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## Digital Transformation as an Enabler of Sustainability Management in the 5.0 Industry

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**Abstrak:** *The emergence of Industry 5.0 marks a fundamental shift in industrial paradigms from technology-centric efficiency toward human-centric, sustainable, and resilient systems. In this context, digital transformation is no longer positioned merely as a tool for operational efficiency, but as a structural enabler of sustainability management. This study aims to systematically synthesize the academic literature on the role of digital transformation in enabling sustainability management within the Industry 5.0 framework. A Systematic Literature Review (SLR) was conducted following PRISMA guidelines, analyzing peer-reviewed journal articles with active DOIs related to digital transformation, sustainability management, and Industry 5.0. The findings reveal that digital transformation enables sustainability management through data integration, adaptive decision-making, transparency, and the alignment of economic, environmental, and social dimensions. However, the literature also identifies critical limitations and risks, including digital readiness gaps, ethical and technological biases, over-reliance on automation, and regulatory inconsistencies. This study concludes that the effectiveness of digital transformation as a sustainability enabler depends on the integration of technological capabilities, human-centered values, and governance structures. The study contributes by clarifying the enabling mechanisms of digital transformation and proposing a conceptual foundation for sustainable management practices in the Industry 5.0 era*

**Keywords:** *Digital Transformation; Industry 5.0; Sustainability Management; Sustainable Development; Technology Governance*

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## INTRODUCTION

The emergence of the Industry 5.0 paradigm marks a fundamental shift in how organizations perceive technology, humans, and sustainability. Unlike Industry 4.0, which emphasizes automation, efficiency, and process optimization based on cyber physical technologies, Industry 5.0 promotes industrial systems that are human centric, sustainable, and resilient. This paradigm positions humans not as components substituted by technology, but as the central source of value who collaborate with technology to achieve broader long term objectives, including economic, environmental, and social sustainability (Ghobakhloo et al., 2024; Martín-Gómez et al., 2024). In this context, digital transformation is no longer understood as an end goal, but as a strategic means that enables the creation of adaptive and value driven sustainability management systems.

Digital transformation has traditionally been positioned as an effort to enhance operational efficiency, speed, and organizational productivity. This perspective aligns with the logic of Industry 4.0, which focuses on process automation and data exploitation for short term competitive advantage. However, as global pressures related to climate change, social inequality, and economic system resilience intensify, an efficiency oriented approach alone is increasingly regarded as insufficient. Industry 5.0 requires digital transformation to function as a structural enabler of sustainability management, namely as a mechanism that enables the integration of technology, humans, and long term value orientation in organizational decision making (De Giovanni, 2023; Hu et al., 2025).

Within the sustainability management framework, organizations are required to manage economic, environmental, and social performance simultaneously and in an integrated manner. The main challenges of sustainability management lie in data complexity, the need for cross functional coordination, and uncertainty in the external environment. This is where digital transformation holds strategic potential as an enabler, through the use of digital technologies for real time data integration, process transparency, and the strengthening of evidence based decision making capacity (Guandalini, 2022; Alojail & Khan, 2023). Accordingly, digital transformation has the potential to shift sustainability management practices from reactive and symbolic reporting approaches toward systems that are proactive, adaptive, and value oriented.

Nevertheless, developments in academic literature indicate that studies on digital transformation and sustainability management are

still evolving in parallel and separately. A number of studies examine the impact of digitalization on sustainability performance, such as resource efficiency, emission reduction, and enhanced transparency (Alsanie, 2025; Cao et al., 2025), while other studies highlight Industry 5.0 dynamics as a normative paradigm emphasizing human values and sustainability (Ghobakhloo et al., 2024; Samuels & Pelser, 2025). However, conceptual integration between these two domains remains limited, such that the mechanisms through which digital transformation concretely enables sustainability management within the Industry 5.0 framework have not yet been systematically explained.

The academic problem becomes more apparent when considering that most digital transformation studies remain confined within the logic of Industry 4.0, which prioritizes automation and efficiency. In this approach, sustainability is often treated as a positive side effect of technological efficiency rather than as a normative objective consciously integrated into organizational digital strategies (Melo et al., 2023). As a result, the human centric and resilience dimensions that constitute the core characteristics of Industry 5.0 receive insufficient attention. This creates conceptual inconsistency in the literature, particularly with regard to the role of digital technology as an enabler of sustainability values rather than merely an instrumental tool.

