

## THE USAGE OF BENCHMARKING IN INDUSTRY 4.0 CONDITIONS

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**Purpose:** The purpose of this publication is to present the usage of benchmarking approach in Industry 4.0 conditions.

**Design/methodology/approach:** Critical literature analysis. Analysis of international literature from main databases and polish literature and legal acts connecting with researched topic.

**Findings:** The integration of benchmarking with Industry 4.0 emerges as a strategic imperative for organizations navigating the complexities of the fourth industrial revolution. As Industry 4.0 transforms manufacturing processes through the incorporation of digital technologies, automation, and data exchange, the demand for heightened efficiency, innovation, and adaptability becomes paramount. Benchmarking, evolving from its early roots in efficiency studies, stands as a dynamic and proactive force, playing a pivotal role in helping businesses stay competitive amid the dynamic changes ushered in by digital transformation. From Frederick W. Taylor's early emphasis on best practices to the structured approaches of the late 20th century, benchmarking's historical journey laid the groundwork for its integration with Industry 4.0. The application of benchmarking in this context spans various dimensions, encompassing digital maturity, smart technologies integration, data analytics, supply chain optimization, innovation, cybersecurity, and collaboration. Tables 2, 3, and 4 provide a comprehensive overview, illustrating examples of integration, emphasizing advantages, and addressing challenges. In leveraging benchmarking not only for traditional metrics but also for digital capabilities, organizations position themselves as agile, competitive, and resilient players in the dynamic landscape of Industry 4.0, reflecting a commitment to continuous improvement and competitiveness.

**Originality/Value:** Detailed analysis of all subjects related to the problems connected with the usage of benchmarking in Industry 4.0 conditions.

**Keywords:** Industry 4.0, Quality 4.0, quality management; quality methods, QFD, benchmarking.

**Category of the paper:** literature review.

## 1. Introduction

In the era of Industry 4.0, benchmarking has emerged as a critical tool for organizations seeking to navigate the complexities of the fourth industrial revolution. Characterized by the integration of digital technologies, automation, and data exchange into manufacturing processes, Industry 4.0 demands a heightened focus on efficiency, innovation, and adaptability. Benchmarking, in this context, plays a pivotal role in helping businesses stay competitive and responsive to the dynamic changes ushered in by the digital transformation. In the Industry 4.0 landscape, benchmarking extends beyond traditional performance metrics to encompass a broader spectrum of factors. Companies now compare not only production efficiency but also the integration of smart technologies, data analytics, and the overall digital maturity of their operations. This expanded scope allows organizations to gain insights into the holistic landscape of Industry 4.0, identifying areas for improvement and innovation (Singh et al., 2023).

The purpose of this publication is to present the usage of benchmarking approach in Industry 4.0 condition.

## 2. The basics of benchmarking approach

Benchmarking is a strategic management tool that involves the systematic comparison of an organization's processes, products, or performance metrics against those of industry leaders or best-in-class competitors. The primary objective of benchmarking is to identify areas for improvement, enhance organizational performance, and adopt best practices to achieve a competitive advantage. This process goes beyond mere performance measurement; it is a proactive approach to continuous improvement. Benchmarking encompasses various types, including internal, competitive, and strategic benchmarking, each serving distinct purposes. Internal benchmarking involves comparing different departments or units within the same organization, fostering a culture of shared learning and improvement (Gajdzik et al., 2023).

Competitive benchmarking evaluates an organization's performance against direct competitors, allowing for insights into relative strengths and weaknesses. Strategic benchmarking, on the other hand, involves analyzing processes and practices of organizations renowned for their excellence, even if they operate in different industries. Successful benchmarking requires a comprehensive understanding of the industry context, clear identification of performance metrics, and a commitment to implementing the insights gained to drive positive change within the organization. Overall, benchmarking is a dynamic and

adaptive process that plays a pivotal role in fostering a culture of continuous improvement and innovation within organizations (Barsalou, 2023; Maganga, Taifa, 2023).

