THE USAGE OF STATISTICAL BALANCED SCORECARD
IN INDUSTRY 4.0 CONDITIONS

Radosław WOLNIAK[1*], Wies GREBSKI[2]

[1] Silesian University of Technology, Organization and Management Department, Economics and Informatics Institute; rwolniak@polsl.pl, ORCID: 0000-0003-0317-9811
[2] Penn State Hazletonne, Pennsylvania State University; wxg3@psu.edu, ORCID: 0000-0002-4684-7608
* Correspondence author

Purpose: The purpose of this publication is to present the usage of balanced scorecard 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 the Statistical Balanced Scorecard (SBSC) with Industry 4.0 signifies a groundbreaking advancement in performance measurement and management. Through the infusion of advanced statistical methodologies and analytics, the SBSC seamlessly adapts the conventional Balanced Scorecard framework to thrive in the data-rich landscape of Industry 4.0. This evolution extends the financial perspective beyond conventional metrics, employing predictive analytics to forecast trends and optimize resource allocation. Within Industry 4.0, the customer perspective transcends understanding needs, incorporating data analytics to tailor products and services, thereby augmenting customer satisfaction. Critical internal processes benefit from statistical process control and data analytics, fostering efficiency and agility. The learning and growth perspective attains heightened significance by emphasizing digital literacy and innovation to navigate the Industry 4.0 paradigm. Tables 2, 3, and 4 provide comprehensive insights into the adaptation, advantages, and challenges associated with this integration, presenting a holistic framework that positions organizations to excel in the digital era through data-driven decision-making, strategic alignment with technological trends, and an unwavering commitment to continuous improvement.

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

Keywords: Industry 4.0; Quality 4.0; quality management; quality methods; balanced scorecard.

Category of the paper: literature review.

1. Introduction

The Statistical Balanced Scorecard builds upon the traditional Balanced Scorecard framework by incorporating advanced statistical methods and analytics. This adaptation allows organizations to harness the vast amount of data generated in Industry 4.0 environments to derive meaningful insights and drive informed decision-making.

In Industry 4.0 conditions, the financial perspective of the SBSC extends beyond mere monetary metrics to include data-driven financial analyses. This involves leveraging predictive analytics and modeling techniques to anticipate financial trends, optimize resource allocation, and enhance overall financial performance.

The customer perspective in an Industry 4.0 context involves not only understanding customer needs but also utilizing data analytics to personalize products and services. Through the integration of customer feedback, sentiment analysis, and real-time data, organizations can tailor their offerings to meet dynamic customer preferences and expectations (Barsalou, 2023; Maganga, Taifa, 2023).

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

2. The basics of balanced scorecard approach

The Balanced Scorecard is a strategic management framework that provides organizations with a comprehensive view of their performance. Developed by Robert S. Kaplan and David P. Norton in the early 1990s, this methodology goes beyond financial metrics to incorporate a balanced set of key performance indicators (KPIs) that align with the organization's strategic objectives (Jokovic et al., 2023).

At its core, the Balanced Scorecard emphasizes four perspectives: financial, customer, internal processes, and learning and growth. These perspectives collectively offer a well-rounded evaluation of an organization's health and effectiveness. The financial perspective assesses traditional financial metrics, such as revenue, profit, and return on investment. The customer perspective focuses on understanding and meeting customer needs, ensuring customer satisfaction and loyalty. Internal processes are examined to identify areas for improvement and efficiency. This perspective involves evaluating the organization's operational processes, innovation, and quality management. The learning and growth perspective highlights the importance of human capital, technology, and organizational culture. It recognizes that continuous improvement and development in these areas contribute to long-term success (Gajdzik et al., 2023).

The Balanced Scorecard serves as a communication tool that aligns the entire organization with its strategic goals. By translating the strategy into specific objectives and performance indicators, it provides clarity and direction for employees at all levels. This alignment ensures that everyone within the organization understands their role in achieving the overall strategy. Additionally, the Balanced Scorecard encourages a cause-and-effect relationship among the different perspectives. It prompts organizations to identify how improvements in one area can positively impact another, fostering a more holistic approach to strategic management.

Overall, the Balanced Scorecard is a dynamic and adaptable methodology that enables organizations to measure and manage performance in a way that goes beyond financial outcomes. By considering multiple perspectives and fostering a strategic mindset, it has become a valuable tool for organizations seeking sustained success in today's complex and competitive business environment (Singh et al., 2023).

