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THE METHODS OF QUALITY MANAGEMENT IN QUALITY 4.0

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Purpose: The purpose of this publication is to present the usage of quality management methods in Quality 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 applications of business analytics in personalized customer experiences span data collection, segmentation, predictive analytics, and multi-channel personalization, delivering greater customer satisfaction, revenue, and competitive advantage. Achieving this transformation requires the use of various software solutions, including CRM systems, marketing automation tools, analytics platforms, predictive analytics software, and recommendation engines. Harnessing the power of data and analytics is the key to gaining a competitive edge in this customer-centric era. Businesses that tailor their offerings to each customer's unique preferences and needs can not only meet but exceed customer expectations, ensuring growth and long-term success. Ultimately, personalized customer experiences, driven by business analytics, are not merely a response to customer demands; they are the path to unlocking the full potential of customer relationships and establishing a strong position in the ever-evolving marketplace.

Keywords: Industry 4.0; Quality 4.0, quality management; quality methods.

Category of the paper: literature review.

1. Introduction

Quality 4.0, also known as Industry 4.0 for Quality, is a modern approach to quality management that leverages digital technologies and data-driven methods to enhance the quality control processes in manufacturing and other industries. It is a response to the evolving technological landscape and the increasing demand for higher product quality, efficiency, and transparency.

Quality 4.0 is a concept that has gained prominence with the advent of Industry 4.0, the fourth industrial revolution characterized by the integration of cyber-physical systems, the Internet of Things (IoT), big data analytics, and artificial intelligence (AI) into various industrial processes. Quality 4.0 extends these technologies into the domain of quality management.

Quality 4.0 utilizes a network of sensors and IoT devices to collect real-time data from machines and processes. These sensors provide continuous monitoring and data capture, allowing for early detection of issues. Quality 4.0 processes vast amounts of data generated by IoT devices and other sources. Advanced analytics and machine learning are used to identify patterns, anomalies, and correlations, which can help in quality prediction and optimization (Bousdekis et al., 2023). AI algorithms are employed for predictive maintenance, quality control, and fault detection. Machine learning models can analyze historical data to make real-time decisions and improvements in quality processes. Quality 4.0 often employs digital twins, which are digital replicas of physical products or processes. These digital models can be used for simulation and analysis, allowing for the virtual testing and optimization of products and processes (Barsalou, 2023).

Blockchain technology is utilized to create transparent and immutable records of product quality and supply chain information. This ensures traceability and trust throughout the production and distribution processes. AR and VR technologies enhance training, maintenance, and quality inspection processes. They provide immersive experiences and aid in troubleshooting and problem-solving. Collaborative robots are used to assist workers in repetitive or precise tasks, enhancing quality and productivity while ensuring worker safety (Maganga, Taifa, 2023).

Quality 4.0 represents a significant shift in how quality management is approached, leveraging digital technologies to improve product quality, process efficiency, and overall competitiveness. As industries continue to embrace digital transformation, Quality 4.0 will play a pivotal role in ensuring that organizations meet the evolving demands of the global market (Antony et al., 2023).

The purpose of this publication is to present the usage of quality management methods in Quality 4.0 conditions.

2. The basics of quality management methods

Quality management is a critical component of any organization's operations, regardless of the industry or sector. It encompasses a set of systematic approaches, principles, and methods aimed at ensuring that products or services consistently meet or exceed customer expectations.

TQM is a comprehensive approach that focuses on involving all employees in the organization to continuously improve processes, products, and services. It emphasizes customer satisfaction and the elimination of waste through methods such as Six Sigma and Lean. Six Sigma is a data-driven approach that seeks to identify and eliminate defects or variations in processes to achieve a level of quality where there are fewer than 3.4 defects per million opportunities. It employs the DMAIC (Define, Measure, Analyze, Improve, Control) methodology to achieve this. Lean principles aim to minimize waste and increase efficiency. It involves identifying and eliminating non-value-added activities, reducing lead times, and improving the flow of processes. International Organization for Standardization (ISO) standards provides a framework for quality management. ISO 9001, for example, outlines requirements for a quality management system, emphasizing customer focus, leadership, and continuous improvement.

SPC uses statistical techniques to monitor and control processes. It involves the use of control charts, histograms, and other statistical tools to maintain process stability and predictability. QFD is a method used to translate customer needs and expectations into specific product or service features. It helps in aligning design and production processes with customer requirements (Maganga, Taifa, 2023).

