

# Bibliometric Mapping and Narrative Review of Macroergonomics in Modern Industry

Mohammad Fajar Nurwildani<sup>1\*</sup>, Hari Purnomo<sup>2</sup>, Hartomo Soewardi<sup>3</sup>, Elisa Kusri<sup>4</sup>  
<sup>1,2,3,4</sup>Department of Industrial Engineering, Doctoral Programs, Universitas Islam Indonesia, Yogyakarta

## Article Info

### Article history:

Received February 01, 2026  
Accepted February 11, 2026  
Published February 20, 2026

### Keywords:

Macro ergonomics,  
Industry 4.0,  
Systematic Literature Review,  
Bibliometric,  
Sociotechnical System

## ABSTRACT

The rapid acceleration of modern industry driven by automation and AI requires a systematic approach to aligning workers, technology, and organizations, a role addressed by macro ergonomics. This study maps the intellectual structure and evolution of macro ergonomics in modern industrial contexts through a hybrid systematic literature review and bibliometric analysis of 233 Scopus-indexed documents. Using R-based bibliometric methods, key trends, collaboration networks, and thematic clusters were identified. The findings show that macro ergonomics has evolved into a critical sociotechnical framework for Industry 4.0/5.0, supporting organizational resilience, safe human-AI integration, and the reduction of systemic risks in automated environments. Three dominant research themes emerge: digital integration, organizational optimization, and human-centered design, alongside notable gaps in global collaboration and SME applications. Overall, this study consolidates the scientific landscape of macro ergonomics and provides guidance for future research and practical implementation of holistic, adaptive, and human-centric work systems.



## Corresponding Author:

Mohammad Fajar Nurwildani,  
Department of Industrial Engineering, Doctoral Programs,  
Universitas Islam Indonesia, Yogyakarta  
Kaliurang Road KM 14 Yogyakarta.  
Email: 22936004@students.uii.ac.id

## 1. INTRODUCTION

The development of modern industry is undergoing an unprecedented acceleration driven by automation, artificial intelligence (AI), and data-driven systems. Within the Industry 4.0 landscape and the emerging vision of Society 5.0, human-human and human-machine interactions are increasingly embedded in complex digital infrastructures. This transformation challenges traditional ergonomic approaches that focus primarily on physical interfaces or individual workstations. Instead, it demands a systemic perspective that can address the dynamic interdependencies between workers, intelligent technologies, organizational structures, and decision-making processes. In this context, macroergonomics emerges as a critical framework for ensuring that technological advancement does not evolve at the expense of human safety, wellbeing, and organizational resilience [1]– [3].

Macroergonomics operates at the level of work systems rather than isolated tasks. It examines how organizational design, work processes, culture, governance, and technology jointly shape system performance and human outcomes. This systems-level orientation is particularly relevant in AI-enabled environments, where algorithmic decision-making, automation, and digital monitoring systems introduce new forms of cognitive load, responsibility diffusion, and safety risks. Recent studies highlight that failures in AI-supported work systems are rarely caused by technological errors alone, but rather by misalignments between human capabilities, organizational policies, and intelligent technologies. Consequently, macroergonomics is

increasingly positioned as a foundational approach for managing digital safety, human–AI interaction, and systemic risk in modern industries.

Despite its growing relevance, macroergonomics research remains conceptually fragmented and methodologically dispersed. The literature spans multiple disciplines—including engineering, human factors, management, and computer science yet often lacks a coherent synthesis that integrates technological, organizational, and human dimensions. While empirical studies addressing productivity, safety, and system performance continue to grow, these contributions are frequently examined in isolation, without a unified framework that explains how macroergonomic principles operate within digitally mediated sociotechnical systems [4]. As industrial transformation accelerates, this fragmentation risks reducing macroergonomics to a loosely defined concept rather than a robust scientific foundation for modern work system design.

This challenge becomes more pronounced when viewed through the lens of Sociotechnical Systems (STS) theory, which emphasizes the joint optimization of social and technical subsystems. Industry 4.0 environments amplify traditional STS challenges by introducing autonomous systems, real-time data flows, and AI-driven coordination mechanisms. In such settings, organizational failures often emerge from imbalances—where technological efficiency is prioritized over human adaptability, or where governance structures lag behind technological complexity. Current research indicates that many digital transformation initiatives struggle to integrate safety, resilience, and human-centered values into system design, underscoring the need for macroergonomic approaches that explicitly address STS challenges in automated and AI-intensive industries.

Without a comprehensive synthesis of existing knowledge, macroergonomics risks losing conceptual clarity at precisely the moment when it is most needed. Few studies have systematically mapped the evolution of macroergonomics research over the past two decades, particularly in relation to AI integration, digital safety, and organizational resilience under global competitive pressure. Key questions remain unresolved: Has macroergonomics research shifted from organizational design toward human–AI system integration? To what extent does existing research address digital safety and psychological wellbeing in automated work systems? Where do significant gaps persist across industries and regions?.

In response to these challenges, this study aims not merely to summarize prior research, but to reconstruct the intellectual landscape of macroergonomics in modern industry. By combining a structured literature synthesis with bibliometric mapping, this research seeks to clarify how macroergonomics has evolved, how it is currently applied within sociotechnical and AI-driven contexts, and where future research efforts should be directed. Such an approach enables a clearer understanding of thematic trends, methodological orientations, and collaborative patterns, while also identifying underexplored domains critical to sustainable and human-centered industrial transformation.

To achieve this objective and avoid conceptual ambiguity, this study adopts a systematic, theory-driven synthesis guided by the PICOS framework. Based on the identified gaps and emerging challenges in Industry 4.0 sociotechnical systems, the following research questions are formulated:

Q1: How can the principles of macroergonomics be implemented in modern digitalized industries to influence organizational resilience, compared to the traditional approach to ergonomics?

Q2: In the work-based ecosystem of artificial intelligence, how does the integration of human-designed AI through a macroergonomics approach contribute to the improvement of safety and quality performance of workers?.

Q3: What role does sociotechnical-based macroergonomics play in reducing risk and failure system breakdown in industries that rely on automated technology, compared to the system organisation?

Q4: What pattern of global evolution of macroergonomics research over the last two decades, and how it changed its thematic focus and its scientific collaborations, formed in response to the transformation of modern industry?

## **2. MATERIALS AND METHOD**

This study adopts a hybrid research design that integrates bibliometric analysis and a structured systematic literature review (SLR) to examine the role of macroergonomics in modern industrial contexts. The methodological framework was developed to ensure transparency, rigor, and reproducibility, following established guidelines for systematic reviews and bibliometric studies. The review process was guided by the PICOS framework, Population, Intervention, Comparison, Outcomes, and Study Design, which structured the formulation of research questions, search strategy, and eligibility criteria.

To enhance methodological clarity, the study explicitly distinguishes between research questions addressed through systematic qualitative synthesis (RQ1–RQ3) and those examined through bibliometric mapping (RQ4). This separation ensures conceptual alignment between analytical methods and research objectives.

### 2.1. Research Questions and Analytical Alignment

The research questions were operationalized according to their analytical purpose:

- 1) RQ1–RQ3 were addressed through systematic qualitative synthesis, focusing on macroergonomic principles, sociotechnical systems, human AI integration, safety, and organizational resilience in modern industry.
- 2) RQ4 was addressed through bibliometric analysis, examining the global evolution, thematic trends, and scientific collaboration patterns in macroergonomics research over the past two decades.

This distinction clarifies the hybrid nature of the study and avoids methodological ambiguity between systematic review and bibliometric approaches.

### 2.2. PICOS Framework

The PICOS framework was applied as follows:

- 1) Population (P): Industrial work systems, organizations, and sociotechnical environments within modern and digitalized industries.
- 2) Intervention (I): Macroergonomics, organizational ergonomics, and sociotechnical system-based approaches.
- 3) Comparison (C): Traditional ergonomics, technocentric system design, or non-systemic organizational approaches (where applicable).
- 4) Outcomes (O): Organizational resilience, safety, performance, productivity, system reliability, and worker wellbeing.
- 5) Study Design (S): Empirical studies, theoretical frameworks, case studies, and structured review articles published in peer-reviewed sources.

### 2.3. Search Strategy Literature

A search was conducted on Scopus due to its wide coverage, standards-based indexing, and compatibility with bibliometric analysis using R. Queries were constructed to capture research on Macroergonomics and its role in modern industry. Boolean operators are used to make searches more precise and compliant with PICOS.

