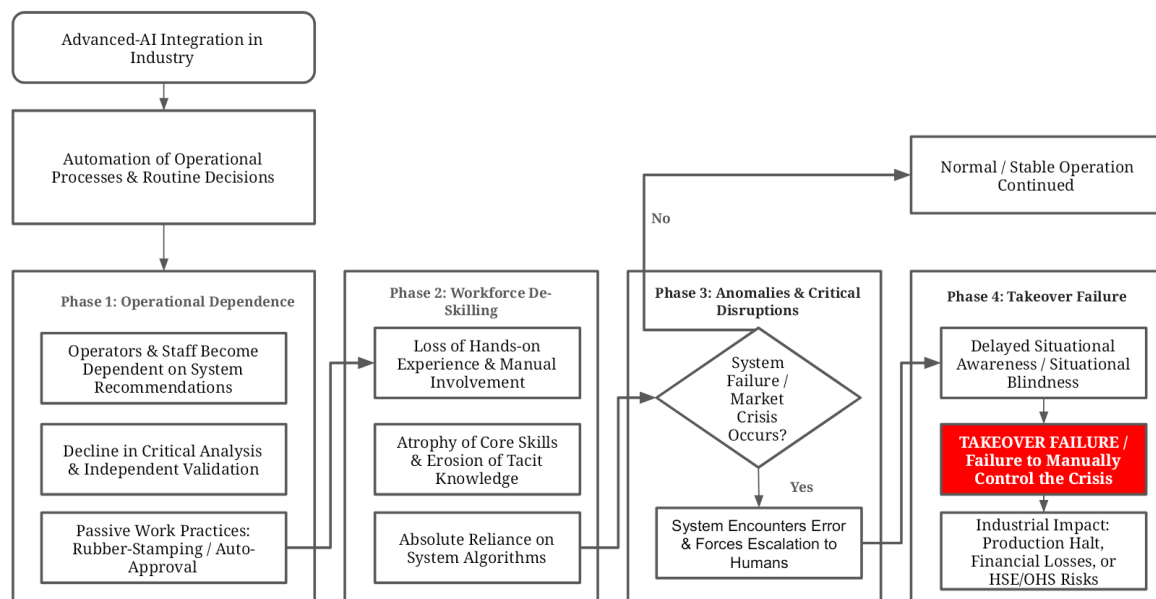


Figure 2. Conceptual pathway from AI dependence to potential deskilling and takeover failure (not empirically validated).

3.2. Proposed Macroergonomic Work System Design Interventions

To address the possible risks of cognitive deskilling and verification-related fatigue in knowledge-intensive service work, the proposed MWSD framework integrates three levels: organizational governance (macro), interface design (meso), and operational practices (micro). Figure 3 illustrates their relationships. The interventions are proposals for later investigation rather than tested controls.

LEVEL 1 Macro-System & Governance (Organizational Structure & Policy)	1.1 Ethical Policy & Social Contract 1. Operational ethical guarantees and protection of staff autonomy 2. Compliance protocols for international standards (ISO 6385, ISO 9241-210)	1.2 Redefining Performance Appraisal 1. Quality of Human Review Depth of ethical & contextual validation 2. Critical Challenge Frequency Frequency of corrections and counter-arguments
LEVEL 2: Meso-System & Interface (Technology & Interface Design)	2.1 Friction-by-Design Mechanism 1. Prevention of auto-approve buttons / zero-click execution 2. Execution block until counter-argument input is fulfilled	2.2 Algorithmic Transparency & Validation 1. Transparent Chain of Thought Tracing AI reasoning paths 2. Uncertainty Scoring System uncertainty indicators / edge cases
LEVEL 3: Micro-System & Operational (Personnel & Work Protocol)	3.1 Staff Cognitive Protocols 1. Shadow-Thinking Protocols Simulating independent thinking prior to viewing AI output 2. Mandatory Synthesis Requirement to synthesize independent summaries	3.2 Mental Fatigue Management (Cognitive Ergonomics) 1. Unassisted Auditing Periodic audits without machine assistance 2. Cognitive Micro Breaks Micro-breaks to mitigate alert fatigue & burnout

Figure 3. Three-level MWSD framework for knowledge-intensive service work with advanced AI.

1) Redefining Key Performance Indicators (KPIs)

Organizational performance measures could extend beyond output volume and speed to include the quality of human review and the frequency of substantive challenges or corrections to AI-generated outputs. These measures are proposed indicators and require clear operational definitions before use.

2) Human Backed Service Guarantee Certification

Organizations could consider requirements for documented human involvement in high-criticality decisions to support transparency and accountability. Research on public acceptance of AI considers systems acting as tools or agents and suggests that perceptions of agency may affect acceptance (Li et al., 2026). However, this literature does not by itself establish that a formal service-guarantee certification would be effective; the proposed mechanism needs contextual justification and testing.