FMEA is a systematic approach to identifying and addressing potential failure modes in a product or process. It assigns a risk priority number to each failure mode, helping organizations prioritize improvements. Kaizen is a Japanese term that means "continuous improvement". It involves making small, incremental changes to processes and systems over time, with the goal of achieving long-term improvements.

The Pareto principle, also known as the 80/20 rule, states that 80% of the problems come from 20% of the causes. This method helps organizations identify and prioritize the most critical issues for improvement. Benchmarking involves comparing an organization's processes and performance against industry best practices or competitors to identify areas for improvement.

Quality circles are small groups of employees who meet regularly to discuss and solve quality-related issues, fostering a culture of employee involvement and continuous improvement. Managing the quality of materials and components supplied by external sources is critical. Techniques such as supplier audits and performance monitoring are used to ensure high-quality inputs.

Table 1 contains quality management methods and provides a brief description of each method. This table provides a concise overview of each quality management method and its key characteristics, making it easier to understand the differences and purposes of these approaches.

Table 1.
Examples of quality management methods

Quality Management Method	Description
Total Quality Management (TQM)	TQM is an organization-wide approach that focuses on continuous improvement and customer satisfaction. It involves all employees in quality-related efforts and emphasizes process efficiency.
Six Sigma	Six Sigma is a data-driven methodology that aims to reduce defects and variations in processes. It uses the DMAIC (Define, Measure, Analyze, Improve, Control) framework to achieve high levels of quality.
Lean Management	Lean principles focus on eliminating waste and improving process efficiency. It emphasizes value stream mapping, just-in-time production, and continuous improvement.
ISO Standards	ISO standards, such as ISO 9001, provide a framework for quality management systems. They promote consistency, customer focus, and continual improvement in organizations.
Statistical Process Control (SPC)	SPC employs statistical techniques to monitor and control processes, helping maintain process stability and predictability through tools like control charts and histograms.
Quality Function Deployment (QFD)	QFD is a method for translating customer needs and expectations into specific product or service features. It aligns product design with customer requirements.
Failure Mode and Effects Analysis (FMEA)	FMEA is a systematic approach to identify and mitigate potential failure modes in products or processes. It assigns a risk priority number to each failure mode.
Kaizen	Kaizen is a Japanese concept that promotes continuous, incremental improvements in processes, products, and operations through the involvement of all employees.
Pareto Analysis	The Pareto Principle (80/20 rule) is used to identify and prioritize the most critical issues by recognizing that 80% of problems often result from 20% of the causes.
Benchmarking	Benchmarking involves comparing an organization's processes and performance with industry best practices or competitors to identify areas for improvement.
Quality Circles	Quality circles are small groups of employees who meet regularly to discuss and solve quality-related issues, fostering a culture of employee involvement and continuous improvement.
Supplier Quality Management	This method focuses on managing the quality of materials and components supplied by external sources, ensuring they meet specified standards.
Root Cause Analysis (RCA)	RCA is used to identify the underlying causes of problems or defects, addressing issues at their source rather than merely treating symptoms.

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 quality management methods are integrated in Quality 4.0 concept

TQM has always emphasized the importance of data for making informed decisions. Quality 4.0 takes this to a new level by providing real-time, high-volume data from IoT sensors and other sources (Escobar et al., 2023). This data is then processed and analyzed using advanced analytics and machine learning algorithms. It allows for more accurate, timely, and predictive decision-making, which aligns with the core principles of TQM. TQM places a strong emphasis on continuous improvement (Sureshchandar, 2023). Quality 4.0 enhances this by providing tools and data that enable organizations to identify areas for improvement with greater precision and agility. The real-time monitoring and analytics capabilities of Quality 4.0 allow companies to make incremental changes swiftly and accurately (Almeida, Abreu, 2023).

Both TQM and Quality 4.0 prioritize customer satisfaction. Quality 4.0, however, leverages big data analytics and customer feedback collected through digital channels to gain deeper insights into customer needs and preferences. This data can be used to tailor products and services to a highly individualized level, thus delivering higher levels of customer satisfaction. Quality 4.0 integrates various digital technologies like IoT, AI, machine learning, and blockchain. These technologies facilitate advanced quality control and risk management. In the context of TQM, this means better process control and faster problem-solving (Jokovic et al., 2023).

TQM often relies on historical data and manual processes for issue identification and resolution. Quality 4.0 is proactive, using predictive analytics and AI to identify potential issues before they escalate. This shift from a reactive to a proactive approach aligns with TQM's objective of preventing defects and improving quality. Quality 4.0 offers real-time monitoring and control of processes through digital tools. This level of transparency and control ensures that quality standards are consistently met and deviations are quickly addressed, in line with TQM's principle of process management (Amat-Lefort et al., 2023).