Several studies have made important contributions in linking digital transformation with sustainability. Guandalini (2022), through a systematic literature review, identifies various relational pathways between digital transformation and sustainability, yet does not explicitly frame them within the Industry 5.0 paradigm. The study by Fraga-Lamas et al. (2021) demonstrates the role of Green IoT and Edge AI as enablers of the transition toward a circular economy in the context of Industry 5.0, while Payer et al. (2024) propose a circular economy monitoring framework that integrates digital transformation and sustainability. Nevertheless, these findings remain dispersed and have not been comprehensively synthesized to explain the enabling mechanisms of digital transformation for sustainability management within a unified conceptual framework.

The research gap becomes increasingly evident when observing that, to date, no systematic literature review has explicitly mapped the role of digital transformation as an enabler of sustainability management within the Industry 5.0 framework.

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Existing literature tends to address partial impacts, such as environmental efficiency or ESG performance, without deeply examining the mechanisms, limitations, and associated risks. In addition, mapping how organizational digital capabilities interact with human centric and resilience dimensions in sustainability management remains limited and has not been consistently conceptualized.

The absence of such a systematic synthesis has implications for the weakness of both theoretical and practical foundations for organizations seeking to align digital transformation strategies with long term sustainability objectives. Without a clear understanding of enabling mechanisms, digital transformation risks being reduced to a technology focused project detached from the sustainability agenda, or even creating new risks such as system dependency, technological bias, and value conflicts with the human centric principles of Industry 5.0 (Bajić et al., 2023; Dossou et al., 2024).

Based on this background, this study aims to systematically synthesize the literature on digital transformation and sustainability management, with a focus on the role of digital transformation as an enabler within the Industry 5.0 framework. Specifically, this study seeks to identify the enabling mechanisms of digital transformation, map its contributions to the economic, environmental, and social dimensions of sustainability, and examine its implementation constraints and challenges. The novelty of this research lies in the development of a conceptual synthesis that integrates digital transformation and sustainability management from an Industry 5.0 perspective, while also proposing a relational framework that can serve as a foundation for the development of digital based sustainability theory and practice.

## METHOD

This study employs a Systematic Literature Review approach to identify, evaluate, and systematically synthesize scientific findings on digital transformation and sustainability management in the context of Industry 5.0. The SLR method is selected because it enables the development of comprehensive and transparent conceptual understanding while minimizing subjective bias in literature selection and interpretation (Snyder, 2019). This approach is relevant given that studies on digital transformation and sustainability are dispersed across disciplines and require cross perspective integration.

The SLR process follows the PRISMA guidelines. The identification stage was conducted

through searches of reputable scientific databases such as Scopus, Web of Science, and Google Scholar using the keywords “digital transformation”, “sustainability management”, and “Industry 5.0”. Articles were then screened based on inclusion criteria, namely reputable journal articles with active DOIs, relevance to digital transformation and sustainability topics, and publication within the last ten years. Articles that were conceptually weak, duplicative, or did not explicitly address enabling mechanisms were excluded from the analysis.

In summary, the PRISMA flow in this study is as follows: Identification (n = 120 articles identified) → Screening (n = 78 articles after duplicate removal and title abstract screening) → Eligibility (n = 46 articles meeting substantive and methodological criteria) → Included (n = 32 articles analyzed in depth). The selected articles were analyzed using thematic synthesis to identify patterns of enabling mechanisms, the multidimensional contributions of digital transformation to sustainability management, and limitations and risks within the Industry 5.0 context.

To ensure the methodological rigor of the reviewed studies, a quality appraisal process was conducted prior to thematic synthesis. Each eligible article was assessed using a structured appraisal framework adapted from prior SLR studies, focusing on four criteria: (1) clarity of research objectives and conceptual framing, (2) appropriateness of research design and methodology, (3) transparency of data sources and analytical procedures, and (4) relevance to the Industry 5.0 sustainability context. Articles that demonstrated weak conceptual grounding, insufficient methodological explanation, or purely descriptive treatment of digital transformation without sustainability relevance were excluded at this stage. This quality appraisal process strengthened the analytical validity of the synthesis by ensuring that only methodologically sound and theoretically relevant studies informed the findings.

