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Editorial

Managing digital transformation in Industry 4.0: from technological innovation to organizational and social impact

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Abstract: Digital transformation and Industry 4.0 have reshaped the way organizations design processes, make decisions, and create value across industrial, public, and social systems. This Special Issue of Transactions on Energy Systems and Engineering Applications brings together a diverse set of contributions that explore digital transformation not only as a technological phenomenon, but as a managerial, organizational, and societal challenge. The selected articles address key dimensions, including disruptive innovation assessment, business intelligence for public-sector decision-making, agile management in traditional industries, artificial intelligence in industrial quality control, operational efficiency through OEE automation, advanced sensing and data-driven modeling, digital inclusion as social innovation, and the socioeconomic impacts of ICT adoption. Together, these works offer a comprehensive view of how Industry 4.0 technologies must be strategically managed to generate sustainable value, enhance organizational performance, and promote inclusive development. This editorial contextualizes the contributions, highlights their interconnections, and outlines practical and research-oriented recommendations for advancing digital transformation management.

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1. Introduction

Digital transformation has become a defining force shaping contemporary industrial, organizational, and societal systems. Driven by the convergence of advanced digital technologies (such as artificial intelligence, data analytics, industrial Internet of Things (IIoT), cloud computing, and cyber–physical systems), Industry 4.0 represents a paradigm shift that goes beyond automation to fundamentally reconfigure value creation, decision-making, and governance structures [1–3].

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While early discussions on Industry 4.0 focused predominantly on technological architectures and manufacturing efficiency, recent research emphasizes that its success largely depends on managerial capabilities, organizational alignment, and the effective integration of digital technologies into existing socio-technical systems [4, 5]. Digital transformation is therefore increasingly understood as a multidimensional process involving strategy, culture, skills, and institutional change, rather than a purely technical upgrade [6, 7].

This managerial perspective is particularly relevant in complex and heterogeneous contexts, such as emerging economies and public-sector organizations, where legacy infrastructures, regulatory constraints, and limited digital maturity coexist with strong pressures for innovation and efficiency [8, 9]. In these environments, digital transformation initiatives must balance operational performance with transparency, inclusiveness, and social impact, reinforcing the need for applied and context-aware research.

Within this evolving landscape, Industry 4.0 technologies have demonstrated significant potential across diverse domains, including industrial process optimization, intelligent monitoring and sensing, data-driven decision support, and human-centered innovation [10, 11]. However, empirical, evidence shows that technological adoption alone does not guarantee value creation. Instead, organizations must develop adaptive management approaches, agile governance models, and data-informed leadership practices capable of navigating uncertainty and accelerating learning [12, 13].

This Special Issue of *Transactions on Energy Systems and Engineering Applications* contributes to this discourse by bringing together applied research that explores digital transformation and Industry 4.0 from complementary technological, managerial, and social perspectives. The selected articles address topics ranging from disruptive innovation assessment and business intelligence for decision-making to agile transformation in traditional industries, artificial intelligence in industrial processes, advanced sensing and data modeling, and inclusive digital innovation. Collectively, these contributions highlight the importance of managing digital transformation as an integrated system of technologies, organizations, and people, providing valuable insights for researchers, practitioners, and policymakers.

2. Context: Digital Transformation and Industry 4.0 as a Management Challenge

Digital transformation in Industry 4.0 environments is inherently complex and multidimensional. Organizations are required to simultaneously innovate, sustain competitiveness, comply with increasingly demanding regulatory frameworks, and respond to growing social and ethical expectations. These pressures transform digitalization into a strategic management challenge rather than a purely technological endeavor [14, 15]. The complexity is particularly pronounced in emerging economies, where digital initiatives must coexist with legacy infrastructures, limited resources, institutional constraints, and heterogeneous levels of digital maturity across sectors and organizations [16, 17].

From a managerial perspective, digital transformation requires aligning technology adoption with organizational structures, decision-making processes, and human capabilities. Research consistently shows that the absence of such alignment often leads to fragmented implementations, limited value creation, and resistance to change [18, 19]. Consequently, leadership, governance models, and cultural readiness play a decisive role in determining whether Industry 4.0 technologies translate into measurable performance improvements.

These challenges manifest across multiple organizational and institutional contexts. Related work highlights on inter-organizational and competitive dynamics, addressing how firms can identify and assess disruptive innovation in highly dynamic IT markets and how agile management practices can be implemented within traditionally structured industries, such as telecommunications. These studies reinforce the importance of adaptive management frameworks capable of navigating uncertainty, fostering strategic alignment, and accelerating organizational learning [20, 21].