Benchmarking, as a strategic management tool, has evolved over the years to become an integral aspect of organizational performance improvement. The history of benchmarking can be traced back to the early 20th century when Frederick W. Taylor, a pioneer in scientific management, emphasized the importance of comparing and adopting best practices for efficiency. Taylor's work laid the foundation for the concept of benchmarking by highlighting the significance of studying successful organizations to enhance one's own processes (Jokovic et al., 2023).

In the mid-20th century, Japan played a pivotal role in shaping the benchmarking landscape. After World War II, Japanese industries faced the challenge of rebuilding and competing on a global scale. They embraced benchmarking as a means to learn from Western practices and improve their own methodologies. The success of Japanese companies in industries such as automotive manufacturing demonstrated the effectiveness of benchmarking in achieving operational excellence.

As the global economy became more interconnected, benchmarking gained prominence in the business world during the latter half of the 20th century. The Xerox Corporation is often credited with popularizing formalized benchmarking in the 1970s. Facing challenges in the copier market, Xerox engaged in systematic performance comparisons with other companies to identify areas for improvement. This marked a shift towards a structured and systematic approach to benchmarking (Yanamandra et al., 2023).

Throughout the 1980s and 1990s, benchmarking methodologies continued to evolve. Various frameworks, such as the Malcolm Baldrige National Quality Award and the International Organization for Standardization (ISO) standards, emerged to provide organizations with structured approaches to benchmarking their processes. The emphasis shifted from merely imitating successful practices to understanding the underlying principles and adapting them to suit the unique needs of each organization.

In the 21st century, the digital revolution has further transformed benchmarking. With the advent of big data analytics and advanced technology, organizations can now access vast amounts of data to compare and analyze performance metrics. This has enabled a more dynamic and real-time approach to benchmarking, allowing companies to adapt swiftly to changing market conditions.

Today, benchmarking is not limited to specific industries or sectors; it has become a cross-industry practice, encompassing various aspects such as quality, innovation, and sustainability. Organizations across the globe recognize benchmarking as a strategic tool for continuous improvement and competitiveness in an ever-evolving business landscape. The history of benchmarking reflects its journey from an informal concept rooted in efficiency studies to a sophisticated and integral part of modern management practices.

One of the primary applications of benchmarking in Industry 4.0 is in the realm of digitalization. As organizations embrace technologies like the Internet of Things (IoT), artificial intelligence, and cloud computing, benchmarking enables them to evaluate their digital strategies against industry standards and best practices. This ensures that companies are not only adopting cutting-edge technologies but also leveraging them effectively to enhance overall operational performance. Moreover, benchmarking serves as a strategic compass for organizations navigating the complexities of interconnected supply chains in Industry 4.0. Companies can assess their logistics and supply chain management against industry benchmarks, optimizing processes for increased agility, reduced lead times, and enhanced customer satisfaction. This is particularly crucial in an environment where rapid response to market changes is a competitive necessity.

In the context of innovation, Industry 4.0 benchmarking fosters a culture of continuous improvement. By comparing their research and development efforts, product life cycles, and innovation processes with industry leaders, organizations can identify areas to enhance creativity, shorten time-to-market, and stay ahead of technological disruptions. Furthermore, as cybersecurity becomes a paramount concern in the digital age, benchmarking assists organizations in fortifying their defenses. By benchmarking their cybersecurity protocols against industry standards and peers, companies can ensure the resilience of their digital infrastructure and protect against evolving cyber threats.

The usage of benchmarking in Industry 4.0 conditions reflects a strategic imperative for organizations aiming to thrive in the digital era. By benchmarking not only traditional performance metrics but also digital capabilities, supply chain integration, innovation processes, and cybersecurity measures, businesses can position themselves as agile, competitive, and resilient players in the dynamic landscape of Industry 4.0.

Table 1 contains description of benchmarking key principles.

**Table 1.**  
Key principles of benchmarking

<b>Key principle</b>	<b>Description</b>
<b>Continuous Improvement</b>	Ongoing, incremental changes are prioritized over radical shifts, fostering steady progress.
<b>Employee Involvement</b>	All members of the organization, from top management to frontline workers, contribute ideas.
<b>Gemba (Real Place)</b>	Solutions are sought at the source of the issue, often on the shop floor or in the workspace.
<b>Standardization</b>	Once improvements are made, standardized processes are established to maintain consistency.
<b>Elimination of Waste</b>	Identification and removal of unnecessary processes, movements, and resources to optimize.
<b>Kaizen Events</b>	Time-limited, focused activities to address specific issues and rapidly implement improvements.
<b>Quality Focus</b>	A commitment to producing high-quality products or services is central to the Kaizen philosophy.
<b>Visual Management</b>	Information is presented visually to enhance understanding and facilitate quick decision-making.

