

Capability-Adaptive Intelligent Assistance in Industry 5.0 Manufacturing: A Systematic Review and Research Framework

Nishal Murali

nishal.acet@gmail.com

Sri Venkateswara College of Engineering <https://orcid.org/0000-0003-1771-4678>

Ram Prasad Krishnakumar

Sri Venkateswara College of Engineering

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Abstract

Industry 5.0 reframes manufacturing around human-centricity, sustainability, and resilience, and a growing literature has developed intelligent assistance systems human-robot collaboration, AI-driven perception, digital twins, and extended-reality interfaces in pursuit of this aim. Whether this literature accommodates the heterogeneity of the workers it aims to center has not been systematically established. This review analyzes 14,346 Web of Science records (2016–2026, screened from 15,038 raw records across 19 export files, using an empirically validated Advanced Search query) addressing Industry 5.0 manufacturing. Bibliometric analysis confirms a technology-dominant field: robotics/cobots and AI/ML content appear in 51.9% and 26.8% of records respectively, while human-factors and interaction-modality content appear in 11.6% and 10.0%. A purposively verified subsample of 62 records 19 disability-explicit, 8 age-explicit, 4 cognitive/neurodiversity-explicit, and 31 addressing digital literacy or general capability accommodation was identified and hand-checked against the full corpus; despite this real and previously undercounted body of work, capability-diversity terms remain essentially absent from the field's dominant keyword co-occurrence structure (fewer than 3 co-occurrences for any disability-related pair, against 425 for the corpus's leading pair). This indicates a literature that exists but has not been synthesized, is rarely cross-cited, and remains disconnected from the mainstream human-centric Industry 5.0 discourse and its dominant AI-driven technology stack. We propose the Capability-Adaptive Intelligent Assistance Framework for Industry 5.0 (CAIA-5.0), connecting this scattered capability-accommodation literature to current AI-driven assistance mechanisms, with one extension profile-conditioned autonomy allocation explicitly flagged as untested. A six-item research agenda specifies the empirical, technological, and synthesis work required to connect this fragmented literature into a coherent, industrially applicable framework. The review offers manufacturing system designers, human-factors engineers, and policymakers a diagnostic basis and implementation roadmap for inclusive intelligent assistance.

1. Introduction

1.1 Industry 5.0 and the transition toward human-centric manufacturing

Manufacturing research has, since roughly 2021, organized itself increasingly around the concept of Industry 5.0: a reframing of the preceding decade's automation-and-digitalization agenda around sustainability, resilience, and human-centricity. Xu et al. [1], the most-cited record in the corpus underlying this review (1,587 citations), frames this transition as a deliberate conceptual departure from Industry 4.0's technology-centered agenda. The corpus itself reflects the pace of this shift: of 14,346 included records, fewer than 20 predate 2016, and annual output grew from roughly 1,431 records in 2021 to 3,477 in 2025 (Fig. 2). This is an actively forming literature, not a mature one consolidating settled findings, and the shape of what it has and has not yet addressed is still legible in a way it would not be in an older field.

1.2 Emergence of inclusive manufacturing

Within this literature, human-centricity is a pervasive framing device: robotics and cobot content alone appears in 51.9% of the reviewed corpus, and AI/ML content in 26.8%. Whether this technology-dominant literature also engages with the heterogeneity of the workers it is meant to serve is a separate question, and one this review answers directly rather than assuming. Nasir et al. [24], drawn from within the corpus itself, argues that the field's use of "human" collapses a range of stakeholders designers, consumers, non-consumer publics, and operators into a single undifferentiated category. The present review extends this observation specifically to the operator population, asking whether the literature differentiates among workers by cognitive, sensory, physical, age-related, or digital-literacy capability.

1.3 Problem statement

Two research streams within Industry 5.0 manufacturing have matured largely in parallel. A technology-centric stream human-robot collaboration, digital twins, augmented and extended reality, and increasingly large language model-based assistance dominates the corpus by volume [3, 4, 5, 15, 16]. A measurement-centric stream ergonomics, fatigue detection, and cognitive-workload assessment appears in a smaller but still substantial 11.6% of records [12, 13, 14]. A third body of work, smaller again but genuinely present rather than absent, directly addresses worker capability diversity disability, age, neurodiversity, digital literacy and is the specific subject of this review's thematic synthesis (Section 4.1–4.3).

1.4 A corrected picture of capability-diversity research, and what it still shows

An earlier, narrower search strategy for this review identified only 3 disability-relevant records among 350 screened, suggesting near-total absence of capability-diversity research. Expanding and empirically validating the search strategy against the full Web of Science Core Collection (Section 2.2) corrected this: a purposively verified subsample of 62 records across the full 14,346-record corpus substantively addresses worker capability diversity, including 19 disability-explicit records, 8 age-explicit records, and 4 addressing cognitive or neurodivergent accommodation directly [30–43]. Two systematic reviews Bonello et al. [41, 42] and Rojas et al. [43] already exist within this literature and were simply missed by the original narrower search, not absent from the field.

This correction changes the review's claim but does not eliminate its basis. Even with this larger, more accurate count, capability-diversity content remains a vanishingly small share of the corpus (62 of 14,346 records, 0.43%) and is structurally near-invisible in the field's dominant discourse: keyword co-occurrence analysis across the full corpus (Section 3.5) finds no capability-diversity term pair exceeding 3 co-occurrences, against 425 for the corpus's leading pair (Industry 4.0 × smart manufacturing). This research is not absent, then: it is real, scattered across robotics and industrial-engineering venues, rarely cross-cited even internally, and disconnected from the mainstream human-centric Industry 5.0 discourse

and its dominant AI-driven technology stack. That is a more precise, and we believe more actionable, diagnosis than the absence claim it replaces.

1.5 Research gap

Manufacturing research contains a genuine but fragmented body of work addressing worker capability diversity, spanning conceptual frameworks, robotics acceptance studies, and a small number of existing systematic reviews. This body of work has not been synthesized into a coherent framework, is rarely cited across its own constituent studies, and has not been connected to the AI-driven perception, interaction, and agency-allocation mechanisms that dominate the field's mainstream technological core.