Internal processes, a critical aspect of the SBSC, are optimized through the application of statistical process control and data analytics. This enables organizations to identify bottlenecks, reduce inefficiencies, and enhance the agility and responsiveness of their operations. Continuous improvement becomes data-driven, ensuring that processes align with strategic objectives in real-time.

The learning and growth perspective in Industry 4.0 conditions emphasizes the importance of cultivating data literacy, digital skills, and fostering a culture of innovation. Statistical analysis of workforce performance, skill development, and organizational culture enables businesses to adapt to technological advancements and stay competitive in a rapidly changing environment.

One of the key advantages of the Statistical Balanced Scorecard in Industry 4.0 is its ability to establish a causal relationship between different performance indicators. By employing advanced analytics, organizations can uncover correlations and dependencies, enabling them to make proactive decisions that positively impact various aspects of their operations.

The adoption of a Statistical Balanced Scorecard in Industry 4.0 conditions empowers organizations to leverage the full potential of data and analytics for strategic performance management. By integrating statistical methods into the traditional Balanced Scorecard framework, businesses can navigate the complexities of Industry 4.0, drive innovation, and achieve sustained success in the digital era (Alrabadi et al., 2023).

Table 1 contains description of balanced scorecard key principles. This table provides a concise overview of the key principles that guide the implementation and effectiveness of the Balanced Scorecard methodology.

Table 1.
Key principles of balanced scorecard

Key principle	Description
Four Perspectives	The Balanced Scorecard incorporates four perspectives: Financial, Customer, Internal Processes, and Learning & Growth. These perspectives provide a holistic view of organizational performance.
Strategy Mapping	It involves creating a visual representation of the cause-and-effect relationships between strategic objectives across the four perspectives. This helps in understanding how actions impact outcomes.
Cascading Objectives	Objectives are cascaded from the top level down to individual departments and employees, ensuring alignment with the overall organizational strategy.
Performance Measures	Identifying and selecting key performance indicators (KPIs) for each perspective to quantitatively measure progress toward strategic goals.
Targets and Initiatives	Setting specific targets for each KPI and defining initiatives or actions to achieve these targets. This ensures a clear roadmap for strategy execution.
Integration with Processes	Linking performance measures to day-to-day business processes, ensuring that employees' daily activities contribute to the achievement of strategic objectives.
Continuous Monitoring and Adaptation	Regularly monitoring performance against targets and adapting strategies and initiatives based on feedback and changing business conditions.
Employee Involvement and Communication	Involving employees at all levels in the development and execution of the Balanced Scorecard, and communicating the strategic objectives and their role in achieving them.
Balance Between Short-Term and Long-Term Goals	Striking a balance between short-term financial objectives and long-term strategic objectives to ensure sustainable growth and value creation.
Feedback and Learning Loop	Establishing a feedback loop to capture lessons learned, adjust strategies, and promote a culture of continuous learning and improvement.

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 balanced scorecard method can be integrated with Industry 4.0 and Quality 4.0 concept

The integration of the Balanced Scorecard method with Industry 4.0 and Quality 4.0 concepts represents a strategic approach to aligning organizational performance measurement with the transformative technologies and methodologies of the fourth industrial revolution. In the context of Industry 4.0, characterized by the extensive use of digital technologies, automation, and data-driven processes, the Balanced Scorecard adapts by incorporating key performance indicators (KPIs) that reflect the impact of these technologies on various business perspectives. The financial perspective extends beyond traditional monetary metrics to include data-driven financial analytics, such as predictive modeling and risk analysis. The customer perspective involves leveraging real-time data analytics to personalize products and services, enhancing customer satisfaction and loyalty (Maganga, Taifa, 2023).

Internal processes, a critical aspect of the Balanced Scorecard, are optimized through the integration of Industry 4.0 technologies. Statistical process control and advanced analytics are employed to identify inefficiencies, predict maintenance needs, and streamline operations. This ensures that processes are not only efficient but also adaptable to the dynamic changes introduced by Industry 4.0 (Bousdekis et al., 2023).

