SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2023
ORGANIZATION AND MANAGEMENT SERIES NO. 179

THE USAGE OF BUSINESS ANALYTICS IN INDUSTRY 4.0 – ADVANTAGES AND PROBLEMS

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 potential usage of business analytics in Industry 4.0.
Design/methodology/approach: Critical literature analysis. Analysis of international literature from main databases and polish literature and legal acts connecting with researched topic.
Findings: Business Analytics and Industry 4.0 represent a dynamic synergy that has the potential to revolutionize industries, drive sustainability, and elevate businesses to new heights. To fully realize these possibilities, organizations must invest in data strategies, talent development, and an organizational culture that embraces data-driven decision-making. The journey ahead is both challenging and promising, and those who navigate it adeptly will shape the future of industry and business in profound ways.
Originality/value: Detailed analysis of all subjects related to the problems connected with the usage of business analytics in Industry 4.0.

Keywords: business analytics, Industry 4.0, digitalization, artificial intelligence, real-time monitoring.

Category of the paper: literature review.

1. Introduction

Industry 4.0, often referred to as the fourth industrial revolution, has ushered in a new era of manufacturing and business operations. It is characterized by the integration of digital technologies, the Internet of Things (IoT), artificial intelligence (AI), and automation into various industries. One of the key enablers of Industry 4.0 is business analytics, which plays a pivotal role in transforming data into actionable insights (Wolniak, 2016; Czerwińska-Lubszczyk et al., 2022; Drozd, Wolniak, 2021; Gajdzik, Wolniak, 2021, 2022; Gębczyńska, Wolniak, 2018, 2023; Grabowska et al., 2019, 2020, 2021; Wolniak et al., 2023; Wolniak,

Grebski, 2023; Wolniak, Skotnicka-Zasadzień, 2023; Jonek-Kowalska, Wolniak, 2023). This article explores the significant usage of business analytics in Industry 4.0 and its impact on modern businesses.

The purpose of this publication is to present how business analytics concepts can be used in Industry 4.0.

2. Business analytics

Business Analytics is the process of using data analysis and statistical methods to make informed, data-driven decisions within a business or organization. It involves the collection, processing, interpretation, and visualization of data to gain valuable insights that can be applied to improve various aspects of an organization's operations, strategy, and decision-making (Cam et al., 2021).

Business analytics starts with the collection of data from various sources, including internal databases, external data providers, customer interactions, social media, sensors, and more. This data can be structured (e.g., databases, spreadsheets) or unstructured (e.g., text, images, videos). Raw data often contains errors, inconsistencies, and missing values. Data cleaning and preparation involve the process of cleaning, transforming, and structuring the data into a usable format for analysis. This step is critical for ensuring the accuracy and reliability of insights (Jonek-Kowalska, Wolniak, 2021, 2022; Jonek-Kowalska et al., 2022; Kordel, Wolniak, 2021, Orzeł, Wolniak, 2021, 2022, 2023; Rosak-Szyrocka et al., 2023; Gajdzik et al., 2023; Ponomarenko et al., 2016; Stawiarska et al., 2020, 2021; Steculа, Wolniak, 2022; Olkiewicz et al., 2021).

Once the data is cleaned and prepared, it undergoes various forms of analysis. This may include descriptive analysis to summarize and explore the data, predictive analysis to make forecasts or predictions, and prescriptive analysis to recommend actions based on the data (Scappini, 2016). Business analytics often employs a wide range of statistical techniques and tools to uncover patterns, trends, and correlations in the data. Common statistical methods include regression analysis, hypothesis testing, clustering, and classification (Charles et al., 2023).

In addition to traditional statistical methods, business analytics also makes use of machine learning algorithms and artificial intelligence (AI) to analyze data. These techniques can handle large datasets, identify complex patterns, and make real-time predictions. Data visualization is a crucial component of business analytics. It involves presenting data in graphical or visual formats such as charts, graphs, and dashboards. Visualization helps in conveying complex information in a comprehensible manner, aiding decision-makers in understanding data insights (Greasley, 2019).

