

DIGITAL KAIZEN: OPPORTUNITIES AND CHALLENGES IN INDUSTRY 5.0

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Abstract: *Kaizen, a continuous improvement methodology, serves as a fundamental element for companies to maintain their competitiveness in an increasingly demanding market. The advent of Industry 4.0, with the support of Kaizen, has been considered to answer these never-ending demands by bringing significant transformations in manufacturing processes through the integration of digital technologies. However, most of the Industry 4.0 implementation challenges report a lack of human resources, as one of the biggest managerial obstacles. Therefore, society moved toward the next phase of the industrial revolution, Industry 5.0, which has a focus shift beyond automation to the integration of human intelligence with advanced digital systems. Thus, Industry 5.0 promotes a human-centric approach to implementing digital sustainable technologies for continuous improvement – Digital Kaizen. This research examines Digital Kaizen, as Industry 5.0 continuous improvement methodology enabled by advanced technologies, mostly human-cyber-physical systems (HCPS) and artificial intelligence of things (AIoT) to be used to improve the workforce's productivity, rather than simply to replace workers.*

Keywords: Digital Kaizen, Smart Manufacturing, Continuous Improvement, Literature Review

1. INTRODUCTION

In an increasingly competitive market, companies must constantly seek ways to improve their processes and maintain their competitiveness. Kaizen, a renowned continuous improvement methodology, has long been recognized as a fundamental element for achieving these objectives (Janjić *et al.*, 2019). With the emergence of Industry 4.0, the integration of digital technologies has brought significant transformations to manufacturing processes, enabling companies to address the ever-increasing demands of the market. However, despite the benefits of Industry 4.0, many implementation challenges persist, with a notable obstacle being the lack of human resources in managing these transformations (Bajic *et al.*, 2021; Papetti *et al.*, 2020; Rikalovic *et al.*, 2022).

Recognizing the limitations of Industry 4.0 and the need for a human-centric approach, the concept of Industry 5.0 has emerged as the next phase of the industrial revolution (European Commission, 2021, 2022). Unlike its predecessor, Industry 5.0 emphasizes the integration of human intelligence with advanced digital systems, moving beyond mere automation (Bajic, Suzic, *et al.*, 2023; Ghobakhloo *et al.*, 2023). This paradigm shift aims to leverage the strengths of both humans and technology, promoting a collaborative and synergistic relationship to achieve sustainable improvements in manufacturing processes (European Commission, 2019).

Within the framework of Industry 5.0, a continuous improvement methodology known as Digital Kaizen has gained prominence (Dang-Pham *et al.*, 2022). Digital Kaizen harnesses the power of advanced technologies, particularly human-cyber-physical systems (HCPS) and artificial intelligence of things (AIoT), to enhance the productivity of the human workforce. Unlike previous industrial revolutions, where technologies often replaced human labor, Digital Kaizen in Industry 5.0 seeks to leverage these technologies to empower and augment human capabilities, leading to increased efficiency and performance (Wang *et al.*, 2022).

This research examines and explores the concept of Digital Kaizen as a continuous improvement methodology within the context of Industry 5.0. By integrating advanced technologies, Digital Kaizen offers new opportunities to improve productivity and performance, while fostering a harmonious collaboration between humans and intelligent systems. This study aims to shed light on the implementation and benefits of Digital Kaizen, providing insights into how organizations can leverage this methodology to enhance their workforce's productivity and efficiency, ultimately leading to sustained competitive advantage.

This research is organized as follows. The traditional Kaizen and Digital Kaizen in Industry 5.0 theoretical background is described in Section 2. Section 3 explains the opportunities and challenges of Digital Kaizen in Industry 5.0. Finally, Section 4 derived the discussion and conclusions of Digital Kaizen, highlighting its potential to drive continuous improvement and create a more resilient and adaptive manufacturing environment.

2. BACKGROUND

2.1 From Traditional Kaizen to Digital Kaizen

Kaizen, a continuous improvement methodology originating from Japan, has a rich scientific background and has been widely adopted by organizations globally (Janjić *et al.*, 2019). Initially developed in the manufacturing sector, Kaizen has evolved to encompass various industries and has become a key element in driving organizational excellence. The scientific foundation of Kaizen lies in its ability to systematically identify and eliminate waste, inefficiencies, and non-value-added activities within processes (Sridhar *et al.*, 2023). This methodology draws heavily from the principles of Lean thinking, which focuses on reducing waste and maximizing customer value (Sundararajan and Terkar, 2022). Kaizen emphasizes employee involvement, data-driven decision-making, and the pursuit of incremental improvements. The success of traditional Kaizen has led to its transition into the digital realm, known as Digital Kaizen. The integration of digital technologies with Kaizen principles presents new opportunities for organizations to further enhance their continuous improvement efforts.

