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CHALLENGES OF IMPLEMENTING QUALITY 4.0 IN ORGANIZATIONS

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A B S T R A C T

Quality 4.0 represents the digital transformation of quality management through the application of modern technologies such as artificial intelligence, the Internet of Things, and big data analytics. The aim of this paper is to explore the key challenges organizations face when implementing Quality 4.0 and to propose strategies for overcoming them. The analysis shows that the main challenges include organizational resistance to change, a lack of employees' digital competencies, and high initial investment costs. Despite these obstacles, successful implementation can bring numerous benefits, including improved operational efficiency and a competitive advantage. The paper emphasizes the importance of education, gradual implementation, and organizational culture adaptation to ensure a successful transition to Quality 4.0. Further research should focus on developing specific methodologies and strategies to facilitate this process).

1. INTRODUCTION

Modern business, which is increasingly focused on digital transformation, also requires the implementation of Quality 4.0 as a key factor in maintaining market competitiveness. The implementation of Quality 4.0 represents a complex phase in the development of organizations, as it involves the integration of advanced technologies, the adaptation of business processes, and the development of new employee competencies (Kovačić et al., 2022a). Some of the fundamental challenges that arise during the integration of Quality 4.0 include employee resistance to digitalization, insufficient training of personnel, and difficulties in integrating new technologies into existing quality management systems (Tadić et al., 2022). On the other hand, research conducted by Foidl and Felderer (2018) emphasizes that the main challenges of implementing Quality 4.0 can be classified into two groups: technological and human. Technological challenges include the integration of IoT into quality management, real-time data analysis, as well as the security and protection of sensitive information. Human factors include the need to develop new competencies, resistance to change, and the need for a shift in organizational culture (Foidl & Felderer, 2018). The digitalization of quality processes entails a complete transformation in the approach to quality management, where traditional methods must be upgraded with intelligent systems and automated control mechanisms. In this context, Zonnenshain and Kenett (2020) analyze the impact of digital technologies on risk management in the context of Quality 4.0, highlighting the importance of predictive analytics and automated systems for real-time defect detection (Zonnenshain & Kenett, 2020). However, effective risk management requires the collection of sufficient data, which is often stored in databases. The development of Industry 4.0 facilitates this by enabling real-time data collection mechanisms in quality management processes through the

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implementation of digital platforms for decision-making enhancement (Buntak et al., 2020).

One of the biggest challenges is the need for competent employees, which in turn creates a demand for different educational programs—both formal and informal—with the goal of developing a sufficient number of skilled professionals capable of addressing emerging challenges (Stefanovic et al., 2024). Beyond technical challenges, regulatory requirements also pose significant issues, particularly regarding employee data collection and the need to ensure restricted access to collected information. In other words, while implementing Quality 4.0 offers numerous advantages, it also introduces cybersecurity challenges, specifically in mitigating the risk of unauthorized third-party access to stored data (Kovačić et al., 2022b).

2. METHODOLOGICAL FRAMEWORK

The paper is based on a conducted secondary research study in which the compilation method was used to review all studies on the challenges organizations face during the implementation of Quality 4.0. The descriptive method was applied to present findings and was supplemented by the methods of analysis and synthesis. The literature used in the research is indexed in relevant databases such as WoS and Scopus and is no older than ten years.

The research posed the following questions:

- What are the biggest challenges organizations face during the implementation of Quality 4.0, and which factors influence the success of this process?
- How can the challenges that arise during the implementation of Quality 4.0 in an organizational system be overcome?

The aim of this research is to identify and analyze key factors influencing the successful implementation of Quality 4.0. The paper is based on secondary research and is divided into six chapters. The first chapter describes the research context and the importance of examining the challenges associated with implementing Quality 4.0. The second chapter outlines the applied methodology. The third chapter provides an overview of existing studies on the implementation of Quality 4.0. The fourth chapter presents a compilation of research on the challenges encountered during this implementation. The fifth chapter consists of the discussion, while the sixth and final chapter presents the conclusion.

3. THEORETICAL FRAMEWORK OF THE RESEARCH

The Fourth Industrial Revolution is enabled by the digital technologies of the Third Industrial Revolution and is characterized by breakthroughs in various fields such as advanced robotics and drones, artificial intelligence and machine learning, biotechnology and precision medicine, virtual, augmented, and mixed reality systems, new approaches to energy generation and storage, multidimensional printing, new materials, and other technologies (Ghobakhloo, 2020).