Quality 4.0, which emphasizes the integration of digital technologies into quality management processes, aligns seamlessly with the Balanced Scorecard. Performance measures related to quality can now include real-time data from sensors, predictive analytics for defect prevention, and continuous monitoring of quality metrics throughout the production process. The Balanced Scorecard, in this context, becomes a tool not only for measuring quality performance but also for driving continuous improvement in quality through data-driven insights (Jonek Kowalska, Wolniak, 2021, 2022).

Moreover, the Learning and Growth perspective of the Balanced Scorecard gains new significance in the Industry 4.0 and Quality 4.0 landscape. Organizations need to foster a culture of digital literacy, data analytics skills, and innovation to adapt to the evolving technological environment. Employee training and development initiatives can be incorporated into the Balanced Scorecard framework to ensure that the workforce is equipped with the skills needed to thrive in the Industry 4.0 era.

The integration of the Balanced Scorecard with Industry 4.0 and Quality 4.0 concepts creates a cohesive framework that not only measures performance across financial, customer, internal processes, and learning and growth perspectives but also ensures that these measurements are aligned with the transformative technologies and methodologies driving the fourth industrial revolution. This strategic alignment enables organizations to leverage Industry 4.0 and Quality 4.0 advancements for sustained success and competitiveness (Antony et al., 2023; Escobar et al., 2023; Antony et al., 2023; Salimbeni, Redchuk, 2023).

Table 2 is listing examples of integration of balanced scorecard method with Industry 4.0. This table provides a concise overview of key aspects that highlight the integration of the Balanced Scorecard with Industry 4.0, emphasizing how each perspective is adapted to leverage the capabilities of the fourth industrial revolution.

Table 2.
Balanced scorecard integration with industry 4.0

Aspect	Description
Financial Perspective in Industry 4.0	Adapting financial metrics to include data-driven financial analytics in Industry 4.0. This involves leveraging predictive modeling, risk analysis, and real-time financial data to enhance decision-making and align financial objectives with the transformative technologies of Industry 4.0.
Customer Perspective in Industry 4.0	Utilizing real-time data analytics to personalize products and services, improving customer satisfaction and loyalty in the digital era. Integrating customer feedback, sentiment analysis, and data-driven insights to enhance the understanding of customer needs and expectations within the context of Industry 4.0.

Cont. table 2.

Internal Processes in Industry 4.0	Optimizing internal processes through Industry 4.0 technologies. Applying statistical process control, advanced analytics, and automation to identify and eliminate inefficiencies, predict maintenance needs, and streamline operations. Ensuring that processes are not only efficient but also adaptive to the dynamic changes introduced by Industry 4.0.
Learning and Growth in Industry 4.0	Fostering a culture of digital literacy, data analytics skills, and innovation. Integrating employee training and development initiatives into the Balanced Scorecard framework to ensure that the workforce is equipped with the skills needed to thrive in the Industry 4.0 era. Recognizing the importance of human capital and skills development in the digital age.
Cascading Objectives in Industry 4.0	Aligning objectives from the top level down to individual departments and employees, ensuring that strategic goals related to Industry 4.0 are communicated and integrated into daily operations. Cascading objectives helps in achieving alignment across the organization and ensures that everyone understands their role in the Industry 4.0 strategy.
Continuous Monitoring in Industry 4.0	Regularly monitoring performance against targets and adapting strategies based on feedback and changing conditions in the Industry 4.0 landscape. Emphasizing the need for real-time data and analytics to enable proactive decision-making, especially in the dynamic and rapidly evolving environment of Industry 4.0.

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 balanced scorecard approach usage in Industry 4.0. This table illustrates how the integration of the Balanced Scorecard with Industry 4.0 brings several strategic advantages, leveraging technological advancements to enhance decision-making, performance management, operational efficiency, customer experience, strategic alignment, and risk management.