The shift to Digital Kaizen is driven by advancements in technology, such as AIoT, big data analytics (BDA), and cloud computing, which have provided organizations with unprecedented access to vast amounts of data and real-time insights (Dang-Pham *et al.*, 2022). This enables more accurate problem identification, root cause analysis, and data-driven decision-making. Finally, Digital Kaizen also emphasizes the concept of "smart manufacturing" which integrates digital technologies and automation to create highly efficient and adaptive manufacturing systems leading to increased efficiency and productivity. The use of AI and machine learning algorithms in Digital Kaizen allows for predictive and prescriptive analytics, enabling companies to anticipate potential issues and take proactive measures (Ming *et al.*, 2019).

2.2 Digital Kaizen for Smart Manufacturing in Industry 5.0

The scientific literature lacks evidence of the practical implementation of Industry 4.0 after a decade since its emergence (Bajic *et al.*, 2021; Rikalovic *et al.*, 2022). The global hype surrounding Industry 4.0 shifted the focus toward fully automated manufacturing, neglecting the importance of the human factor (Demir *et al.*, 2019; Jiao *et al.*, 2020). The aim was to transition from traditional to smart manufacturing (Meng *et al.*, 2018) by leveraging advanced technologies (Bajic *et al.*, 2021; Rikalovic *et al.*, 2022). This vision of smart manufacturing foresees the integration of physical objects and software through the Industrial Internet of Things (IIoT), enabling the exchange of manufacturing data among different components (Bajic *et al.*, 2021; Rikalovic *et al.*, 2022). However, both industry and academia have consistently highlighted the challenge of excluding the human aspect from the manufacturing process (Neumann *et al.*, 2021).

Recognizing the significance of human assets in companies and the limitations of excluding the human factor from manufacturing processes, the European Commission (EC) has shifted its focus from a technology-oriented approach to a sustainable, resilient, and human-centric strategy (European Commission, 2021). The EC emphasizes that human workers surpass machines and robots in terms of dexterity, intelligence, flexibility, and creativity (European Commission, 2021, 2022).

In response to this perspective, the concept of Industry 5.0 has been introduced (European Commission, 2021, 2022). Industry 5.0 emphasizes the role of the research and innovation sector in supporting the industry's long-term service to humanity. It highlights the need for a human-centric approach and emphasizes the integration of advanced technologies, including artificial intelligence, robotics, and edge computing (European Commission, 2020) into a sustainable manufacturing environment. Similarly, to Industry 5.0, Digital Kaizen emerges as a transformative approach that places significant emphasis on the value of human contribution and continuous improvement using digital technologies. Industry 5.0 represents the evolution of industrial processes, where advanced technologies like automation, artificial intelligence, and robotics are integrated with human capabilities to create a harmonious and productive working environment recognizing the importance of human skills, creativity, and problem-solving abilities (Nahavandi, 2019). Digital Kaizen aligns with this vision and seeks to leverage digital technologies to augment human potential and foster a culture of continuous improvement.

Figure 1. represents a dynamic Industry 5.0 ecosystem interconnected with Digital Kaizen, as a continuous improvement concept (adapted from (Fraga-Lamas *et al.*, 2021). The nodes represent various advanced technologies, namely: AI, IoT/IIoT, robotics, Big Data, cloud/fog/edge computing, and so on (Angulo *et al.*, 2023; Bajic, Suzic, *et al.*, 2023) that enable resilience of manufacturing system. These nodes are interconnected, symbolizing the integration and collaboration between different technological

components. Besides, the usage of advanced technologies provides sustainability reflected in waste reduction, energy consumption, and process optimization. At the center of this network, visualize a group of human figures representing the human workforce, engineers, and data scientists. They are depicted as active participants, engaged in collaboration with the technological nodes. This representation highlights the human-centric approach of Industry 5.0, with humans working alongside and leveraging the potential of advanced technologies. Surrounding the network, visualize circular arrows representing the continuous improvement process of Digital Kaizen. These arrows symbolize the iterative and ongoing nature of improvement, emphasizing the idea of continuous learning, adaptation, and optimization. This reflects the commitment to continuous improvement within the Industry 5.0 ecosystem, where both humans and technologies evolve and enhance their capabilities over time.