<b>Cross-Functional Teams</b>	Collaboration among individuals from different departments to address issues comprehensively.
<b>Data-Driven Decision-Making</b>	Analysis of data guides decision-making, ensuring changes are based on evidence and facts.

Source: (Almeida, Abreu, 2023; Jokovic et al., 2023; Khourshed, Gouhar, 2023; Maganga, Taifa, 2023; Liu et al., 2023; Yanamandra et al., 2023; Escobar et al., 2023; Bousdekis et al., 2023; Antony et al., 2023).

### 3. How benchmarking method can be integrated with Industry 4.0 and Quality 4.0 concept

The integration of benchmarking with Industry 4.0 encompasses several key aspects critical to the success of organizations navigating the complexities of the fourth industrial revolution. Firstly, the assessment of digital maturity is paramount. This involves a thorough evaluation of an organization's level of digitalization, including the adoption and effective utilization of technologies such as the Internet of Things (IoT), artificial intelligence, and cloud computing. Benchmarking against industry standards ensures that the organization optimally leverages digital tools for enhanced operational efficiency (Bousdekis et al., 2023).

Another crucial aspect is the integration of smart technologies into manufacturing processes. Organizations must assess how well automation, robotics, and sensor networks are incorporated into their operations. Benchmarking strategies in this realm facilitates the identification of best practices, allowing companies to streamline their processes for increased efficiency and responsiveness (Alrabadi et al., 2023).

Data analytics capabilities play a pivotal role in Industry 4.0, and benchmarking helps organizations gauge their proficiency in utilizing data for decision-making. By comparing their data analytics practices against industry benchmarks, companies can ensure effective extraction of insights from big data, contributing to informed and strategic decision-making.

Supply chain optimization is a key consideration in the benchmarking process. Organizations assess their logistics and supply chain management against industry standards, aiming to achieve increased agility, reduced lead times, and heightened customer satisfaction. This aspect acknowledges the interconnected nature of supply chains in the Industry 4.0 landscape.

Innovation processes are also subject to benchmarking scrutiny. Companies compare their research and development efforts, product life cycles, and overall innovation strategies with industry leaders. This facilitates the identification of areas for improvement, fostering a culture of continuous innovation and ensuring a faster time-to-market for new products and solutions (Antony et al., 2023; Escobar et al., 2023; Antony et al., 2023; Salimbeni, Redchuk, 2023).

The integration of benchmarking with Industry 4.0 extends to cybersecurity protocols. In an era where digital threats are prevalent, organizations benchmark their cybersecurity measures against industry standards. This safeguards the integrity and resilience of digital infrastructure, protecting against evolving cyber threats associated with increased connectivity. Furthermore, the integration of interconnected systems is a critical benchmarking aspect. Organizations evaluate how well their systems and platforms are integrated, benchmarking against industry leaders to enhance interoperability and communication between interconnected systems (Maganga, Taifa, 2023).

Collaboration and ecosystem engagement are emphasized in Industry 4.0, and benchmarking helps organizations assess their level of collaboration with external partners. Benchmarking against successful collaboration models enhances innovative and agile practices in a networked environment. Sustainability considerations are also integrated into benchmarking practices. Organizations benchmark their sustainability practices against industry benchmarks, assessing the environmental impact of operations. This aspect aligns with Industry 4.0 principles and identifies opportunities for green initiatives (Maganga, Taifa, 2023).

Lastly, the benchmarking of employee skills and training programs is crucial. Organizations compare their workforce's skills and training programs related to Industry 4.0 technologies against industry standards. This ensures that the workforce is equipped with the necessary skills to effectively contribute to the organization's digital transformation efforts (Jonek-Kowalska, Wolniak, 2021; 2022).