Implementing such a guarantee raises open questions: who bears accountability, how human involvement would be verified, what it would cost, and whether mandatory involvement could conflict with efficiency in low-risk services. The guarantee is therefore proposed as a context-dependent option applied in proportion to task criticality, rather than a universal requirement.

3) Implementation of Friction by Design (Calibrated Resistance)

Friction-by-design is proposed as a way to reduce uncritical, one-click approval of AI-generated outputs in consequential tasks. For example, an interface might ask a reviewer to record a counterargument, identify uncertainty, or provide an independent justification before approval. Any additional steps should be proportionate to task risk, because excessive friction could itself increase cognitive burden or delay service. Whether such measures improve critical engagement should be assessed rather than assumed.

4) Interface Explainability and Uncertainty Scoring

Where technically feasible, interfaces could present interpretable explanations, relevant supporting evidence, explicit limitations, and calibrated uncertainty indicators to support human review. A proposed automatic-execution threshold of 99% is illustrative only; no empirical basis for that particular value is established in this study. Any operational threshold would have to be validated for the task, model, consequence of error, and quality of the confidence estimate. Human escalation should follow the application's actual risk profile rather than a universal confidence cut-off.

5) Shadow Thinking Protocols (Unassisted Reasoning)

Periodic tasks performed without AI assistance could help organizations assess whether workers retain independent reasoning, task proficiency, and readiness to intervene. This remains a proposed preventive and assessment measure.

6) Rotation Schedules and Cognitive Micro Breaks

Structured breaks and work rotation might help manage attention during demanding AI-review tasks. A maximum continuous review period of 90 minutes is offered solely as an illustrative design parameter, not as an empirically validated limit. Evidence concerning micro-breaks in other work contexts, including academic staff, suggests potential benefits for fatigue and attention (Altruisa & Suseno, 2025); transferability to AI oversight needs direct examination. The duration, frequency, and effectiveness of breaks should therefore be evaluated with relevant workload and performance measures.

7) First Line of Defense (Risk Mitigation)

At decisions with substantial consequences, organizations could introduce defined human checkpoints, limit unattended execution, and document the basis for approval. These practices are intended to improve error detection and takeover readiness, but their effectiveness should be evaluated using task-specific error rates, decision quality, and workflow measures.

8) Preservation of Value Added Differentiation (Human Differentiation)

Human–AI task allocation should continue to recognize the value of empathy, ethical judgment, and contextual understanding in service delivery; the extent of human involvement should be assessed against the task and the needs of those affected.

Tables 2A and 2B present complementary parts of the proposed intervention crosswalk. Table 2A maps intervention levels to sociotechnical principles and risk mechanisms; Table 2B summarizes the proposed design actions, hypothesized outcomes, and possible measures for future evaluation. These are analytical propositions, not findings from intervention trials.

Table 2A. Proposed intervention levels, sociotechnical principles, and risks.

No.	Level	Intervention	STS design principle	Risk addressed
1	Macro	Redefined KPIs	Joint optimization (performance measures aligned with human–AI work, not output alone)	Rubber-stamping and automation bias encouraged by speed-only incentives
2	Macro	Human Backed Service Guarantee	Responsible autonomy and clear accountability boundaries	Diffuse accountability; loss of ethical legitimacy
3	Meso	Friction-by-design	Joint optimization at the human–technology interface	Automation bias, rubber-stamping, expertise atrophy
4	Meso	Explainability and uncertainty scoring	Variance control and support for human judgment	Uncritical acceptance; takeover failure; miscalibrated trust

No.	Level	Intervention	STS design principle	Risk addressed
5	Micro	Shadow-thinking protocols	Adaptability and continued skill development of the social subsystem	Core expertise atrophy; reduced takeover readiness
6	Micro	Rotation schedules and micro-breaks	Joint optimization of workload and human capacity	Alert fatigue; cognitive exhaustion from verification spikes
7	Micro/ Meso	Human checkpoints (First Line of Defense)	Variance control at the source	Undetected AI errors, bias, and hallucinations reaching the public domain
8	Cross-level	Human differentiation	Joint optimization (allocation of tasks between human and AI)	Erosion of the human value proposition

Table 2B. Proposed mechanisms, hypothesized outcomes, and candidate validation indicators.