Quality 4.0 integrates blockchain technology to create transparent and immutable records of product quality and supply chain information. This ensures complete traceability, which is vital in TQM for tracking defects and ensuring accountability. TQM promotes employee involvement in quality initiatives. Quality 4.0 supports this by providing digital platforms and collaborative tools for employees to actively participate in quality management. This aligns with the collaborative spirit of TQM. Quality 4.0 can help organizations reduce costs and improve operational efficiency by optimizing processes in real time. The efficient use of resources, a key goal of TQM, is enhanced through data-driven optimization (Maganga, Taifa, 2023).

Six Sigma relies on data and statistical analysis to identify and reduce defects and variations in processes. Quality 4.0 takes this to the next level by providing real-time data from IoT sensors, machines, and various sources. This high-volume data is processed and analyzed using advanced analytics and machine learning algorithms. Quality 4.0 enhances the accuracy and speed of data-driven decision-making in the Six Sigma process (Yanamandra et al., 2023). In traditional Six Sigma, control charts and historical data are used to monitor processes and identify deviations. Quality 4.0 introduces predictive analytics, allowing organizations to identify potential issues before they occur. This shift from reactive to proactive quality control aligns with the core goals of Six Sigma, which are to prevent defects and improve process efficiency (Khourshed, Gouhar, 2023).

Both Six Sigma and Quality 4.0 emphasize continuous improvement. Quality 4.0 enhances this by providing tools and data that enable organizations to identify areas for improvement with greater precision and agility. The real-time monitoring and analytics capabilities of Quality 4.0 enable companies to make incremental changes quickly and accurately. Quality 4.0 integrates various advanced technologies such as IoT, AI, machine learning, and blockchain (Alrabadi et al., 2023). These technologies offer new opportunities for quality control, process optimization, and risk management, complementing the methodologies used in Six Sigma. Both Six Sigma and Quality 4.0 focus on customer satisfaction. Quality 4.0 leverages big data analytics to gain deeper insights into customer needs and preferences. This data-driven approach allows organizations to tailor products and services to meet customer expectations more precisely, aligning with the customer-centric objectives of Six Sigma (Antony et al., 2023).

Quality 4.0 offers advanced problem-solving tools, such as real-time root cause analysis, which enables organizations to quickly identify and address issues (Salimbeni, Redchuk, 2023). This rapid problem resolution aligns with the DMAIC (Define, Measure, Analyze, Improve, Control) methodology of Six Sigma. Quality 4.0 provides real-time monitoring and control of processes through digital tools, enhancing the process control aspects of Six Sigma (Saihi et al., 2023). This ensures that quality standards are consistently met and deviations are quickly addressed. Six Sigma encourages employee involvement in quality initiatives. Quality 4.0 supports this by providing digital platforms and collaborative tools for employees to actively participate in quality management, fostering a culture of data-driven improvement (Swarnakar et al., 2023). Quality 4.0 is a natural extension of the principles and methodologies of Six Sigma. By integrating digital technologies, data-driven decision-making, real-time monitoring, and predictive analytics, Quality 4.0 empowers organizations to achieve even higher levels of quality, efficiency, and process improvement, ultimately ensuring customer satisfaction and competitive excellence (Singh et al., 2023).

Quality 4.0 integrates blockchain technology to create transparent and immutable records of product quality and supply chain information. This ensures complete traceability, a critical aspect in both Six Sigma and Quality 4.0 for tracking defects and ensuring accountability (Liu et al., 2023).

Table 2 is listing examples of integration of selected quality management methods with Quality 4.0. By integrating these quality management methods into Quality 4.0, organizations can harness the full potential of digital technologies and data-driven approaches to achieve higher quality, efficiency, and transparency in their operations.