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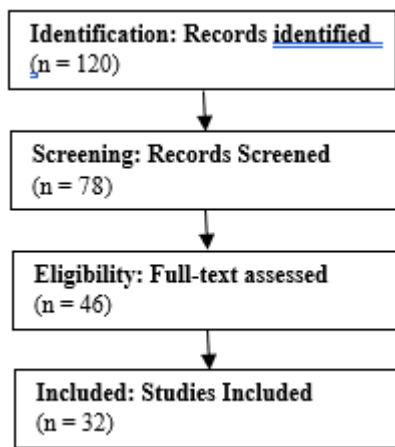


Figure 1. PRISMA Flowchart

## RESULTS AND DISCUSSION

### Digital Transformation as a Structural Enabler of Sustainability Management within the Industry 5.0 Framework

The literature synthesis indicates that within the Industry 5.0 framework, digital transformation undergoes a conceptual repositioning from an instrument of operational efficiency to a structural enabler of sustainability management. Digital transformation is no longer interpreted as a separate technological project, but rather as an integrative foundation that enables organizations to systematically align decision making, governance, and sustainability oriented value frameworks (Guandalini, 2022; Ghobakhloo et al., 2024). In this context, digital technologies function as cognitive and organizational infrastructures that support adaptive and enduring sustainability practices.

This structural enabling role is particularly evident in the capacity of digital transformation to integrate data across functions and time horizons in support of sustainability related decisions. Digital systems enable the collection, processing, and visualization of environmental, social, and economic data in real time, thereby allowing sustainability management to move beyond reliance on periodic and retrospective reporting (Alojail & Khan, 2023). Such data integration strengthens organizational capacity for sense making regarding sustainability impacts and for dynamically adjusting strategies, which represents a critical characteristic of Industry 5.0 systems that emphasize resilience.

Furthermore, the literature highlights a functional shift of technology from an efficiency tool toward an enabler of sustainability value. Under the Industry 4.0 paradigm, digital transformation was generally oriented toward cost reduction,

productivity enhancement, and process optimization through automation (Melo et al., 2023). In contrast, Industry 5.0 requires digital technologies to support the creation of long term value that balances economic performance, environmental responsibility, and human well being (Martín-Gómez et al., 2024). This shift transforms the way organizations design their digital architectures, from being technology driven to being value driven.

Differences in the enabling characteristics of digital transformation between Industry 4.0 and Industry 5.0 are also evident in decision making orientation. In Industry 4.0, data driven decisions tend to focus on optimizing internal processes. In Industry 5.0, digitally supported decisions are directed toward managing sustainability trade offs and incorporating ethical considerations and social impacts (De Giovanni, 2023; Hu et al., 2025). Accordingly, digital transformation functions as a mechanism that enables the integration of human centric values into organizational management systems.

The relationship between digital capabilities and adaptive sustainability management systems constitutes another central theme in the literature. Studies indicate that organizations with mature digital capabilities, including data infrastructure, analytical competencies, and digital governance, are better positioned to develop proactive and integrated sustainability systems (He & Chen, 2024; Ren et al., 2025). These capabilities enable organizations not only to respond to external pressures, but also to anticipate sustainability risks and value innovation opportunities.

Overall, the synthesis results demonstrate that digital transformation within the Industry 5.0 framework functions as a structural enabler that shapes how organizations understand, manage, and internalize sustainability. This enabling role is systemic in nature, extending beyond the adoption of individual technologies, and depends on the alignment between digital capabilities, value orientation, and organizational design.

Despite broad agreement in the literature that digital transformation enables sustainability management, important theoretical tensions emerge regarding its actual role within Industry 5.0. While several studies portray digital technologies as inherently supportive of sustainability through transparency and data integration (Guandalini, 2022; Alojail & Khan, 2023), other scholars caution that digital transformation may reinforce efficiency-driven logics inherited from Industry 4.0 rather than genuinely advancing human-centric sustainability goals (Melo et al., 2023; Bajić et al., 2023). This

divergence suggests that digital transformation does not automatically function as a sustainability enabler, but may instead reproduce instrumental rationality if sustainability values are not explicitly embedded in governance and system design.

Furthermore, tensions arise between adaptive decision-making and organizational control. While real-time digital analytics enhance responsiveness and resilience, they may also centralize decision authority within algorithmic systems, potentially marginalizing human judgment and ethical deliberation. Some studies emphasize digital systems as tools for empowerment and resilience, whereas others highlight risks of technological dominance and reduced reflexivity in strategic decision processes. These contradictions indicate that the enabling role of digital transformation is contingent rather than universal and depends on how organizations negotiate the balance between automation, human agency, and sustainability values within the Industry 5.0 paradigm.