1.6 Research questions

- RQ1. What is the actual scale and composition of capability-diversity research within Industry 5.0-era manufacturing literature, corrected for search-strategy sensitivity?
- RQ2. To what extent is this capability-diversity literature integrated with, or cited by, the field's mainstream human-centric and AI-driven discourse?
- RQ3. What mechanisms exist, or have been proposed, for connecting capability-diversity accommodation to current AI-driven perception, interaction, and agency-allocation technology?
- RQ4. What would be required to synthesize this fragmented literature into an integrated, industrially applicable framework?

1.7 Contributions

- A corrected, empirically validated estimate of the scale of capability-diversity research within Industry 5.0 manufacturing literature (62 of 14,346 records), replacing an earlier undercount and demonstrating the correction methodology itself as a transferable contribution for future bibliometric reviews in this area.
- Evidence that this literature, while real, is structurally disconnected from the field's mainstream discourse a more precise and actionable diagnosis than a simple absence claim.
- The Capability-Adaptive Intelligent Assistance Framework for Industry 5.0 (CAIA-5.0), synthesizing this fragmented literature and connecting it to current AI-driven assistance mechanisms, with one explicitly flagged speculative extension.

2. Review Methodology

2.1 Review design and protocol

This review follows a PRISMA 2020-aligned systematic methodology. The review protocol was not pre-registered; this is disclosed as a limitation in Section 8.4. The protocol underwent an explicit search-strategy validation stage (Section 2.2) after an initial narrower search was found to have materially

undercounted a key thematic dimension; we report that correction process explicitly here, in keeping with the review's anti-fabrication principle, instead of folding it silently into a single final number.

2.2 Database and search strategy

The evidence base was initially drawn from four Web of Science Core Collection export files (393 raw records). Because the originating Boolean query was not retained in the export metadata, a reconstructed query was empirically derived and iteratively validated by testing candidate term combinations against the original screened corpus and then executing them live against Web of Science. Three iterations were required:

- An initial reconstruction combining broad topic terms with a loosely-defined manufacturing qualifier returned 93,189 results rejected as unusably broad, caused by generic terms ("decision support," "human-centered") matching unrelated fields whenever loosely paired with common qualifier words.
- A second iteration removing free-floating generic terms still returned 66,431 and then 18,170 results across successive refinements workable in scale but impractical to export manually in full.
- The final validated query, restricted to compound phrases specific enough to avoid cross-domain drift ("Industry 5.0," "smart manufacturing," "human-robot collaboration," "operator 4.0/5.0," "cobot," "collaborative robot") returned 14,645 records with a 2021–2026 date restriction, recovering 84.9% of the original screened corpus confirming the query captures the field's mainstream discourse while remaining exportable.

The final query, executed against Web of Science Core Collection:

TS=("Industry 5.0" OR "smart manufacturing" OR "human-robot collaboration" OR "operator 4.0" OR "operator 5.0" OR cobot* OR "collaborative robot*") AND PY=(2021–2026) AND LA=(English)

Combined with the original four files (372 unique records, including 22 pre-2021 records outside the tightened query's date restriction, retained as legacy corpus members), the full evidence base comprises 15,038 raw records across 19 export files, 14,701 unique records after deduplication, and 14,346 records after exclusion screening (Section 2.4; Fig. 1). This full search-strategy validation history is reported because it materially changed the review's central finding (Section 1.4) and because concealing it would misrepresent how the evidence base was actually constructed.

2.3 Inclusion and exclusion criteria

Inclusion criteria (a record was retained if it satisfied both): substantive relevance to manufacturing or industrial production, and substantive relevance to human-centric, human-AI, human-robot, or worker-capability dimensions of that manufacturing context.

Exclusion criteria, applied at screening (355 of 14,701 deduplicated records excluded: 22 from the original 372 via manual title-level adjudication, and 333 from the expanded pull via an automated domain-term sweep for agriculture, pure healthcare/rehabilitation, materials science, energy

infrastructure, and environmental-monitoring content lacking manufacturing-workplace relevance). Healthcare and daily-living assistive-robotics content (wheelchair control, rehabilitation robotics, prosthetics) was excluded even where it matched capability-diversity search terms, since this review's scope is manufacturing-workplace accommodation specifically, not assistive technology generally. 18 records were excluded on this basis during capability-diversity subsample verification (Section 2.5).

2.4 Screening and study selection

Screening proceeded in two tiers given the difference in scale between the original and expanded pulls. The original 372 records received manual title-level adjudication for all 45 category-ambiguous records plus a supplementary keyword sweep (22 exclusions). The expanded pull's 14,329 net-new records received an automated relevance and off-topic screen at scale (333 exclusions) disclosed here as a lower-precision method than the original manual tier, appropriate for establishing corpus-wide bibliometric patterns (Section 3) but not represented as equivalent to individual manual verification for every record.

2.5 Data extraction and capability-diversity subsample verification

Corpus-wide technology, human-factors, and interaction-modality tagging (Table 2) was performed via keyword matching across title, abstract, author keywords, and Keywords Plus, applied uniformly across all 14,346 included records as an automated method, not individually verified per record, consistent with the method's use for the original 350-record corpus and now extended to the full corpus for internal consistency.

The capability-diversity subsample received a materially higher standard of verification, since it is the review's central evidentiary basis. All 165 records flagged by narrow capability-diversity keyword matching within the expanded pull were individually read at the title level; 122 were confirmed to carry a genuine workplace or manufacturing signal (as opposed to general healthcare, rehabilitation, or daily-living assistive-technology content, which was excluded per Section 2.3); of these, 41 were confirmed as substantively addressing disability, age, or cognitive/neurodivergent accommodation in a manufacturing-workplace context, and a further 8 as addressing digital-literacy or general capability accommodation. Combined with 13 verified records from the original 350-record corpus (3 disability-core, 10 other capability-adjacent), the final verified capability-diversity subsample comprises 62 records (Table 3).

