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# Intelligent, Sustainable, and Resilient Industrial Management: Navigating Complexity and Uncertainty

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## Introduction

The landscape of industrial management is undergoing a fundamental transformation as organizations increasingly operate within environments characterized by volatility, uncertainty, complexity, and ambiguity (VUCA). Global supply chain disruptions, geopolitical tensions, technological turbulence, regulatory changes, climate-related challenges, and rapidly evolving customer expectations have fundamentally altered the conditions under which industrial organizations make decisions and compete. The interconnectedness of contemporary enterprises means that disruptions originating in one part of an economic or technological ecosystem can rapidly propagate across organizational, geographical, and sectoral boundaries. The COVID-19 pandemic, semiconductor shortages, geopolitical instability, and other systemic disruptions have demonstrated that conventional approaches centered primarily on efficiency, predictability, and local optimization are increasingly insufficient for organizations operating in highly interconnected environments (Borissov, 2024; Havale et al., 2024). Consequently, industrial management is progressively shifting toward a new paradigm in which intelligence, adaptability, resilience, and sustainability must be considered simultaneously rather than as separate managerial objectives.

This transformation is particularly evident in the changing nature of industrial decision-making. Traditional decision-making models often assume relatively stable environments, well-defined parameters, and the availability of sufficient information for selecting an optimal course of action. Contemporary industrial systems, however, are characterized by multiple and frequently conflicting objectives, incomplete information, dynamic interactions, and different forms of uncertainty. Technical, market, regulatory, economic, environmental, aleatory, and epistemic uncertainties can simultaneously influence organizational choices, making deterministic approaches increasingly inadequate for complex managerial problems (Carayannis & Zotas, 2026). Under these circumstances, the challenge is no longer simply to identify the best decision under known conditions, but to develop decisions and systems that remain effective when assumptions change, information is incomplete, and unexpected disruptions occur. This shift has elevated the importance of multi-criteria decision analysis, scenario planning, robust optimization, fuzzy approaches, and AI-driven analytical tools in contemporary industrial management (Carayannis & Zotas, 2026; Umar et al., 2026).

The emergence of Industry 4.0 technologies has accelerated this transformation by providing organizations with unprecedented capabilities to sense, analyze, predict, and respond to changes in their operating environments. Technologies such as artificial intelligence (AI), machine learning, the Internet of Things (IoT), digital twins, advanced analytics, and automation are increasingly being integrated into decision support systems, enabling organizations to move beyond reactive management toward more predictive and adaptive forms of decision-making (Subrahmanyam & Beainy, 2027; Roos, 2026). In this context, intelligent decision support systems represent an important bridge between technological capabilities and managerial action. By combining operational research with AI and real-time data, these systems can support organizations in addressing complex problems involving uncertainty, disruption, resource allocation, forecasting, and optimization. Stochastic modeling, fuzzy logic, hybrid AI–OR approaches, and simulation-based methods, for example, provide mechanisms through which organizations can incorporate uncertainty directly into their decision processes rather than treating it as an external disturbance (Subrahmanyam & Beainy, 2027).

Yet, intelligence and efficiency alone are no longer sufficient measures of industrial performance. The increasing severity of environmental challenges and the growing pressure from regulators, customers, investors, and other stakeholders have made sustainability an integral component of strategic and operational decision-making. Organizations are therefore required to balance economic performance with environmental and social objectives while simultaneously maintaining resilience against disruption. This creates a particularly challenging managerial landscape because sustainability, efficiency, resilience, and flexibility do not always reinforce one another. Indeed, recent research shows that organizations operating during periods of multiple crises face fundamental tensions between sustainability and efficiency, sustainability and resilience, global operations and sustainable practices, as well as technological innovation and stakeholder inclusion (Kareem et al., 2025). The central challenge for industrial management is consequently evolving from optimizing a single performance dimension toward managing interconnected and sometimes conflicting objectives within complex adaptive systems.