Table 2 is listing examples of integration of benchmarking method with industry 4.0.

**Table 2.**  
*Benchmarking integration with industry 4.0*

<b>Aspect</b>	<b>Description</b>
<b>Digital Maturity</b>	Evaluate the organization's level of digitalization, including the adoption of IoT, artificial intelligence, and cloud computing. Benchmark against industry standards to ensure optimal utilization of digital technologies.
<b>Smart Technologies Integration</b>	Assess how well smart technologies are integrated into manufacturing processes. Compare strategies for automation, robotics, and sensor networks to enhance efficiency and responsiveness.
<b>Data Analytics Capabilities</b>	Evaluate the organization's proficiency in utilizing data analytics for decision-making. Benchmark against industry best practices to ensure effective extraction of insights from big data.
<b>Supply Chain Optimization</b>	Benchmark logistics and supply chain management practices against industry standards. Optimize processes to achieve increased agility, reduced lead times, and improved customer satisfaction.
<b>Innovation Processes</b>	Compare research and development efforts, product life cycles, and innovation strategies. Identify areas for improvement to foster a culture of continuous innovation and faster time-to-market.
<b>Cybersecurity Protocols</b>	Benchmark cybersecurity measures against industry standards to ensure the resilience of digital infrastructure. Protect against evolving cyber threats in the era of increased connectivity.
<b>Interconnected Systems Integration</b>	Assess how well interconnected systems and platforms are integrated within the organization. Benchmark against industry leaders to enhance interoperability and communication between systems.

Cont. table 2.

<b>Collaboration and Ecosystem Engagement</b>	Evaluate the level of collaboration with external partners and ecosystem engagement. Benchmark against successful models to enhance collaborative innovation and agility in a networked environment.
<b>Sustainability and Environmental Impact</b>	Benchmark sustainability practices against industry benchmarks. Assess the environmental impact of operations and identify opportunities for green initiatives in alignment with Industry 4.0 principles.
<b>Employee Skills and Training</b>	Evaluate the skills and training programs related to Industry 4.0 technologies. Benchmark against industry standards to ensure the workforce is equipped with the necessary skills for digital transformation.

Source: (Almeida, Abreu, 2023; Jokovic et al., 2023; Khourshed, Gouhar, 2023; Maganga, Taifa, 2023; Liu et al., 2023; Amat-Lefort et al., 2023; Alrabadi et al., 2023; Singh et al., 2023; Barsalou, 2023; Antony et al., 2023; Saihi et al., 2023; Sureshchandar, 2023; Swarnakar et al., 2023; Gimerska et al., 2023; Salimbeni, Redchuk, 2023; Yanamandra et al., 2023; Escobar et al., 2023; Bousdekis et al., 2023; Antony et al., 2023).

Table 3 is describe the advantages benchmarking approach usage in industry 4.0. This table provides a brief overview of some of the key advantages associated with integrating benchmarking practices with Industry 4.0.