Table 2.
Quality management methods in Quality 4.0

Quality Management Method	Integration with Quality 4.0
Total Quality Management (TQM)	TQM, when integrated into Quality 4.0, becomes a holistic approach to quality that harnesses digital tools and data. Quality 4.0 utilizes IoT devices and real-time data analytics to continuously improve processes, enhance customer satisfaction, and involve all employees in quality-related efforts. This approach promotes a culture of data-driven decision-making, transparency, and agility in adapting to changing customer needs.
Six Sigma	In the context of Quality 4.0, Six Sigma leverages advanced analytics, machine learning, and IoT data to identify and reduce defects. This method is driven by data and focuses on achieving high levels of quality through the DMAIC framework. It provides a structured approach to quality control, enhancing precision and efficiency by predicting issues before they occur.
Lean Management	Quality 4.0 augments Lean Management by using real-time data from IoT devices to eliminate waste and optimize process efficiency. With digital tools such as value stream mapping and continuous improvement platforms, organizations can make data-driven decisions to streamline their operations and minimize resources while maintaining product quality.
ISO Standards	ISO standards serve as the foundation for Quality 4.0's digital quality management systems. These standards help establish compliant and consistent quality processes within the context of Industry 4.0. Quality 4.0 integrates data-driven decision-making and real-time monitoring, ensuring that ISO requirements are met with greater efficiency and transparency.
Statistical Process Control (SPC)	Quality 4.0 enhances SPC by incorporating sensors and IoT devices for real-time process monitoring and control. Advanced analytics and machine learning algorithms enable a more precise analysis of process data, ensuring process stability and predictability while identifying issues and defects as soon as they occur.
Quality Function Deployment (QFD)	In Quality 4.0, QFD benefits from the use of digital twin models, which allow for advanced simulations and virtual assessments of customer needs. These digital replicas enable organizations to align their product design more precisely with customer requirements and improve the product development process.
Failure Mode and Effects Analysis (FMEA)	Quality 4.0 enhances FMEA by using predictive analytics and AI to identify potential failure modes and their impact in real-time. This proactive approach to risk assessment ensures that issues are addressed before they lead to defects, improving overall product quality and reliability.
Kaizen	Quality 4.0 augments Kaizen by providing real-time data analytics and collaborative digital tools. This allows employees to make data-driven, incremental improvements continuously. It encourages a culture of continuous improvement and agility in adapting to changing circumstances, ultimately leading to higher quality and efficiency.
Pareto Analysis	In Quality 4.0, Pareto analysis becomes more efficient by using advanced data analytics to identify and prioritize critical issues more accurately. By considering the digital data landscape, organizations can focus their efforts on the most impactful areas for improvement, resulting in better resource allocation and faster problem resolution.
Benchmarking	Quality 4.0 integrates benchmarking by using real-time data and digital tools to compare processes with industry leaders. This allows organizations to make immediate adjustments and improvements to their processes, ensuring that they remain competitive in the digital era.
Quality Circles	In the context of Quality 4.0, quality circles benefit from digital communication and collaborative tools. Remote problem-solving and data-driven discussions become more effective, allowing employees to contribute to continuous improvement efforts from anywhere in the world.

Cont. table 2.

Supplier Quality Management	Quality 4.0 enhances supplier quality management by incorporating real-time monitoring and blockchain technology. This transparency in the supply chain tracking ensures that the quality of materials and components from external sources is maintained, meeting specified standards and ensuring product quality.
Root Cause Analysis (RCA)	RCA in Quality 4.0 benefits from data-driven insights and predictive analytics. It identifies the root causes of problems more accurately and quickly by analyzing large datasets. This approach facilitates more efficient problem resolution and prevents recurrence, leading to improved product quality and customer satisfaction.

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

The advent of Quality 4.0, a response to the ever-evolving technological landscape, has transformed the way organizations approach quality management. This modern approach leverages digital technologies and data-driven methodologies to enhance quality control processes in manufacturing and other industries. It aligns with the broader concept of Industry 4.0, which integrates cyber-physical systems, IoT, big data analytics, and artificial intelligence into industrial processes.

Quality 4.0 capitalizes on a network of sensors and IoT devices, which continuously collect real-time data from machines and processes. This data is then analyzed using advanced analytics, machine learning, and AI, facilitating predictive quality control and optimization. Moreover, digital twins enable virtual testing and optimization, and blockchain technology ensures transparent and immutable records for traceability.

In the context of Quality 4.0, traditional quality management methods are seamlessly integrated to further improve product quality, process efficiency, and overall competitiveness. Total Quality Management (TQM), for instance, benefits from real-time data and advanced analytics, supporting a culture of data-driven decision-making and process improvement. Six Sigma, which traditionally relies on data analysis and historical information, now thrives on real-time data and predictive analytics in Quality 4.0. This shift from reactive to proactive quality control aligns perfectly with the goals of defect prevention and process enhancement.