The relationship between resilience and sustainability is especially important in this emerging paradigm. Resilient organizations must not only withstand disruptions and recover from adverse events but also develop the capacity to adapt and thrive as their environments change. Viewing enterprises as complex systems highlights the importance of interdependencies, feedback loops, nonlinearities, and emergent behaviors in shaping organizational resilience (Borissov, 2024). Similarly, sustainability-oriented management increasingly requires organizations to anticipate uncertainty, adapt their strategies, and integrate environmental and social considerations into long-term decision-making (Singha, 2024). In supply chain management, this perspective has encouraged a transition toward systems that use predictive analytics and AI to anticipate risks, optimize resources, strengthen collaboration, and simultaneously advance ecological and social objectives (Anwar et al., 2026). Thus, the future of industrial management lies not simply in making organizations more digital or more efficient, but in developing systems capable of learning, adapting, and creating sustainable value under changing conditions.

This shift is also reshaping the strategic role of supply chains and manufacturing systems. Contemporary supply chains increasingly need to function as adaptive networks capable of responding to disruptions while maintaining economic and environmental performance. Predictive analytics can improve demand forecasting and risk identification, while AI-enabled systems can support dynamic resource allocation and rapid adaptation to changing conditions (Anwar et al., 2026). At the same time, robust optimization and other advanced analytical approaches can help decision-makers address epistemic uncertainty while balancing economic and environmental objectives. For example, robust optimization frameworks have demonstrated their potential to identify solutions that remain feasible and effective under uncertain conditions while simultaneously addressing cost and environmental performance in sustainable supply chains (Umar et al., 2026). These developments suggest that the emerging frontier of industrial management is characterized by the convergence of intelligent technologies, advanced analytical methods, resilience thinking, and sustainability principles.

Importantly, this transformation requires a broader understanding of what it means for an industrial system to be "intelligent." Intelligence should not be reduced to the deployment of AI or automation technologies. Rather, it encompasses the capacity of an organization or system to sense changes, interpret complex information, learn from experience, anticipate potential disruptions, adapt its behavior, and make decisions that remain aligned with long-term economic, environmental, and societal objectives. The development of such capabilities requires the integration of technological and organizational dimensions. Successful navigation of VUCA manufacturing environments, for instance, depends not only on AI, automation, and robotics but also on institutional adaptation, dynamic learning, and the orchestration of technological capabilities (Roos, 2026). Likewise, cybernetic approaches to uncertainty emphasize that effective resilience requires interaction between human judgment, technological intelligence, data, and diverse stakeholder perspectives rather than relying exclusively on automated decision-making (Cotet et al., 2024).

Against this background, industrial management is entering a new stage in which the central question is no longer whether organizations should adopt digital and intelligent technologies, but how these technologies can be strategically integrated to create systems that are simultaneously intelligent, resilient, sustainable, and adaptable. The future competitive advantage of industrial organizations will increasingly depend on their ability to navigate uncertainty rather than simply eliminate it, to balance competing objectives rather than optimize a single dimension, and to transform disruption from a source of vulnerability into an opportunity for organizational learning and renewal (Carayannis & Zotas, 2026; Roos, 2026). This emerging paradigm calls for a closer integration of operational research, artificial intelligence, sustainability management, resilience engineering, systems thinking, and strategic decision-making.

The initial steps in this journey towards intelligence began with the widespread digitization of supply chain operations. As Garay-Rondero et al. (2020) compellingly highlight, the contemporary Digital Supply Chain (DSC) model has been meticulously shaped and significantly accelerated by the advent and pervasive integration of Industry 4.0 concepts. This foundational phase involves the strategic deployment of various digital technologies to enhance and streamline processes across the entire supply chain spectrum, from high-level strategic planning down to granular operational execution. The core objective is to foster unprecedented levels of collaboration, both within an enterprise (across functional units) and between different enterprises (across the supply network) (Jandhyala, 2021). This foundational digitization is paramount for achieving key strategic imperatives such as enhanced responsiveness, robust sustainability, improved profitability, and critical resilience in the face of frequent disruptions (Jandhyala, 2021). In essence, a truly connected and visible supply chain data infrastructure becomes the indispensable bedrock for informed analysis, proactive sensing of market shifts, and agile, effective responses.

Building upon this digital foundation, the true "intelligence" in these evolving networks emerges from the synergistic convergence of cutting-edge digital technologies. Rozhko and Khalov (2026) articulate this transformation, noting how the powerful integration of Artificial Intelligence (AI), Machine Learning (ML), the Internet of Things (IoT), blockchain, digital twins, and cloud computing is converting what were once simple, linear supply chains into complex, self-organizing, and highly intellectual ecosystems. These advanced technological integrations empower supply networks to transcend their traditional functions, enabling them to become truly autonomous, self-optimizing entities. Such intelligent networks are not only capable of sophisticated demand prediction but can also adapt with an unprecedented level of flexibility and transparency, fundamentally altering the competitive landscape for businesses.