Other contributions emphasize digital transformation within public-sector and institutional settings, illustrating how business intelligence platforms and data-driven tools can enhance transparency, monitoring, and decision-making in government-funded projects. Prior studies highlight that, in public organizations, digital transformation must balance efficiency gains with accountability, regulatory compliance, and public value creation, making managerial capabilities and change management critical success factors [22, 23].

In parallel, industrial-oriented studies demonstrate how Industry 4.0 technologies contribute to operational excellence when embedded within coherent managerial and operational frameworks. Applications such as automated OEE management systems, computer vision for quality control, and advanced fiber optic sensing illustrate how data integration, real-time analytics, and system interoperability enhance efficiency, reliability, and scalability in industrial environments [24–26]. These contributions underline that technological performance is closely linked to how systems are designed, governed, and used by decision-makers.

In this broader perspective, social and socioeconomic considerations expand the scope of Industry 4.0 beyond industrial efficiency. Articles addressing digital inclusion for older adults and the impact of ICT use on income and labor equity highlight the societal implications of digital transformation. Empirical evidence suggests that while digital technologies can foster productivity and income growth, they may also exacerbate inequalities if access, skills, and institutional support are unevenly distributed [27, 28]. As such, managing digital transformation increasingly requires an inclusive and human-centered approach that integrates technological progress with social sustainability.

3. Technical Background: From Data and AI to Integrated Systems and Business Value

From both a technical and managerial standpoint, data emerges as the foundational asset of digital transformation in Industry 4.0 environments. The ability to systematically collect, integrate, and analyze large volumes of heterogeneous data enables organizations to transition from intuition-driven management toward evidence-based, predictive, and increasingly autonomous decision-making models [29, 30]. In this sense, data is not merely a technical resource, but a strategic asset that underpins competitiveness, operational resilience, and long-term value creation.

Artificial intelligence (AI) and machine learning play a central role in unlocking this value. By transforming raw data into actionable insights, predictive signals, and optimization mechanisms, AI-driven solutions enhance process efficiency, quality assurance, and strategic planning. These technologies have a great relevance across multiple domains. Industrial applications based on deep learning and computer vision enhance quality control and reduce reliance on manual inspection. Meanwhile data-driven models for health and socioeconomic analysis support risk assessment, resource allocation, and policy design. These examples reinforce the idea that AI in Industry 4.0 should be understood as a managerial capability that augments human decision-making and organizational responsiveness, rather than as an isolated technological artifact [24, 31].

Beyond individual algorithms and analytical models, the growing importance of integrated systems and digital platforms has become evident as enablers of scalable and sustainable business value. Business intelligence ecosystems built on platforms such as Power BI, Power Apps, and Power Automate demonstrate how low-code environments and analytics platforms reduce implementation barriers while delivering tangible benefits to organizations. By integrating data sources, automating workflows, and visualizing key performance indicators, these platforms enhance transparency, coordination, and accountability across strategic, tactical, and operational levels of the organization [23, 32].

In industrial contexts, the development of web-based systems for Overall Equipment Effectiveness (OEE) management exemplifies how the convergence of operational technologies (OT) and information

technologies (IT) supports real-time monitoring and continuous improvement. The integration of PLC connectivity, data acquisition layers, analytics, and visualization dashboards enables organizations to align shop-floor performance with managerial objectives and strategic priorities. This alignment highlights the role of systems architecture and platform design as critical components of Industry 4.0 initiatives, directly influencing operational excellence and business performance [33, 34].

Importantly, business value does not emerge from isolated technological deployments, but from the orchestration of data, AI models, systems, and platforms within coherent organizational and governance frameworks. Factors such as system interoperability, data quality, model generalization, cybersecurity, and usability determine whether digital solutions evolve from experimental prototypes into production-ready capabilities. Prior research consistently shows that organizations capture sustained value from digital transformation only when these technical components are integrated into broader managerial, architectural, and strategic structures [15, 20]. Consequently, Industry 4.0 success depends on managing digital technologies as interconnected socio-technical systems that align with organizational goals and create business value.

From an engineering perspective, these findings reinforce the importance of architectural thinking in digital transformation initiatives. Industry 4.0 solutions increasingly rely on multi-layered architectures that integrate data acquisition, analytics, control systems, and digital platforms across IT and OT domains. Decisions related to system modularity, interoperability standards, cybersecurity, and scalability directly affect not only technical performance but also managerial flexibility and long-term sustainability. As such, engineering design choices become strategic decisions that link system architecture with the creation of organizational value.