Business analytics provides decision support by offering actionable insights and recommendations based on data analysis. These insights assist organizations in making informed decisions related to marketing strategies, product development, customer service, supply chain management, and more. Analytics is not a one-time process; it involves continuous monitoring and measurement of key performance indicators (KPIs). This allows organizations to assess the impact of decisions, track progress toward goals, and adapt strategies accordingly (Hurwitz et al., 2015).

Business analytics is closely related to business intelligence, which involves the use of data and analytics tools to generate reports, dashboards, and visualizations for business users. BI tools enable non-technical personnel to access and understand data easily (Nourani, 2021). Business analytics plays a pivotal role in strategic planning. Organizations use data-driven insights to formulate long-term strategies, identify market opportunities, mitigate risks, and allocate resources effectively. Effective business analytics can provide a competitive advantage by enabling organizations to respond quickly to market changes, optimize operations, improve customer satisfaction, and innovate based on data-driven insights (Peter et al., 2023).

3. Industry 4.0

Industry 4.0 is a transformative concept that represents the fourth industrial revolution in manufacturing and business. It's a paradigm shift characterized by the integration of digital technologies, automation, data analytics, the Internet of Things (IoT), artificial intelligence (AI), and other advanced technologies into industrial processes and operations (Adel, 2022).

Industry 4.0 relies heavily on the digitalization of physical assets and processes. Machines, sensors, and devices are interconnected through the IoT, creating a seamless flow of data. This connectivity enables real-time monitoring, control, and communication between various components of a manufacturing system (Cillo et al., 2022). Data is at the heart of Industry 4.0. Enormous volumes of data are generated from sensors, machines, and operations. This data is collected, processed, and analyzed to extract valuable insights. Businesses use this data to make informed decisions, optimize processes, and gain a competitive edge (Sułkowski, Wolniak, 2015, 2016, 2018; Wolniak, Skotnicka-Zasadzień, 2008, 2010, 2014, 2018, 2019, 2022; Wolniak, 2011, 2013, 2014, 2016, 2017, 2018, 2019, 2020, 2021, 2022; Gajdzik, Wolniak, 2023; Hys, Wolniak, 2018).

Industry 4.0 introduces the concept of smart manufacturing, where machines and systems are not just automated but also intelligent. These smart systems can self-optimize, self-diagnose issues, and adapt to changing conditions (Di Marino et al., 2023). This results in increased efficiency, reduced downtime, and improved productivity. Industry 4.0 emphasizes the

collaboration between humans and machines. While automation plays a significant role, human workers are still essential for complex decision-making, creativity, and tasks that require emotional intelligence. Humans and machines work together synergistically to achieve better results (Wolniak, Sułkowski, 2015, 2016; Wolniak, Grebski, 2018; Wolniak et al., 2019, 2020; Wolniak, Habek, 2015, 2016; Wolniak, Skotnicka, 2011; Wolniak, Jonek-Kowalska, 2021; 2022).

Industry 4.0 enables mass customization, allowing products to be tailored to individual customer needs without sacrificing efficiency or cost-effectiveness. Production processes become more flexible and responsive to changing market demands (Ghibakholl et al., 2022). Traditional hierarchical decision-making structures are replaced by decentralized decision-making in Industry 4.0. Intelligent systems at various levels of the production process can make autonomous decisions based on real-time data, reducing response times and increasing agility (Akundi et al., 2022).

With increased connectivity, there's a growing emphasis on cybersecurity and data privacy. Protecting sensitive data and systems from cyber threats becomes paramount to maintain the integrity and security of operations. Industry 4.0 also promotes sustainability by optimizing resource usage and reducing waste. Data analytics can help identify areas for improvement in energy consumption, materials usage, and overall environmental impact (Olsen, 2023).

Industry 4.0 has a global reach, with interconnected supply chains that can adapt to changing market dynamics. It allows for better coordination and efficiency across the entire supply chain network. Industry 4.0 is a dynamic and evolving concept. It encourages organizations to embrace a culture of continuous innovation, as new technologies and approaches are constantly emerging (Aslam et al., 2020).

Industry 4.0 represents a fundamental shift in the way businesses and industries operate. It offers the promise of increased efficiency, competitiveness, and sustainability through the intelligent use of technology and data. As it continues to evolve, it will reshape various sectors, from manufacturing and logistics to healthcare and beyond, impacting the global economy and the way we live and work (Bakir, Dahlan, 2022).