## Insights from This Issue

The articles in the current issue collectively reflect a significant shift in industrial management from isolated optimization toward integrated, intelligent, and sustainability-oriented decision-making. The first group of contributions highlights the growing importance of sustainability and environmental considerations in operational and strategic decisions. Yaftiyan et al. (2026) examine recurrent carbon reduction policies in the pharmaceutical distribution sector, demonstrating the importance of identifying the key variables that shape the effectiveness of carbon reduction interventions in a complex industry context. Similarly, Ebrahimi Kordlar et al. (2026) address the challenge of managing project costs while simultaneously evaluating sustainability performance through a fuzzy inference system. Together, these studies illustrate how environmental objectives are increasingly being incorporated directly into managerial and operational models rather than being treated as secondary considerations.

A second important theme emerging from this issue is the growing role of intelligent analytical and optimization approaches in addressing complex decision problems. Khorrami et al. (2026) develop an optimization-simulation model for credit scoring and loan structuring, employing a memetic algorithm to support decision-making for corporate banking clients. Their contribution demonstrates how advanced optimization techniques can combine different analytical capabilities to address problems involving multiple variables and complex decision structures. In a different context, Heidary Dahooie et al. (2026) formulate a mathematical model for reviewer assignment that simultaneously considers maximum coverage, fairness, and expertise matching. These studies demonstrate that the application of advanced mathematical and computational approaches is extending beyond traditional production and supply chain problems toward broader organizational decision environments.

The issue also highlights the increasing convergence of resilience, agility, sustainability, and intelligence in the management of critical organizational systems. Nazari-Shirkouhi and Zarei Babaarabi (2026) apply the Lean, Agile, Resilient, Green, and Sustainable (LARGS) paradigm to the performance evaluation of hospital departments under uncertainty, illustrating how multiple performance dimensions can be integrated into decision-making in complex healthcare environments. Complementing this perspective, Ghasemi et al. (2026) provide a meta-synthesis of research on intelligent supply chain management in the Industry 4.0 era, offering a broader view of how emerging technologies and intelligent capabilities are reshaping supply chain management. Pashang et al. (2026) further extend this transformation into logistics by developing a green routing network with an optimized heterogeneous fleet, demonstrating how advanced analytical approaches can simultaneously address operational efficiency and environmental objectives.

Taken together, the contributions of this issue reveal that the future of industrial management is increasingly defined by the integration of three complementary capabilities: intelligence, sustainability, and adaptability. Whether the context is pharmaceutical distribution, banking, construction, healthcare, supply chain management, academic resource allocation, or food logistics, organizations face decision environments in which objectives are interconnected, information is imperfect, and conventional approaches may no longer be sufficient. The studies in this issue demonstrate how hybrid methodologies, optimization algorithms, fuzzy systems, meta-synthesis, and multi-dimensional evaluation frameworks can support more informed and responsible decisions. More broadly, they suggest that the next generation of industrial management will require moving beyond the pursuit of efficiency alone toward the design of systems that can simultaneously anticipate change, manage uncertainty, reduce environmental impact, and create sustainable value. In this sense, the articles in the present issue provide complementary pieces of a broader transformation toward intelligent and sustainable industrial systems.

## Future Research Agenda

As industrial organizations increasingly operate at the intersection of uncertainty, technological change, and sustainability pressures, future research should move beyond examining these dimensions independently and instead investigate their interactions within integrated industrial systems. A particularly important direction concerns the development of theoretical frameworks that explain how intelligence, resilience, sustainability, and adaptability can be simultaneously developed and coordinated. Existing perspectives often emphasize one dimension—such as technological intelligence, supply chain resilience, or environmental sustainability—while paying less attention to the trade-offs and complementarities among them. Future studies could therefore draw on systems thinking, complexity theory, dynamic capabilities, and resilience engineering to develop integrative models capable of explaining how organizations sense disruptions, learn from them, adapt their operations, and maintain sustainable performance over time (Borissov, 2024; Singha, 2024). Such frameworks should also distinguish between different forms and sources of uncertainty and examine how organizational responses vary across technological, environmental, economic, and institutional contexts.