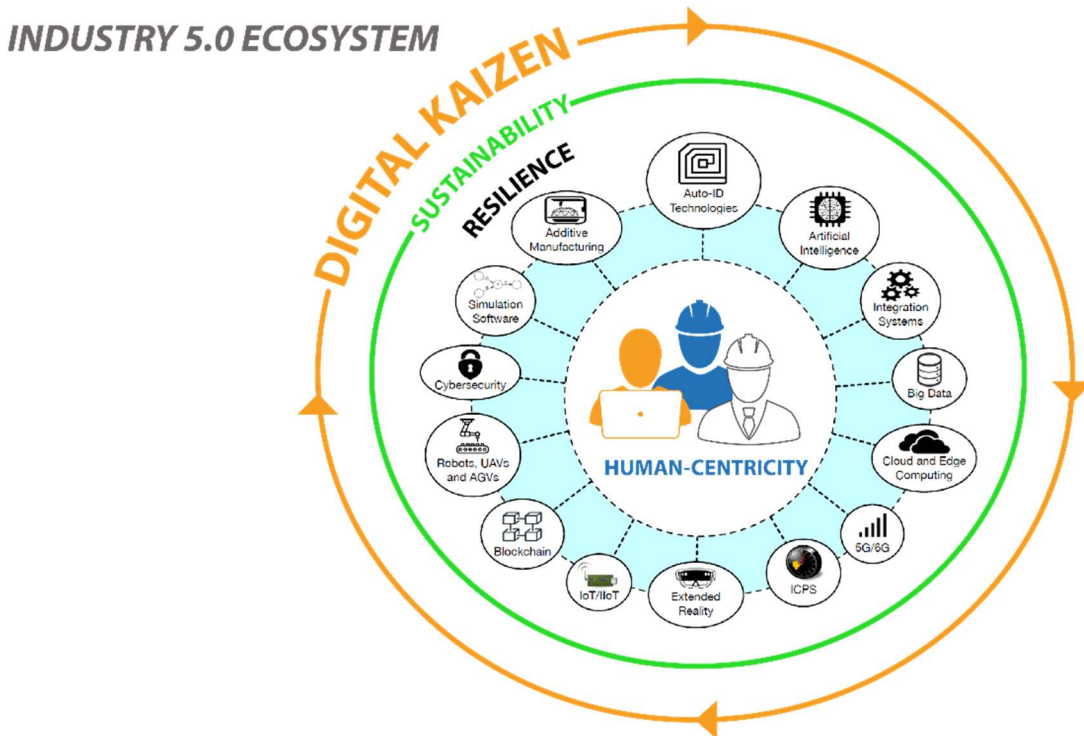


Figure 1: Industry 5.0 ecosystem interconnected with Digital Kaizen

3. OPPORTUNITIES AND CHALLENGES OF DIGITAL KAIZEN IN INDUSTRY 5.0

3.1 Opportunities of Digital Kaizen

Kaizen is rooted in the philosophy of incremental and continuous improvement, aiming to create a culture of constant learning and innovation within an organization (Sridhar *et al.*, 2023). It emphasizes the collective effort of all employees, from top management to frontline workers, in identifying and implementing improvements at all levels of the organization. Unlike large-scale transformation projects, Kaizen focuses on small, incremental changes that, when accumulated over time, lead to significant improvements in quality (Sundararajan and Terkar, 2022).

In today's world, the process of digitalization has become deeply integrated into social processes, thereby impacting the contexts in which human actions take place. By integrating advanced technologies into a human-centric and sustainable manufacturing environment, Industry 5.0 aims to harness the unique capabilities of human workers while leveraging the potential of digital innovations. This approach seeks to foster a harmonious collaboration between humans and technology, leading to increased productivity, innovation, and overall societal well-being (Papetti *et al.*, 2020). Therefore, the key elements of Digital Kaizen in Industry 5.0 with a focus on humans and continuous improvement include:

- **Human empowerment:** Digital Kaizen acknowledges that humans possess unique qualities, such as critical thinking, emotional intelligence, and adaptability, which are essential for innovation and complex decision-making. It aims to empower individuals by providing them with the tools, training, and support to take an active role in driving continuous improvement efforts (Dang-Pham *et al.*, 2022; Ghobakhloo *et al.*, 2022).

- Skill development and upskilling: Industry 5.0 places a premium on skills that complement technological advancements. Digital Kaizen promotes ongoing skill development and upskilling initiatives to ensure that the workforce remains adaptable and capable of effectively utilizing digital tools. This includes training programs, mentoring, and cross-functional collaboration to foster a learning culture (Ghobakhloo *et al.*, 2022; Roblek *et al.*, 2021).
- Human-machine collaboration: Digital Kaizen recognizes that the combination of human expertise and technological capabilities can yield superior results. It promotes collaboration between humans and machines, where technology automates routine and repetitive tasks, freeing up human workers to focus on higher-value activities such as problem-solving, creativity, and innovation (Angulo *et al.*, 2023; European Commission, 2019).
- Continuous improvement mindset: In Industry 5.0, organizations need to continuously adapt and improve to remain competitive. Digital Kaizen instills a mindset of continuous improvement at all levels of the organization. It encourages employees to seek out inefficiencies, identify areas for improvement, and experiment with new approaches. This culture of continuous improvement ensures that organizations remain agile and responsive to evolving market conditions (Janjić *et al.*, 2019).
- Data-driven decision-making: Digital Kaizen leverages data analytics and insights to drive decision-making processes. By collecting and analyzing data from various sources, organizations can gain valuable insights into operational performance, customer behavior, and market trends. This data-driven approach enables informed decision-making and identifies areas where continuous improvement initiatives can be implemented (Bajic *et al.*, 2020, 2022).