**Table 3.**

*The advantages of benchmarking integration with industry 4.0*

<b>Advantage</b>	<b>Description</b>
<b>Enhanced Operational Efficiency</b>	Benchmarking with Industry 4.0 allows organizations to identify and adopt best practices, leading to improved operational processes and overall efficiency.
<b>Real-time Data Analysis and Decision Making</b>	Integration with Industry 4.0 enables the utilization of real-time data for benchmarking, facilitating quicker and more informed decision-making processes.
<b>Innovation and Technology Adoption</b>	Benchmarking in the context of Industry 4.0 encourages the adoption of innovative technologies and practices, keeping businesses at the forefront of industry trends.
<b>Improved Quality and Productivity</b>	By comparing processes and performance metrics, organizations can identify areas for improvement, leading to enhanced product quality and increased productivity.
<b>Cost Reduction and Resource Optimization</b>	Industry 4.0 benchmarking helps in identifying cost-effective solutions and optimizing the use of resources, contributing to overall cost reduction strategies.
<b>Supply Chain Optimization</b>	Benchmarking integration with Industry 4.0 assists in optimizing supply chain processes, ensuring seamless and efficient coordination among various elements.
<b>Enhanced Customer Satisfaction</b>	Continuous improvement through benchmarking in Industry 4.0 leads to better products and services, ultimately resulting in higher customer satisfaction levels.
<b>Agility in Response to Market Changes</b>	Organizations can become more agile and adaptable to market changes by benchmarking with Industry 4.0, adjusting strategies based on real-time industry standards.
<b>Enhanced Predictive Maintenance</b>	Integration with Industry 4.0 allows for the implementation of predictive maintenance strategies, reducing downtime by identifying potential equipment failures before they occur.
<b>Increased Employee Engagement</b>	Benchmarking fosters a culture of continuous improvement, engaging employees in identifying and implementing best practices, leading to higher job satisfaction.
<b>Sustainable Practices Adoption</b>	Organizations can benchmark sustainable practices within Industry 4.0, promoting eco-friendly initiatives and reducing the environmental impact of operations.
<b>Global Competitiveness</b>	Benchmarking against global industry standards helps organizations stay competitive by aligning their practices with the best in the world.
<b>Accelerated Time-to-Market</b>	Industry 4.0 benchmarking enables faster product development cycles by incorporating efficient processes and technologies employed by industry leaders.
<b>Risk Mitigation and Compliance</b>	Identifying and adopting industry best practices through benchmarking helps mitigate risks and ensures compliance with evolving regulatory standards.

Cont. table 3.

<b>Cross-Functional Collaboration</b>	Benchmarking encourages collaboration among different departments and functions within an organization, breaking down silos and fostering a cohesive working environment.
<b>Improved Cybersecurity Measures</b>	Integrating benchmarking with Industry 4.0 allows organizations to assess and enhance their cybersecurity measures, safeguarding critical digital assets.
<b>Data-driven Decision Validation</b>	Organizations can validate their strategic decisions by benchmarking data-driven insights, ensuring that choices align with industry trends and proven successful approaches.
<b>Enhanced Supplier Relationships</b>	Benchmarking practices extend to suppliers, fostering stronger relationships and collaboration to improve overall supply chain efficiency and product quality.

Source: (Almeida, Abreu, 2023; Jokovic et al., 2023; Khourshed, Gouhar, 2023; Maganga, Taifa, 2023; Liu et al., 2023; Amat-Lefort et al., 2023; Alrabadi et al., 2023; Singh et al., 2023; Barsalou, 2023; Antony et al., 2023; Saihi et al., 2023; Sureshchandar, 2023; Swarnakar et al., 2023; Gimerska et al., 2023; Salimbeni, Redchuk, 2023; Yanamandra et al., 2023; Escobar et al., 2023; Bousdekis et al., 2023; Antony et al., 2023).

Table 4 is describe the problems of benchmarking approach usage in Industry 4.0 and methods to overcome them. Addressing these problems requires a strategic and thoughtful approach, involving a combination of technological solutions, organizational change management, and ongoing adaptation to evolving industry standards and practices.

**Table 4.**

*The problems of benchmarking integration with Industry 4.0*

<b>Problems</b>	<b>Description of Problem</b>	<b>Overcoming Strategies</b>
<b>Data Security and Privacy Concerns</b>	Integrating benchmarking with Industry 4.0 involves sharing sensitive operational data, raising concerns about data security and privacy.	Implement robust encryption protocols, establish secure data sharing agreements, and comply with relevant data protection regulations.
<b>Lack of Standardization in Data Formats</b>	Industry 4.0 may involve diverse data formats, making it challenging to compare and benchmark data consistently across different systems and platforms.	Establish industry standards for data formats, invest in interoperable technologies, and utilize data conversion tools to ensure compatibility.
<b>Technological Incompatibility</b>	Varied technological infrastructures among different organizations may hinder seamless integration for benchmarking purposes.	Invest in adaptable technologies, conduct thorough compatibility assessments, and collaborate on developing standardized technology frameworks.
<b>Difficulty in Identifying Comparable Metrics</b>	Identifying comparable metrics for benchmarking purposes in the dynamic environment of Industry 4.0 can be challenging, leading to inaccurate or incomplete comparisons.	Develop industry-specific benchmarking metrics, collaborate with stakeholders to define standardized metrics, and continuously adapt benchmarks to changing industry trends.
<b>Rapidly Evolving Technology Landscape</b>	The fast-paced evolution of Industry 4.0 technologies may result in benchmarks quickly becoming outdated, making it challenging to maintain relevance.	Establish a flexible benchmarking strategy, conduct regular reviews and updates, and foster a culture of continuous learning to stay abreast of technological advancements.
<b>Lack of Collaboration and Knowledge Sharing</b>	In some cases, organizations may be hesitant to share critical insights and best practices, hindering the effectiveness of benchmarking initiatives.	Promote a culture of open collaboration, incentivize knowledge sharing, and establish secure platforms for confidential information exchange to encourage transparency.