During the implementation of Quality 4.0, organizations face numerous challenges arising from the complexity of Industry 4.0. It is essential to ensure the reliability and quality of data, as automated quality management systems depend on the accuracy and integrity of large volumes of data. Additionally, digitalization and autonomous systems can reduce human control, creating new risks in quality management processes (Carvalho et al., 2021). Another significant challenge is sustainability, as Quality 4.0 must align with sustainable business requirements, minimizing negative environmental impacts. Furthermore, Quality 4.0 should not have adverse effects on employees in organizations, ensuring that they are not discriminated against in any way due to the implementation and use of new technologies (Fonseca et al., 2021). Moreover, digital transformation leads to changes in job roles and potential unemployment in traditional sectors, requiring additional measures for workforce retraining (llack& Ufimtseva, 2020). Generally speaking, there are four key dimensions of challenges in implementing Industry 4.0, and consequently Quality 4.0: employees, the market, organizational aspects, and the technological dimension (Ranjith Kumar et al., 2022). Keeping up with Industry 4.0 requires a higher level of knowledge compared to previous demands. This necessitates an advanced approach to quality to adequately understand Industry 4.0 technologies and their applications. Questions regarding what constitutes this higher level of knowledge, what an advanced approach entails, and what needs to be understood can be addressed by analyzing the causes of inefficiencies in the automation and digitalization processes observed so far, from the perspective of quality management principles and approaches.

Employee-related challenges involve the need for new digital skills, resistance to change, and fear of job loss (Kowal et al., 2022). Market challenges include the adaptation of companies to new business models and competitiveness in the digital environment. The organizational aspect entails adjusting internal processes and company culture to new technologies, while the technological dimension covers the complexity of integrating digital tools, data security, and compliance with regulations (Doiro et al., 2019). Addressing these challenges requires a comprehensive approach, which includes investing in employees' digital competencies, applying advanced quality management systems, and developing strategies that enable the sustainable and successful implementation of Quality 4.0 in organizations.

4. CHALLENGES OF IMPLEMENTING INDUSTRY 4.0

The implementation of Industry 4.0 technologies is considered an extremely complex challenge compared to

the application of automated solutions, ERP (Enterprise Resource Planning) systems, and similar technologies. The primary reason for these challenges lies in the fact that decision-making processes within Industry 4.0 are decentralized, leading to complete organizational restructuring, in contrast to traditional systems where decision-making is entirely centralized. Consequently, these restructurings affect employees, infrastructure, technologies, culture, procedures, and organizational goals. During the implementation of Industry 4.0, employees within organizations face numerous challenges, including financial challenges, challenges related to organizational restructuring, and challenges associated with the need for integration and coordination within the supply chain (Maresova et al., 2019). A particular issue is the level of acceptance of Industry 4.0 technologies by employees. Since Industry 4.0 entails a fundamental change in the way businesses operate, unions may resist these changes, either due to insufficient knowledge of the Industry 4.0 concept or a lack of trust during the initial implementation phases (Sony & Naik, 2019). Furthermore, during the implementation of Industry 4.0 in modern manufacturing industries, various difficulties and challenges arise. One of the key issues is investment, as implementing Industry 4.0 requires substantial financial resources, and the company must secure a significant level of expenditure to successfully apply all the pillars of Industry 4.0 (Bryndin, 2018).

Additionally, ensuring the high quality and integrity of data collected within the manufacturing system is a challenge, as data encompasses a wide range of annotations, further complicating the integration of different databases with various semantic structures, which are essential for advanced data analysis (Alosert et al., 2022). Another significant challenge is the need for high-speed networking protocols (Internet Way Of Networking Protocol - IWN) necessary for the implementation of Industry 4.0. However, current IWN systems are unable to support intensive communication and the transfer of large amounts of data, which further complicates the application of the Industry 4.0 concept in manufacturing processes (Vaidya et al., 2018).

Moreover, the skills and qualifications of employees within the company, such as problem-solving abilities, fault analysis, and the ability to adapt to continuous changes and entirely new job roles, represent one of the biggest challenges for companies that wish to adopt Industry 4.0. In practice, employees should be allowed to experiment with certain Industry 4.0 technologies to gain experience in activities of a new level of complexity, such as data collection, processing, and visualization related to manufacturing processes.