Table 1 summarizes how data, artificial intelligence, integrated systems, and digital platforms interact across multiple layers to generate organizational and business value in Industry 4.0 environments. Rather than operating in isolation, these layers must be orchestrated within coherent managerial and governance frameworks to enable scalable, sustainable, and value-driven digital transformation.

Table 1. From Data and AI to Integrated Systems and Business Value in Industry 4.0

Layer	**Core Capability**	**Typical Systems / Platforms**	**Managerial Impact**	**Business Value**
Data	Data collection, integration, and quality	Data pipelines, BI systems, data lakes	Evidence-based decision-making	Transparency, control, faster decisions
Analytics & AI	Prediction, classification, optimization	ML pipelines, AI services, analytics engines	Improved decision quality and foresight	Efficiency, quality, risk reduction
Systems Integration	IT/OT interoperability	PLC interfaces, sensors, APIs, middleware	Alignment between operations and management	Reliability, real-time visibility
Digital Platforms	Automation and visualization	Low-code platforms, dashboards, web systems	Organizational agility and coordination	Scalability, cost efficiency
Governance & Use	Adoption, trust, and accountability	Governance frameworks, security layers	Sustainable use of digital capabilities	Long-term value creation

Figure 1 provides a conceptual representation of how digital transformation in Industry 4.0 environments is driven by the orchestration of data, artificial intelligence, integrated systems, and digital platforms. The figure illustrates a clear value creation flow in which digital capabilities are integrated and operationalized

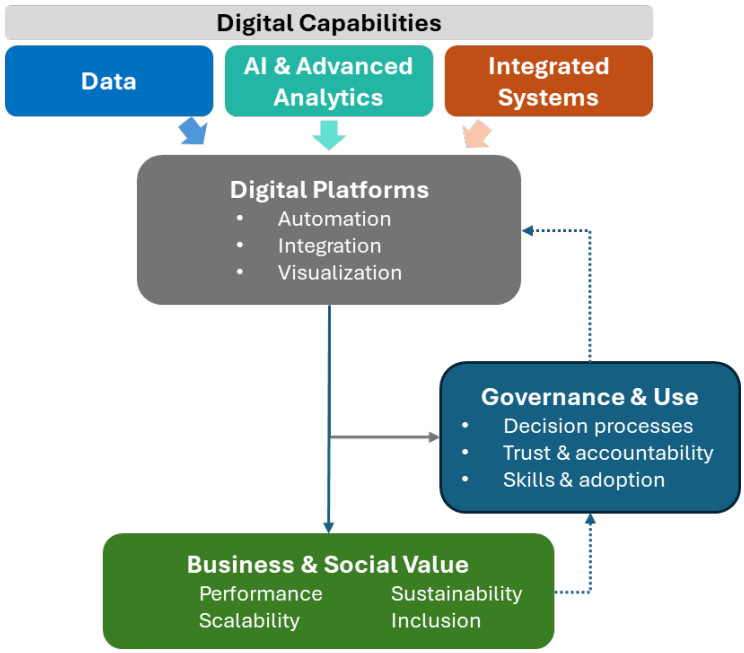

Figure 1. Orchestrating digital capabilities, platforms, and governance for business and social value in Industry 4.0.

through platforms that enable automation, integration, and visualization, ultimately leading to business and social value. In parallel, governance and use mechanisms shape how platforms are designed, adopted, and exploited, while feedback from achieved value informs continuous adjustments in decision processes, skills development, and accountability structures. This representation reinforces the idea that digital transformation is an ongoing, socio-technical process in which value emerges from coordinated capabilities rather than isolated technologies.

4. Cross-Cutting Themes and Managerial Insights

Digital transformation and Industry 4.0 initiatives consistently reveal a set of cross-cutting themes that transcend specific technologies, sectors, or organizational contexts. One of the most salient themes is the central role of decision-making as a driver of organizational value. The increasing availability of data, analytics, dashboards, and performance indicators enables organizations to move toward more transparent, evidence-based, and timely decisions. However, the managerial challenge lies not only in deploying analytical tools, but in embedding data-driven reasoning into everyday management practices and strategic processes.

