KAPITEL 1 / *CHAPTER 1* [1]
BUSINESS PROCESSES MANAGEMENT IN CONDITIONS OF DIGITAL TRANSFORMATIONS

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Introduction

Industrial revolutions have profoundly shaped the course of human development, driving fundamental transformations in production systems and technologies. The First Industrial Revolution marked the beginning of mechanization through the use of water and steam power, replacing traditional manual methods of production. The Second Industrial Revolution emerged with the adoption of electricity, enabling mass production and triggering a significant industrial boom. The Third Industrial Revolution, also known as the Digital Revolution, was driven by the rise of computer technologies and automation, once again transforming manufacturing processes. Today, in the era of Industry 4.0, we are witnessing the convergence of physical and digital systems, enabled by the Internet of Things (IoT), artificial intelligence (AI), machine learning, and other advanced technologies. These developments are opening new frontiers for innovative entrepreneurship and smart manufacturing. Such technologies enhance the efficiency, productivity, adaptability, and resilience of production systems (Cotteleer & Sniderman, 2017; A beginner's, 2023).

Review of recent publications

Recent studies highlight the substantial impact of digital transformation on economic processes and business models within the context of Industry 4.0. Emphasis is placed on the implementation of Industry 4.0 and 5.0 concepts in shaping the smart economy and driving digital business transformation, underlining the significant potential of digital technologies to enhance economic efficiency (Suntsova, 2022). Researchers are examining the influence of digital transformation on the contemporary economy, especially its implications for business processes and socio-economic systems. They emphasize that key innovative technologies are reshaping traditional

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industries and opening new avenues for growth and development (Koval & Lyshak, 2024). The COVID-19 pandemic accelerated digital transformation processes, further reinforcing the need for in-depth analysis and strategic adaptation to the new conditions (Gryniuk, 2021). At the same time, despite the evident trends toward digital transformation and the adoption of Industry 4.0 technologies, global challenges persist. There is a growing focus on the need for modern firms to adapt to these new realities and successfully integrate digital technologies into production systems (Stupnytskyi & Shved, 2020). Thus, the analysis of recent scholarly contributions confirms that digital transformation in the context of Industry 4.0 is a critical driver of economic development. However, it also underscores the necessity of a comprehensive approach to overcoming related challenges and maximizing the benefits of this transformation.

1.1. Transformation of business environment

Considering the socio-economic dimensions, challenges, and benefits of implementing Industry 4.0 and the broader trend of *global digitalization*, it is possible to outline current and future features of the concept. These features demonstrate how the interconnection of people, objects, and systems – forming dynamic, real-time, optimized, and self-organizing value creation networks between companies – affects all organizational processes when firms decide to adopt this new way of organizing business operations (Mohamed, 2018).

The main challenges of digital transformation, categorized by key domains of implementation, can be summarized as follows:

1. Information and communication technologies (ICT): The development of ICT forms the backbone of global digitalization. Technologies such as the Internet, mobile communications, cloud computing, big data, and artificial intelligence (AI) offer opportunities for new business models, enhanced efficiency, and increased productivity.

2. E-Governance: The adoption of digital solutions in governmental processes

promotes transparency, efficiency, and accessibility of public services. This includes the use of electronic documents, digital signatures, online registrations, and other e-government services.

3. Digital economy: Global digitalization is reshaping traditional business models. E-commerce, fintech, digital marketing, online education, and other forms of digital activity are becoming increasingly integral to the global economy.

4. Social change: Digitalization influences all areas of social life – from social media to online communities – transforming how people communicate, collaborate, and share information.

5. Education: Digitalization offers new opportunities for education. Online courses, virtual classrooms, interactive learning materials, and other digital tools are making quality education more accessible to a broader population (Sági et al.).

In order for businesses and countries to effectively respond to these challenges, they must develop the capacity to work with large volumes of real-time data, which requires the creation of new digital infrastructures. Nevertheless, the implementation of Industry 4.0 presents evident advantages, including greater flexibility, quality standards, and operational efficiency. Ultimately, these capabilities allow companies to meet evolving customer demands and create new value propositions.

1.2. New values emerging in conditions of digital transformation

Among the core values evolving within the framework of Industry 4.0 are the following:

The value and importance of data. Industry 4.0 introduces not only a new approach to doing business but also a novel source of value creation, particularly for traditional manufacturing enterprises. One of the most significant distinctions between Industry 4.0 and previous industrial revolutions is the increasing importance and value of data. The perception and role of data are undergoing a fundamental shift—data are now regarded as a crucial resource or raw material. Companies that possess large

volumes of data or are capable of processing them effectively gain a considerable competitive advantage. Consequently, organizations must shift their focus toward the management of big data and information flows. A critical competency in this environment is the ability to integrate processed data across various cross-functional areas or departments to support effective managerial decision-making.