With the arrival of the Industry 4.0 paradigm, companies will not only face challenges in finding qualified employees but also with other issues related to the existing workforce, which will need to be adapted and supported through skills development programs. These include (Sony & Naik, 2019):

- Up-skilling: Companies will need to enhance the skills of their workforce through internal or external training centers. For example, a worker on the production line performing manual assembly will need to learn how to use different tools or operate robots. They must develop new skills to manage new tools and machines effectively.
- Re-skilling: Industry 4.0 will likely lead to the loss of certain jobs, but new positions will also emerge. Similar to the past with the advent of cars, horses, and automobiles, some jobs will disappear, while new ones will find their place.
- Continuous learning: Technologies will become obsolete rapidly. New strategies will be needed for continuous professional development to help employees adjust to the significant changes required by technological advancements.
- Mindset change: The workforce will need to adapt to numerous changes, with some employees offering resistance and opposing the implementation of new technologies. Companies will need to plan strategies to change their employees' mindsets. It will be essential to ensure a smooth transition to technologically advanced manufacturing processes.

These steps represent the key to preparing the workforce for the challenges and changes brought by Industry 4.0. To remain competitive, modern companies must produce products of the highest quality to meet growing customer demands, not only regarding quality but also regarding environmental impact, sustainability, and social responsibility (Bal & Erkan, 2019). Today and in the future, the quality of products, services, and processes is essential for creating value for organizations, as well as for achieving sustainable economic success and ensuring competitiveness, where the application of lean manufacturing tools is very important (Sanders et al., 2016). In the process of adopting Industry 4.0, companies will face numerous challenges related to the skill levels of their workforce. Skills that are important today will cease to be relevant in the future, and workers will be expected to possess new skills in areas such as information technology, data analysis, and more. A large portion of both existing and new jobs will prioritize cognitive abilities and system skills over physical abilities, while emotional intelligence and its relationship with employability will play a crucial role.

In addition to human resources, innovations, technological components, advancements in digital transformation, and the increasing interconnectedness of systems play a significant role in every organization and are closely linked to the challenges of implementing Industry 4.0. Full digitization of all physical resources and the integration of all partners in the value chain into digital ecosystems are an essential part of Industry 4.0, whose goal is to create a new production model (Gold et al., 2019). However, most businesses, especially small and medium-sized enterprises in the sector, show a certain reluctance regarding the initiation of the digital transformation process. This uncertainty arises from the various implementation challenges manufacturers face, with very limited progress in applying the Industry 4.0

concept (Mohamed, M2018). In the distributed and integrated environment of Industry 4.0, it is almost impossible to virtually protect the entire business of a company. Although technologies like encryption and machine learning are progressing rapidly, complete control is still impossible in networks that are porous, interconnected, and dynamic (Lezzi et al., 2018). The goal of achieving full cybersecurity remains elusive, primarily due to financial constraints, but also because of the negative impact of security applications and practices on the speed and agility of the organization (Lezzi et al., 2018).

Cybersecurity threats in Industry 4.0 arise from the increased use of sensors, Wi-Fi connections, the Internet of Things (IoT), point-of-sale (POS) terminals, and many other sources that increase the number of entry points for user access, thereby compromising the security of any company. Additionally, many corporate controls and procedures become ineffective due to the shifting of work processes to public cloud systems, which are not entirely secure. An additional risk is the fact that official laptops and smartphones are increasingly used for personal purposes, while personal devices are used to access sensitive company data and applications. Finally, networks are becoming increasingly interconnected within both IT environments and with infrastructure and operational technologies, further increasing cybersecurity risks for companies (Lezzi et al., 2018). Furthermore, twenty years ago, when the internet was just beginning to develop, cybersecurity was not a significant issue. However, today, cybercriminals continuously find new ways to exploit the Internet of Things (IoT), one of the main pillars of Industry 4.0, for their malicious activities, just as they do with every new technology. This leads to a greater number of attack channels and potential targets for hackers, as more devices are connected to the network.

There are several reasons why devices in Industry 4.0 become targets for hacking attacks. One of the key reasons is that many industrial facilities have equipment that operates for weeks or months without security updates or antivirus software. Also, many controllers used in Industrial Control System (ICS) networks were developed when cybersecurity was not a priority, making them vulnerable to interruptions, either due to improper network traffic or a large amount of correctly formed data that overloads the system (Benias & Markopoulos, 2017).