The integration of Lean Management principles in Quality 4.0 leads to waste reduction and efficiency improvement, with data-driven decisions contributing to enhanced value stream mapping and continuous process improvement. ISO standards provide a framework for Quality 4.0's digital quality management systems, emphasizing consistency, customer focus, and continuous improvement, thus ensuring organizations meet evolving industry demands more efficiently.

Statistical Process Control (SPC) benefits from real-time data and digital tools to monitor and control processes, maintaining predictability and stability. Quality Function Deployment (QFD) translates customer needs into specific features more precisely, aligning product design with customer requirements in the digital landscape.

These are just a few examples of the integration of quality management methods in Quality 4.0. Each method harnesses the power of digital technologies and data-driven approaches to achieve higher quality, efficiency, and transparency. Quality 4.0 serves as a pivotal driver in the ongoing digital transformation, ensuring organizations remain competitive and meet the ever-changing demands of the global market. It is a testament to the continuous evolution of quality management in the face of technological advancement.

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. Drozd, R., Wolniak, R. (2021). Metrisable assessment of the course of stream-systemic processes in vector form in industry 4.0. *Quality and Quantity*, 1-16, DOI: 10.1007/s11135-021-01106-w.
10. Drozd, R., Wolniak, R. (2021). Systematic assessment of product quality. *Journal of Open Innovation: Technology, Market, and Complexity, 7(4),* 1-12.
11. 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*.
12. Gajdzik, B., Grebski, M., Grebski, W., Wolniak, R. (2022). *Human factor activity in lean management and quality management.* Toruń: Towarzystwo Naukowe Organizacji i Kierownictwa. Dom Organizatora.
13. 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.
14. Gajdzik, B., Wolniak, R. (2021). Digitalisation and innovation in the steel industry in Poland - selected tools of ICT in an analysis of statistical data and a case study. *Energies, 14(11),* 1-25.
15. Gajdzik, B., Wolniak, R. (2021). Influence of the COVID-19 crisis on steel production in Poland compared to the financial crisis of 2009 and to boom periods in the market. *Resources, 10(1),* 1-17.
16. Gajdzik, B., Wolniak, R. (2021). Transitioning of steel producers to the steelworks 4.0 - literature review with case studies. *Energies, 14(14),* 1-22.
17. Gajdzik, B., Wolniak, R. (2022). Framework for R&D&I Activities in the Steel Industry in Popularizing the Idea of Industry 4.0. *Journal of Open Innovation: Technology, Market, and Complexity, 8(3),* 133.
18. Gajdzik, B., Wolniak, R. (2022). Influence of Industry 4.0 Projects on Business Operations: literature and empirical pilot studies based on case studies in Poland. *Journal of Open Innovation: Technology, Market, and Complexity, 8(1),* 1-20.
19. Gajdzik, B., Wolniak, R. (2022). Smart Production Workers in Terms of Creativity and Innovation: The Implication for Open Innovation. *Journal of Open Innovations: Technology, Market and Complexity, 8(1),* 68.
20. Gajdzik, B., Wolniak, R., Grebski, W. (2023). Process of Transformation to Net Zero Steelmaking: Decarbonisation Scenarios Based on the Analysis of the Polish Steel Industry. *Energies, 16(8), 3384,* https://doi.org/10.3390/en16083384.
21. Gajdzik, B., Wolniak, R., Grebski, W.W. (2022). An econometric model of the operation of the steel industry in Poland in the context of process heat and energy consumption. *Energies, 15(21),* 1-26, 7909.
22. Gajdzik, B., Wolniak, R., Grebski, W.W. (2023). Electricity and heat demand in steel industry technological processes in Industry 4.0 conditions. *Energies, 16(2),* 1-29.