Decentralization and digitalization. Production under Industry 4.0 is becoming increasingly decentralized and digitalized, where components of the manufacturing system can autonomously monitor and control themselves. Digitalization refers to the convergence of the physical and virtual worlds and is expected to have a profound impact on every economic sector. The value of this transformation lies in the optimization of production processes, with a minimized role for centralized oversight and human intervention – while simultaneously improving quality standards and reducing defects (Trierveiler et al., 2019).

Mass customization. In the context of Industry 4.0, products are becoming increasingly modular and customizable, enabling mass customization to meet specific customer needs (Vogelsang et al., 2018). Through the principle of product personalization, even ordinary consumers can partially or fully tailor their orders without incurring high costs. This customization extends beyond technical specifications to include various product or service attributes such as color, size, taste, and service timelines.

Innovative business models. Value chains are becoming more responsive, enhancing competitiveness by eliminating barriers between digital and physical systems. Business model innovations under Industry 4.0 – such as the Product-as-a-Service (PaaS) model – are redefining the notion of ownership, reducing the importance of possession, and increasing access to goods at the point of need (Vogelsang et al., 2018). Sharing economy models have gained considerable popularity, allowing highly profitable operations without the need to own extensive physical assets. The key value of these models lies in their information-centric and synergistic structure, driven by peer-to-peer (P2P) frameworks.

Acceleration of production processes. Industry 4.0 technologies have

significantly increased the speed of production processes. Downtime is minimized through real-time monitoring and control of operations. These innovations play a critical role in boosting productivity and competitiveness, enhancing operational efficiencies across the board by leveraging data to optimize and accelerate both production and business processes.

Growth in revenue and investment. Industry 4.0 is widely regarded as a major driver of income growth, even though its implementation often requires substantial investments. With appropriate strategic planning, revenue growth can outpace the costs associated with automation and digitalization of production processes. However, there are instances where investments in digital transformation fail to deliver the expected returns, which is typically due to inadequate planning or low levels of digital literacy.

Socio-economic equality. Industry 4.0 and the emerging digital production paradigm have the potential to reduce income and wealth polarization while fostering the creation of new values. New professions and employment opportunities are emerging, highlighting the need to reform mechanisms such as minimum wage policies by linking them to intensified production enabled by robotics, automation, and digitalization. This may offer a viable pathway toward addressing economic inequality. In addition, new marketing and distribution models, along with improvements in material, resource, and production efficiency offered by smart manufacturing systems, are expected to enhance the availability and accessibility of goods and services (Ghobakhloo, 2020).

The implementation of Industry 4.0 provides substantial benefits for both businesses and society. Among the most significant advantages are the increased value of data, the decentralization and digitalization of production processes, mass product customization, innovative business models, accelerated production speeds, growth in revenue and investment, and the promotion of socio-economic equality. By embracing these emerging value propositions, companies can leverage data more effectively, automate operations, and reduce costs while simultaneously enhancing flexibility and adaptability. These developments not only create new opportunities for value generation and improve access to goods and services but also contribute to reducing

economic inequality. As a result, Industry 4.0 serves as a critical driver of economic growth and innovation in the digital era.

1.3. Challenges in the implementation of Industry 4.0 technologies

Alongside the numerous advantages, the transition to Industry 4.0 technologies also presents a range of new challenges. These challenges are systematized and presented in Table 1.

Table 1 – Classification of challenges in the transition to Industry 4.0 technologies

No.	Challenge	Essence
1.	Barriers to the implementation of digital technologies and uncertainty	Significant barriers to the adoption of digital technologies are preventing companies from initiating digital transformation (Fernanda et al., 2022). Uncertainty regarding financial benefits – due to the lack of demonstrated business cases justifying such investments – further amplifies these barriers. The implementation of digital technologies is a particularly problematic investment for small and medium-sized enterprises (SMEs), for whom initial investment costs may be prohibitively high (Ristuccia, 2019; Neto et al., 2023). Finally, uncertainty about achieving clear outcomes and difficulties in transforming strategic vision undermine confidence in the effectiveness of such investments
2.	Lack of specialized knowledge	The absence of foundational knowledge in big data analysis and processing, a shortage of qualified professionals, and an underdeveloped education and training system adapted to new technological demands are key barriers to the transition toward Industry 4.0 (Fernanda et al., 2022). The lag of traditional education systems behind the needs of the labor market poses a serious challenge for modern enterprises, which require new competencies to effectively apply advanced technologies
3.	Cybersecurity	Cybersecurity represents one of the greatest challenges for manufacturers and service providers that currently use or aim to adopt Industry 4.0 technologies. It is essential to develop new data transmission protocols that offer greater protection against cyber threats in order to safeguard critical industrial systems and production lines (Fernanda et al., 2022)
4.	Horizontal and vertical integration	In the context of digital transformation and Industry 4.0, both horizontal and vertical integration face multiple challenges. Horizontal integration, which involves linking enterprises into unified value chains, encounters coordination difficulties between entities, data privacy and security concerns, and the risk of losing control over specific segments of production and logistics chains. These issues highlight the need for well-defined interaction protocols, efficient communication mechanisms, and integrated information management systems, all of which require significant investments in digital infrastructure. Vertical integration,