Two other significant reasons are the following:

- Many ICS networks are still built as a large, flat network without physical or virtual segregation between different subsystems, which allows malware to spread quickly, even to remote industrial plants.
- Cybersecurity threats can access ICS networks through multiple entry points, bypassing existing protection mechanisms.

In addition to recognizing cybersecurity threats, it is crucial to have a quick overview of how data can be protected and which systems are involved. The terms "security by design" and "privacy by design" emerged in the late 1990s in response to the growing need to consider the security and privacy of user data during the design phase of any information technology-based system, rather than as a subsequent measure (Chattopadhyay et al., 2020). This need was further emphasized by the development of big data systems, cloud computing infrastructures, the Internet of Things (IoT), and other environments for data communication and storage. Nevertheless, the basic concept of secure systems can be found in cryptographic techniques developed even before the 1990s. Although cryptographic systems allow complete data protection, they are often viewed as defensive measures against threats, as even the most complex mathematical algorithms can be compromised with enough time and advanced attack methods. As a result, cryptographic mechanisms are usually upgraded only after an attack occurs, highlighting the need for continuous improvements in security measures within Industry 4.0 (Alexan et al., 2019).

5. DISCUSSION

The implementation of Quality 4.0 in organizations represents a significant challenge due to the complexity of integrating digital technologies with existing quality management systems. The analysis conducted in this paper shows that the key challenges include organizational resistance to change, the lack of necessary digital competencies, and the high initial costs of investing in new technologies.

Organizational resistance to change often arises from insufficient employee awareness of the benefits of digitalization in quality management systems. Traditional approaches to quality, which have ensured business success for a long time, can lead to skepticism toward the new methods introduced by Quality 4.0. To reduce this resistance, organizations need to invest in education and ensure clear communication about the advantages of digital tools in the context of quality. Furthermore, the research results indicate that many organizations lack employees with sufficiently developed digital competencies needed for the effective application of tools such as artificial intelligence, the Internet of Things (IoT), and big data analytics. This obstacle can be overcome through a systematic approach to competency development via targeted training, workshops, and collaboration with the academic community. The financial aspect of implementing Quality 4.0 is also highlighted as one of the key challenges. Despite the long-term benefits that digital transformation can bring, high initial costs and uncertainty regarding the return on investment often delay the decision to implement it. Strategies need to be developed that will allow for gradual and sustainable integration of digital technologies through pilot projects and phased approaches, thereby reducing financial risk.

The research also showed that organizations that have successfully integrated Quality 4.0 achieve significant

advantages, including improved operational efficiency, greater accuracy in data analysis, and increased flexibility in decision-making. This confirms that, despite the challenges, the implementation of Quality 4.0 can result in a competitive advantage. In conclusion, although the challenges of introducing Quality 4.0 into organizations are not negligible, systematically addressing them through education, gradual implementation, and organizational culture adaptation can ensure a successful transition to a modernized quality management system. Further research should focus on analyzing specific strategies and methodologies that can accelerate and facilitate this process.

6. CONCLUSION

Based on the analysis of the challenges and opportunities of implementing Quality 4.0 in organizations, it can be concluded that the successful application of this concept is conditioned by the synergy of technological, organizational, and human factors. Industry 4.0 and Quality 4.0 represent an essential response to the demands of modern business, but their implementation comes with numerous challenges, including the complexity of integrating new technologies, data security, regulatory frameworks, and adapting employees to digital transformation.

The research showed that the key factors for successful implementation include the development of digital competencies, investment in infrastructure, and adapting business strategies to new technological frameworks. Technologies such as artificial intelligence, machine learning, big data analytics, and the Internet of Things can significantly improve quality management processes, but their application is dependent on effective change management within organizations.

In addition to technological aspects, the human factor represents one of the biggest challenges. Resistance to change, lack of knowledge and skills, and fear of job loss can significantly slow down digital transformation. Therefore, it is essential for organizations to invest in continuous training and employee development, as well as in building a culture of innovation acceptance.

Quality 4.0 is not just a technological innovation, but a holistic approach to quality management that involves a comprehensive transformation of business operations. Successful implementation of this concept requires strategic planning, a clear vision, investment in resources, and, most importantly, a change in organizational culture to ensure long-term sustainability and competitiveness in the market.

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