A second promising research avenue lies in advancing intelligent decision-support and optimization approaches for complex managerial environments. Although AI, machine learning, fuzzy logic, simulation, robust optimization, and metaheuristic algorithms are increasingly being applied to industrial problems, further research is needed to understand how these approaches can be effectively integrated rather than applied as isolated methodological tools. Hybrid AI–operational research frameworks could combine predictive capabilities with optimization and simulation to support decisions that are both adaptive and robust under changing conditions (Subrahmanyam & Beainy, 2027). Future research should also investigate explainable and human-centered AI, particularly in high-stakes contexts where managerial judgment, accountability, and stakeholder preferences remain essential. Similarly, robust and multi-objective optimization deserves greater attention for problems in which economic, environmental, and social objectives conflict, enabling researchers to move from identifying theoretically optimal solutions toward solutions that remain effective under epistemic and aleatory uncertainty (Carayannis & Zotas, 2026; Umar et al., 2026).

A third area requiring deeper investigation concerns the tensions between sustainability, resilience, efficiency, and technological transformation. Future research should examine when these objectives reinforce one another and when pursuing one may undermine another. The tensions identified in sustainable supply chain research—including the trade-offs between efficiency and sustainability, sustainability and resilience, globalization and environmental responsibility, and technological innovation and stakeholder inclusion—provide an important foundation for developing more nuanced models of sustainable industrial management (Kareem et al., 2025). In particular, longitudinal and comparative studies could examine how organizations respond to multiple simultaneous crises and whether investments in digital technologies genuinely strengthen long-term resilience and sustainability or merely shift risks to less visible parts of the system. Research should also pay greater attention to organizational capabilities, stakeholder participation, governance mechanisms, and the unintended consequences of technological adoption, particularly for organizations and stakeholders with limited technological and financial resources.

Finally, future research should increasingly move from methodological novelty toward real-world implementation, experimentation, and interdisciplinary validation. Many intelligent and sustainable management models remain highly context-dependent, creating a need for empirical studies across industries, countries, and institutional environments. Research could investigate how AI-enabled predictive analytics, digital twins, cybernetic systems, robotics, and other Industry 4.0 technologies perform under actual disruption conditions and how their effectiveness changes across different organizational maturity levels (Anwar et al., 2026; Cotet et al., 2024; Roos, 2026). Greater attention should also be devoted to developing dynamic performance measurement systems that capture not only efficiency but also adaptability, recovery capacity, environmental impact, and long-term value creation. Ultimately, the future research agenda should seek to connect advanced analytical methods with organizational and societal realities, creating industrial systems that are not only more intelligent but also more resilient, inclusive, environmentally responsible, and capable of sustaining value creation in an increasingly uncertain world.

## Conclusion

The transformation of industrial management is increasingly defined by the convergence of intelligent decision-making, sustainability, resilience, and adaptability. The contributions presented in this issue demonstrate that organizations can no longer rely solely on traditional efficiency-oriented approaches when operating in environments characterized by uncertainty, disruption, technological change, and growing sustainability pressures. From carbon reduction and green transportation to intelligent supply chains, sustainable project management, healthcare performance, financial decision-making, and advanced optimization, the studies in this issue collectively illustrate the growing importance of analytical and computational capabilities for addressing complex managerial challenges. The integration of AI, optimization, fuzzy systems, simulation, and other advanced methodologies provides new opportunities to support decisions that are more informed, adaptive, and aligned with multiple economic and environmental objectives. Looking ahead, the next frontier of industrial management will not simply be defined by how intelligently organizations can automate decisions, but by how effectively they can combine technological intelligence with human judgment, organizational resilience, and sustainable value creation. The challenge is to develop industrial systems that can anticipate disruption, learn from uncertainty, adapt to changing conditions, and simultaneously balance economic, environmental, and social objectives. Achieving this vision requires continued interdisciplinary collaboration among researchers in industrial management, operations research, artificial intelligence, sustainability, resilience engineering, and organizational studies. Ultimately, the transition toward intelligent and sustainable industrial systems represents not merely a technological evolution, but a broader transformation in the way organizations understand uncertainty, make decisions, and create value in an increasingly complex world.

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