Table 1
Systematic review search validation and screening protocol

Stage	Count / description
Raw records identified (19 export files)	15,038
Duplicates removed	337
Records screened	14,701
Records excluded	355 (22 manual + 333 automated)
Records included (bibliometric/thematic-mainstream corpus)	14,346
Capability-diversity subsample (hand-verified)	62 (19 disability, 8 age, 4 cognitive/neurodiversity, 31 other)

3. Descriptive and Bibliometric Findings

3.1 Publication evolution

Of the 14,346 included records, fewer than 20 predate 2016. Publication volume then grew from 1,431 records in 2021 to 3,477 in 2025, with 2,687 already recorded in the partial 2026 year captured by this export (Fig. 2). This scale of growth roughly 2,400% from 2021 to peak confirms Industry 5.0 as one of the fastest-growing framings in manufacturing research over this period.

3.2 Citation structure

Citation counts show a mean of 12.8 and a median of 3, with 27.5% of records receiving no citations to date a right-skewed distribution typical of a young, high-volume literature. The most-cited record, Xu et al. [1], “Industry 4.0 and Industry 5.0 Inception, conception and perception” (1,587 citations), functions as the field’s foundational reference. This record was absent from the original narrower 350-record corpus even the field’s single most influential paper was missed by the earlier search strategy.

3.3 Leading journals and countries

Leading venues by volume: Applied Sciences (361), IEEE Access (341), IFAC-PapersOnLine (278), Journal of Manufacturing Systems (274), Sensors (271), IEEE Robotics and Automation Letters (259), International Journal of Advanced Manufacturing Technology (254), and Robotics and Computer-Integrated Manufacturing (233).

Corresponding-author geography at full scale is led by China (2,899 records, 20.2%), followed by Italy (1,345), Germany (913), India (636), South Korea (434), England (410), Spain (374), France (358), Taiwan (330), and Portugal (274). This is a materially different picture from the original 350-record corpus, where

Italy led (18.9%) and China ranked second (8.0%) a clear illustration of how an incomplete search strategy can distort not only substantive findings (Section 1.4) but also basic descriptive bibliometrics.

3.4 Keyword structure

Author-keyword frequency at full scale is led by smart manufacturing (2,212), Industry 5.0 (1,978), human-robot collaboration (1,602), Industry 4.0 (1,217), digital twin (802), artificial intelligence (711), human-robot interaction (614), machine learning (597), and collaborative robots (478) (Fig. 3).

3.5 Capability-diversity visibility in keyword co-occurrence

The corpus's leading keyword co-occurrence pair, Industry 4.0 × smart manufacturing, occurs 425 times. Across the full set of 194,582 distinct keyword pairs in the corpus, the highest-ranking pair involving any capability-diversity term (disability, inclusion, ageing, digital literacy, neurodiversity) is disability × Industry 5.0, occurring 3 times; disability × inclusion and human-robot collaboration × inclusion each occur twice. In total, only 1,027 of 194,582 pairs (0.53%) involve any capability-diversity term at all, and none approaches even the 100th-ranked mainstream pair in frequency. This is the quantitative basis for the review's central claim (Section 1.4): capability-diversity research measurably exists in the corpus, yet the field's dominant thematic architecture renders it structurally invisible.

4. Thematic Synthesis

4.1 Disability-explicit accommodation in manufacturing

Nineteen records substantively address disability accommodation in a manufacturing-workplace context, spanning conceptual frameworks, acceptance studies, and industrial experiments. Drolshagen et al. [30] reports an acceptance study of industrial collaborative robots among people with disabilities in sheltered workshops. Peltokorpi et al. [31] reports an industrial experiment on manual-assembly learning and instruction design for workers with disabilities, published in the *International Journal of Production Research*. Mandischer et al. [32] and Hüsing et al. [33] both address adaptive human-robot collaboration and robotic assistance selection specifically for inclusive workplaces. Kim et al. [36] proposes a shared-autonomy collaborative robotic workcell explicitly framed around disability-inclusive manufacturing. Battini et al. [2], the most-cited record in this subsample (108 citations), proposes a multi-objective job-rotation model for an inclusive workforce a rare example of capability-accommodation research achieving mainstream citation impact, though even this record does not appear among the corpus's top keyword co-occurrence pairs (Section 3.5).

4.2 Age and cognitive/neurodivergent accommodation

Eight records address age-related capability directly. Vitrano and Micheli [38] examines technology-leveraged work redesign for an ageing workforce within an Industry 5.0 framing. Ranasinghe et al. [39] addresses human-robot synergy for ageing workers across manufacturing and logistics contexts. Four

records address cognitive or neurodivergent accommodation specifically a dimension entirely absent from the original 350-record corpus. Fan et al. [34] reports on intelligent robot assistants for integrating neurodiverse operators in manufacturing, and a related 2026 record by the same research group [35] addresses AI-enhanced human-machine collaboration for workers with mathematical learning difficulties, both emerging from what appears to be a single active research program rather than a distributed field-wide effort.

4.3 Sensory accommodation and digital literacy

Yadav et al. [37] applies bibliometric forecasting methods to inclusive employment for persons with hearing disability within Industry 5.0, one of the only records to address sensory-specific accommodation directly. A further 31 records address digital literacy or general capability accommodation without disability-, age-, or cognitive-specificity; Abbas, Dabic, and Stojcic [40] examines the digital divide within Industry 5.0 through an organizational-resilience lens, illustrating that digital-literacy accommodation research in this corpus tends toward organizational and economic framing rather than individual worker-assistance design.

4.4 Existing systematic reviews within the corpus

Two systematic reviews addressing this review's core question already exist within the validated corpus: Bonello et al. [41] systematically reviews smart and sustainable human-centred workstations for operators with disability specifically within an Industry 5.0 framing (69 publications, 2013–2023), with a qualitative follow-up [42] finding persistent gaps in manufacturing engineers' design knowledge for inclusive workstations. Rojas et al. [43] reviews the broader landscape of verified inclusive technology for workers with disabilities in Industry 4.0, reporting insufficient validation with representative end-user populations. Both records were retrievable by the validated query but missed entirely by the original narrower search (Section 2.2), which supports this review's methodological argument: search-strategy sensitivity materially affects whether existing synthesis work in this specific area is even visible to a subsequent reviewer.