4. The usage of Business Analytics in Industry 4.0

In Industry 4.0, data is generated at an unprecedented rate and from various sources, including sensors, machines, production lines, and customer interactions. Business analytics facilitates the collection and integration of this data, allowing organizations to gain a holistic view of their operations. Data can be gathered in real-time, providing decision-makers with up-to-the-minute information to make informed choices.

One of the standout applications of business analytics in Industry 4.0 is predictive maintenance. Through the analysis of historical data and the real-time monitoring of machinery and equipment, analytics models can predict when maintenance is required, thus preventing costly downtime and ensuring continuous production. This proactive approach enhances efficiency and reduces maintenance costs.

Business analytics plays a vital role in optimizing supply chains in Industry 4.0. By analyzing data related to demand forecasts, inventory levels, transportation, and supplier performance, organizations can make data-driven decisions to streamline their supply chain operations. This results in reduced lead times, lower carrying costs, and improved customer satisfaction (Javaid et al., 2020).

Maintaining high-quality standards is essential in modern manufacturing. Business analytics can be employed to monitor the production process, detect defects or anomalies in real-time, and make immediate adjustments to maintain product quality. This level of precision ensures that defective products are minimized, reducing waste and rework.

Inventory management is a critical aspect of Industry 4.0, where just-in-time production and reduced stock levels are key objectives. Business analytics helps organizations optimize their inventory by forecasting demand accurately and aligning procurement and production processes accordingly. This not only saves costs but also ensures that products are readily available when needed.

Table 1.
Table summarizing the key relationships between business analytics and Industry 4.0

Aspect of Industry 4.0	Role of Business Analytics
Data Collection and Integration	Facilitates data collection and integration from various sources, enabling real-time data access and analysis.
Predictive Maintenance	Utilizes historical and real-time data to predict maintenance needs, minimizing downtime and increasing operational efficiency.
Supply Chain Optimization	Analyzes demand forecasts, inventory levels, and supplier data to optimize supply chain operations for cost savings and efficiency.
Quality Control	Monitors production processes in real-time, detecting defects and anomalies to ensure consistent product quality.
Inventory Management	Improves inventory management by accurately forecasting demand, aligning procurement and production processes, and reducing carrying costs.
Personalized Customer Experiences	Utilizes customer data and behavior analysis to offer personalized products and services, enhancing customer satisfaction and loyalty.
Process Optimization	Identifies inefficiencies and areas for improvement in operations, allowing for continuous process optimization.
Cost Reduction and Profitability	Enables data-driven decisions to identify cost-saving opportunities, allocate resources efficiently, and respond to market changes, ultimately improving profitability.

Source: (Adel, 2022; Akundi et al., 2022; Olsen, 2023; Aslam et al., 2020; Bakir, Dahlan, 2022; Cillo et al., 2022; Ghibakholl et al., 2022, Javaid, Haleem, 2020, Javaid et al., 2020; Cam et al., 2021; Charles et al., 2023; Greasley, 2019; Hurwitz et al., 2015; Nourani, 2021; Peter et al., 2023).

In Industry 4.0, businesses can harness the power of analytics to offer personalized customer experiences. By analyzing customer data and behavior, companies can tailor their products and services to individual preferences. This level of customization enhances customer satisfaction and loyalty (Javaid, Haleem, 2020).

Table 2.
Benefits of using business analytics in Industry 4.0.

Benefits of Business Analytics in Industry 4.0	Description
Data-Driven Decision-Making	Enables informed decisions based on real-time data insights.
Operational Efficiency	Optimizes processes, reduces waste, and improves productivity.
Predictive Maintenance	Prevents unplanned downtime, extends equipment life, and lowers maintenance costs.
Supply Chain Optimization	Enhances supply chain visibility, reduces lead times, and minimizes carrying costs.
Quality Control	Ensures consistent product quality, reducing defects and rework.
Customization and Personalization	Allows for mass customization and personalized customer experiences.
Inventory Management	Reduces excess inventory, minimizing storage costs while meeting demand.
Cost Reduction	Identifies cost-saving opportunities and reduces operational expenses.
Improved Customer Satisfaction	Enhances customer service, responsiveness, and overall satisfaction.
Competitive Advantage	Provides a competitive edge through better decision-making and efficiency.
Sustainability	Supports sustainability efforts by optimizing resource usage.
Global Supply Chain Coordination	Enables better coordination in global supply chains, reducing disruptions.
Continuous Innovation	Fosters a culture of innovation and adaptation to changing market conditions.
Risk Mitigation	Helps identify and mitigate risks through data analysis.
Data Security and Compliance	Ensures data security and compliance with data protection regulations.