Cont. table 4.

<b>Resource Intensity and High Implementation Costs</b>	Implementing Industry 4.0 benchmarking initiatives may require significant resources, making it prohibitive for some organizations, especially smaller ones.	Prioritize cost-effective solutions, collaborate on shared resources, and consider phased implementations to manage costs more efficiently.
<b>Resistance to Change and Cultural Barriers</b>	Employees and leadership may resist changes associated with benchmarking and Industry 4.0, creating cultural barriers that hinder effective integration.	Implement comprehensive change management strategies, provide training and education, and foster a culture that embraces innovation and continuous improvement.

Source: (Almeida, Abreu, 2023; Jokovic et al., 2023; Khoureshed, Gouhar, 2023; Maganga, Taifa, 2023; Liu et al., 2023; Amat-Lefort et al., 2023; Alrabadi et al., 2023; Singh et al., 2023; Barsalou, 2023; Antony et al., 2023; Saihi et al., 2023; Sureshchandar, 2023; Swarnakar et al., 2023; Gimerska et al., 2023; Salimbeni, Redchuk, 2023; Yanamandra et al., 2023; Escobar et al., 2023; Bousdekis et al., 2023; Antony et al., 2023).

## 4. Conclusion

The integration of benchmarking with Industry 4.0 represents a strategic imperative for organizations navigating the complexities of the fourth industrial revolution. As Industry 4.0 reshapes manufacturing processes through the integration of digital technologies, automation, and data exchange, the need for heightened efficiency, innovation, and adaptability becomes paramount. Benchmarking emerges as a critical tool in this context, playing a pivotal role in helping businesses stay competitive and responsive to the dynamic changes ushered in by the digital transformation.

The evolution of benchmarking from its early roots in efficiency studies to a sophisticated and integral part of modern management practices reflects its adaptability and relevance in the ever-changing business landscape. The principles of continuous improvement, employee involvement, and data-driven decision-making underscore the dynamic and proactive nature of benchmarking, making it a driving force for innovation and competitiveness. The historical journey of benchmarking, from Frederick W. Taylor's emphasis on best practices in the early 20th century to the structured approaches of the late 20th century, laid the groundwork for its integration with Industry 4.0. The digital revolution of the 21st century further transformed benchmarking, enabling a more dynamic, real-time approach with the advent of big data analytics and advanced technologies.

The application of benchmarking in Industry 4.0 extends across various dimensions, including digital maturity, smart technologies integration, data analytics capabilities, supply chain optimization, innovation processes, cybersecurity protocols, and collaboration. Benchmarking ensures that organizations not only adopt cutting-edge technologies but also leverage them effectively to enhance overall operational performance.

Table 2 illustrates examples of benchmarking integration with Industry 4.0, emphasizing its multifaceted applications. The advantages highlighted in Table 3 underscore the positive impact of benchmarking on operational efficiency, decision-making, innovation, quality, cost reduction, and more. However, as outlined in Table 4, organizations may encounter challenges such as data security concerns, lack of standardization, technological incompatibility, and resistance to change. Overcoming these challenges requires strategic solutions, including robust encryption protocols, standardization efforts, adaptable technologies, and comprehensive change management strategies.

In the era of Industry 4.0, the usage of benchmarking as a strategic management tool reflects a commitment to continuous improvement and competitiveness. By embracing benchmarking not only for traditional performance metrics but also for digital capabilities, supply chain integration, innovation processes, and cybersecurity measures, organizations position themselves as agile, competitive, and resilient players in the dynamic landscape of Industry 4.0.

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