A second recurring theme concerns cultural and organizational transformation. The introduction of agile practices, digital tools, and platform-based ways of working often clashes with deeply rooted structures, routines, and mindsets, particularly in traditionally hierarchical or functionally siloed organizations. Successfully navigating this tension requires leadership capable of fostering trust, experimentation, and learning, while aligning new ways of working with organizational purpose and strategic objectives. In this sense, digital transformation is as much a cultural endeavor as it is a technological one.

Scalability and replicability also emerge as critical managerial concerns. Digital initiatives increasingly seek to move beyond isolated pilots toward solutions that can be extended across units, organizations, or even sectors. Achieving this scalability depends on modular architectures, standardized processes, and adaptable frameworks that allow digital solutions to be contextualized without losing coherence. From

a management perspective, scalability is closely linked to governance, architectural decisions, and the capacity to institutionalize learning.

Equally important are the human and social dimensions of digital transformation. Beyond efficiency and productivity gains, Industry 4.0 initiatives have profound implications for inclusion, skills development, and equity. Issues such as digital inclusion, intergenerational learning, and gender-related disparities highlight that technological progress can generate uneven outcomes if not accompanied by deliberate policies and managerial attention. Addressing these dimensions requires a human-centered approach that integrates social impact considerations into digital strategies.

Finally, a persistent theme across digital transformation initiatives is the need to bridge research and practice. The most impactful transformations tend to be grounded in real-world experimentation, iterative implementation, and close collaboration between technical experts, managers, and institutional stakeholders. This interaction not only enhances practical relevance, but also supports organizational learning and continuous improvement.

Taken together, these cross-cutting themes reinforce the idea that managing digital transformation in Industry 4.0 environments requires balance: between technical expertise and strategic leadership, between innovation and inclusion, and between short-term efficiency gains and long-term sustainability. Organizations that recognize and actively manage these tensions are better positioned to translate digital technologies into enduring organizational and societal value.

Table 2 synthesizes the main cross-cutting managerial themes that characterize digital transformation and Industry 4.0 initiatives across organizational contexts. Rather than focusing on specific technologies or implementation details, the table emphasizes recurrent managerial challenges and the strategic questions they raise for decision-makers. By explicitly linking each theme to practical implications, the table provides a structured lens for interpreting digital transformation as a leadership and governance challenge, highlighting the need for coherent decision-making processes, cultural alignment, scalable architectures, inclusive strategies, and continuous learning through practice. As such, the table complements the discussion by translating conceptual insights into actionable considerations for managers and policymakers.

Table 2. Cross-Cutting Managerial Themes in Digital Transformation and Industry 4.0

Theme	Managerial Challenge	Key Question for Leaders	Implication for Practice
Data-driven decision-making	Moving from intuition to evidence	How do we embed analytics in everyday decisions?	Redesign decision processes and KPIs
Organizational culture	Resistance to new ways of working	How do we align agility with existing structures?	Invest in leadership and change management
Scalability	From pilots to enterprise-wide impact	How can solutions scale without losing coherence?	Design modular and interoperable architectures
Human and social dimensions	Uneven access and outcomes	How do we ensure inclusive digital transformation?	Integrate skills, inclusion, and ethics into strategy
Research–practice linkage	Gap between theory and execution	How do we learn while transforming?	Promote experimentation and collaboration

5. Overview of Contributions to the Special Issue

This special issue of Transactions on Energy Systems and Engineering Applications showcases digital transformation across sectors: from a framework to identify disruptive innovation [35]; BI architectures for project governance [36]; agile telecom transformation practices [37]; real-time automated OEE for Industry 4.0 operations [38]; computer-vision quality control in agroindustry [39]; MobileNet sensing models [40];

and inclusive digital-skills programs for older adults [41]; applied socio-technical modeling to labor context [42]; and data-analysis to health applications [43]. The topics cover several socio-technical areas with deliverables, approximations, and contributions to engineering, management, health and societal issues.

In their paper Zeidanloo and Špaček, introduce a robust framework to detect disruptive innovation in the IT sector by quantifying intercompany impact, enabling firms and policymakers to benchmark disruptive potential beyond product-level signals. For the special issue, it strengthens technology forecasting and strategic resilience by integrating multi-criteria assessment and dynamics into an evaluation approach. [35]

Sánchez-Gómez et.al., demonstrate how Microsoft 365, Power Platform, and BI dashboards can operationalize data-driven governance for royalty-funded projects, automating workflows, consolidating indicators, and accelerating executive decisions. Its special-issue contribution lies in showing an implementable digital architecture that improves transparency, traceability, and resource control in public programs through analytics-enabled project management. [36]