23. Gębczyńska, A., Wolniak, R. (2018). *Process management level in local government.* Philadelphia: CreativeSpace.
24. 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.
25. Grabowska, S., Saniuk, S., Gajdzik, B. (2022). Industry 5.0: improving humanization and sustainability of Industry 4.0. *Scientometrics*, *127(6)*, 3117-3144, https://doi.org/10.1007/s11192-022-04370-1.
26. Grabowska, S., Grebski, M., Grebski, W., Saniuk, S., Wolniak, R. (2021). *Inżynier w gospodarce 4.0.* Toruń: Towarzystwo Naukowe Organizacji i Kierownictwa – Stowarzyszenie Wyższej Użyteczności "Dom Organizatora".
27. Grabowska, S., Grebski, M., Grebski, W., Wolniak, R. (2019). *Introduction to engineering concepts from a creativity and innovativeness perspective.* New York: KDP Publishing.
28. Grabowska, S., Grebski, M., Grebski, W., Wolniak, R. (2020). *Inżynier – zawód przyszłości. Umiejętności i kompetencje inżynierskie w erze Przemysłu 4.0.* Warszawa: CeDeWu.
29. Hąbek, P., Wolniak, R. (2013). Analysis of approaches to CSR reporting in selected European Union countries. *International Journal of Economics and Research*, *4(6)*, 79-95.
30. Hąbek, P., Wolniak, R. (2016). Assessing the quality of corporate social responsibility reports: the case of reporting practices in selected European Union member states. *Quality & Quantity*, *50(1)*, 339-420.
31. Hąbek, P., Wolniak, R. (2016). Factors influencing the development of CSR reporting practices: experts' versus preparers' points of view. *Engineering Economy*, *26(5)*, 560-570.
32. Hąbek, P., Wolniak, R. (2016). Relationship between management practices and quality of CSR reports. *Procedia – Social and Behavioral Sciences*, *220*, 115-123.
33. Hys, K., Wolniak, R. (2018). Praktyki przedsiębiorstw przemysłu chemicznego w Polsce w zakresie CSR. *Przemysł Chemiczny*, *9*, 1000-1002.
34. 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.
35. Jonek-Kowalska, I., Wolniak, R. (2021). Economic opportunities for creating smart cities in Poland. Does wealth matter? *Cities*, *114*, 1-6.
36. Jonek-Kowalska, I., Wolniak, R. (2021). The influence of local economic conditions on start-ups and local open innovation system. *Journal of Open Innovations: Technology, Market and Complexity*, *7(2)*, 1-19.
37. 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.

38. Jonek-Kowalska, I., Wolniak, R., Marinina, O.A., Ponomarenko, T.V. (2022). *Stakeholders, Sustainable Development Policies and the Coal Mining Industry. Perspectives from Europe and the Commonwealth of Independent States*. London: Routledge
39. Khourshed, N., Gouhar, N. (2023). Developing a Systematic and Practical Road Map for Implementing Quality 4.0. *Quality Innovation Prosperity, 27(2),* 96-121.
40. 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.
41. Kwiotkowska, A., Gajdzik, B., Wolniak, R., Vveinhardt, J., Gębczyńska, M. (2021). Leadership competencies in making Industry 4.0 effective: the case of Polish heat and power industry. *Energies*, *14(14),* 1-22.
42. Kwiotkowska, A., Wolniak, R., Gajdzik, B., Gębczyńska, M. (2022). Configurational paths of leadership competency shortages and 4.0 leadership effectiveness: an fs/QCA study. *Sustainability*, *14(5),* 1-21.
43. 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.
44. 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.
45. Maganga, D.P., Taifa, I.W.R. (2023). Quality 4.0 transition framework for Tanzanian manufacturing industries. *TQM Journal*, *35(6),* 1417-1448.
46. Maganga, D.P., Taifa, I.W.R. (2023). The readiness of manufacturing industries to transit to Quality 4.0. *International Journal of Quality and Reliability Management*, *40(7),* 1729-1752.
47. Michalak, A., Wolniak, R. (2023). The innovativeness of the country and the renewables and non-renewables in the energy mix on the example of European Union. *Journal of Open Innovation: Technology, Market, and Complexity, 9(2),* https://doi.org/10.1016/j.joitmc.2023.100061.
48. Olkiewicz, M., Olkiewicz, A., Wolniak, R., Wyszomirski, A. (2021). Effects of pro-ecological investments on an example of the heating industry - case study. *Energies*, *14(18),* 1-24, 5959.
49. 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.
50. Orzeł, B., Wolniak, R. (2021). Clusters of elements for quality assurance of health worker protection measures in times of COVID-19 pandemic. *Administrative Science*, *11(2),* 1-14, 46.