**Contribution of Digital Transformation to the Economic, Environmental, and Social Dimensions of Sustainability**

The literature indicates that the contribution of digital transformation to sustainability management within Industry 5.0 is multidimensional, encompassing economic, environmental, and social dimensions simultaneously. Within the economic dimension, digital technologies contribute to resource efficiency, optimization of investment processes, and the strengthening of organizational economic resilience. Kalinin et al. (2024) show that digital transformation enhances economic security through more transparent and informed investment decision making, while simultaneously integrating environmental considerations into these processes.

Within the environmental dimension, digital transformation plays a significant role in reducing environmental impacts through energy consumption monitoring, waste management, and optimization of resource use. Technologies such as Green IoT, Edge AI, and advanced analytics systems enable organizations to precisely identify environmental inefficiencies and implement timely interventions (Fraga-Lamas et al., 2021; Alsanie, 2025). In the Industry 5.0 context, these environmental contributions do not stand alone, but are integrated with long term value objectives and circular economy principles (Payer et al., 2024).

The social dimension represents a key differentiating factor between the Industry 4.0 and Industry 5.0 approaches. The literature emphasizes

that digital transformation in Industry 5.0 must support workforce well being, human capability development, and organizational resilience (Cao et al., 2025; Samuels & Pelser, 2025). Human centric technology focuses not only on human machine collaboration, but also on the creation of work environments that are safe, inclusive, and meaningful. Accordingly, digital transformation contributes to sustainability management through the strengthening of human and social capital. To summarize these multidimensional contributions, Table 1 presents a synthesis of the roles of digital transformation across each sustainability dimension within the Industry 5.0 framework.

**Table 1.** Contributions of Digital Transformation to Sustainability Dimensions in Industry 5.0

Sustainability Dimension	Key Digital Enablers	Main Contributions
Economic	Data integration, analytics, digital investment systems	Resource efficiency, economic resilience, value creation
Environmental	Green IoT, Edge AI, real-time monitoring	Energy efficiency, waste reduction, circular practices
Social	Human-centric digital systems, collaboration platforms	Workforce well-being, inclusion, organizational resilience

Although digital transformation contributes simultaneously to economic, environmental, and social sustainability, the literature reveals inherent trade-offs among these dimensions. Economic efficiency gained through digital optimization may conflict with social sustainability when automation reduces job autonomy or increases work intensification, particularly if human-centric design principles are weakly implemented. Similarly, environmental performance improvements driven by digital monitoring and analytics may require significant energy consumption and digital infrastructure investment, potentially offsetting sustainability gains if not governed responsibly.

The social dimension, which constitutes a defining feature of Industry 5.0, is often the most vulnerable in digitally driven sustainability strategies. While digital platforms can enhance workforce well-being and inclusion, several studies indicate that social benefits are frequently subordinated to economic and environmental metrics that are more easily quantified. This imbalance reflects a persistent measurement bias

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that privileges data-intensive sustainability indicators over qualitative human-centric outcomes.

These trade-offs suggest that sustainability management enabled by digital transformation is not a harmonized process, but a continuous negotiation among competing objectives. Industry 5.0 therefore requires organizations to consciously manage tensions between efficiency, environmental performance, and human well-being, rather than assuming that digital transformation will align these dimensions automatically. Recognizing and governing these trade-offs is essential to prevent sustainability management from reverting to a technologically optimized yet socially fragmented model.

The table indicates that the contribution of digital transformation to sustainability is interrelated and cannot be separated across dimensions. Economic efficiency achieved through digitalization, for example, often depends on the successful management of environmental impacts and the strengthening of the social dimension. This confirms that sustainability management within Industry 5.0 requires a holistic approach that leverages digital transformation as a cross dimensional enabler, rather than as a fragmented sectoral solution. Accordingly, the results of this synthesis confirm that digital transformation contributes significantly to sustainability management when positioned within a human centric and value oriented Industry 5.0 framework. Such contributions can only be realized optimally when organizations are able to align digital strategies with long term sustainability objectives and inclusive governance.

### **Limitations, Risks, and Challenges of Digital Transformation in Industry 5.0 Sustainability Management**

Although digital transformation functions as a key enabler in sustainability management in the Industry 5.0 era, the literature also emphasizes the presence of several limitations, risks, and challenges that must be managed systemically. The most fundamental challenge relates to disparities in digital readiness and organizational capabilities. Not all organizations possess adequate data infrastructure, analytical competencies, and digital governance to integrate sustainability objectives into their operational systems. Studies by Melo et al. (2023) and Ren et al. (2025) show that differences in digital maturity levels have direct implications for variations in the quality of sustainability management practices, thereby creating the risk that digital transformation may widen sustainability performance gaps across organizations and sectors.