This second study presented by Sánchez-Gómez et.al. in agile transformation in a Colombian telecommunications firm, linking Scrum practices to faster adaptation under volatile markets. It contributes to the special issue by offering guidance on aligning routines, roles, and metrics with digital transformation goals, highlighting organizational levers that sustain delivery, stakeholder engagement, and process standardization. [37]

On the other hand, Gomez et.al., present AutOEE, an automated OEE management system integrating PLC connectivity (Snap7), databases, and real-time visualization to convert shop-floor signals into actionable performance insights. As a special-issue contribution, it provides an Industry 4.0 blueprint for continuous improvement, enabling rapid diagnosis of losses, measurable uptime improvements, and corrective actions. [38]

The paper presented by Arias et al., develops a deep-learning computer-vision model to classify fresh versus rotten fruits in industrial lines, supporting quality control with reduced manual inspection. Its special-issue value is the applied AI workflow—from dataset curation to evaluation—that reliably transfers to agroindustrial contexts to lower waste, protect safety, and maintain throughput. [39]

The work elaborated by Huertas-Montes et al. evaluates MobileNet-based CNNs for temperature prediction in simulated specklegram fiber-optic sensors, emphasizing generalization through mixed synthetic datasets and data augmentation. For the special issue, it advances trustworthy ML deployment in sensing by quantifying robustness across conditions, offering a methodological template for improving model transferability in low-data experimental environments. [40]

The paper presented by Manrique-Rojas et al. proposes an intergenerational social innovation strategy where university students train older adults in essential digital skills using a five-phase implementation and evaluation framework. Its special-issue contribution is demonstrating inclusive digital transformation with clear impact metrics, positioning universities as scalable agents to reduce the digital divide and improve community cohesion. [41]

Meza-Fregoso adds an applied socio-technical lens to the special issue by modeling labor income formation in a border-city ecosystem through the use of ICT and sociodemographic drivers employing linear regression, and informs evidence-based policies for equitable digitalization and workforce development in complex urban labor markets [42]

Consuegra, Sanmartin-Mendoza, Heredia-Vizcaino, and Huerta contribute a structured data-analysis model to categorize cardiovascular risk tailored to Atlántico (Colombia), aligning health analytics with engineering applications by mapping components, relationships, and validation considerations needed to operationalize risk prediction for local decision-making. [43]

6. Conclusions and Recommendations

Digital transformation and Industry 4.0 should be understood not as ends in themselves, but as means to enhance organizational performance, public value creation, and social well-being. As discussed throughout this editorial, the effective use of data, artificial intelligence, integrated systems, and digital platforms enables organizations to improve decision-making, increase operational efficiency, and respond more adaptively to complex and dynamic environments. However, realizing this potential depends fundamentally on how these technologies are managed, governed, and embedded within organizational and institutional contexts.

The analysis highlights that successful digital transformation requires context-aware management approaches that balance technological innovation with cultural alignment, scalability, and human-centered considerations. Data and AI emerge as critical enablers of value creation only when orchestrated within coherent systems architectures and platform-based ecosystems that support transparency, coordination, and accountability. At the same time, issues such as organizational culture, skills development, inclusion, and equity underscore that digital transformation is inherently a socio-technical process rather than a purely technical one.

From an engineering standpoint, managing digital transformation also involves navigating trade-offs between performance, complexity, cost, security, and scalability, reinforcing the need for interdisciplinary collaboration between engineers, managers, and decision-makers.

From a managerial perspective, these insights point to the need for leadership capable of integrating technical expertise with strategic vision. Managers must move beyond isolated digital initiatives toward integrated transformation strategies that align analytics, automation, and systems integration with organizational objectives and long-term sustainability. This includes investing in governance structures, fostering learning-oriented cultures, and designing scalable solutions that can evolve over time.

From a research and policy standpoint, the discussion reinforces the importance of interdisciplinary and practice-oriented inquiry into digital transformation and Industry 4.0. Future work would benefit from comparative and longitudinal studies that examine how data-driven systems, AI-enabled decision-making, and digital platforms generate value across sectors and regions, particularly in emerging economies. Greater attention to social and ethical dimensions will also be essential to ensure that digital transformation contributes to more inclusive, resilient, and sustainable organizational and societal systems.

Ultimately, managing digital transformation in Industry 4.0 environments is a strategic and ongoing endeavor. Organizations that approach it as an integrated process—combining data, AI, systems, platforms, and human capabilities—are better positioned to translate technological potential into enduring organizational and societal value.

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