51. Orzeł, B., Wolniak, R. (2022). Digitization in the design and construction industry - remote work in the context of sustainability: a study from Poland. *Sustainability, 14(3),* 1-25.
52. Ponomarenko, T.V., Wolniak, R., Marinina, O.A. (2016). Corporate Social responsibility in coal industry (Practices of russian and european companies). *Journal of Mining Institute, 222,* 882-891.
53. Rosak-Szyrocka, J., Żywiołek J., Wolniak, R. (2023). Main reasons for religious tourism - from a quantitative analysis to a model. *International Journal for Quality Research, 1(17),* 109-120.
54. 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.
55. Salimbeni, S., Redchuk, A. (2023). Quality 4.0 and Smart Product Development. *Lecture Notes in Networks and Systems,* 614 LNNS, 581-592.
56. 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.
57. Stawiarska, E., Szwajca, D., Matusek, M., Wolniak, R. (2020). *Wdrażanie rozwiązań przemysłu 4.0 w wybranych funkcjonalnych obszarach zarządzania przedsiębiorstw branży motoryzacyjnej: próba diagnozy.* Warszawa: CeDeWu.
58. Stawiarska, E., Szwajca, D., Matusek, M., Wolniak, R. (2021). Diagnosis of the maturity level of implementing Industry 4.0 solutions in selected functional areas of management of automotive companies in Poland. *Sustainability, 13(9),* 1-38.
59. Stecuła, K., Wolniak, R. (2022). Advantages and Disadvantages of E-Learning Innovations during COVID-19 Pandemic in Higher Education in Poland. *Journal of Open Innovation: Technology, Market, and Complexity, 8(3),* 159.
60. Stecuła, K., Wolniak, R. (2022). Influence of COVID-19 Pandemic on Dissemination of Innovative E-Learning Tools in Higher Education in Poland. *Journal of Open Innovations: Technology, Market and Complexity, 8(1),* 89.
61. 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.
62. 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.
63. Wolniak, R., Skotnicka-Zasadzień, B. (2014). The use of value stream mapping to introduction of organizational innovation in industry. *Metalurgija, 53(4),* 709-713.
64. Wolniak, R. (2011). *Parametryzacja kryteriów oceny poziomu dojrzałości systemu zarządzania jakością.* Gliwice: Wydawnictwo Politechniki Śląskiej.
65. Wolniak, R. (2013). Projakościowa typologia kultur organizacyjnych. *Przegląd Organizacji, 3,* 13-17.

66. Wolniak, R. (2014). Korzyści doskonalenia systemów zarządzania jakością opartych o wymagania normy ISO 9001:2009. *Problemy Jakości*, *3,* 20-25.
67. Wolniak, R. (2016). Kulturowe aspekty zarządzania jakością. *Etyka biznesu i zrównoważony rozwój. Interdyscyplinarne studia teoretyczno-empiryczne*, *1,* 109-122.
68. Wolniak, R. (2016). *Metoda QFD w zarządzaniu jakością. Teoria i praktyka*. Gliwice: Wydawnictwo Politechniki Śląskiej.
69. Wolniak, R. (2016). Relations between corporate social responsibility reporting and the concept of greenwashing. *Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacji i Zarządzanie, 87,* 443-453.
70. Wolniak, R. (2016). The role of QFD method in creating innovation. *Systemy Wspomagania Inżynierii Produkcji, 3*, 127-134.
71. Wolniak, R. (2017). Analiza relacji pomiędzy wskaźnikiem innowacyjności a nasyceniem kraju certyfikatami ISO 9001, ISO 14001 oraz ISO/TS 16949. *Kwartalnik Organizacja i Kierowanie, 2,* 139-150.
72. Wolniak, R. (2017). Analiza wskaźników nasycenia certyfikatami ISO 9001, ISO 14001 oraz ISO/TS 16949 oraz zależności pomiędzy nimi. *Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacji i Zarządzanie*, *108*, 421-430.
73. Wolniak, R. (2017). The Corporate Social Responsibility practices in mining sector in Spain and in Poland – similarities and differences. *Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacji i Zarządzanie*, *111*, 111-120.
74. Wolniak, R. (2017). The Design Thinking method and its stages. *Systemy Wspomagania Inżynierii Produkcji, 6,* 247-255.
75. Wolniak, R. (2017). The use of constraint theory to improve organization of work. 4th International Multidisciplinary Scientific Conference on Social Sciences and Arts. SGEM 2017, 24-30 August 2017, Albena, Bulgaria. Conference proceedings. Book 1, *Modern science. Vol. 5, Business and management*. Sofia: STEF92 Technology, 1093-1100.
76. Wolniak, R. (2018). Functioning of social welfare on the example of the city of Łazy. *Zeszyty Naukowe Wyższej Szkoły, Humanitas. Zarządzanie, 3,* 159-176.
77. Wolniak, R. (2018). Methods of recruitment and selection of employees on the example of the automotive industry. *Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacja i Zarządzanie*, *128*, 475-483.
78. Wolniak, R. (2019). Context of the organization in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *133*, 121-136.
79. Wolniak, R. (2019). Downtime in the automotive industry production process - cause analysis. *Quality, Innovation, Prosperity*, *2,* 101-118.
80. Wolniak, R. (2021). Performance evaluation in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *151*, 725-734.

