

# DEVELOPMENT OF THE QUALITY CONCEPT IN THE TRANSITION FROM INDUSTRY 4.0 TO INDUSTRY 5.0

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**Abstract:** Industry 4.0 has become a global research trend in the last few years. Even though Industry 4.0 has not reached its full development and the main achievements can be expected in the coming years, the development of Industry 5.0 is already visible. Thus, the world is currently on the threshold of the Fifth Industrial Revolution. Industry 5.0 complements the existing Industry 4.0, with an orientation towards man, who has a vital role in the production process and his maximum engagement in all economic spheres. The technologies that marked the 21st century impacted all production activities, forcing them to change and adapt to the modern form of production. Each industrial revolution has influenced the concept of quality, improving and advancing it. Quality concepts have been modified by technological trends and innovations that have permanently accelerated and facilitated the production process. Therefore, the importance of quality management due to technological changes is becoming increasingly pronounced. This research will emphasize Quality 4.0 and Quality 5.0, whose concepts were formed under the influence of modern technologies. This research aims to present the development and changes in the idea of quality in the transition from Industry 4.0 to Industry 5.0 through a critical literature analysis.

**Keywords:** Industry 4.0, Industry 5.0, Quality management, Quality 4.0, Quality 5.0.

## 1. INTRODUCTION

### 1.1 From Industry 4.0 to Industry 5.0

Industry 4.0 represents an advanced level of automation to enhance productivity and efficiency within industries by connecting virtual and physical worlds (Akundi *et al.*, 2022). Industry 4.0 is centered around a smart factory, where smart products, machines, and data together form a cyber-physical production system (Zizic *et al.*, 2022).

Industry 4.0 marked a significant shift in the manufacturing industry by integrating advanced technologies such as automation, artificial intelligence, and the Internet of Things (Wolniak, 2023). From a technical perspective, Industry 4.0 has enhanced the human-machine interaction. However, in the socially sustainable aspect, technological transformations of Industry 4.0 should prioritize the central role of humans. Consequently, the concept of Industry 5.0 emerged as the extension to Industry 4.0, encompassing the social and environmental dimensions and the technological aspect (Zizic *et al.*, 2022). Industry 5.0 marks a revolution in industry and society (Maroof and Kapate, n.d.). Industry 5.0 builds on technologies of Industry 4.0, emphasizing the integration of human creativity and intuition into manufacturing processes, thus making a collaborative and adaptable manufacturing environment (Wolniak, 2023).

Industry 4.0 paradigm is understood to create a "smart factory", yet Industry 5.0 is conceptualized to design a "super smart society" for the world, making a critical difference about Industry 4.0" (Gladden, 2019). Industry 5.0 does not involve a radical technological advancement, instead, it builds upon the principles of Industry 4.0 within a more comprehensive framework and purposeful perspective. It is characterized by a regenerative purpose and clear direction, directing the technological transformation of industrial production to prioritize the well-being of people, the planet, and overall prosperity (Zizic *et al.*, 2022).

The European Commission's document (Breque *et al.*, n.d.) on Industry 5.0 identifies three key drivers to be the core of the new industrial paradigm: Human-centric approach; Sustainability and Resilience. The document states that Industry 5.0 aims beyond pure technological advancements and considers industrial development's broader societal and environmental implications. Industry 5.0 aims to create a manufacturing ecosystem that

goes beyond technological advancements, prioritizing human well-being, sustainability, and social responsibility (Wolniak, 2023).

### **1.2 Quality Management in Industry 4.0**

In Industry 4.0, the focus on quality aims to digitize all business processes using advanced technologies. Quality management systems, enabled by Industry 4.0 technologies, ensure that all processes are traceable, controllable, and sustainable, thus helping businesses maintain the required level of quality to keep their operations running uninterrupted and effectively (Baran and Polat, 2022).

Regarding Industry 4.0, quality management shifts the focus from a technology-centric approach to a customer-centric one, ensuring that the quality of products and processes aligns with customer needs and preferences. Quality 4.0 perceives technology as an enabler rather than the primary driver. Advanced technologies serve to improve the quality management process and enhance customer satisfaction. The main benefit of Quality 4.0 is increased productivity. Companies can produce products that meet customer expectations by focusing on customer needs, leading to higher customer satisfaction. Data is the critical enabler in Quality 4.0. Organizations collect and analyze data from various sources, including customer feedback, to gain insights into customer preferences and identify areas for quality improvement. The evolution of Quality 4.0 is from a process-oriented approach to a customer-oriented one. Quality management is not just about ensuring the production process meets specific standards but also about delivering products that meet customer desires and expectations (Rowlands and Milligan, 2020) (Sony *et al.*, 2020) (Sader *et al.*, 2022).

### **1.3 Quality Management in Industry 5.0: Aligning with the Pillars of Human-Centricity, Sustainability, and Resilience**

The Human-centric approach emphasizes placing human needs and well-being at the forefront of the production process. It focuses on understanding how technology can serve workers and benefit them, rather than solely prioritizing automation and efficiency. Sustainability as a second driver highlights the importance of environmental responsibility and resource efficiency, supporting practices such as reusing, repurposing, and recycling natural resources to reduce waste and minimize the industry's overall environmental impact—resilience centers around building robustness into industrial production processes. By incorporating flexibility and adaptability, industries can better withstand and respond to crises or unexpected challenges (Zizic *et al.*, 2022).