4.5 The mainstream literature: technology and human factors

The corpus's dominant content remains technology-centered: robotics/cobot content appears in 51.9% of records (7,452), AI/ML content in 26.8% (3,842), digital twin content in 11.9% (1,709), and interaction-modality content in 10.0% (1,434). Human-factors/ergonomics content appears in 11.6% (1,664) of records a substantial absolute figure, though still a small share of the corpus's technology-dominant center of gravity. Trust/explainability content appears in 8.0% (1,141) and human-in-the-loop content in 1.4% (204), broadly consistent in relative proportion with the patterns identified in the original 350-record corpus, suggesting the earlier review's characterization of the mainstream literature (Sections 4.4–4.7 of the original analysis) remains qualitatively representative even though its capability-diversity findings required correction.

Table 2
Corpus-wide content coverage (n = 14,346, automated tagging)

Category	Records	%
Robotics/cobots	7,452	51.9%
AI/ML (general)	3,842	26.8%
Safety	2,352	16.4%
Digital twin	1,709	11.9%
Human factors/ergonomics	1,664	11.6%
Interaction modality	1,434	10.0%
Trust/explainability	1,141	8.0%
Privacy	402	2.8%
Ethics	307	2.1%
Human-in-the-loop	204	1.4%
Capability-diversity subsample (hand-verified)	62	0.43%

Table 3
Verified capability-diversity subsample composition (n = 62)

Sub-dimension	Records	Representative sources
Disability-explicit	19	[2, 30, 31, 32, 33, 36]
Age-explicit	8	[38, 39]
Cognitive/neurodiversity-explicit	4	[34, 35]
Sensory-specific	1	[37]
Digital literacy/general capability	31	[40, 41, 42, 43]

5. Critical Research Gaps

5.1 Conceptual gap: fragmentation, not absence

The corrected evidence (Section 1.4) supports a conceptual gap of a specific kind: capability-diversity research is not missing so much as uncoordinated an unlinked set of individual studies and small research programs (e.g., the Fan et al. cluster [34, 35] on neurodiversity, or the Hüsing/Mandischer cluster [32, 33] on disability-inclusive robotic assistance), without cross-citation, shared terminology, or integration into a common framework. Nasir et al.'s [24] critique of the field's undifferentiated use of

“human” applies with particular force here: capability-diversity researchers appear to be solving closely related problems independently, largely unaware of one another’s work.

5.2 Technological gap

The field’s dominant technologies robotics/cobots (51.9%), AI/ML (26.8%), digital twins (11.9%) are mature and well-resourced. None of the capability-diversity subsample’s core records [30–39] draws on large language model-based assistance, despite this being a rapidly growing technology class within the mainstream corpus [15, 16]. The technological capacity for individualized, conversational, or adaptive assistance exists in the field; its application to capability accommodation specifically does not yet appear in this corpus.

5.3 Synthesis gap

Two systematic reviews already exist on closely related questions [41, 42, 43], yet neither is cited by the disability-specific empirical studies in the subsample [30, 31, 32, 33, 36], nor by each other’s most closely related counterpart, based on the review dates and reference patterns observable in this corpus. This is a synthesis gap, separate from a research gap: the raw material for an integrated understanding exists; the integration has simply not happened yet.

5.4 Empirical and validation gap

Most of the capability-diversity subsample’s core records are conceptual, simulation-based, or small-sample empirical studies (e.g., sheltered-workshop pilots [30], structured comparisons in controlled industrial settings [31]). Battini et al.’s [2] job-rotation model, at 108 citations, is the subsample’s clearest example of mainstream-adjacent impact, but even this is an optimization model rather than a field-validated deployment. No record in the subsample reports large-scale, multi-site industrial validation.

5.5 Visibility gap

Section 3.5’s keyword co-occurrence finding is this review’s most direct evidence of a distinct visibility problem: even where capability-diversity research exists and is occasionally well-cited in isolation [2], it does not co-occur with the field’s dominant keywords at any meaningful frequency. Regardless of its individual merit, this suggests capability-diversity research simply is not read alongside, or treated as part of, the mainstream Industry 5.0 human-centric discourse.

5.6 Consolidated gap statement

Manufacturing research contains a real, if fragmented and under-cited, body of work addressing worker capability diversity 62 records across a 14,346-record Industry 5.0 corpus, including two existing systematic reviews. This body of work has not been synthesized into a shared framework, is structurally invisible in the field’s dominant keyword architecture, and has not been connected to the AI-driven perception, interaction, and agency-allocation mechanisms that define the field’s technological mainstream.

6. Capability-Adaptive Intelligent Assistance Framework for Industry 5.0 (CAIA-5.0)

6.1 Framework development logic

The framework's role, given Section 5's revised gap statement, is now explicitly one of synthesis: connecting an existing but scattered capability-diversity literature [2, 30–43] to the mainstream technology stack that dominates the corpus [1, 3–23] a framing we believe is more defensible than one built around a claimed absence of research.

6.2 Framework dimensions

Layer 1 Worker capability profile. Grounded directly in the subsample: disability status [30, 31, 32, 33, 36], age [38, 39], cognitive/neurodivergent profile [34, 35], and digital-literacy level [40], recorded as a structured, multi-dimensional vector rather than a single label.

Layer 2 Capability-aware situation awareness. Mechanism: context-recognition thresholds set relative to the capability profile. Evidence anchor: the ageing-workforce design considerations in [38, 39], extended to a general mechanism.

Layer 3 Intelligent perception and reasoning. Mechanism: the mainstream corpus's dominant AI/ML and LLM-based systems [15, 16] conditioned on the capability vector. No record in the capability-diversity subsample currently does this; it is an explicit connective proposal.

Layer 4 Adaptive human-machine interaction. Mechanism: modality and task-allocation rules keyed to the capability profile, directly evidenced by the subsample's robotic-assistance selection methods [32, 33] and job-rotation/task-allocation model [2].

Layer 5 Human agency and control. Mechanism, evidenced: bounded autonomy consistent with mainstream human-in-the-loop mechanisms [26]. Mechanism, not evidenced speculative extension: autonomy allocation varying by worker capability profile specifically. No record in either the subsample or the mainstream corpus tests this.