Table 3.
The advantages of balanced scorecard integration with industry 4.0

Advantage	Description
Real-time Decision-Making	Integration with Industry 4.0 enables the Balanced Scorecard to leverage real-time data and analytics. This advantage allows organizations to make informed decisions promptly, responding to dynamic changes in the production environment, market conditions, and customer preferences. The ability to access and analyze data in real-time enhances agility and responsiveness across all business perspectives.
Data-Driven Performance Management	Industry 4.0 provides a wealth of data generated by sensors, IoT devices, and interconnected systems. Integrating the Balanced Scorecard with Industry 4.0 allows organizations to utilize this data for comprehensive and data-driven performance management. This advantage facilitates a more accurate assessment of key performance indicators, leading to proactive management of financial, customer, internal process, and learning and growth objectives.
Optimized Operational Efficiency	The integration of the Balanced Scorecard with Industry 4.0 supports the optimization of internal processes through technologies such as automation, artificial intelligence, and advanced analytics. This advantage enables organizations to streamline operations, identify and eliminate bottlenecks, and improve overall operational efficiency. Industry 4.0 technologies contribute to achieving process-related objectives more effectively.

Cont. table 3.

Enhanced Customer Experience	Industry 4.0 allows for personalized and data-driven customer experiences. When integrated with the Balanced Scorecard, organizations can align their customer perspective with the capabilities of Industry 4.0, resulting in improved customer satisfaction and loyalty. Real-time data analytics and customer feedback mechanisms contribute to the continuous refinement of products and services, ensuring they meet evolving customer expectations.
Strategic Alignment with Technology Trends	The integration of the Balanced Scorecard with Industry 4.0 ensures strategic alignment with the ongoing technological advancements characteristic of the fourth industrial revolution. This advantage allows organizations to stay at the forefront of innovation, adapting their strategic objectives to capitalize on new technologies and maintain a competitive edge in the rapidly evolving digital landscape.
Proactive Risk Management	Industry 4.0 integration enhances the Balanced Scorecard's ability to incorporate predictive analytics and risk management strategies. This advantage enables organizations to proactively identify and mitigate risks associated with financial, operational, and technological factors. The real-time monitoring and predictive capabilities support a more resilient and risk-aware approach to strategic decision-making and goal attainment.

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 balanced scorecard approach usage in Industry 4.0 and methods to overcome them. This table highlights potential problems associated with integrating the Balanced Scorecard with Industry 4.0 and suggests methods to overcome these challenges, focusing on data management, integration complexity, cybersecurity, workforce readiness, financial considerations, and standardization efforts.

Table 4.
The problems of balanced scorecard integration with industry 4.0

Problems	Description of Problem	Overcoming Strategies
Data Overload and Quality Issues	The influx of data from Industry 4.0 technologies may lead to information overload, making it challenging to discern relevant data and ensure data accuracy and quality.	• Implement data governance and quality control measures to ensure data accuracy and reliability. • Utilize advanced analytics tools and algorithms to filter and analyze relevant data. • Establish clear data management protocols and standards.
Integration Complexity	Integrating Industry 4.0 technologies with the Balanced Scorecard may be complex due to the diversity of systems, devices, and data sources. The compatibility and seamless integration of these technologies can pose challenges.	• Conduct a comprehensive analysis of existing systems and technologies to identify compatibility issues. • Invest in middleware solutions or platforms that facilitate smooth integration. • Collaborate with experienced IT professionals and vendors for seamless implementation.
Cybersecurity Risks	Industry 4.0 introduces a higher level of connectivity, increasing the vulnerability to cybersecurity threats. The integration of the Balanced Scorecard with Industry 4.0 may expose sensitive data to potential cyber risks.	• Implement robust cybersecurity measures, including encryption, firewalls, and regular security audits. • Provide cybersecurity training to employees to enhance awareness and prevent potential breaches. • Stay informed about the latest cybersecurity threats and updates.

Cont. table 4.

Skill Gaps and Workforce Resistance	The transition to Industry 4.0 may require new skills and competencies that the existing workforce may lack. Resistance to change from employees accustomed to traditional processes can hinder successful integration.	• Invest in comprehensive training programs to upskill the workforce in digital literacy and Industry 4.0 technologies. • Foster a culture of continuous learning and change management to address resistance. • Involve employees in the transition process and communicate the benefits of Industry 4.0.
Costs and Return on Investment (ROI)	The upfront costs associated with implementing Industry 4.0 technologies can be substantial. Achieving a positive ROI and demonstrating the tangible benefits of integration may be challenging in the short term.	• Conduct a thorough cost-benefit analysis before implementation to assess the potential return on investment. • Prioritize technology investments based on their strategic impact and alignment with organizational goals. • Monitor and evaluate performance metrics regularly to demonstrate the long-term benefits.
Lack of Standardization	The lack of standardized frameworks and protocols in the Industry 4.0 landscape can lead to interoperability challenges and hinder seamless integration with the Balanced Scorecard.	• Advocate for industry-wide standardization efforts to establish common protocols. • Collaborate with technology partners that adhere to recognized standards. • Stay informed about emerging standards and update integration strategies accordingly.