No.	Proposed design mechanism	Hypothesized outcome	Candidate validation indicator	Evidence basis
1	KPI set extended with Quality of Human Review and Critical Challenge Frequency	More active review and less passive approval	Share of reviewed outputs with substantive correction or challenge; review-quality audit scores	Conceptual proposal
2	Minimum threshold of human involvement, applied in proportion to task criticality	Clearer accountability; human retains decision authority	Share of high-criticality decisions with documented human sign-off	Li et al. (2026) on AI acceptance; rest is conceptual proposal
3	No one-click execution; counter-argument and independent synthesis required before approval	Sustained active engagement with AI outputs	Rate of approvals without documented counter-argument; correction rate	Conceptual proposal
4	Visible reasoning paths and confidence scores; automated execution suppressed below a calibrated threshold (99% is illustrative)	Better-calibrated reliance; human handles low-confidence cases	Agreement with AI when it is right versus wrong; successful takeover rate in low-confidence cases	Conceptual proposal
5	Periodic complex cases solved without AI assistance	Maintained task proficiency and takeover readiness	Accuracy on periodic unassisted cases over time	Oettl et al. (2026) and El Tarhouny & Farghaly (2026) on deskilling; intervention is a conceptual proposal
6	Capped evaluation periods (90 min is illustrative) with recovery intervals	Reduced fatigue; sustained vigilance	Self-reported mental workload; error rate across a session	Altruisa & Suseno (2025) on micro-breaks (academic staff); Knisely et al. (2021) on workload
7	Mandatory human checkpoint at critical decisions; limited automated execution authority	Errors caught before external impact	Errors or hallucinations caught before release	Conceptual proposal
8	Empathy, ethical judgment, and contextual understanding kept with human personnel	Preserved service differentiation	Client-rated service quality and perceived empathy	Conceptual proposal

Source: Developed by the author.

3.3. Research Limitations

This research is a prospective, scenario-based conceptual analysis with important limitations. First, the framework is based on a structured narrative review and policy sources rather than a documented exhaustive literature search, primary field observations, experimental testing, or quantitative workload measurement. Its proposed mechanisms, outcomes, and indicators should therefore be understood as hypotheses, not demonstrated causal relationships. Second, its intended setting is knowledge-intensive service work, including legal, financial, and strategic consulting tasks; transferability to

other sectors and routine tasks remains uncertain. Third, fully realized artificial superintelligence has not been empirically observed. The anticipated risks are extrapolated from current AI and related research and may change with technology, organizational practice, and safeguards. Fourth, the proposed interface thresholds, rotation intervals, and human-involvement requirements have not been calibrated and may introduce additional cost, delay, or workload. Subsequent research should investigate feasibility and unintended effects through pilot studies, risk-stratified comparisons, validated workload measures, and longitudinal assessments of independent task performance.

4. Conclusion

This study has proposed a prospective, conceptual framework for mitigating cognitive deskilling and verification-related cognitive load in knowledge-intensive service work as AI systems become more capable and autonomous. Fully realized Artificial Superintelligence (ASI) has not yet been empirically observed; the risks discussed here, namely automation bias, passive approval (rubber-stamping), core expertise atrophy, and takeover failure, are therefore treated as plausible scenarios extrapolated from current AI literature rather than as established effects. Rather than framing advanced AI as a force that necessarily eliminates human cognitive roles, the framework treats it as an opportunity to re-engineer work systems so that human judgment remains active and accountable.

Grounded in the Macroergonomic Analysis and Design (MEAD) approach and Sociotechnical Systems Theory, and informed by relevant ergonomics standards (ISO 6385 and ISO 9241-210), the proposed Macroergonomic Work System Design (MWSD) framework is organized into three tiers. At the macro level, it suggests redefining performance indicators around the Quality of Human Review and Critical Challenge Frequency, and exploring human-backed service guarantees, subject to further analysis of responsibility, verification, and cost. At the meso level, it proposes friction-by-design mechanisms to reduce one-click approvals, together with transparent reasoning pathways and uncertainty indicators to support informed human oversight. At the micro level, it proposes shadow-thinking protocols, unassisted auditing practices, and structured cognitive micro-breaks to help sustain independent reasoning and reduce alert fatigue. Taken together, these measures are intended to support joint optimization between the social and technical subsystems.

The contribution of this study is conceptual: it integrates governance, interface, and operational interventions within a single macroergonomic structure, whereas existing human-in-the-loop and human-centred AI proposals may address these levels separately. Its applicability is bounded by several conditions. The framework is derived from literature and secondary policy analysis, has not been empirically tested, and is intended mainly for knowledge-intensive service domains. Its suitability may also vary with task criticality, organizational context, and the degree of AI autonomy. Future research should therefore evaluate the framework through field studies, simulations, or quantitative workload and performance measurement, test the proposed causal pathways, and examine whether the interventions reduce deskilling and cognitive load without compromising efficiency or service quality. Until such evidence is available, the framework should be regarded as a structured hypothesis and design guide rather than a validated solution.

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