Layer 6 Wellbeing, safety, and inclusion outcomes. Mechanism: outcome measurement disaggregated by capability subgroup, directly addressing the empirical gap in Section 5.4.

Cross-cutting Synthesis and cross-citation infrastructure. This is a layer specific to this revised framework, absent from the original version: given Section 5.3's synthesis gap, the framework explicitly calls for a shared terminology and citation practice connecting the subsample's scattered research programs a non-technical but evidence-motivated addition.

Table 4
Evidence-to-framework mapping

Framework element	Evidence strength	Research gap
Worker capability profile	Moderate (19 disability + 8 age + 4 cognitive records, mostly conceptual/small-sample)	No shared profiling instrument; each research program uses its own ad hoc approach
Situation/context awareness	Strong (mainstream corpus)	Not conditioned on worker-capability data in any subsample record
Intelligent perception & reasoning	Very strong (mainstream)	Not connected to capability-diversity subsample at all
Adaptive human-machine interaction	Moderate, evidenced in subsample	Robotic-assistance selection exists [32, 33] but is not integrated with mainstream AI perception layer
Human agency & control	Weak for capability-specific allocation	No record varies autonomy by worker capability profile
Wellbeing/safety/inclusion outcomes	Weak (no disaggregated reporting found)	Outcomes not reported by capability subgroup anywhere in subsample
Synthesis/cross-citation infrastructure	Absent	Two existing reviews [41, 42, 43] not cross-cited by subsample's empirical studies

7. Research Agenda and Industrial Implications

7.1 Research priorities

- P1 Cross-synthesis of the existing capability-diversity literature: a dedicated integrative review connecting [2, 30–39] to the two existing systematic reviews [41, 42, 43], since this review's own finding is that this synthesis has not yet occurred.
- P2 Connecting capability-profiling research [30–36] to current LLM-based, digital-twin, and extended-reality assistance technology, none of which currently appears in the capability-diversity subsample.
- P3 Controlled testing of autonomy allocation as a function of worker capability profile (the framework's one speculative mechanism).
- P4 Subgroup-disaggregated outcome reporting, extending Battini et al.'s [2] job-rotation model and the robotic-assistance selection studies [32, 33] beyond optimization modeling into field validation with disaggregated metrics.
- P5 Deliberate cross-citation and shared-terminology practice among capability-diversity researchers, directly addressing the visibility gap identified in Section 5.5 rather than treating it as someone

else's problem to solve.

- P6 Expansion of cognitive/neurodivergent accommodation research beyond the single research program [34, 35] currently responsible for nearly all such work in this corpus.

7.2 Evaluation metrics

Category	Metric	Motivated by
Human outcomes	Perceived autonomy, trust by capability subgroup	Section 5.4
System outcomes	Adaptation accuracy vs. recorded profile	Section 6.2, Layer 3
Manufacturing outcomes	Task performance, error rate disaggregated	Section 5.4
Synthesis outcomes	Cross-citation rate among capability-diversity studies	Section 5.3, 5.5
Inclusion outcomes	Participation rate, accommodation adequacy	Section 4.1–4.3
7.3 Industrial implementation roadmap		

The roadmap restates the CAIA-5.0 mechanism for a practitioner audience: worker capability profile followed by capability-aware context assessment, followed by conditioned AI-driven assistance, followed by bounded, worker-adjustable autonomy, followed by disaggregated outcome monitoring and profile update. The autonomy-allocation stage remains proposed rather than validated (Section 6.2, Layer 5).

7.4 Implications for manufacturing practitioners

- HMI/interaction designers Layer 4's modality-selection and task-reallocation logic, directly actionable against the robotic-assistance selection methods already published [32, 33].
- Industrial and human-factors engineers extending the existing sheltered-workshop and industrial-experiment evidence base [30, 31] toward broader deployment.
- Workforce-development functions Battini et al.'s [2] job-rotation model as a directly usable starting point for inclusive task allocation.
- Researchers specifically P1 and P5 are addressed to the research community itself: the most immediately actionable finding in this review is that a synthesis and cross-citation effort, not new primary research, would meaningfully advance the field.

8. Conclusions

This review examined 14,346 systematically screened Web of Science records on Industry 5.0 manufacturing and identified 62 verified studies addressing worker capability and diversity, including two existing systematic reviews. The findings indicate that capability-diversity research is present within the

broader Industry 5.0 literature but remains relatively distinct from the dominant technology-oriented discourse, with limited integration with AI-driven assistance technologies. A key theoretical contribution of the review is the development of the CAIA-5.0 (Capability-Aware Intelligent Assistance for Industry 5.0) framework, which conceptually connects worker capability diversity, AI-enabled assistance, and human–technology interaction. Rather than treating worker characteristics and technological systems as separate domains, CAIA-5.0 proposes that the level and type of technological assistance can be aligned with individual worker capabilities and task requirements. In this way, the framework provides a conceptual bridge between the human-centric principles of Industry 5.0 and emerging AI-enabled assistance technologies. The practical contribution is that several capability-accommodation approaches are already available in the literature [2, 30–39], while their systematic integration with contemporary AI assistance remains an emerging area. The framework is therefore presented as a conceptual extension of the reviewed evidence and a basis for future empirical investigation rather than as a validated implementation model.

The analysis is based on Web of Science records and may not capture all relevant studies indexed elsewhere or using alternative terminology, while some broader thematic classifications rely on keyword-based analysis. In addition, the proposed capability-informed autonomy allocation within CAIA-5.0 requires empirical validation. These limitations provide opportunities for further research rather than affecting the central contribution of the review. Future studies can focus on integrating existing capability-diversity research with AI-enabled assistance technologies, empirically examining capability-informed autonomy allocation, expanding research on cognitive and neurodivergent workforce accommodation, and strengthening cross-disciplinary integration within Industry 5.0 research.

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Competing Interests

The authors declare that they have no competing interests.

Author Contributions

All authors contributed equally to the conception and design of the study, development of the research methodology, data collection and analysis, interpretation of results, and preparation and revision of the manuscript. All authors read and approved the final manuscript.