81. Wolniak, R. (2022). Engineering ethics – main principles. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *155*, 579-594.
82. Wolniak, R. (2023). Analiza danych w czasie rzeczywistym. *Zarządzanie i Jakość*, *2(5)*, 291-312.
83. Wolniak, R. (2023). Analysis of the Bicycle Roads System as an Element of a Smart Mobility on the Example of Poland Provinces. *Smart Cities, 6(1),* 368-391; https://doi.org/10.3390/smartcities6010018.
84. Wolniak, R. (2023). Design thinking and its use to boast innovativeness. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *170*, 647-662.
85. Wolniak, R., Grebski, M.E. (2018). Innovativeness and creativity as factors in workforce development – perspective of psychology. *Zeszyty Naukowe Politechniki Ślaskiej. Seria Organizacja i Zarządzanie*, *116*, 203-214.
86. Wolniak, R., Grebski, M.E. (2018). Innovativeness and creativity as nature and nurture. *Zeszyty Naukowe Politechniki Ślaskiej. Seria Organizacja i* Zarządzanie, *116*, 215-226.
87. Wolniak, R., Grebski, M.E. (2018). Innovativeness and Creativity of the Workforce as Factors Stimulating Economic Growth in Modern Economies. *Zeszyty Naukowe Politechniki Ślaskiej. Seria Organizacja i Zarządzanie*, *116*, 227-240.
88. Wolniak, R., Grebski, M.E., Skotnicka-Zasadzień, B. (2019). Comparative analysis of the level of satisfaction with the services received at the business incubators (Hazleton, PA, USA and Gliwice, Poland). *Sustainability*, *10*, 1-22.
89. Wolniak, R., Hąbek, P. (2015). Quality management and corporate social responsibility. *Systemy Wspomagania w Inżynierii Produkcji*, *1,* 139-149.
90. Wolniak, R., Hąbek, P. (2016). Quality assessment of CSR reports – factor analysis. *Procedia – Social and Behavioral Sciences*, *220*, 541-547.
91. Wolniak, R., Jonek-Kowalska, I. (2021). The level of the quality of life in the city and its monitoring. *Innovation (Abingdon*), *34(3),* 376-398.
92. Wolniak, R., Jonek-Kowalska, I. (2021). The quality of service to residents by public administration on the example of municipal offices in Poland. *Administration Management Public*, *37,* 132-150.
93. Wolniak, R., Jonek-Kowalska, I. (2022). The creative services sector in Polish cities. *Journal of Open Innovation: Technology, Market, and Complexity*, *8(1),* 1-23.
94. Wolniak, R., Saniuk, S., Grabowska, S., Gajdzik, B. (2020). Identification of energy efficiency trends in the context of the development of industry 4.0 using the Polish steel sector as an example. *Energies*, *13(11),* 1-16.
95. Wolniak, R., Skotnicka, B. (2011). *Metody i narzędzia zarządzania jakością – Teoria i praktyka, cz. 1*. Gliwice: Wydawnictwo Naukowe Politechniki Śląskiej.
96. Wolniak, R., Skotnicka-Zasadzień, B. (2008). *Wybrane metody badania satysfakcji klienta i oceny dostawców w organizacjach.* Gliwice: Wydawnictwo Politechniki Śląskiej.

97. Wolniak, R., Skotnicka-Zasadzień, B. (2010). *Zarządzanie jakością dla inżynierów.* Gliwice: Wydawnictwo Politechniki Śląskiej.
98. Wolniak, R., Skotnicka-Zasadzień, B. (2018). Developing a model of factors influencing the quality of service for disabled customers in the condition s of sustainable development, illustrated by an example of the Silesian Voivodeship public administration. *Sustainability*, *7, 1*-17.
99. Wolniak, R., Skotnicka-Zasadzień, B. (2022). Development of photovoltaic energy in EU countries as an alternative to fossil fuels. *Energies*, *15(2),* 1-23.
100. Wolniak, R., Skotnicka-Zasadzień, B., Zasadzień, M. (2019). Problems of the functioning of e-administration in the Silesian region of Poland from the perspective of a person with disabilities. *Transylvanian Review of Public Administration*, *57E*, 137-155.
101. Wolniak, R., Wyszomirski, A., Olkiewicz, M., Olkiewicz, A. (2021). Environmental corporate social responsibility activities in heating industry - case study. *Energies*, *14(7),* 1-19, 1930.
102. 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.