The following Boolean search query is used:

```
("macro ergonomic *" OR "macro-ergonomic*" OR "macroergonomics " OR "organizational ergonomics" OR "sociotechnical system*" OR "sociotechnical system*")  
AND  
("industry 4.0" OR "modern industry *" OR "smart manufacturing" OR "automation" OR "digitized industry*" OR "human-machine interaction" OR "human-AI interaction")  
AND  
("performance" OR "productivity" OR "safety" OR "work system design" OR "organizational resilience" OR "wellbeing" OR "work efficiency")
```

The exclusive use of the Scopus database was a deliberate methodological decision based on its comprehensive multidisciplinary coverage, standardized indexing, and reliable citation metadata, which are essential for consistent bibliometric mapping in an interdisciplinary field such as macroergonomics. The screening process was designed to ensure conceptual relevance by prioritizing studies that explicitly addressed macroergonomics, sociotechnical systems, and industrial contexts, while excluding micro-ergonomic or non-industrial works to maintain analytical coherence. Bibliometric clustering was conducted as an exploratory step to identify dominant thematic structures and research trajectories within the dataset, and these clusters subsequently informed the qualitative synthesis. This sequential linkage ensured that the narrative analysis was grounded in the empirical structure of the literature, allowing the study to connect macro-level publication patterns with in-depth interpretation of how macroergonomic principles are conceptualized and applied in modern industrial systems.

### 2.4. Study Selection Process and PRISMA Flow

The study selection process followed the PRISMA 2020 guidelines. After removing 284 duplicate records and 100 records excluded during preliminary filtering (e.g., non-industrial or irrelevant focus), 1,102 records remained for title and abstract screening. During this stage, 690 records were excluded due to insufficient relevance. Figure 1 is a PRISMA 2020 guidelines.

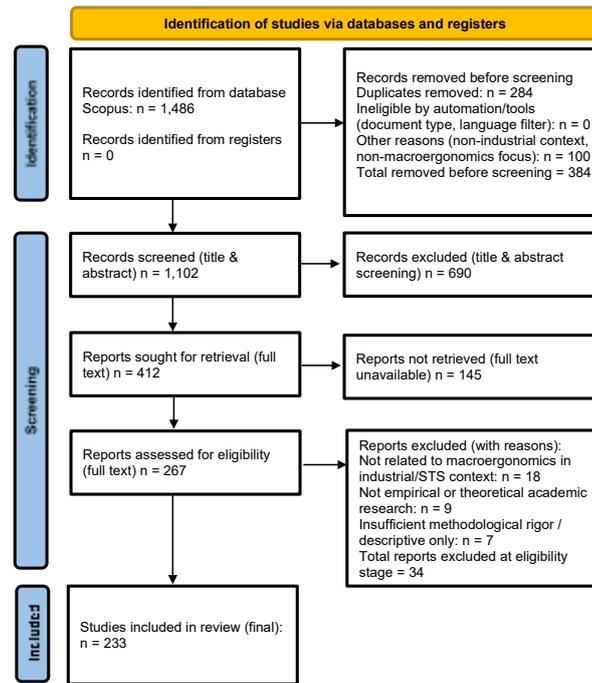


Figure. 1. Prisma 2020 Flow Diagram

## 2.5. Inclusion and Exclusion Criteria

The inclusion criteria in this study encompass research focusing on macroergonomics, organizational ergonomics, or sociotechnical systems within industrial settings; studies addressing Industry 4.0, automation, digitalization, or AI-enabled work systems; and empirical, theoretical, or structured review research. Eligible publications include peer-reviewed journal articles, conference proceedings, books, and book chapters written in English. Conversely, the exclusion criteria comprise studies limited to micro-ergonomics without system-level or organizational implications; research exclusively focused on healthcare or clinical ergonomics; non-academic publications such as editorials or commentaries; and studies lacking sufficient methodological transparency or analytical rigor.

## 2.6. Data Analysis

This study employed a sequential hybrid analytical approach, in which bibliometric analysis was conducted prior to the systematic qualitative synthesis. The purpose of this sequencing was to ensure that the subsequent SLR was thematically informed, focused, and analytically grounded, rather than arbitrarily selecting studies from a large corpus.

In the first stage, a bibliometric analysis was performed on the complete dataset of 233 included studies using the Bibliometrix package in R. This stage aimed to map the intellectual structure of macroergonomics research by identifying publication trends, citation patterns, collaboration networks, and keyword co-occurrence clusters. The bibliometric mapping served as an exploratory and structuring mechanism, enabling the identification of dominant research themes, emerging topics, and conceptual clusters within the field.

In the second stage, findings from the bibliometric analysis were used to guide the systematic qualitative synthesis. Specifically, thematic clusters identified through keyword co-occurrence and conceptual mapping informed the selection of a thematically relevant subset of studies for in-depth analysis addressing RQ1–RQ3. This subset was examined using a structured narrative synthesis approach, focusing on how macroergonomic principles are applied within sociotechnical systems, AI enabled work environments, and automated industrial contexts. The synthesis emphasized comparison, conceptual integration, and interpretation across studies rather than descriptive summarization.

Importantly, RQ4—which concerns the global evolution, thematic shifts, and scientific collaboration patterns in macroergonomics research was addressed exclusively through the bibliometric analysis of the full dataset. In contrast, RQ1–RQ3 were addressed through the systematic qualitative synthesis, ensuring methodological alignment between research questions and analytical techniques [11].

### 3. RESULTS AND DISCUSSION

Table 1 presents summary characteristics of the primary bibliometric dataset analyzed in this study. This information provides an initial overview of the distribution publication, the intensity of author collaboration, and the type of variation documents that form the basis for mapping development research in macroergonomics within the context of modern industry. The summary serves as a basis for understanding the dynamic literature before it is carried out, analyzing the thematic and mapping further scientific research.

Table 1. Summary Characteristics Bibliometrics Publication Macroergonomics in Modern Industry

Category	Information
Publication Period	2020 –2026
Number of Sources	125
Number of Documents	233
Average Document Age	6.88 years
Average Citations per Document	25.43
Keywords Plus	1,666
Author Keywords	771
Total Authors	654
Single Author	38
Single Author Document	48
Average Authors per Document	3.32
International Collaboration	21.46%
Document Type – Journal Article	117
Document Type – Book	3
Document Type – Book Chapter	13
Document Type – Conference Proceedings	80
Document Type – Conference Overview	10
Document Type – Article Review	10

#### 3.1. Trends Publication

Figure 2 illustrates the trend of annual publications related to macroergonomics over more than four decades. This visualization shows how the intensity of research evolves, while also highlighting periods of acceleration and contributions to science related to emerging technologies, new industries such as automation, systems, intelligent systems, and the integration of human-machine systems..

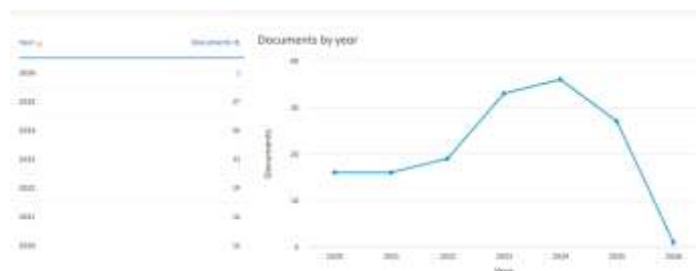


Figure. 2. Trends Publication Annual in Macroergonomics (2020–2026)

The annual publication trend presented in Figure 2 reflects more than a simple fluctuation in research output; it reveals a structural shift in the intellectual trajectory of macroergonomics. The relatively stable publication pattern observed between 2020 and 2022 suggests that macroergonomics was still positioned within established domains, primarily linked to organizational design and traditional industrial ergonomics [12]. The sharp increase since 2023 marks a turning point, likely driven by accelerated digital transformation, widespread AI adoption, and rising concerns over human-machine interaction in automated environments. This surge reflects not only growing academic interest but also systemic industrial pressures. The 2023–2024 research expansion shows the need to reinterpret macroergonomics amid sociotechnical complexity, where

technological adoption outpaces organizational adaptation. The concentration of publications during this period indicates that macroergonomics is increasingly being mobilized as a framework for addressing uncertainty, safety, and resilience in digitally mediated work systems rather than merely improving operational efficiency [13]. The decline in 2025–2026, partly due to indexing delays, may also indicate a transitional phase. Rapid growth is often followed by consolidation, shifting research from expansion to theoretical refinement and practical implementation. This suggests macroergonomics is moving from descriptive mapping toward more integrative, practice-oriented inquiry, especially in AI governance, system resilience, and human-centered automation.

Figure 3 presents the yearly distribution of documents based on their publication sources, providing insight into the consistency of different journals or outlets in contributing to macroergonomics research over time. The visualization highlights variations in source activity, enabling the identification of which publication channels have demonstrated sustained or emerging interest in the topic.