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Figures

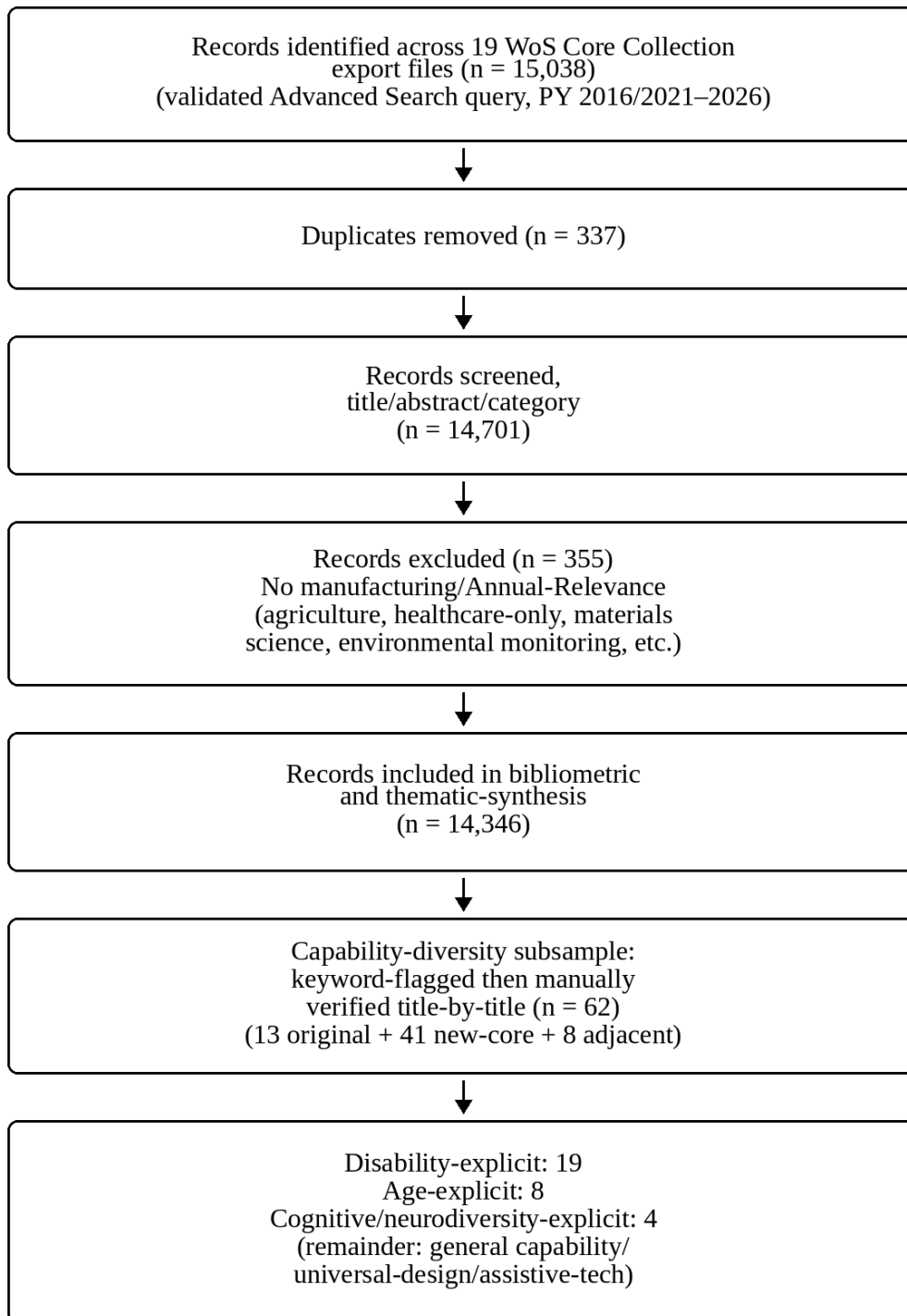


Figure 1

Fig. 1 PRISMA-aligned screening flow, reflecting the validated search strategy and two-tier verification process