Source: (Adel, 2022; Akundi et al., 2022; Olsen, 2023; Aslam et al., 2020; Bakir, Dahlan, 2022; Cillo et al., 2022; Ghibakholl et al., 2022, Javaid, Haleem, 2020, Javaid et al., 2020; Cam et al., 2021; Charles et al., 2023; Greasley, 2019; Hurwitz et al., 2015; Nourani, 2021; Peter et al., 2023).

Business analytics enables continuous process optimization in Industry 4.0. Through the analysis of operational data, organizations can identify bottlenecks, inefficiencies, and areas for improvement. This data-driven approach empowers organizations to make changes that enhance productivity and reduce waste.

In table 1 there is an analysis of relations between business analytics and Industry 4.0. These relationships showcase how business analytics is integral to Industry 4.0, driving data-driven decision-making and optimizing various aspects of modern business operations.

A table 2 summarizing the key benefits of using business analytics in Industry 4.0. These benefits demonstrate how business analytics in Industry 4.0 can drive improvements across various aspects of business operations, from efficiency and cost reduction to customer satisfaction and innovation.

The table 3 summarizing some of the common problems and challenges associated with the usage of business analytics in Industry 4.0. These challenges highlight the complexity and multifaceted nature of implementing business analytics in the context of Industry 4.0.

Overcoming these issues requires careful planning, investment, and a commitment to data-driven decision-making.

Table 3.
Common problems and challenges associated with the usage of business analytics in Industry 4.0.

Challenges in Using Business Analytics in Industry 4.0	Description
Data Quality Issues	Poor data quality, including inaccuracies, inconsistencies, and missing data, can lead to unreliable insights.
Data Privacy and Security	Concerns about data privacy, cyber threats, and compliance with data protection regulations can be significant.
Complexity of Data Sources	Managing and integrating data from diverse sources, including IoT devices, can be complex and challenging.
Skill Shortages	A shortage of skilled data analysts, data scientists, and IT professionals with analytics expertise can hinder progress.
Data Silos	Data may be fragmented and stored in isolated systems, making it difficult to access and analyze holistically.
Cost of Implementation	Implementing analytics solutions and infrastructure can be costly, particularly for small and medium-sized enterprises (SMEs).
Resistance to Change	Organizational resistance to adopting data-driven decision-making culture can impede progress.
Lack of Clear Objectives	Without well-defined objectives and goals, businesses may struggle to derive meaningful insights from analytics.
Interoperability Issues	Compatibility and integration challenges between different systems and technologies can arise.
Data Overload	The sheer volume of data generated in Industry 4.0 can lead to information overload, making it hard to extract meaningful insights.
Ethical Concerns	Ethical considerations related to the use of data, AI, and automation, such as bias in algorithms, may arise.
Maintaining Analytics Models	Models and algorithms require continuous maintenance and updates to remain effective.
Limited Understanding of Analytics	Decision-makers and employees may have limited understanding of how to interpret and use analytics insights.
Vendor Lock-In	Depending heavily on specific analytics vendors may result in vendor lock-in and limited flexibility.
Scalability Challenges	Scaling analytics solutions to meet growing data demands and business needs can be complex.

Source: (Adel, 2022; Akundi et al., 2022; Olsen, 2023; Aslam et al., 2020; Bakir, Dahlan, 2022; Cillo et al., 2022; Ghibakholl et al., 2022, Javaid, Haleem, 2020, Javaid et al., 2020; Cam et al., 2021; Charles et al., 2023; Greasley, 2019; Hurwitz et al., 2015; Nourani, 2021; Peter et al., 2023).