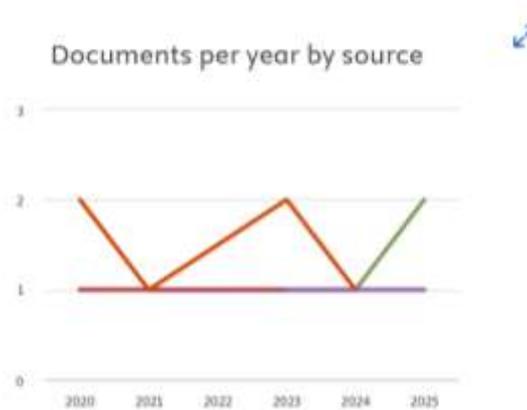


Figure. 3. Development based on the Article Source

The pattern in Figure 3 indicates that macroergonomics research is dispersed across a wide range of publication sources, with most journals contributing only a small number of articles annually. At first glance, this may suggest a healthy distribution of scholarly attention; however, a deeper interpretation points to a field that lacks a stable institutional core [14]. The lack of consistently dominant publication outlets suggests macroergonomics has not yet consolidated into a distinct discipline, remaining at the intersection of engineering, management, human factors, and industrial systems research. Publication peaks in certain years indicate it often arises in response to broader technological agendas rather than sustained theoretical development. This episodic visibility shows the field is mobilized as a response to industrial transformation, such as automation, digitalization, and AI integration rather than operating as an autonomous research tradition with a stable trajectory.

The emergence of new publication sources in 2024–2025 may reflect increasing recognition of macroergonomics within interdisciplinary communities, yet it also signals fragmentation. When a field expands across multiple outlets without a central scholarly anchor, knowledge accumulation becomes uneven, and conceptual coherence may weaken [15]. This diffusion can hinder theoretical consolidation because insights are spread across disciplines with differing methods and assumptions. The absence of dominant journals also questions how macroergonomics knowledge is legitimized and shared. While established fields have core publication platforms shaping standards and agendas, macroergonomics evolves through integration with adjacent disciplines, indicating its growth is driven more by external technological demands than by internally sustained theoretical development.

Figure 4 illustrates the distribution of macroergonomics publications by the most productive authors. This visualization highlights key contributors in the field and helps reveal which researchers have played a central role in shaping the current body of knowledge.

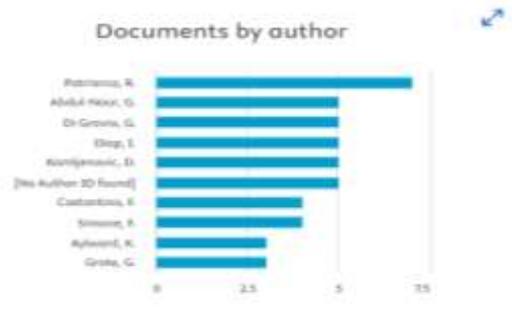


Figure 4. Article Based on Author

The exclusive use of Scopus was a deliberate methodological choice due to its broad multidisciplinary coverage, standardized indexing, and reliable citation metadata, ensuring consistent bibliometric mapping in an interdisciplinary field like macroergonomics. Screening prioritized studies explicitly addressing macroergonomics, sociotechnical systems, and industrial contexts, excluding micro-ergonomic or non-industrial works to maintain coherence. Bibliometric clustering served as an exploratory step to identify dominant themes and research trajectories, which then guided the qualitative synthesis. This sequence grounded the narrative analysis in the literature's empirical structure, linking publication patterns with deeper interpretation of how macroergonomic principles are conceptualized and applied in modern industrial systems. Figures 5 and 6 present the distribution of macroergonomics publications based on document type and subject area. Together, these visualizations provide an overview of how research outputs are categorized and which academic fields contribute most actively to the field of macroergonomics scholarship.

The exclusive use of Scopus was a deliberate methodological choice due to its broad multidisciplinary coverage, standardized indexing, and reliable citation metadata, ensuring consistent bibliometric mapping in an interdisciplinary field like macroergonomics. Screening prioritized studies explicitly addressing macroergonomics, sociotechnical systems, and industrial contexts, excluding micro-ergonomic or non-industrial works to maintain coherence. Bibliometric clustering served as an exploratory step to identify dominant themes and research trajectories, which then guided the qualitative synthesis. This sequence grounded the narrative analysis in the literature's empirical structure, linking publication patterns with deeper interpretation of how macroergonomic principles are conceptualized and applied in modern industrial systems. Figures 5 and 6 present the distribution of macroergonomics publications based on document type and subject area. Together, these visualizations provide an overview of how research outputs are categorized and which academic fields contribute most actively to the field of macroergonomics scholarship.

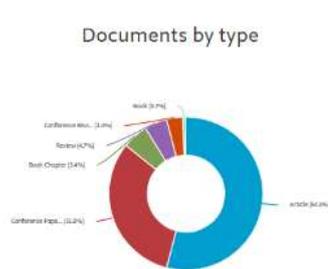


Figure 5. Article Based on Type

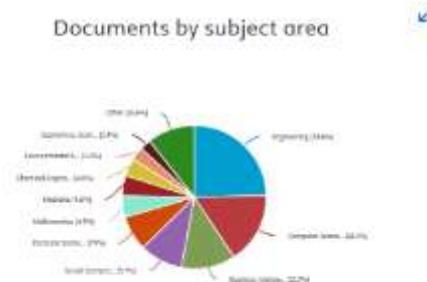


Figure 6. Article Based on Research Area

The distribution of document types reveals that macroergonomics research is predominantly communicated through journal articles, with a substantial number of conference papers also supporting this research. This pattern highlights the field's active engagement in both formal scientific publication and ongoing technical discourse within academic and industrial forums. The smaller share of books, book chapters, and review papers indicates that synthesized or theoretical contributions exist but are not the primary mode of knowledge dissemination, reinforcing that macroergonomics continues to evolve through incremental empirical findings [17].

Across subject areas, the dominance of engineering and computer science shows macroergonomics remains closely linked to technology-oriented disciplines, especially system design, automation, and human-machine interaction. Publications in business, management, and social sciences indicate expanding relevance to organizational structure, work culture, and decision-making, while contributions from medicine and

environmental science reflect interdisciplinary spread but remain secondary. Collectively, the two figures underscore that macroergonomics is a technically grounded yet increasingly cross-disciplinary field, shaped by the convergence of engineering innovation and organizational needs in modern industrial contexts [18].

Figure 7 illustrates the geographical distribution of macroergonomics publications, with the United States and Italy emerging as the dominant contributors, followed by the United Kingdom, Brazil, and China. This pattern reflects a direct correlation between research productivity and a nation's level of industrialization and technological adoption. The dominance of countries with advanced manufacturing bases confirms that macroergonomics has evolved primarily in response to the complexities inherent in modern industrial systems. However, the limited contribution from developing nations highlights a significant research gap. It underscores a potential for future growth through international collaboration, which could introduce diverse perspectives and applications to the field.

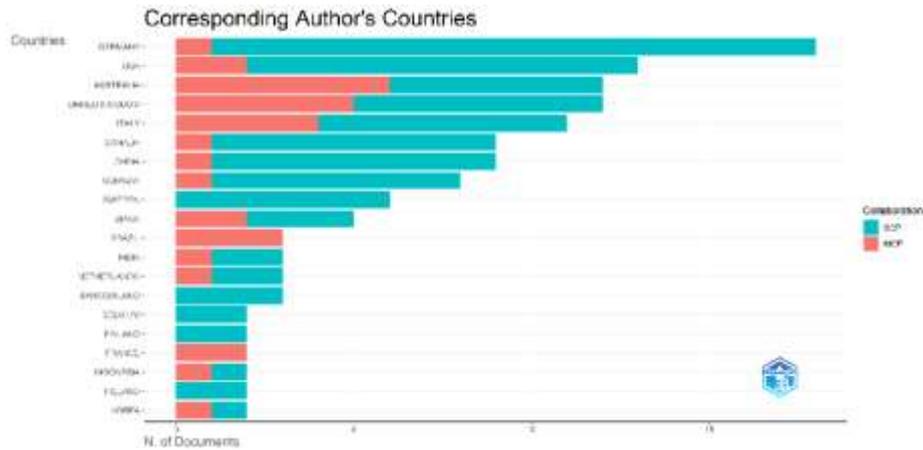


Figure. 7. Article By Country of Author

### 3.2. Collaboration Between Authors

Figure 8 visualizes the international collaboration network among authors in macroergonomics research, depicting the patterns of cross-country co-authorship.



Figure. 8. Collaborative Article between Writers from Different Countries

The analysis reveals that international collaboration remains limited and concentrated within several major clusters, with the United States and European nations forming the primary hubs. This pattern indicates that research cooperation predominantly develops through established academic networks and geographical proximity. The minimal involvement of researchers from developing countries demonstrates untapped potential for enriching research perspectives. Strengthening global collaboration emerges as a strategic imperative for developing macroergonomics that is truly inclusive and relevant to diverse industrial contexts worldwide.