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).

4. Conclusion

In conclusion, the integration of the Statistical Balanced Scorecard (SBSC) with Industry 4.0 represents a strategic leap forward in performance measurement and management. By incorporating advanced statistical methods and analytics, the SBSC adapts the traditional Balanced Scorecard framework to the data-rich environment of Industry 4.0. This adaptation extends the financial perspective beyond traditional metrics, leveraging predictive analytics to anticipate trends and optimize resource allocation.

The customer perspective in Industry 4.0 goes beyond understanding needs; it embraces data analytics to personalize products and services, enhancing customer satisfaction. Internal processes, a critical aspect of SBSC, benefit from statistical process control and data analytics, optimizing efficiency and agility. The learning and growth perspective gains significance by emphasizing digital literacy and innovation to navigate the Industry 4.0 landscape. The traditional Balanced Scorecard, developed by Kaplan and Norton, provides a foundational understanding of strategic management, emphasizing financial, customer, internal processes, and learning and growth perspectives. It serves as a communication tool aligning the organization with strategic goals, fostering a cause-and-effect relationship among perspectives.

The SBSC optimizes internal processes through statistical analysis, making continuous improvement data-driven. Learning and growth emphasize skills needed in Industry 4.0, aligning human capital with technological advancements. The SBSC establishes causal relationships between indicators, enabling proactive decision-making. The integration of the Balanced Scorecard with Industry 4.0 and Quality 4.0 aligns organizational performance measurement with transformative technologies. Financial metrics adapt to data-driven analytics, the customer perspective embraces real-time data, and internal processes optimize through Industry 4.0 technologies. Quality 4.0 aligns with the Balanced Scorecard, driving continuous improvement through data-driven insights.

Table 2 highlights aspects of Balanced Scorecard integration with Industry 4.0, emphasizing adaptation across financial, customer, internal processes, learning and growth, cascading objectives, and continuous monitoring. Table 3 outlines the advantages of this integration, such as real-time decision-making, data-driven performance management, optimized operational efficiency, enhanced customer experience, strategic alignment, and proactive risk management. Table 4 addresses potential problems and suggests overcoming strategies, including data governance, integration analysis, robust cybersecurity measures, comprehensive training programs, thorough cost-benefit analysis, and advocacy for standardization.

The integration of the Balanced Scorecard with Industry 4.0, enhanced by statistical methods, positions organizations to thrive in the digital era. It empowers data-driven decision-making, strategic alignment with technology trends, and continuous improvement, paving the way for sustained success and competitiveness.

References

1. Almeida, S., Abreu, L.P.M. (2024). The Quality Manager in the Industry 4.0 Era. *Lecture Notes in Mechanical Engineering*, 468-474.
2. Alrabadi, T.D.S., Talib, Z.M., Abdullah, N.A.B. (2023). The role of Quality 4.0 in supporting digital transformation: Evidence from telecommunication industry. *International Journal of Data and Network Science*, *7(2),* 717-728.
3. Amat-Lefort, N., Barravecchia, F., Mastrogiacomo, L. (2023). Quality 4.0: big data analytics to explore service quality attributes and their relation to user sentiment in Airbnb reviews. *International Journal of Quality and Reliability Management*, *40(4),* 990-1008.
4. Antony, J., McDermott, O., Sony, M., Cudney, E.A., Doulatabadi, M. (2023). Benefits, challenges, critical success factors and motivations of Quality 4.0–A qualitative global study. *Total Quality Management and Business Excellence*, *34(7-8),* 827-846.
5. Antony, J., Sony, M., McDermott, O., Jayaraman, R., Flynn, D. (2023). An exploration of organizational readiness factors for Quality 4.0: an intercontinental study and future

research directions. *International Journal of Quality and Reliability Management*, *40(2)*, 582-606.

6. Antony, J., Swarnakar, V., Sony, M., McDermott, O., Jayaraman, R. (2023). How do organizational performances vary between early adopters and late adopters of Quality 4.0? An exploratory qualitative study. *TQM Journal*.