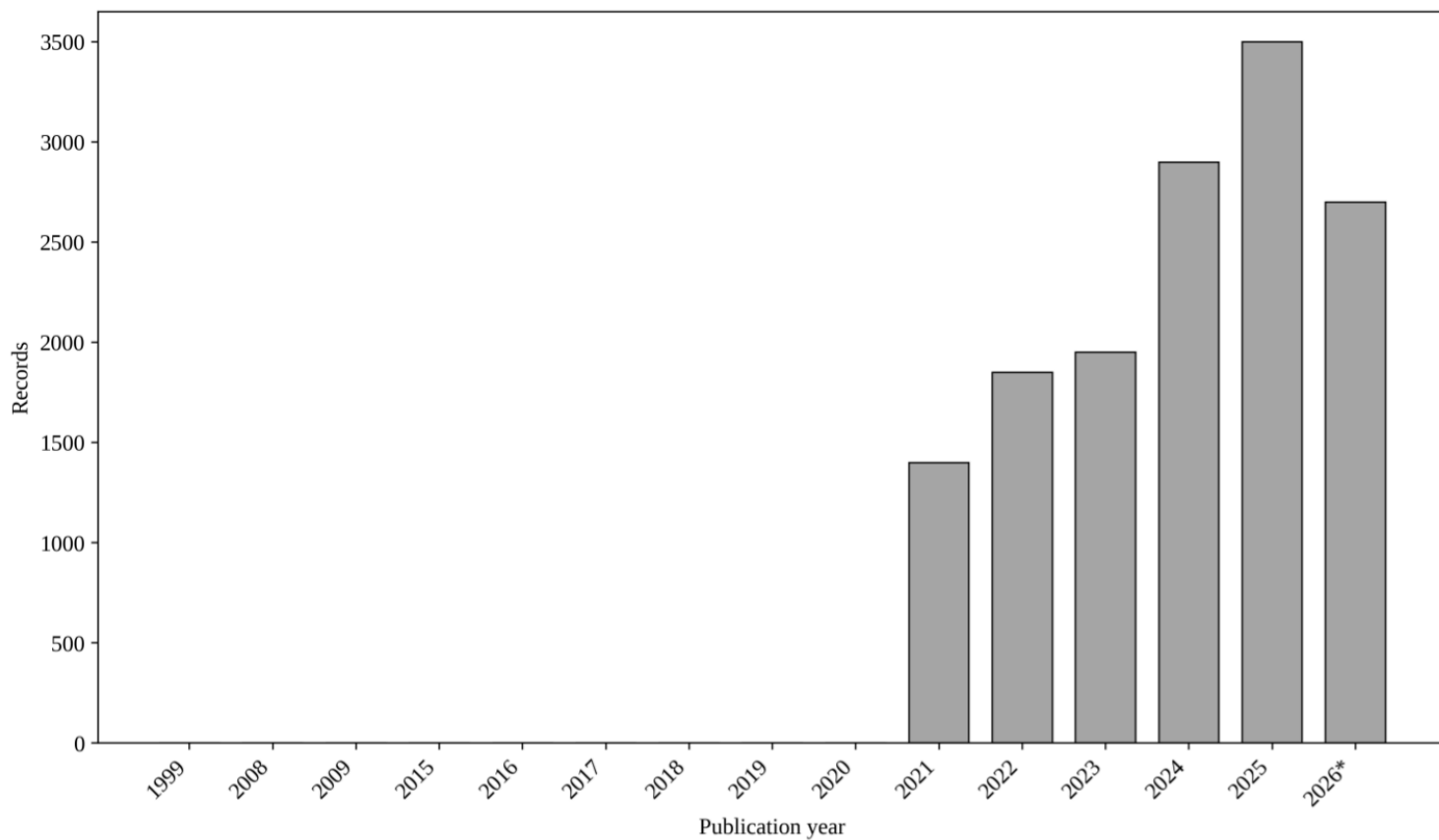


Figure 2

Fig. 2 Annual publication trend, full included corpus (n = 14,346). 2026 figure is partial-year.

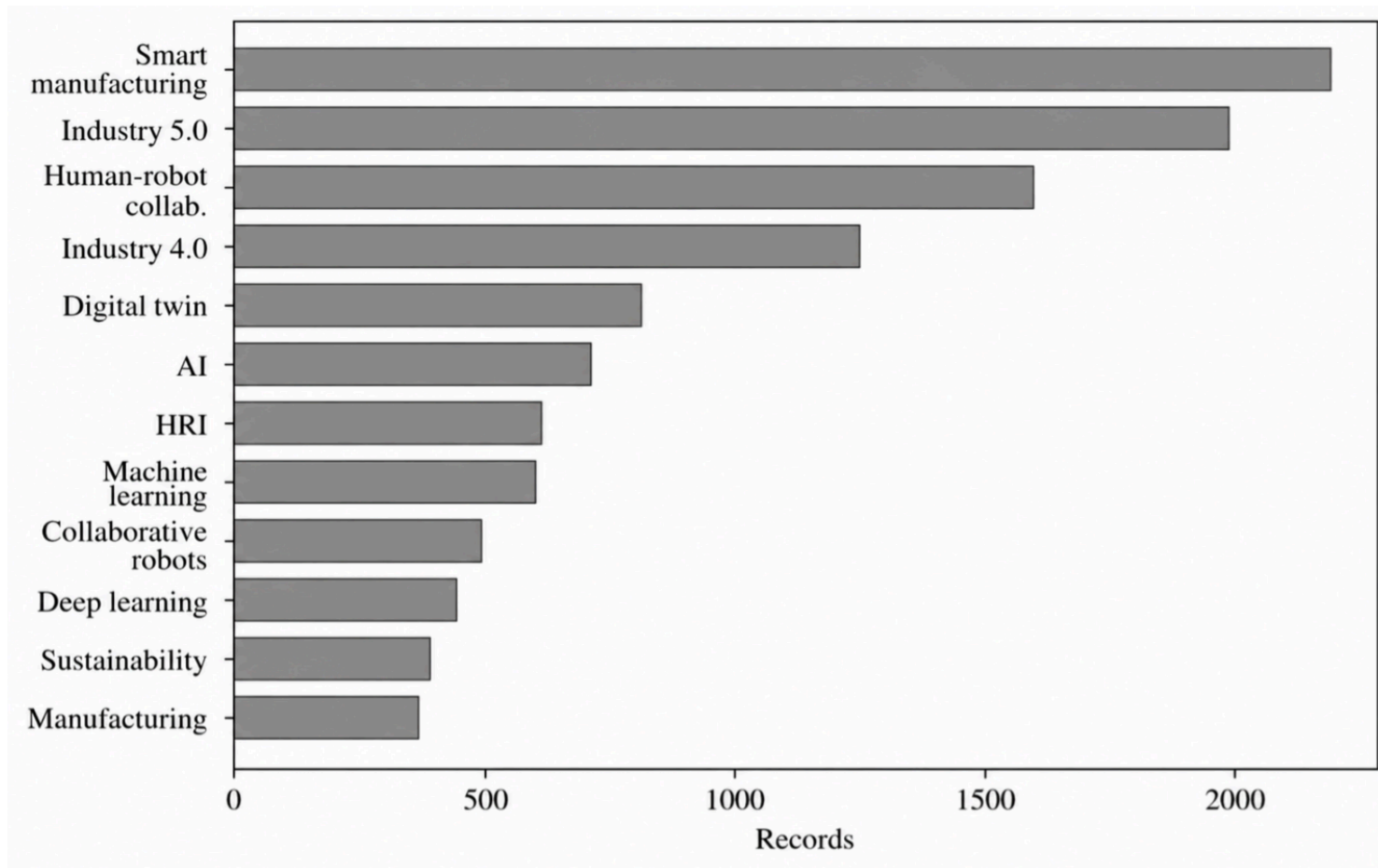


Figure 3

Fig. 3 Most frequent author keywords, full corpus (n = 14,346)