Figure 9 illustrates the co-authorship network within macroergonomics research, mapping the collaborative relationships between individual researchers.

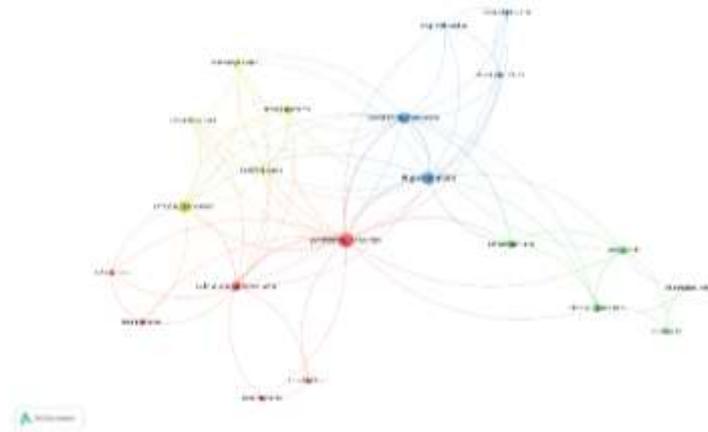


Figure 9. Co-author

The co-authorship network shows a decentralized structure of small to medium clusters, indicating a collaborative yet fragmented field. Rather than a cohesive intellectual community with shared priorities, collaboration often forms around specific projects, funding, or institutions. This affects knowledge development: specialization in areas like human–machine interaction, organizational systems, and safety enables depth, but weak links between clusters limit conceptual integration and slow cumulative theory building.

The absence of a dominant, interconnected research hub suggests macroergonomics is still defining its disciplinary boundaries. Unlike mature fields with central research centers and common standards, it relies on dispersed networks with varied epistemological approaches encouraging innovation but also inconsistencies in frameworks, terminology, and methods. Limited cross-cluster interaction also mirrors sectoral divisions in industry manufacturing, digital systems, and management so macroergonomics is applied across contexts but not consistently integrated among them.

### 3.3. Keyword Interrelationship Map

Figure 10 presents the keyword co-occurrence network analysis, mapping the conceptual structure and thematic relationships within macroergonomics research.

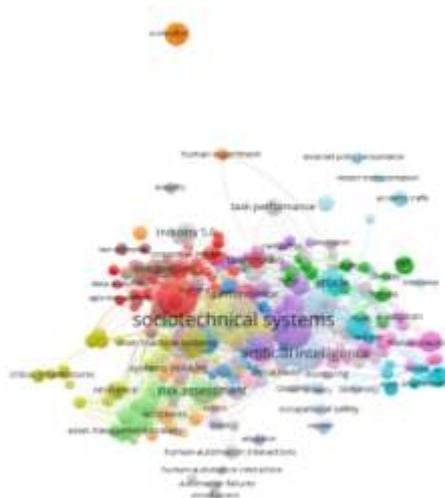


Figure 10. Co-occurrence

The thematic network reveals three dominant clusters human-centered system design, Industry 4.0 technologies, and organizational performance yet their configuration reflects more than disciplinary specialization; it exposes a structural tension within macroergonomics research. While each cluster demonstrates strong internal coherence, the relatively weak integration between them suggests that the field continues to evolve along parallel trajectories rather than through fully integrated sociotechnical frameworks [19]. The central position of “macroergonomics” and “human factors” confirm a commitment to human–system integration, but the network shows this integration remains largely conceptual rather than operational. Research on Industry 4.0 and automation often develops separately from organizational and behavioral studies, meaning

system design and human-centered considerations are not always addressed together. The growing link between Industry 4.0 and safety reflects a shift toward risk management in digitalized environments, recognizing new vulnerabilities from automation and AI. However, weak connections between technological and organizational clusters reveal a persistent gap: technology advances quickly, while institutional adaptation, governance, and workforce transformation lag behind. This imbalance reflects a broader pattern in industrial research where measurable technical performance dominates sociotechnical concerns. Consequently, macroergonomics is often used to improve efficiency rather than critically examine effects on resilience, human agency, and long-term sustainability. Limited cross-cluster integration also shows the field has not yet realized its potential as a unifying framework; without stronger links between technology, organization, and human-centered design, it risks remaining a multidisciplinary reference rather than an integrative scientific paradigm

### 3.4. Evolution Theme Research Macroergonomics

Figure 11 displays the word cloud visualization of prominent themes in macroergonomics research, where keyword size reflects their frequency and significance in the literature.

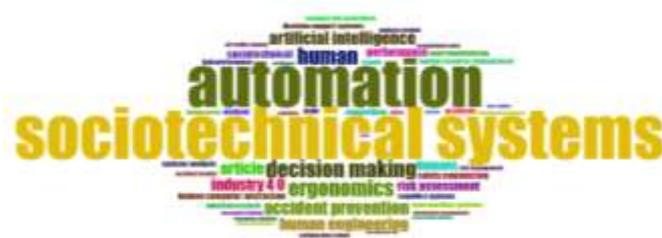


Figure 11. Word Cloud

The prominence of terms such as “human,” “system,” and “design” reinforces macroergonomics’ foundational orientation toward human-centered system thinking. However, the simultaneous dominance of “industry,” “performance,” and “safety” suggests that the field is increasingly shaped by operational and outcome-driven priorities. This indicates that macroergonomics is being mobilized not only as a conceptual discipline but as a pragmatic tool to support industrial efficiency, risk reduction, and performance optimization. The emergence of themes such as “Industry 4.0” and “resilience” alongside traditional ergonomic concepts reflects an ongoing transition in the field. Macroergonomics is no longer confined to organizational or work design contexts but is being repositioned within digitally mediated and technologically intensive environments. This coexistence signals adaptation, yet it also reveals a tension between established theoretical foundations and rapidly evolving industrial demands. The parallel appearance of “organization” and “technology” keywords points to the field’s sociotechnical ambition—an attempt to integrate structural, behavioral, and technological dimensions of work systems. Nevertheless, the imbalance in keyword prominence suggests that technological narratives continue to overshadow organizational transformation. While digitalization and automation dominate discourse, comparatively less attention is given to governance structures, institutional change, and human agency within evolving work systems. This asymmetry highlights a broader epistemic pattern: technological advancement tends to receive immediate scholarly and industrial attention, whereas organizational adaptation unfolds more gradually and is less visible in measurable outcomes. As a result, macroergonomics risks being framed as a facilitator of technological implementation rather than as a critical lens for examining how technology reshapes power relations, decision-making processes, and system resilience.

### 3.5. Key Research Themes

The current body of literature on macroergonomics in modern industrial contexts coalesces around three dominant and interconnected research themes. The first theme focuses on the integration of Industry 4.0 and 5.0 paradigms, where macroergonomics is identified as essential for balancing rapid technological adoption with the preservation of human welfare in smart manufacturing environments. The second theme centers on organizational optimization, exploring how macroergonomic frameworks can systematically align and synergize people, technology, work processes, and governance structures. The third theme emphasizes human-centered design, advocating for a holistic approach that places human needs and capabilities at the core of system development. As emphasized by Grażyna Płaza et al. (2025), macroergonomics provides the critical methodology to ensure technological advancement does not come at a human cost, while M. Dainoff et al. (2023) demonstrate its practical application in creating frameworks for the joint optimization of all system components.

The current body of literature on macroergonomics in modern industrial contexts converges around three dominant and interconnected themes—digital integration, organizational optimization, and human-centered

system design. However, these themes should not be interpreted merely as descriptive categories; rather, they reflect the shifting priorities and unresolved tensions shaping the evolution of the field [20]–[22]. The first theme, centered on the integration of Industry 4.0 and 5.0 paradigms, positions macroergonomics as a mediating framework between rapid technological advancement and human wellbeing. This orientation underscores a growing recognition that automation, AI, and digital infrastructures cannot be implemented effectively without systemic consideration of human capabilities and organizational readiness. Yet, the literature reveals a persistent imbalance: technological innovation often drives research agendas, while macroergonomics is introduced retrospectively as a corrective mechanism to mitigate risks and unintended consequences. This reactive positioning limits the discipline’s potential to function as a proactive design philosophy guiding industrial transformation from its inception. The second theme highlights organizational optimization, positioning macroergonomics as a means to align people, technology, processes, and governance. While this reinforces its systemic nature, it reflects a managerial focus on efficiency and coordination. Few studies examine how interventions affect power structures, decision hierarchies, and institutional dynamics, so optimization is often treated as a technical alignment issue rather than a socio-political process of negotiation, adaptation, and cultural change. The third theme centers on human-centered design, placing human needs, cognition, and wellbeing at the core of system development. Yet a paradox appears: although widely promoted, implementation often occurs in technology-dominated settings where productivity metrics still drive priorities. Macroergonomics thus risks becoming a compensatory layer that humanizes technology rather than reshaping its design logic. Together, these themes show a field transitioning from traditional ergonomics toward sociotechnical system governance, balancing efficiency vs. wellbeing, automation vs. autonomy, and complexity vs. stability. However, they remain insufficiently integrated and often operate in parallel, reflecting fragmentation across engineering, management, and human factors research.