Another limitation arises from ethical risks and technological bias inherent in digital systems. Data driven and algorithm based systems tend to reflect assumptions, interests, and biases embedded in training data and system design. In the context of sustainability management, such bias may influence decision priorities, for instance by emphasizing easily measurable economic indicators over social dimensions that are qualitative and context dependent (He & Chen, 2024). This condition contradicts the Industry 5.0 emphasis on value balance and social justice, thereby necessitating strong ethical governance frameworks in the implementation of digital transformation.

Excessive dependence on digital systems also represents a significant risk in sustainability management. The literature notes that organizations that rely too heavily on automation and digital analytics risk losing reflective capacity and human judgment in strategic decision making (Bajić et al., 2023). Within the Industry 5.0 framework, technology is expected to strengthen human machine collaboration rather than replace the critical role of human judgment in evaluating values, ethics, and long term implications. Such systemic dependence may weaken organizational resilience when digital systems experience disruptions or fail to respond to unpredictable environmental dynamics.

Another conceptual challenge highlighted in the literature concerns the potential conflict between automation and the human centric values of Industry 5.0. Digital transformation driven by efficiency and standardization logics may reduce opportunities for human participation, limit job autonomy, and diminish the quality of work experience (Samuels & Pelser, 2025). In the context of sustainability management, this conflict is particularly critical because the social dimension of sustainability depends heavily on human well being and engagement. Therefore, digital transformation must be designed according to human in the loop principles so that technology functions as a support rather than a substitute for human capacity.

Regulatory and standardization gaps also represent a major challenge in digital based sustainability practices. The literature indicates that digital technological developments often outpace existing regulatory frameworks, creating gray areas in accountability, transparency, and sustainability reporting (Latisha & Dirkharehsha, 2024). Without clear standards, digital based sustainability management practices risk becoming symbolic or being exploited for greenwashing. Within the Industry 5.0 context, such regulatory gaps hinder

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alignment between digital innovation and long term sustainability objectives.

In addition, cross sectoral and cross national challenges affect the effectiveness of digital transformation as a sustainability enabler. Differences in institutional contexts, organizational cultures, and levels of technology adoption lead to varied implementation outcomes (Dossou et al., 2024). This indicates that no single universal approach exists for integrating digital transformation and sustainability management. Instead, contextual adaptation is required, taking into account sector characteristics, regulatory environments, and organizational capacities.

Overall, the synthesis results indicate that the enabling role of digital transformation in Industry 5.0 sustainability management is conditional and not free from risk. Digital transformation can function as a sustainability enabler only when accompanied by ethical governance, strengthened human capabilities, and adequate regulatory alignment. Without these prerequisites, digital transformation risks creating a sustainability paradox, in which technological advancement generates new risks that ultimately undermine sustainability objectives themselves.

## CONCLUSIONS

The literature synthesis in this study affirms that digital transformation functions as a key enabler in sustainability management in the Industry 5.0 era by enabling data integration, adaptive decision making, and the alignment of economic, environmental, and social objectives. In contrast to the Industry 4.0 paradigm, which is oriented toward efficiency and automation, Industry 5.0 positions digital transformation as a strategic means to create systems that are human centric, sustainable, and resilient. The findings indicate that the effectiveness of this enabling role is strongly determined by organizational digital capabilities, value orientation, and governance design that balances the integration of technology and human involvement.

This study also demonstrates that digital transformation entails limitations and risks that cannot be ignored, including disparities in digital readiness, technological bias, system dependency, conflicts with human centric values, and regulatory gaps. These risks underscore that digital transformation is not an automatic solution for sustainability, but rather a strategic process that requires ethical control, human participation, and clear regulatory frameworks. Accordingly, digitally based sustainability management must be

understood as a complex socio technical practice rather than merely a technological implementation. Based on these findings, this study recommends strengthening conceptual frameworks that integrate digital transformation and sustainability management from an Industry 5.0 perspective, while encouraging organizations to align digital strategies with long term sustainability objectives. From a practical standpoint, management needs to position digital technology as a value enabler rather than solely as an efficiency tool, and to ensure meaningful human involvement in decision making processes. Future research is recommended to empirically test the proposed conceptual framework through cross sectoral and cross national studies in order to strengthen the generalizability of the findings.

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