3.2 Challenges of Digital Kaizen

The implementation of traditional Kaizen requires active participation and engagement from employees at all levels, a culture of continuous improvement, effective communication channels, and the support of management to foster a collaborative and learning-oriented environment (Sundararajan and Terkar, 2022). However, the transition to Digital Kaizen presents its own challenges. Some of the biggest issue when implementing Digital Kaizen in Industry 5.0 refers to:

- Change Management and Organizational Readiness: The successful adoption of Digital Kaizen requires organizational change and a shift in work processes. Managing and overcoming resistance to change from employees, stakeholders, and existing organizational structures poses a challenge. It necessitates effective change management strategies, leadership support, and employee engagement to foster a positive attitude towards digital transformation and continuous improvement initiatives (Bajic, Moraca, *et al.*, 2023).
- Workforce Resistance to Change: The successful implementation of Digital Kaizen relies on a skilled workforce capable of effectively utilizing digital tools and technologies. However, upskilling and reskilling the workforce to adapt to new technologies and tools presents challenges ((Bajic *et al.*, 2021). It requires identifying the necessary skill gaps, designing, and implementing training programs, and fostering a continuous learning culture within the organization (Dang-Pham *et al.*, 2022). Besides, in Industry 5.0 vast amounts of data from various sources, including sensors, machines, and customer interactions are generated. Effectively collecting, managing, analyzing, and extracting valuable insights from this data requires skilled data professionals to handle the data in real-time or near real-time (Bajic *et al.*, 2021).
- Technological Integration and Complexity: Industry 5.0 involves the integration of advanced technologies, which can be complex due to the diverse range of technologies and their interdependencies. Ensuring seamless interoperability, compatibility, and synchronization between these technologies poses a challenge in terms of technical implementation and system integration (Rikalovic *et al.*, 2022).
- Cybersecurity and Data Privacy: With the increased connectivity and reliance on digital technologies, ensuring cybersecurity and protecting sensitive data become critical challenges. Safeguarding against cyber threats, implementing robust security measures, and adhering to data privacy regulations are essential. It requires continuous monitoring, threat detection mechanisms, and encryption techniques to mitigate risks and maintain data integrity and privacy (Bajic *et al.*, 2021; Rikalovic *et al.*, 2022).
- Cost and Return on Investment (ROI): Implementing Digital Kaizen involves substantial investments in technology infrastructure, training programs, and process improvements.

Assessing the costs and evaluating the expected return on investment pose challenges. Organizations need to carefully analyze the potential benefits and costs associated with Digital Kaizen initiatives to ensure long-term sustainability and ROI (Bajic et al., 2021). Addressing these scientific challenges requires multidisciplinary approaches, including advanced engineering, organizational behavior, data management, cybersecurity, and financial analysis. Organizations need to leverage scientific research, best practices, and collaboration between academia and industry to overcome these challenges and achieve successful implementation of Digital Kaizen in Industry 5.0.

4. DISCUSSION AND CONCLUSIONS

This research highlights the transformative potential of Digital Kaizen in driving continuous improvement and fostering a more resilient and adaptive manufacturing environment. The integration of digital technologies and data analytics in the Kaizen methodology offers new avenues for process optimization, waste reduction, and increased productivity. By leveraging real-time data and advanced analytics tools, organizations can identify bottlenecks, anticipate potential issues, and implement timely corrective measures. Moreover, Digital Kaizen enables enhanced collaboration and knowledge sharing across teams and departments, facilitating faster problem-solving and innovation. The ability to rapidly adapt and respond to changing market demands and unforeseen disruptions is paramount in today's dynamic business landscape, and Digital Kaizen emerges as a powerful approach to achieving this agility. However, successful implementation requires a holistic approach encompassing not only technology adoption but also a cultural shift towards data-driven decision-making, employee empowerment, and a learning mindset. As organizations continue to embrace Digital Kaizen, they position themselves for greater competitiveness, resilience, and success in an increasingly complex and challenging smart manufacturing.

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