### **3.6. Impact on Performance**

Empirical research demonstrates that macroergonomic interventions yield significant and measurable enhancements in both operational performance and human wellbeing. Quantitative evidence from a manufacturing case study by A. Amri et al. (2024) revealed that the systematic application of a macroergonomic analysis and design method directly increased productivity by two additional ship components per day, concurrently achieving a substantial 37.32% reduction in worker fatigue levels. This correlation between improved working conditions and output is further supported at a conceptual level by Bassam Hasanain et al. (2024), who contend that the objectives of sustainable manufacturing are unattainable without the foundational integration of human-factor ergonomics. Collectively, these findings underscore that macroergonomics serves as a critical driver for achieving synergistic benefits, where enhancements in worker welfare directly contribute to tangible gains in organizational productivity and sustainability.

Empirical evidence consistently indicates that macroergonomic interventions contribute to measurable improvements in both operational performance and human wellbeing. Case-based studies demonstrate that systematic redesign of work systems—integrating human capabilities, technological processes, and organizational coordination—can simultaneously enhance productivity and reduce physical and cognitive strain. These outcomes reinforce the foundational premise of macroergonomics: performance gains and human welfare are not competing objectives but mutually reinforcing dimensions of effective system design [23]–[25]. However, a deeper examination of the literature reveals that the relationship between macroergonomics and performance is often framed within short-term operational metrics. Productivity increases, efficiency gains, and fatigue reduction are commonly reported, yet fewer studies investigate long-term organizational resilience, learning capacity, or adaptability in rapidly evolving industrial environments. This suggests that macroergonomics is frequently evaluated through immediate performance indicators rather than its broader systemic contributions. Another key observation is the contextual nature of performance outcomes. Many empirical studies are sector-specific and conducted in controlled organizational settings, limiting generalizability across industries with different technological maturity, labor structures, and institutions. Gains seen in advanced manufacturing may not transfer to resource-constrained or unstable sectors. The literature also often assumes a linear link between working conditions and productivity; although macroergonomic interventions improve both, the mechanisms are underexplored. Organizational culture, managerial practices, and worker participation likely mediate effectiveness but are rarely examined, risking attribution of improvements to technical redesign alone rather than broader sociotechnical alignment. Conceptually, macroergonomics views performance as an emergent result of system integration. Productivity increases when human wellbeing, organizational coordination, and technological function are optimized together, challenging efficiency models that treat human factors as constraints instead of strategic assets.

### **3.7. Research Gaps**

Despite the demonstrated contributions of macroergonomics to industrial performance and human wellbeing, the literature reveals several structural research gaps that limit the field’s ability to respond

---

effectively to emerging industrial transformations. These gaps are not merely empirical absences but reflect deeper conceptual and contextual imbalances in how macroergonomics is currently developed and applied. One of the most prominent gaps lies in the intersection between macroergonomics and emerging technological paradigms. Although Industry 4.0, AI, and automation dominate contemporary industrial discourse, their integration with core macroergonomic principles—particularly participatory ergonomics and sociotechnical design remains insufficiently explored. Existing research often treats technological adoption and human-centered system design as sequential processes rather than as mutually constitutive elements. This separation weakens the capacity of macroergonomics to shape technological transformation proactively [26]–[29]. A second gap concerns implementation across diverse economic and organizational contexts. Empirical evidence indicates that macroergonomic frameworks are more frequently applied in technologically advanced industries, while their adoption in small and medium-sized enterprises and developing economies remains limited. Barriers such as resource constraints, institutional readiness, and limited access to expertise hinder the translation of macroergonomic knowledge into practice. This imbalance risks reinforcing a global asymmetry in industrial development, where human-centered system design becomes concentrated in high-capacity environments.

Another critical gap emerges at the conceptual level. While macroergonomics emphasizes systemic integration, many studies continue to examine isolated dimensions technology, organization, or human factors without fully capturing their interdependencies. As a result, the field often advances through parallel streams rather than through integrative theoretical models capable of explaining complex sociotechnical dynamics [30]–[32]. The literature also reveals a methodological gap. Case-based and cross-sectional studies dominate empirical research, while longitudinal investigations examining how macroergonomic interventions evolve over time remain scarce. Without such temporal perspectives, it is difficult to assess whether performance gains and organizational improvements are sustained or whether they diminish as technological systems mature and organizational conditions change.

Finally, there is a gap between academic discourse and industrial practice. Macroergonomics is widely recognized as a valuable framework, yet its translation into actionable guidelines for policymakers, system designers, and industry leaders remains limited. This disconnect suggests that the field has achieved conceptual maturity but still faces challenges in operationalization and institutional adoption.

### **1) Q1: Implementation of Macro ergonomics Principles in Digitalized Industries**

The implementation of macroergonomic principles in digitalized industries reflects a deeper structural transformation than a mere extension of traditional ergonomic practices. The shift from workstation-level optimization to system-level integration indicates that macroergonomics is increasingly positioned as a framework for managing complexity within technologically mediated work environments. Digitalization introduces interconnected layers of human–machine interaction, algorithmic decision-making, and organizational coordination, where performance outcomes depend not on isolated interventions but on the alignment of entire sociotechnical systems [33]–[36]. However, the literature suggests that this transition remains uneven and often reactive. In many cases, macroergonomics is applied after technological systems are introduced, functioning as a corrective mechanism to address emerging risks, inefficiencies, or human adaptation challenges. This reactive positioning limits its potential as a proactive design philosophy capable of shaping digital transformation from the outset. As a result, macroergonomics is frequently associated with improving implementation rather than guiding technological and organizational strategy.

Another critical insight concerns the evolving role of governance within digitalized work systems. As automation and AI reshape workflows and decision processes, the boundaries between human authority, machine autonomy, and organizational accountability become increasingly blurred. Macroergonomics therefore expands beyond physical and organizational design into institutional and strategic domains, where coordination, responsibility distribution, and risk management become central considerations [37]–[40]. Furthermore, the growing cognitive demands associated with digital environments challenge traditional ergonomic assumptions. Real-time data processing, continuous monitoring, and adaptive systems require workers to operate within fluid and unpredictable contexts, where decision-making is shared between human and algorithmic actors. Macroergonomics must therefore address not only physical and organizational alignment but also cognitive resilience, learning capacity, and adaptive system behavior.

### **2) Q2: Human-Designed AI Integration Through Macroergonomics**

Regarding the integration of human-designed AI, a macroergonomic approach proves critical for achieving substantive improvements in both safety and quality performance [41]–[43]. This approach moves beyond technical implementation to address the profound human psychological dimensions of working with AI. As Mario Passalacqua et al. (2024) found, the success of human-centered AI in an Industry 5.0 context is contingent on a deep understanding of workers' psychological experiences, including the development of AI trust, the preservation of autonomy, the sustenance of motivation, and the management of stress factors. This human-centric focus is echoed in organizational practices; Uma Murugesan et al. (2023) demonstrated that AI

applications within human resource systems underscore wellbeing and safety as vital outcomes, where AI effectively supports human adaptability and capability development. Furthermore, to fully realize these benefits, Violeta Firescu et al. (2022) argue that macroergonomic strategies for human-robot collaboration must adopt a holistic perspective, encompassing not just the systemic but also the emotional and spiritual aspects of Work to support employee wellbeing comprehensively. Therefore, macroergonomics provides the essential framework for ensuring that AI integration enhances human Work rather than merely displacing or devaluing it, thereby directly contributing to superior safety and quality outcomes [44]–[47].