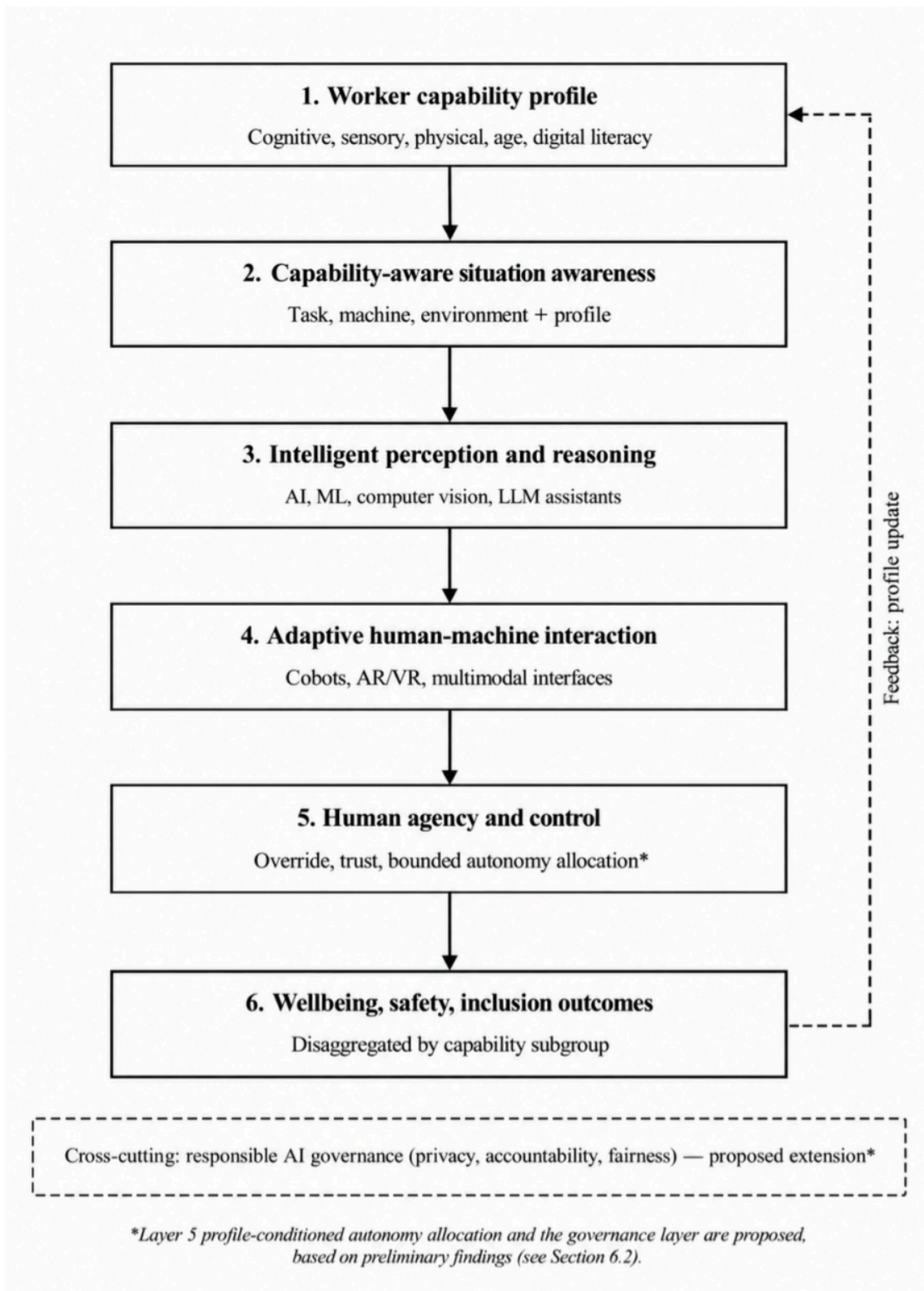


Figure 4

Fig. 5 Proposed CAIA-5.0 framework, revised to reflect the corrected evidence base: layers 1, 2, 4, and 6 are grounded in the verified subsample; layer 3 is a connective proposal; layer 5's profile-conditioned autonomy allocation remains an explicitly flagged, untested extension

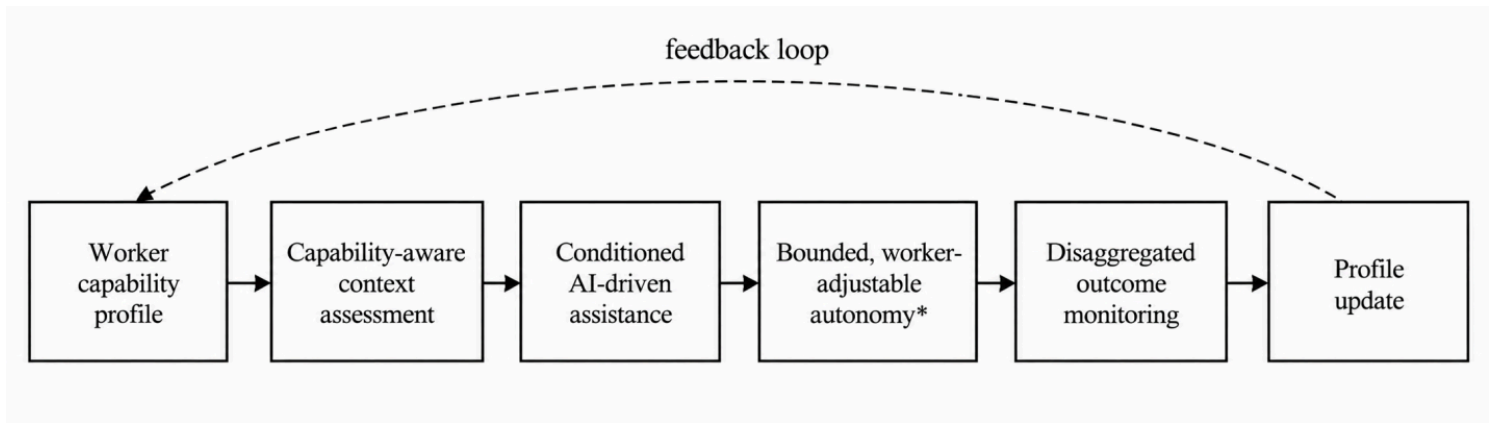


Figure 5

Fig. 6 Industrial implementation roadmap derived from the CAIA-5.0 mechanism