5. Conclusion

This paper has explored two pivotal concepts that are reshaping the landscape of modern business and industry: Business Analytics and Industry 4.0. Business Analytics, as discussed in Section 2, is the process of harnessing the power of data analysis and statistical methods to drive informed, data-driven decisions within organizations. It encompasses various stages,

from data collection and cleaning to analysis and visualization, and is a cornerstone for achieving efficiency, competitiveness, and innovation.

On the other hand, Industry 4.0, as detailed in Section 3, represents the fourth industrial revolution characterized by the integration of cutting-edge technologies, such as IoT, AI, and automation, into industrial processes. It introduces the concept of smart manufacturing, emphasizes human-machine collaboration, and champions sustainability, driving businesses toward a more connected, efficient, and adaptable future. The next section underscores the synergy between Business Analytics and Industry 4.0, highlighting how data-driven decision-making powered by analytics plays a vital role in the success of Industry 4.0. Whether it's predictive maintenance to minimize downtime, supply chain optimization for cost savings, or quality control for consistent product excellence, Business Analytics is the catalyst that enables organizations to harness the full potential of Industry 4.0.

Furthermore, we have outlined the significant benefits of this symbiotic relationship, including data-driven decision-making, improved efficiency, enhanced customer experiences, and competitive advantage. However, it is crucial to acknowledge the challenges posed by data quality, security, and skill shortages, as presented in Section 5.

As organizations navigate the complex terrain of Industry 4.0 and continue to leverage Business Analytics, they must tread carefully, addressing these challenges while embracing the transformative opportunities. In this era of digitalization and data-driven insights, the ability to adapt, innovate, and make informed decisions will be the defining factors that separate successful organizations from the rest.

Summing up Business Analytics and Industry 4.0 represent a dynamic synergy that has the potential to revolutionize industries, drive sustainability, and elevate businesses to new heights. To fully realize these possibilities, organizations must invest in data strategies, talent development, and an organizational culture that embraces data-driven decision-making. The journey ahead is both challenging and promising, and those who navigate it adeptly will shape the future of industry and business in profound ways.

References

1. Adel, A. (2022). Future of industry 5.0 in society: human-centric solutions, challenges and prospective research areas. *Journal of Cloud Computing*, *11(1),* 40.
2. Akundi, A., Euresti, D., Luna, S., Ankobiah, W., Lopes, A., Edinbarough, I. (2022). State of Industry 5.0-Analysis and Identification of Current Research Trends. *Applied System Innovation, 5(1),* DOI: 10.3390/asi5010027.

3. Aslam, F., Wang, A.M., Li, M.Z., Rehman, K.U. (2020). Innovation in the Era of IoT and Industry 5.0: Absolute Innovation Management (AIM) Framework. *Information, 11(2),* doi:10.3390/info11020124
4. Bakir, A., Dahlan, M. (2022). Higher education leadership and curricular design in industry 5.0 environment: a cursory glance. *Development and Learning in Organizations*.
5. Cam, J.D., Cochran, J.J., Ohlmann, M.J.F. (2021). *Business analytics : descriptive, predictive, prescriptive.* Boston: Cengage.
6. Charles, V., Garg, P., Gupta, N., Agrawal, M. (2023). *Data Analytics and Business Intelligence: Computational Frameworks, Practices, and Applications.* New York: CRS Press.
7. Cillo, V., Gregori, G.L., Daniele, L.M., Caputo, F., Bitbol-Saba, N. (2022). Rethinking companies' culture through knowledge management lens during Industry 5.0 transition. *Journal of Knowledge Management, 26(10),* 2485-2498.
8. Dameri, R.P. (2016). Smart City and ICT. Shaping Urban Space for Better Quality of Life. *Information and Communication Technologies in Organizations and Society*. Cham, Switzerland, Springer International Publishing.
9. Di Marino, C., Rega, A., Vitolo, F., Patalano, S. (2023). Enhancing Human-Robot Collaboration in the Industry 5.0 Context: Workplace Layout Prototyping. *Lecture Notes in Mechanical Engineering*, 454-465.
10. 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.
11. Drozd, R., Wolniak, R. (2021). Systematic assessment of product quality. *Journal of Open Innovation: Technology, Market, and Complexity, 7(4),* 1-12.
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. Ghibakholl, M., Iranmanesh, M, Mubarak, M.F., Mubarik, M. Rejeb, A. Nilashi, M. (2022). Identifying industry 5.0 contributions to sustainable development: A strategy roadmap for delivering sustainability values, *Sustainable Production and Consumption, 33,* 716-737.
25. 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".
26. Grabowska, S., Grebski, M., Grebski, W., Wolniak, R. (2019). *Introduction to engineering concepts from a creativity and innovativeness perspective.* New York: KDP Publishing.
27. Grabowska, S., Grebski, M., Grebski, W., Wolniak, R. (2020). *Inżynier – zawód przyszłości. Umiejętności i kompetencje inżynierskie w erze Przemysłu 4.0.* Warszawa: CeDeWu.
28. 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.
29. Greasley, A. (2019). *Simulating Business Processes for Descriptive, Predictive, and Prescriptive Analytics.* Boston: deGruyter.
30. 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.