### **3) Q3: Sociotechnical Macroergonomics in Risk Reduction**

The application of a sociotechnical macroergonomics perspective in risk reduction reflects a fundamental shift in how failures in automated industrial systems are understood. Rather than being attributed solely to technical malfunction or human error, risks increasingly emerge from misalignments between technological capabilities, organizational structures, and human adaptation processes. In highly automated environments, system vulnerability often arises when efficiency-driven objectives dominate design decisions, leaving governance, communication flows, and human capacity development insufficiently integrated [48]–[51]. The literature indicates that sociotechnical macroergonomics provides a framework for identifying these hidden interdependencies. By emphasizing the joint optimization of people, technology, processes, and governance, this approach reframes risk as an emergent property of system imbalance rather than as an isolated operational issue. Failures in automated systems frequently occur not because a component underperforms, but because interactions between components remain poorly coordinated or inadequately anticipated. However, existing research also reveals a persistent limitation. Many macroergonomic interventions are implemented after risks become visible, positioning the discipline as a corrective mechanism rather than a preventive design paradigm. In the context of human–robot collaboration and AI-supported operations, safety strategies are often introduced during implementation stages instead of being embedded at the conceptual design phase. This reactive orientation reduces the capacity of macroergonomics to shape system architecture proactively and to anticipate cascading risks before they materialize.

Another critical insight concerns the expanding nature of risk in digitalized industries. Traditional safety models focus on physical hazards and operational reliability, whereas sociotechnical macroergonomics highlights cognitive overload, decision ambiguity, and accountability diffusion as emerging risk domains. As automation redistributes control between humans and intelligent systems, failures increasingly stem from coordination breakdowns, trust misalignment, and organizational rigidity rather than mechanical faults alone. The literature also suggests that effective risk reduction depends heavily on institutional readiness and participatory system design. Where workers, managers, and system designers are actively involved in shaping technological integration, macroergonomic interventions are more likely to produce resilient outcomes. Conversely, when automation is implemented in a top-down manner without sociotechnical alignment, systemic vulnerabilities persist despite technological sophistication. Collectively, these findings position sociotechnical macroergonomics as a critical lens for understanding risk in modern industry, yet they also reveal its incomplete institutionalization [52]–[55]. The discipline is recognized as essential for managing complexity, but its integration into early-stage system design, governance frameworks, and industrial policy remains limited. For macroergonomics to function as a preventive paradigm rather than a reactive tool, future research must prioritize anticipatory design, cross-disciplinary integration, and the development of organizational capabilities that support adaptive risk management in automated and AI-driven environments

### **4) Q4: Global Evolution Patterns of Macroergonomics Research**

The global evolution of macroergonomics research reflects a transformation from its origins in workplace design toward a broader role in understanding and managing complex sociotechnical systems. This shift mirrors the trajectory of industrial change itself, where ergonomic concerns have expanded from physical work conditions to encompass digital infrastructures, human–AI interaction, and organizational adaptability. However, this evolution is not linear; it represents a gradual redefinition of the discipline as it responds to successive waves of technological disruption [59], [60]. Early macroergonomic interventions, particularly participatory ergonomics programs, were primarily concerned with improving organizational efficiency and worker wellbeing within stable industrial environments. As digitalization accelerated, these approaches were recontextualized to address the uncertainties of Industry 4.0, where automation, cyber-physical systems, and real-time data integration reshape the nature of work. Yet, the literature indicates that this adaptation remains incomplete interventions (Afif et al., 2021; Raffaghelli & Stewart, 2020; Widmann et al., 2020). Research related to emerging concepts such as Operator 4.0 and human–AI collaboration is still relatively limited, suggesting that macroergonomics is responding to technological change rather than actively shaping its trajectory. The expansion of research themes including human–cyber-physical systems, digital twins, and human–robot collaboration—signals the growing relevance of macroergonomics within technologically intensive domains. However, this thematic growth also reveals a structural imbalance. While the field is

increasingly visible within automation discourse, its influence remains comparatively weak in broader “future of work” debates involving governance, labor transformation, organizational policy, and socio-economic restructuring. This partial integration indicates that macroergonomics has yet to fully position itself as a central framework for understanding systemic change beyond technological implementation [61]–[64].

Another critical dimension of this evolution is the emergence of Industry 5.0 as a human-centric paradigm emphasizing sustainability, resilience, and ethical technological integration. Macroergonomics aligns conceptually with this vision, yet its institutional and policy-level integration remains uneven across regions and sectors. In many cases, the discipline continues to operate at the level of design and implementation rather than shaping strategic industrial planning or regulatory frameworks. The trajectory of macroergonomics research therefore reflects both maturation and limitation. On one hand, the field is expanding in scope and relevance, increasingly addressing human–AI collaboration and system resilience. On the other, its development remains reactive, often following technological trends rather than establishing anticipatory frameworks for sociotechnical transformation.

#### **4. CONCLUSION**

This study advances the macroergonomics literature by moving beyond descriptive bibliometric mapping and fragmented thematic reviews toward an integrated understanding of how macroergonomics is repositioned within digitally mediated industrial systems. Unlike previous studies that examine either technological adoption, organizational ergonomics, or human factors in isolation, this research synthesizes bibliometric structure and narrative interpretation to explain how macroergonomics is evolving as a systems-level framework for managing sociotechnical complexity in Industry 4.0 and emerging Industry 5.0 environments. The findings demonstrate that macroergonomics is no longer confined to workstation design or organizational efficiency but is increasingly functioning as a strategic integrator of people, technology, processes, and governance. This repositioning represents a conceptual advancement over earlier literature that treated macroergonomics primarily as a methodological tool rather than as a guiding paradigm for system design, resilience, and human-centered digital transformation. A key contribution of this study lies in revealing the structural imbalance within the current research landscape. While technological themes such as automation, AI integration, and cyber-physical systems dominate scholarly attention, organizational adaptation, governance, and human agency remain comparatively underdeveloped. By linking bibliometric clusters with qualitative interpretation, this research highlights how macroergonomics can bridge the persistent divide between technological innovation and sociotechnical sustainability an area insufficiently addressed in prior reviews. Furthermore, the study provides a global perspective on the evolution of macroergonomics, showing that knowledge production remains concentrated in technologically advanced regions while implementation challenges persist in developing economies and SMEs. This insight extends beyond existing literature by positioning macroergonomics not only as an industrial design framework but also as a developmental and institutional challenge shaped by regional capacity and socio-economic context. The study also contributes conceptually by reframing performance outcomes as emergent properties of sociotechnical alignment rather than as direct results of technological optimization. This perspective challenges efficiency-centered paradigms and positions macroergonomics as a strategic mechanism for building long-term resilience, adaptive capacity, and sustainable work systems. Despite these contributions, several limitations remain, including reliance on a single database, sectoral concentration of empirical evidence, and limited longitudinal research. Addressing these limitations presents a clear agenda for future studies, particularly in developing integrative governance models, context-sensitive macroergonomic frameworks, and empirical investigations of human–AI collaboration over time.

#### **ACKNOWLEDGEMENT**

The authors would like to express their sincere gratitude to all parties who have contributed to the completion of this research. The authors appreciate the participation of SMEs and respondents who provided valuable insights during the data collection process. The authors also acknowledge the constructive input from colleagues and reviewers, which has helped improve the quality of this manuscript.

#### **AUTHOR CONTRIBUTIONS**

All authors contributed equally to the conceptualization, methodology, software development, validation, formal analysis, investigation, resources, data maintenance, writing—creating the initial design, writing—reviewing and editing, visualization, monitoring, and project management. Funding procurement was conducted collaboratively. All authors have read and agreed to the published version of the manuscript. Authorship is limited to individuals who made a significant contribution to the reported work, as described in the CT file.

