EVOLVING LEADERSHIP IN THE DIGITAL ERA: COMPETENCIES AND STRATEGIES FOR NAVIGATING INDUSTRY 4.0

Domagoj Hruška
Full Professor at Faculty of Economics and Business Zagreb
dhruska@efzg.hr

Radoslav Barišić
Assistant Professor at Faculty of Economics and Business Zagreb
rbarisic@efzg.hr

Tomislav Baković
Full Professor at Faculty of Economics and Business Zagreb
tbakovic@efzg.hr

EXTENDED ABSTRACT

Purpose The rapid implementation of Industry 4.0, driven by the integration of digital technologies, automation, big data analytics, and cyber-physical systems, represents a transformative shift in industrial paradigms. This Fourth Industrial Revolution is unique in its fusion of technologies, which blur the boundaries between the physical, digital, and biological domains (Schwab, 2017). The technological advancements embedded within Industry 4.0 significantly impact leadership in organizations. As the complexity and dynamism of Industry 4.0 environments grow, there is a pressing need for new leadership competencies that emphasize agility, digital fluency, and collaborative capabilities (Faller and Feldmüller, 2015). In parallel, the education sector within the European Union has recognized the importance of preparing future leaders to address not only the digital challenges of Industry 4.0 but also the societal and economic complexities of the 21st century. The concept of entrepreneurial leadership in EU education acknowledges these emerging trends and seeks to cultivate leaders equipped with emotional intelligence and intercultural competence. This chapter aims to conceptualize a model of entrepreneurial leadership that bridges the gap between theoretical learning and real-world applications, particularly in the context of rapidly evolving industrial and educational landscapes.

As traditional leadership models may no longer be adequate to meet the demands of Industry 4.0, leaders must evolve, becoming facilitators of digital transformation and enablers of innovation within their organizations (Kagermann, 2015). Similarly, the proposed model of entrepreneurial leadership in EU education emphasizes the development of leaders who can foster experiential learning and cross-cultural collaboration, skills that are essential for thriving in the interconnected, technology-driven world of Industry 4.0.

Digital transformation technologies have changed contemporary organizational environments and operations (Ly, 2023). The practitioners agreed on visionary thinking, agility, understanding the value of data, data-driven decision-making, knowledge of strategy, and accepting change as the most important requirements for managing digital transformation (Philip *et al.*, 2023).

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Table 1: Key competencies of leaders in the era of Industry 4.0

Competency	Description	Source
Digital Literacy	Ability to understand and apply digital tools	Faller and Feldmüller (2015)
Strategic Vision	Long-term planning and forecasting trends	Kagermann (2015)
Emotional Intelligence	Managing emotions and communicating with diverse teams	Schwab (2017)
Intercultural Competence	Ability to work in a global, intercultural environment	Oberer and Erkollar (2018)
Agility	Rapid adaptation to changing circumstances	North, Maier, and Haas (2018)

(Source: Authors analysis)

By integrating the core elements of Industry 4.0 into leadership education, this research seeks to explore how educational strategies and leadership competencies can be aligned to foster innovation, adaptability, and workforce engagement. Both Industry 4.0 and the evolving leadership models within EU education converge on a common objective: equipping future leaders with the tools and skills necessary to navigate the complexities of a rapidly changing technological and societal landscape.

Methodology The proposed research will adopt a qualitative approach to explore the evolving leadership competencies required in Industry 4.0. By focusing on the qualitative dimension of leadership, this study aims to capture in-depth insights into how leaders are navigating the challenges of digital transformation and fostering innovation in their organizations. This approach will provide a more nuanced understanding of the leadership styles and strategies that are most effective in the context of the Fourth Industrial Revolution.

Data collection will occur through two primary methods: semi-structured interviews and case studies. Firstly, a series of semi-structured interviews will be conducted with a select group of participants who have demonstrated leadership success in the digital age. These participants will be chosen based on their experience and proven track record in leading organizations through digital transformation initiatives. The interviews will explore key aspects of their leadership practices, including decision-making processes, approaches to fostering collaboration, and strategies for overcoming the complexities associated with Industry 4.0. The semi-structured format will allow for flexibility in the interviews, enabling participants to share their experiences while ensuring that key themes relevant to Industry 4.0 leadership are addressed. Thematic analysis will be applied to the interview data to identify recurring patterns, themes, and insights (Guest *et al.*, 2012). In addition to interviews, this research will employ case studies of organizations that have successfully embraced Industry 4.0 technologies. These case studies will provide concrete examples of leadership practices in action, offering valuable contextual insights. Through an examination of these organizations, the research will explore how leadership competencies, organizational culture, and strategic decision-making have influenced the successful implementation of digital technologies. The case studies will help to illuminate the specific factors that contribute to leadership efficacy in the Industry 4.0 environment, providing practical examples of leadership models that can be applied across different sectors.

In parallel, this study will draw on the conceptual framework of entrepreneurial leadership in EU education. The qualitative data gathered from interviews and case studies will also be

analyzed in light of the evolving educational strategies aimed at developing entrepreneurial leadership competencies. By comparing leadership practices in Industry 4.0 with educational models that emphasize emotional intelligence, intercultural competence, and experiential learning, the research aims to offer a comprehensive perspective on how leadership can be cultivated in both industrial and educational settings.

This combined methodological approach-semi-structured interviews, thematic analysis, and case studies offer a detailed, context-rich understanding of the leadership competencies required for success in the rapidly changing landscape of Industry 4.0, as well as provide insights for enhancing leadership education in the EU.