31. 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.
32. 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.
33. Hąbek, P., Wolniak, R. (2016). Relationship between management practices and quality of CSR reports. *Procedia – Social and Behavioral Sciences, 220,* 115-123.
34. Hurwitz, J., Kaufman, M., Bowles, A. (2015). *Cognitive Computing and Big Data Analytics.* New York: Wiley.
35. Hys, K., Wolniak, R. (2018). Praktyki przedsiębiorstw przemysłu chemicznego w Polsce w zakresie CSR. *Przemysł Chemiczny, 9,* 1000-1002.
36. Javaid, M., Haleem, A. (2020). Critical Components of Industry 5.0 Towards a Successful Adoption in the Field of Manufacturing. *Journal of Industrial Integration and Management-Innovation and Entrepreneurship, 5(2),* 327-348, doi: 10.1142/S2424862220500141.
37. Javaid, M., Haleem, A., Singh, R.P., Haq, M.I.U., Raina, A., Suman, R. (2020). Industry 5.0: Potential Applications in COVID-19. *Journal of Industrial Integration and Management-Innovation and Entrepreneurs*hip, *5(4),* 507-530, doi: 10.1142/S2424862220500220.
38. Jonek-Kowalska, I., Wolniak, R. (2021). Economic opportunities for creating smart cities in Poland. Does wealth matter? *Cities, 114,* 1-6.
39. 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.
40. 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.
41. Jonek-Kowalska, I., Wolniak, R. (2023). *Smart Cities in Poland. Towards sustainability and a better quality of life?* London: Routledge.
42. 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.
43. 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.
44. 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.

45. 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.
46. 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.
47. Nourani, C.F. (2021). *Artificial Intelligence and Computing Logic: Cognitive Technology for AI Business Analytics (Innovation Management and Computing).* New York: CRC Press.
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. Peter, G.S., Amit, C.B., Deokar, V., Patel, N.R. (2023). *Machine Learning for Business Analytics: Concepts, Techniques and Applications in RapidMiner.* New York: Wiley.
53. 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.
54. 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.
55. Scappini, A. (2016). *80 Fundamental Models for Business Analysts: Descriptive, Predictive, and Prescriptive Analytics Models with Ready-to-Use Excel Templates.* New York: Create Space.
56. 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.
57. 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.

58. Steculа, 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.
59. Steculа, 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.
60. Sułkowski, M., Wolniak, R. (2016). Przegląd stosowanych metod oceny skuteczności i efektywności organizacji zorientowanych na ciągłe doskonalenie. *Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacja i Zarzadzanie, 67*, 63-74.
61. Sułkowski, M., Wolniak, R. (2018). *Poziom wdrożenia instrumentów zarządzania jakością w przedsiębiorstwach branży obróbki metali.* Częstochowa: Oficyna Wydawnicza Stowarzyszenia Menedżerów Produkcji i Jakości.
62. Wolniak R., Skotnicka-Zasadzień. B. (2023). Development of Wind Energy in EU Countries as an Alternative Resource to Fossil Fuels in the Years 2016–2022. *Resources, 12(8),* 96.
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). A typology of organizational cultures in terms of improvement of the quality management. *Manager, 17(1),* 7-21.
66. Wolniak, R. (2013). Projakościowa typologia kultur organizacyjnych. *Przegląd Organizacji, 3,* 13-17.
67. Wolniak, R. (2014). Korzyści doskonalenia systemów zarządzania jakością opartych o wymagania normy ISO 9001:2009. *Problemy Jakości, 3,* 20-25.
68. Wolniak, R. (2016). Kulturowe aspekty zarządzania jakością. *Etyka biznesu i zrównoważony rozwój. Interdyscyplinarne studia teoretyczno-empiryczne, 1,* 109-122.
69. Wolniak, R. (2016). *Metoda QFD w zarządzaniu jakością. Teoria i praktyka*. Gliwice: Wydawnictwo Politechniki Śląskiej.
70. 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.
71. Wolniak, R. (2016). The role of QFD method in creating innovation. *Systemy Wspomagania Inżynierii Produkcji, 3*, 127-134.
72. 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.
73. 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.