## REFERENCE

- [1] S. Ansari, F. Naghdy, and H. Du, "Human-Machine Shared Driving: Challenges and Future Directions," *IEEE Trans. Intell. Veh.*, vol. 7, no. 3, pp. 499–519, 2022, doi: 10.1109/tiv.2022.3154426.
- [2] J. Kasperuniene and V. Zydziunaite, "A Systematic Literature Review on Professional Identity Construction in Social Media," *Sage Open*, vol. 9, no. 1, 2019, doi: 10.1177/2158244019828847.
- [3] P. Jing, G. Xu, Y. Chen, Y. Shi, and F. Zhan, "The Determinants behind the Acceptance of Autonomous Vehicles: A Systematic Review," *Sustainability*, vol. 12, no. 5, p. 1719, 2020, doi: 10.3390/su12051719.
- [4] A. Ghio, Z. Occhipinti, and R. Verona, "The Consideration of Diversity in the Accounting Literature: A Systematic Literature Review," *Eur. Account. Rev.*, vol. 33, no. 5, pp. 1667–1691, 2024, doi: 10.1080/09638180.2024.2330089.
- [5] J. Tan, F. J. Tan, and S. Ramakrishna, "Transitioning to a Circular Economy: A Systematic Review of Its Drivers and Barriers," *Sustainability*, vol. 14, no. 3, p. 1757, 2022, doi: 10.3390/su14031757.
- [6] M.-T. (Brian) Lin, D. Zhu, C. Liu, and P. B. Kim, "A systematic review of empirical studies of pro-environmental behavior in hospitality and tourism contexts," *Int. J. Contemp. Hosp. Manag.*, vol. 34, no. 11, pp. 3982–4006, 2022, doi: 10.1108/ijchm-12-2021-1478.
- [7] K. B. Moral et al., "Moral Hazard Behaviors and Mitigation Strategies: A Systematic Review," *J. Ekon. Malaysia*, vol. 58, no. 1, 2024, doi: 10.17576/jem-2024-5801-01.
- [8] B. Klimova, M. Pikhart, and J. Kacetl, "Ethical issues of the use of AI-driven mobile apps for education," *Front. Public Heal.*, vol. 10, 2023, doi: 10.3389/fpubh.2022.1118116.
- [9] R. Belahouaoui and E. H. Attak, "Digital taxation, artificial intelligence and Tax Administration 3.0: improving tax compliance behavior – a systematic literature review using textometry (2016–2023)," *Account. Res. J.*, vol. 37, no. 2, pp. 172–191, 2024, doi: 10.1108/arj-12-2023-0372.
- [10] P. Velte, "Determinants and consequences of corporate social responsibility assurance: a systematic review of archival research," *Soc. Bus. Rev.*, vol. 16, no. 1, pp. 1–25, 2020, doi: 10.1108/sbr-05-2020-0077.
- [11] M. A. Camilleri, "The rationale for <sc>ISO</sc> 14001 certification: A systematic review and a cost–benefit analysis," *Corp. Soc. Responsib. Environ. Manag.*, vol. 29, no. 4, pp. 1067–1083, 2022, doi: 10.1002/csr.2254.
- [12] D. Masoumi and O. Noroozi, "Developing early career teachers' professional digital competence: a systematic literature review," *Eur. J. Teach. Educ.*, vol. 48, no. 3, pp. 644–666, 2023, doi: 10.1080/02619768.2023.2229006.
- [13] S. Carmine and V. De Marchi, "Reviewing Paradox Theory in Corporate Sustainability Toward a Systems Perspective," *J. Bus. Ethics*, vol. 184, no. 1, pp. 139–158, 2022, doi: 10.1007/s10551-022-05112-2.
- [14] A. E. A. Ibrahim, K. Hussainey, T. Nawaz, C. Ntim, and A. Elamer, "A systematic literature review on risk disclosure research: State-of-the-art and future research agenda," *Int. Rev. Financ. Anal.*, vol. 82, p. 102217, 2022, doi: 10.1016/j.irfa.2022.102217.
- [15] H. Andersson, A. Svensson, C. Frank, A. Rantala, M. Holmberg, and A. Bremer, "Ethics education to support ethical competence learning in healthcare: an integrative systematic review," *BMC Med. Ethics*, vol. 23, no. 1, 2022, doi: 10.1186/s12910-022-00766-z.
- [16] G. Marmat, P. Jain, and P. N. Mishra, "Understanding ethical/unethical behavior in pharmaceutical companies: a literature review," *Int. J. Pharm. Healthc. Mark.*, vol. 14, no. 3, pp. 367–394, 2020, doi: 10.1108/ijphm-03-2018-0016.
- [17] F. Alvino, A. Di Vaio, R. Hassan, and R. Palladino, "Intellectual capital and sustainable development: a systematic literature review," *J. Intellect. Cap.*, vol. 22, no. 1, pp. 76–94, 2020, doi: 10.1108/jic-11-2019-0259.
- [18] A. Redine, S. Deshpande, C. Jebarajakirthy, and J. Surachartkumtonkun, "Impulse buying: A systematic literature review and future research directions," *Int. J. Consum. Stud.*, vol. 47, no. 1, pp. 3–41, 2022, doi: 10.1111/ijcs.12862.
- [19] A. Saha, "Financial reporting quality during a crisis: a systematic review," *J. Account. Lit.*, vol. 44, no. 2/3, pp. 154–176, 2022, doi: 10.1108/jal-01-2022-0013.
- [20] L. Theodorakopoulos and A. Theodoropoulou, "Leveraging Big Data Analytics for Understanding Consumer Behavior in Digital Marketing: A Systematic Review," *Hum. Behav. Emerg. Technol.*, vol. 2024, no. 1, 2024, doi: 10.1155/2024/3641502.
- [21] V. Sima, I. G. Gheorghe, J. Subić, and D. Nancu, "Influences of the Industry 4.0 Revolution on the Human Capital Development and Consumer Behavior: A Systematic Review," *Sustainability*, vol. 12, no. 10, p. 4035, 2020, doi: 10.3390/su12104035.
- [22] W. J. Salisu, N. Dehghan Nayeri, I. Yakubu, and F. Ebrahimpour, "Challenges and facilitators of professional socialization: A systematic review," *Nurs. Open*, vol. 6, no. 4, pp. 1289–1298, 2019, doi: 10.1002/nop2.341.
- [23] N. Yusoff, M. Alias, and N. Ismail, "Drivers of green purchasing behaviour: a systematic review and a research agenda," *F1000Research*, vol. 12, p. 1286, 2023, doi: 10.12688/f1000research.140765.1.
- [24] J. A. Oskam and A. De Visser-Amundson, "A systematic review of ethical issues in hospitality and tourism innovation," *J. Hosp. Tour. Insights*, vol. 5, no. 4, pp. 782–803, 2022, doi: 10.1108/jhti-11-2021-0305.
- [25] L. Corvo, L. Pastore, M. Mastrodascio, and D. Cepiku, "The social return on investment model: a systematic literature review," *Meditari Account. Res.*, vol. 30, no. 7, pp. 49–86, 2022, doi: 10.1108/medar-05-2021-1307.
- [26] C. S. Sullivan, M. Gemtou, E. Anastasiou, and S. Fountas, "Building trust: A systematic review of the drivers and barriers of agricultural data sharing," *Smart Agric. Technol.*, vol. 8, p. 100477, 2024, doi: 10.1016/j.atech.2024.100477.