Findings The research is anticipated to yield several significant insights into the evolving role of leadership within the context of Industry 4.0. Through an in-depth analysis of qualitative data gathered from interviews and case studies, the study aims to uncover essential leadership competencies that will define success in this technology-driven era. One of the primary findings is the identification of a core set of competencies, including digital literacy, strategic vision, and the ability to lead diverse, cross-functional teams. These skills are crucial for leaders to navigate the complexities of a rapidly changing technological landscape, where traditional boundaries between departments and roles are increasingly blurred. Emotional intelligence and intercultural competence, as emphasized in the entrepreneurial leadership model in EU education, will also emerge as critical competencies for managing global and interconnected teams in this new industrial paradigm.

In addition to identifying core competencies, the research is expected to provide empirical evidence on the relationship between leadership styles and organizational outcomes, particularly in fostering innovation and employee engagement. Leadership styles that prioritize transformational and servant leadership are likely to be associated with higher levels of organizational adaptability and creativity. These styles, which emphasize fostering a culture of continuous improvement and putting people first, are expected to play a vital role in navigating the challenges of digital transformation in Industry 4.0 environments.

The study will also offer practical recommendations for leadership development programs designed to equip leaders with the skills necessary for Industry 4.0. These programs will need to emphasize continuous learning and agility, ensuring that leaders remain adaptable in the face of rapidly evolving technologies and market conditions. Developing interdisciplinary knowledge that blends technical, strategic, and interpersonal skills will be critical to preparing leaders for the multifaceted challenges posed by Industry 4.0.

Qualitative findings will provide further insights into how leaders manage the interplay between technology and human factors in practice. As organizations become more automated, leaders will need to address ethical concerns related to automation, data privacy, and artificial intelligence, while ensuring that technological advancements align with organizational values. Maintaining a human-centric approach in leadership, which balances the increasing role of automation with the need to preserve human creativity and collaboration, will be vital for fostering a cohesive and motivated workforce.

Finally, the case studies will serve as valuable models of best practices, offering a roadmap for leaders guiding their organizations through digital transformation. These case studies will highlight effective leadership strategies for integrating Industry 4.0 technologies, overcoming common challenges such as resistance to change, and ensuring the workforce is equipped to thrive in a technology-driven environment. Overall, the research is expected to bridge the gap between theoretical leadership models and their real-world application, providing valuable insights for both industry leaders and educators who are shaping the next generation of leaders.

Value of the study The value of this research lies in its significant contribution to the evolving understanding of leadership in the digital age. While much of the existing literature on Industry 4.0 has focused on its technological aspects—such as automation, big data, and cyber-physical

systems—there is a notable gap in research on the human element, particularly the role of leadership in guiding organizations through these profound changes. By emphasizing leadership, this study addresses a critical gap in the literature and offers practical implications for industry practitioners (Avolio and Yammarino, 2013).

One of the primary contributions of this research is its exploration of the leadership competencies required to navigate the complexities of Industry 4.0. The findings will provide a deeper understanding of the skills, styles, and strategies that leaders must adopt to foster innovation, drive digital transformation, and engage their workforce in technology-driven environments. For organizational leaders and policymakers, these insights will be invaluable in developing leadership frameworks and training programs tailored to the demands of Industry 4.0. The study will guide efforts to cultivate leadership that is agile, technologically fluent, and capable of managing cross-functional, diverse teams.

Moreover, the interdisciplinary approach of this research- combining leadership theory with insights from technology management and organizational behavior—adds a valuable dimension to the existing body of knowledge. By integrating perspectives from multiple fields, the study will provide a more holistic understanding of how organizations can thrive in an era of rapid technological change. This comprehensive perspective is essential as it highlights the intersection between human factors and technology, offering a balanced view of how leaders can effectively manage both the technological and human challenges posed by Industry 4.0.

As the digital era continues to reshape the industrial landscape, the insights from this research will be instrumental in helping leaders guide their organizations toward long-term success and sustainability. The study's findings will serve not only as a resource for industry practitioners seeking to implement effective leadership strategies but also as a foundation for future academic research on leadership in the context of technological transformation. By shedding light on the evolving role of leadership in Industry 4.0, this research will ultimately contribute to the development of more adaptive, innovative, and resilient organizations.

Conclusion Leadership in the age of Industry 4.0 presents both significant challenges and unprecedented opportunities for those responsible for guiding organizations through the complex processes of digital transformation. This research will make a vital contribution to understanding how leadership must evolve to remain effective within this new industrial paradigm. By focusing on the human element of Industry 4.0, the study will help fill a critical gap in the current literature, providing valuable insights into the competencies, leadership styles, and strategies that are essential for success.

The findings will serve as a blueprint for developing leadership that is not only adaptable and innovative but also ethically grounded, enabling leaders to navigate the complexities of technological disruption while maintaining organizational values and fostering human-centric approaches. Ultimately, this research aims to offer practical solutions for industry practitioners and policymakers, helping them shape leadership frameworks that ensure long-term organizational success and sustainability in an increasingly digital and automated world. As technological advancements continue to reshape industries globally, the study’s contributions will be instrumental in preparing leaders for the future challenges and opportunities of Industry 4.0.

Keywords: *Industry 4.0, Leadership competencies, Digital transformation, Entrepreneurial leadership, Innovation management.*

JEL classification: *JEL O32.*

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