74. 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.
75. Wolniak, R. (2017). The Design Thinking method and its stages. *Systemy Wspomagania Inżynierii Produkcji, 6*, 247-255.
76. 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.
77. Wolniak, R. (2018). Functioning of social welfare on the example of the city of Łazy. *Zeszyty Naukowe Wyższej Szkoły, Humanitas. Zarządzanie, 3,* 159-176.
78. 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.
79. Wolniak, R. (2019). Context of the organization in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *133*, 121-136.
80. Wolniak, R. (2019). Downtime in the automotive industry production process - cause analysis. *Quality, Innovation, Prosperity*, *2*, 101-118.
81. Wolniak, R. (2019). Leadership in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *133*, 137-150.
82. Wolniak, R. (2019). Support in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *137*, 247-261.
83. Wolniak, R. (2019). The level of maturity of quality management systems in Poland-results of empirical research. *Sustainability*, *15*, 1-17.
84. Wolniak, R. (2020). Design in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *148*, 769-781.
85. Wolniak, R. (2020). Operations in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *148*, 783-794.
86. Wolniak, R. (2020). Quantitative relations between the implementation of industry management systems in European Union countries. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *142*, 33-44.
87. Wolniak, R. (2021). Internal audit and management review in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *151*, 724-608.
88. Wolniak, R. (2021). Performance evaluation in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *151*, 725-734.
89. Wolniak, R. (2022). Engineering ethics – main principles. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *155*, 579-594.

90. Wolniak, R. (2022). Individual innovations. *Silesian University of Technology Scientific Papers. Organization and Management Series, 166*, 861-876.
91. Wolniak, R. (2022). Management of engineering teams. *Silesian University of Technology Scientific Papers. Organization and Management Series, 157*, 667-674.
92. Wolniak, R. (2022). Problems of Covid-19 influence on small and medium enterprises activities – organizing function. *Silesian University of Technology Scientific Papers. Organization and Management Series, 167*, 599-608.
93. Wolniak, R. (2022). Project management in engineering. *Silesian University of Technology Scientific Papers. Organization and Management Series, 157*, 685-698.
94. Wolniak, R. (2022). Project management standards. *Silesian University of Technology Scientific Papers. Organization and Management Series, 160*, 639-654.
95. Wolniak, R. (2022). Sustainable engineering. *Silesian University of Technology Scientific Papers. Organization and Management Series, 160*, 655-667.
96. Wolniak, R. (2022). The role of the engineering profession in developing and implementing sustainable development principles. *Silesian University of Technology Scientific Papers. Organization and Management Series, 155*, 595-608.
97. Wolniak, R. (2022). Traits of highly innovative people. *Silesian University of Technology Scientific Papers. Organization and Management Series, 166*, 877-892.
98. Wolniak, R. (2023). Analiza danych w czasie rzeczywistym. *Zarządzanie i Jakość, 2(5),* 291-312.
99. 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.
100. Wolniak, R. (2023). Design thinking and its use to boast innovativeness. *Silesian University of Technology Scientific Papers. Organization and Management Series, 170*, 647-662.
101. Wolniak, R. (2023). Deskryptywna analiza danych. *Zarządzanie i Jakość, 2(5),* 272-290.
102. Wolniak, R. (2023). European Union Smart Mobility - aspects connected with bike road systems extension and dissemination. *Smart Cities*, 6, 1-32.
103. Wolniak, R. (2023). European Union Smart Mobility–Aspects Connected with Bike Road System's Extension and Dissemination, *Smart Cities, 6(2),* 1009-1042; https://doi.org/10.3390/smartcities6020049.
104. Wolniak, R. (2023). Functioning of real-time analytics in business. *Silesian University of Technology Scientific Papers. Organization and Management Series, 172*, 659-677.
105. Wolniak, R. (2023). Industry 5.0 – characteristic, main principles, advantages and disadvantages. *Silesian University of Technology Scientific Papers. Organization and Management Series, 170*, 663-678.
106. Wolniak, R. (2023). Innovations in industry 4.0 conditions, *Silesian University of Technology Scientific Papers. Organization and Management Series, 169*, 725-742.
107. Wolniak, R. (2023). Smart biking w smart city. *Zarządzanie i Jakość, 2(5),* 313-328.