7. Barsalou, M. (2023). Root Cause Analysis in Quality 4.0: A Scoping Review of Current State and Perspectives. *TEM Journal*, *12(1),* 73-79.

8. Bousdekis, A., Lepenioti, K., Apostolou, D., Mentzas, G. (2023). Data analytics in quality 4.0: literature review and future research directions. *International Journal of Computer Integrated Manufacturing, 36(5),* 678-701.

9. Escobar, C.A., Macias-Arregoyta, D., Morales-Menendez, R. (2023). The decay of Six Sigma and the rise of Quality 4.0 in manufacturing innovation. *Quality Engineering*.

10. Gajdzik, B., Jaciow, M., Wolniak, R., Wolny R., Grebski, W.W. (2023). Energy Behaviors of Prosumers in Example of Polish Households. *Energies, 16(7), 3186*; https://doi.org/10.3390/en16073186.

11. Gimerská, V., Šoltés, M., Mirdala, R. (2023). Improving Operational Efficiency through Quality 4.0 Tool: Blockchain Implementation and Subsequent Market Reaction. *Quality Innovation Prosperity, 27(2),* 16-32.

12. Jokovic, Z., Jankovic, G., Jankovic, S., Supurovic, A., Majstorović, V. (2023). Quality 4.0 in Digital Manufacturing – Example of Good Practice. *Quality Innovation Prosperity*, *27(2),* 177-207.

13. Jonek-Kowalska, I., Wolniak, R. (2021). Economic opportunities for creating smart cities in Poland. Does wealth matter? *Cities*, *114*, 1-6.

14. Jonek-Kowalska, I., Wolniak, R. (2022). Sharing economies' initiatives in municipal authorities' perspective: research evidence from Poland in the context of smart cities' development. *Sustainability*, *14(4),* 1-23.

15. Khourshed, N., Gouhar, N. (2023). Developing a Systematic and Practical Road Map for Implementing Quality 4.0. *Quality Innovation Prosperity, 27(2),* 96-121.

16. Kordel, P., Wolniak, R. (2021). Technology entrepreneurship and the performance of enterprises in the conditions of Covid-19 pandemic: the fuzzy set analysis of waste to energy enterprises in Poland. *Energies*, *14(13),* 1-22.

17. Liu, H.-C., Liu, R., Gu, X., Yang, M. (2023). From total quality management to Quality 4.0: A systematic literature review and future research agenda. *Frontiers of Engineering Management, 10(2),* 191-205.

18. Maganga, D.P., Taifa, I.W.R. (2023). Quality 4.0 conceptualisation: an emerging quality management concept for manufacturing industries. *TQM Journal*, *35(2),* 389-413.

19. Olsen, C. (2023). Toward a Digital Sustainability Reporting Framework in Organizations in the Industry 5.0 Era: An Accounting Perspective. *Lecture Notes in Networks and Systems*, *557*, 463-473.

20. Saihi, A., Awad, M., Ben-Daya, M. (2023). Quality 4.0: leveraging Industry 4.0 technologies to improve quality management practices – a systematic review. *International Journal of Quality and Reliability Management*, *40(2),* 628-650.

21. Salimbeni, S., Redchuk, A. (2023). Quality 4.0 and Smart Product Development. *Lecture Notes in Networks and Systems, 614* LNNS, 581-592.

22. Singh, J., Ahuja, I.S., Singh, H., Singh, A. (2023). Application of Quality 4.0 (Q4.0) and Industrial Internet of Things (IIoT) in Agricultural Manufacturing Industry. *AgriEngineering*, *5(1),* 537-565.

23. Sureshchandar, G.S. (2023). Quality 4.0 – a measurement model using the confirmatory factor analysis (CFA) approach. *International Journal of Quality and Reliability Management, 40(1),* 280-303.

24. Wang, Y., Mo, D.Y., Ma, H.L. (2023). Perception of time in the online product customization process. *Industrial Management and Data Systems*, *123(2),* pp. 369-385.

25. Yanamandra, R., Abidi, N., Srivastava, R., Kukunuru, S., Alzoubi, H.M. (2023). *Approaching Quality 4.0: The Digital Process Management as a Competitive Advantage.* 2nd International Conference on Business Analytics for Technology and Security, ICBATS 2023.