- [27] D. Mills and K. Inouye, "Problematising 'predatory publishing': A systematic review of factors shaping publishing motives, decisions, and experiences," *Learn. Publ.*, vol. 34, no. 2, pp. 89–104, 2020, doi: 10.1002/leap.1325.
- [28] S. A. Hazaea, J. Zhu, S. F. A. Khatib, and A. A. Elamer, "Mapping the literature of internal auditing in Europe: a systematic review and agenda for future research," *Meditari Account. Res.*, vol. 31, no. 6, pp. 1675–1706, 2022, doi: 10.1108/medar-01-2022-1584.
- [29] B. Kaur, K. Sood, and S. Grima, "A systematic review on forensic accounting and its contribution towards fraud detection and prevention," *J. Financ. Regul. Compliance*, vol. 31, no. 1, pp. 60–95, 2022, doi: 10.1108/jfrc-02-2022-0015.
- [30] S. A. Hazaea, E. M. Al-Matari, S. F. A. Khatib, K. Albitar, and J. Zhu, "Internal Auditing in the Arab World: A Systematic Literature Review and Directions for Future Research," *Sage Open*, vol. 13, no. 4, 2023, doi: 10.1177/21582440231202332.
- [31] S. Elhoushy and P. Lanzini, "Factors Affecting Sustainable Consumer Behavior in the MENA Region: A Systematic Review," *J. Int. Consum. Mark.*, vol. 33, no. 3, pp. 256–279, 2020, doi: 10.1080/08961530.2020.1781735.
- [32] O. Turetken, S. Jethefer, and B. Ozkan, "Internal audit effectiveness: operationalization and influencing factors," *Manag. Audit. J.*, vol. 35, no. 2, pp. 238–271, 2019, doi: 10.1108/maj-08-2018-1980.
- [33] L. Joseph, M. Standen, A. Paungmali, R. Kuisma, P. Silitertpisan, and U. Pirunsan, "Prevalence of musculoskeletal pain among professional drivers: A systematic review," *J. Occup. Health*, vol. 62, no. 1, 2020, doi: 10.1002/1348-9585.12150.
- [34] J. M. Fernández-Batanero, M. Montenegro-Rueda, J. Fernández-Cerero, and I. García-Martínez, "Digital competences for teacher professional development. Systematic review," *Eur. J. Teach. Educ.*, vol. 45, no. 4, pp. 513–531, 2020, doi: 10.1080/02619768.2020.1827389.
- [35] G. M. Gomes, N. Moreira, and A. R. Ometto, "Role of consumer mindsets, behaviour, and influencing factors in circular consumption systems: A systematic review," *Sustain. Prod. Consum.*, vol. 32, pp. 1–14, 2022, doi: 10.1016/j.spc.2022.04.005.
- [36] L. Fogt Jacobsen, S. Pedersen, and J. Thøgersen, "Drivers of and barriers to consumers' plastic packaging waste avoidance and recycling – A systematic literature review," *Waste Manag.*, vol. 141, pp. 63–78, 2022, doi: 10.1016/j.wasman.2022.01.021.
- [37] D. Streimikiene, B. Svagzdiene, E. Jasinskis, and A. Simanavicius, "Sustainable tourism development and competitiveness: The systematic literature review," *Sustain. Dev.*, vol. 29, no. 1, pp. 259–271, 2020, doi: 10.1002/sd.2133.
- [38] R. F. Guzzo, J. Abbott, and J. M. Madera, "A Micro-Level View of CSR: A Hospitality Management Systematic Literature Review," *Cornell Hosp. Q.*, vol. 61, no. 3, pp. 332–352, 2019, doi: 10.1177/1938965519892907.
- [39] C. S. Dabas and C. Whang, "A systematic review of drivers of sustainable fashion consumption: 25 years of research evolution," *J. Glob. Fashion. Mark.*, vol. 13, no. 2, pp. 151–167, 2022, doi: 10.1080/20932685.2021.2016063.
- [40] S. Farrell, C. McKernan, T. Benson, C. Elliott, and M. Dean, "Understanding farmers' and veterinarians' behavior in relation to antimicrobial use and resistance in dairy cattle: A systematic review," *J. Dairy Sci.*, vol. 104, no. 4, pp. 4584–4603, 2021, doi: 10.3168/jds.2020-19614.
- [41] A. Chițimiea, M. Minciu, A.-M. Manta, C. N. Ciocoiu, and C. Veith, "The Drivers of Green Investment: A Bibliometric and Systematic Review," *Sustainability*, vol. 13, no. 6, p. 3507, 2021, doi: 10.3390/su13063507.
- [42] M. A. Latapí Agudelo, L. Johannsdottir, and B. Davidsdottir, "Drivers that motivate energy companies to be responsible. A systematic literature review of Corporate Social Responsibility in the energy sector," *J. Clean. Prod.*, vol. 247, p. 119094, 2020, doi: 10.1016/j.jclepro.2019.119094.
- [43] M. Kassar and M. Jizi, "Artificial intelligence and robotic process automation in auditing and accounting: a systematic literature review," *J. Appl. Account. Res.*, pp. 1–25, 2025, doi: 10.1108/jaar-05-2024-0175.
- [44] A. Di Vaio, R. Hassan, G. D'Amore, and R. Tiscini, "Responsible innovation and ethical corporate behavior in the Asian fashion industry: A systematic literature review and avenues ahead," *Asia Pacific J. Manag.*, vol. 41, no. 3, pp. 1129–1173, 2022, doi: 10.1007/s10490-022-09844-7.
- [45] D. Aloini, R. Dulmin, V. Mininno, A. Stefanini, and P. Zerbino, "Driving the Transition to a Circular Economic Model: A Systematic Review on Drivers and Critical Success Factors in Circular Economy," *Sustainability*, vol. 12, no. 24, p. 10672, 2020, doi: 10.3390/su122410672.
- [46] S. Potthoff et al., "The relationship between habit and healthcare professional behaviour in clinical practice: a systematic review and meta-analysis," *Health Psychol. Rev.*, vol. 13, no. 1, pp. 73–90, 2019, doi: 10.1080/17437199.2018.1547119.
- [47] A. M. Dattilo, R. S. Carvalho, R. Feferbaum, S. Forsyth, and A. Zhao, "Hidden Realities of Infant Feeding: Systematic Review of Qualitative Findings from Parents," *Behav. Sci. (Basel)*, vol. 10, no. 5, p. 83, 2020, doi: 10.3390/bs10050083.
- [48] A. Orellano, C. Valor, and E. Chuvieco, "The Influence of Religion on Sustainable Consumption: A Systematic Review and Future Research Agenda," *Sustainability*, vol. 12, no. 19, p. 7901, 2020, doi: 10.3390/su12197901.
- [49] K. Shahzad and S. A. Khan, "The relationship between motivational factors and librarians' professional development (PD): A systematic review," *J. Librariansh. Inf. Sci.*, vol. 55, no. 2, pp. 383–402, 2022, doi: 10.1177/09610006221083685.
- [50] C. Keyworth, T. Epton, J. Goldthorpe, R. Calam, and C. J. Armitage, "Delivering Opportunistic Behavior Change Interventions: a Systematic Review of Systematic Reviews," *Prev. Sci.*, vol. 21, no. 3, pp. 319–331, 2020, doi: 10.1007/s11121-020-01087-6.

- [51] W. Murikah, J. K. Nthenge, and F. M. Musyoka, "Bias and ethics of AI systems applied in auditing - A systematic review," *Sci. African*, vol. 25, p. e02281, 2024, doi: 10.1016/j.sciaf.2024.e02281.
- [52] A. Naudé, J. Bornman, and A. Kanji, "A Systematic Review of Ethics Knowledge in Audiology Literature: A Follow-Up Study (2011–2020)," *Am. J. Audiol.*, vol. 31, no. 3, pp. 835–844, 2022, doi: 10.1044/2022\_aja-22-00043.
- [53] M. Daradkeh, "Navigating the Complexity of Entrepreneurial Ethics: A Systematic Review and Future Research Agenda," *Sustainability*, vol. 15, no. 14, p. 11099, 2023, doi: 10.3390/su151411099.
- [54] S. Ed-Dafali, Z. Adardour, A. Derj, A. Bami, and K. Hussainey, "A PRISMA-Based Systematic Review on Economic, Social, and Governance Practices: Insights and Research Agenda," *Bus. Strateg. Environ.*, vol. 34, no. 2, pp. 1896–1916, 2024, doi: 10.1002/bse.4069.
- [55] E. Lee, T. Lewis-Liu, S. Khurana, and M. Lu, "A systematic review of the link between public service motivation and ethical outcomes," *Asia Pacific J. Public Adm.*, pp. 1–28, 2023, doi: 10.1080/23276665.2023.2247101.
- [56] J. E. Raffaghelli and B. Stewart, "Centering complexity in 'educators' data literacy' to support future practices in faculty development: a systematic review of the literature," *Teach. High. Educ.*, vol. 25, no. 4, pp. 435–455, 2020, doi: 10.1080/13562517.2019.1696301.
- [57] K. Afif, C. Rebollo, and J. Roy, "Drivers, barriers and performance outcomes of sustainable packaging: a systematic literature review," *Br. Food J.*, vol. 124, no. 3, pp. 915–935, 2021, doi: 10.1108/bfj-02-2021-0150.
- [58] M. Widmann, F. Follert, and M. Wolz, "What is it going to cost? Empirical evidence from a systematic literature review of audit fee determinants," *Manag. Rev. Q.*, vol. 71, no. 2, pp. 455–489, 2020, doi: 10.1007/s11301-020-00190-w.
- [59] T. Nasreen, R. Baker, and D. Rezaia, "Sustainability reporting – a systematic review of various dimensions, theoretical and methodological underpinnings," *J. Financ. Report. Account.*, vol. 23, no. 3, pp. 1057–1088, 2023, doi: 10.1108/jfra-01-2022-0029.
- [60] M. Li and Z. Yu, "Teachers' Satisfaction, Role, and Digital Literacy during the COVID-19 Pandemic," *Sustainability*, vol. 14, no. 3, p. 1121, 2022, doi: 10.3390/su14031121.
- [61] M. Bascopé, P. Perasso, and K. Reiss, "Systematic Review of Education for Sustainable Development at an Early Stage: Cornerstones and Pedagogical Approaches for Teacher Professional Development," *Sustainability*, vol. 11, no. 3, p. 719, 2019, doi: 10.3390/su11030719.
- [62] W. Ahmed Al-Husseini, M. L. Mat Kiah, P. Lip Yee, and B. B. Zaidan, "A systematic review on sensor-based driver behaviour studies: coherent taxonomy, motivations, challenges, recommendations, substantial analysis and future directions," *PeerJ Comput. Sci.*, vol. 7, p. e632, 2021, doi: 10.7717/peerj-cs.632.
- [63] S. Schaltegger, K. L. Christ, J. Wenzig, and R. L. Burritt, "Corporate sustainability management accounting and multi-level links for sustainability – A systematic review," *Int. J. Manag. Rev.*, vol. 24, no. 4, pp. 480–500, 2022, doi: 10.1111/ijmr.12288.
- [64] J. I. Steinert, D. Atika Nyarige, M. Jacobi, J. Kuhnt, and L. Kaplan, "A systematic review on ethical challenges of 'field' research in low-income and middle-income countries: respect, justice and beneficence for research staff?," *BMJ Glob. Heal.*, vol. 6, no. 7, p. e005380, 2021, doi: 10.1136/bmjgh-2021-005380.