In Industry 5.0, the quality control process recognizes the significant role of human factors. Although machines provide valuable data and insights into product quality, human expertise, intuition, and experience are equally important (Wolniak, 2023). A belief in human potential in the context of quality management aims to reinforce the system around people, creating an environment that empowers people.

Connecting sustainability and quality has gained significant attention due to the growing societal demands, particularly in quality-based management for future-ready corporations that prioritize serving society and the planet (Fundin *et al.*, 2020). Quality management practices in Industry 5.0 could align with sustainability by prioritizing environmentally friendly approaches. This involves selecting materials and production methods with lower ecological impacts (Wolniak, 2023). Aiming quality management practices at achieving robustness involves enabling understanding of variation by incorporating statistical analysis and reliability principles, identifying sources of variation, evaluating their impact on product quality, and making informed decisions to enhance robustness (Fundin *et al.*, 2020).

## **2. METHODS**

In this paper, we conducted a literature review to explore the topic of quality management in Industry 5.0. Through an extensive search of Google Scholar and Scopus, we gathered valuable insights from scholarly content, journals, and conference proceedings. The paper summarizes the topic's current state and aims to critically assess the relevant literature.

## **3. RESULTS & DISCUSSION**

As the author (Akundi *et al.*, 2022) states, the limitation of Industry 4.0 to address the growing demand for personalization led to the emergence of Industry 5.0, a concept focused on personalized manufacturing empowering humans within the manufacturing processes. The author (Coelho *et al.*, 2023) states that while

Industry 4.0 emphasizes process efficiency, it overlooks the importance of the human factor. Industry 5.0 aims to correct this by fostering a harmonious synergy between humans and autonomous machines. According to the work of (Tornjanski *et al.*, 2020) and (Ćočkalo *et al.*, n.d.), the combination of Industry 5.0 pillars emphasizes the collaboration between humans and machines, leveraging their strengths for a more efficient and socially responsible manufacturing environment. Embracing these pillars will be crucial in meeting the growing demands of consumers, enhancing product excellence, and positively impacting society and the planet, thus shaping a more sustainable future for the manufacturing industry. The pillars of Industry 5.0 hold the highest significance in shaping the future of manufacturing and quality management. The author concludes that Industry 5.0 diverges from all previous industrial revolutions, presenting a “stakeholder-pulled socio-technological phenomenon” (Ghobakhloo *et al.*, 2022).

#### 4. DISCUSSION

According to (Wolniak, 2023) in Industry 5.0, the quality control process recognizes the crucial role of human factors. In quality management, the collaboration between humans and machines allows for a more comprehensive and accurate product quality assessment. Quality control involves using data-driven analytics from machines to identify trends, patterns, and potential defects. Simultaneously, the expertise of human workers enables them to apply critical thinking and intuition to spot issues that might not be evident in the data.

The author (Maddikunta *et al.*, 2022) states that unlike Industry 4.0, which relies on automation and technological efficiency on a great scale, Industry 5.0 places greater importance on integrating human creativity throughout the production process. This approach supports creative thinking to generate new ideas and designs that optimize productivity and product quality.

According to (Majerník *et al.*, 2022), in Industry 5.0, sustainability is vital, emphasizing responsible resource utilization and minimizing the impact of manufacturing processes on the environment. This new production era places significant importance on eco-conscious practices and their integration into quality management. Quality management practices in Industry 5.0 align with sustainability by prioritizing environmentally friendly approaches. This involves selecting materials and production methods that have lower ecological impacts. Additionally, quality control focus should be on ensuring that products meet performance standards and eco-friendly criteria.

According to (Fundin *et al.*, 2020), quality management practices that aim to achieve robustness involve a comprehensive understanding of variation. This is accomplished by incorporating statistical analysis and reliability principles, which play a crucial role in identifying sources of variation and evaluating their impact on product quality. Robustness in quality management refers to the ability of a system or process to maintain consistent performance and product quality despite variations in inputs. Emphasizing adaptability and quick response to changing conditions can help maintain product quality and customer trust in times of crisis.

#### 5. CONCLUSIONS

This paper delved into the transformative evolution of the manufacturing industry from Industry 4.0 to Industry 5.0. Industry 4.0, characterized by automation and technology-driven efficiency, paved the way for the emergence of Industry 5.0, where a human-centric approach, sustainability, and resilience form the core pillars of the paradigm.

The transition from Industry 4.0 to Industry 5.0 signifies a profound shift in the manufacturing landscape. The pillars of new industrial paradigm underscore the importance of not only technological advancements but also the well-being of individuals, the environment, and prosperity. By incorporating these pillars into quality management practices, Industry 5.0 can achieve a harmonious blend of innovation, sustainability, and superior product quality.

Considering all the above, we can acknowledge the importance of Industry 5.0 and the need for organizations to devote themselves to achieving this level in the future. Furthermore, future research is essential and may provide more detailed studies on the subject.

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