No.	Challenge	Essence
		which takes place within a single enterprise across all levels – from managerial decision-making to production execution – also presents notable challenges. These include the need for fundamental changes in organizational structure, implementation of comprehensive information systems, staff adaptation to new digital technologies, and the management of real-time data flows
5.	Lifecycle management and data analytics	From the perspective of end-to-end engineering, the key challenge lies in ensuring high quality and consistency of data collected from various manufacturing systems and technological processes. This task is complicated by the diversity and heterogeneity of data originating from multiple sources. For example, data may vary in format, semantics, and annotations, which significantly complicates their integration into a unified analytics system. As a result, enterprises face the need to develop universal solutions capable of combining and analyzing data stored in information systems with fundamentally different structures and standards. A typical case involves large manufacturing complexes using separate systems for inventory management, equipment monitoring, quality control, and logistics – each generating data with its own semantic logic. Addressing this challenge requires the implementation of standardized data exchange protocols, semantic models, and advanced machine learning systems to enable the integration and effective analysis of diverse information flows
6.	Decentralization and organizational complexity	The growing organizational complexity of manufacturing systems eventually exceeds the capacity for centralized control. Decision-making is delegated from a central authority to decentralized units, which act autonomously by processing local information. Decisions may be made by workers or equipment using artificial intelligence methods
7.	Innovation and technological components	Another significant challenge for businesses in the Industry 4.0 era lies in innovation and the integration of new technological components. Despite the availability of advanced technologies such as the Internet of Things (IoT) and modern communication networks, companies often struggle to collect meaningful and relevant data for effective decision-making. Difficulties arise in ensuring compatibility between different systems, integrating innovative components into existing processes, and creating a unified data analytics ecosystem. For instance, companies using IoT sensors to monitor production lines may find that collected data is insufficiently structured or fails to provide actionable insights. Solving this issue requires careful planning of technology integration, infrastructure development for data analytics, and continuous adaptation of business processes to rapid technological change
8.	Sustainability	Sustainability encompasses complex tasks related to achieving both economic and environmental efficiency in production. Rising resource costs are placing additional pressure on businesses to adopt more efficient and eco-friendly technologies. Beyond economic factors, societal changes and increasing demands for environmental responsibility are pushing businesses to implement sustainable practices and innovative solutions. Thus, sustainability in Industry 4.0 involves not only the rational use of resources but also the development of new technological approaches that minimize environmental impacts while creating added value for enterprises and society

No.	Challenge	Essence
9.	Labor market transformation	One of the key challenges in implementing Industry 4.0 is the transformation of the labor market (Ghobakhloo, 2020; Yaqub & Alsabban, 2023). Digitalization and automation lead to substantial changes in employment structures, including the emergence of new professions related to big data, artificial intelligence, robotics, and cybersecurity. At the same time, there is a growing risk of job displacement due to the automation of routine and repetitive tasks. This creates a need for continuous upskilling and workforce adaptation. Addressing this challenge requires active involvement from educational institutions and the development of new training programs tailored to the needs of the digital economy
10.	Legal and regulatory challenges	The rapid implementation of digital technologies often outpaces the development of corresponding legal frameworks and regulations. This creates legal uncertainty, which can hinder the effective deployment of innovations. Key issues include the protection of personal data, intellectual property rights, and the assignment of liability for outcomes produced by autonomous systems

Modern companies must take into account the outlined classification of key challenges associated with digital transformation in Industry 4.0 when planning and implementing their digital transformation strategies.

Effectively overcoming the challenges of adopting Industry 4.0 technologies requires a systemic approach. This includes the development of a clear digital strategy, substantial investments in modern digital infrastructure, the implementation of agile management practices, and the promotion of innovation-driven activities (Wolf et al., 2018; Ernst & Frische, 2015). An essential component of this process is collaboration between businesses, government institutions, and research organizations (Propris & Bailey, 2020), which facilitates the exchange of knowledge, technologies, and best practices – thus creating favourable conditions for a rapid and effective transition toward a digital economy.

Conclusions

Thus, the digital transformation of the economy within the framework of Industry 4.0 presents significant opportunities for both enterprises and society, fostering the creation of new value and fundamentally reshaping approaches to production, management, and consumption. However, alongside the clear advantages – such as increased productivity, efficiency, and competitiveness – digitalization also entails a number of substantial challenges. These include the need for large initial investments, a shortage of qualified personnel, cybersecurity risks, issues related to horizontal and vertical integration, the management and analysis of vast volumes of data, and concerns about environmental sustainability.

To successfully implement the Industry 4.0 concept, companies must develop appropriate infrastructures, enhance digital literacy, and establish effective mechanisms for adapting to continuous technological change. Overcoming these challenges will be a critical factor in ensuring the sustainable development of the economy, enabling both economic efficiency and social equity. Therefore, it is imperative that public institutions, educational establishments, and businesses prioritize the active support of digital transformation processes at all levels of society.

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