108. Wolniak, R. (2023). Smart mobility in a smart city concept *Silesian University of Technology Scientific Papers. Organization and Management Series*, *170*, 679-692.
109. Wolniak, R. (2023). Smart mobility in smart city – Copenhagen and Barcelona comparision. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *172*, 678-697.
110. Wolniak, R. (2023). Smart mobility jako element koncepcji smart city. *Zarządzanie i Jakość, 1(5),* 208-222.
111. Wolniak, R. (2023). Team innovations, *Silesian University of Technology Scientific Papers. Organization and Management Series*, *169*, 773-758.
112. Wolniak, R. (2023). The concept of descriptive analytics. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *172*, 698-715.
113. Wolniak, R., Gajdzik B., Grebski, W. (2023). Environmental sustainability in business, *Silesian University of Technology Scientific Papers. Organization and Management Series*, *175*, 611-630.
114. 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.
115. Wolniak, R., Grebski, M.E. (2018). Innovativeness and creativity as nature and nurture. *Zeszyty Naukowe Politechniki Ślaskiej. Seria Organizacja i* Zarządzanie, *116*, 215-226.
116. 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.
117. 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.
118. Wolniak, R., Grebski, W. Functioning of predictive analytics in business. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *175*, 631-649.
119. Wolniak, R., Grebski, W. The concept of diagnostic analytics. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *175*, 650-669.
120. Wolniak, R., Hąbek, P. (2015). Quality management and corporate social responsibility. *Systemy Wspomagania w Inżynierii Produkcji*, *1*, 139-149.
121. Wolniak, R., Hąbek, P. (2016). Quality assessment of CSR reports – factor analysis. *Procedia – Social and Behavioral Sciences*, *220*, 541-547.
122. 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.
123. 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.

124. 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.
125. 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.
126. Wolniak, R., Skotnicka, B. (2011).: *Metody i narzędzia zarządzania jakością – Teoria i praktyka, cz. 1.* Gliwice: Wydawnictwo Naukowe Politechniki Śląskiej.
127. Wolniak, R., Skotnicka-Zasadzień, B. (2008). *Wybrane metody badania satysfakcji klienta i oceny dostawców w organizacjach.* Gliwice: Wydawnictwo Politechniki Śląskiej.
128. Wolniak, R., Skotnicka-Zasadzień, B. (2010). *Zarządzanie jakością dla inżynierów.* Gliwice: Wydawnictwo Politechniki Śląskiej.
129. 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.
130. Wolniak, R., Skotnicka-Zasadzień, B. (2022). Development of photovoltaic energy in EU countries as an alternative to fossil fuels. *Energies, 15(2),* 1-23.
131. 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.
132. Wolniak, R., Sułkowski, M. (2015). Motywy wdrażanie certyfikowanych Systemów Zarządzania Jakością. *Problemy Jakości, 9,* 4-9.
133. Wolniak, R., Sułkowski, M. (2015). Rozpowszechnienie stosowania Systemów Zarządzania Jakością w Europie na świecie – lata 2010-2012. *Problemy Jakości, 5,* 29-34.
134. Wolniak, R., Sułkowski, M. (2016). The reasons for the implementation of quality management systems in organizations. *Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacji i Zarządzanie, 92,* 443-455.
135. 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.