SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2023
ORGANIZATION AND MANAGEMENT SERIES NO. 182

BUSINESS ANALYTICS IN THE CASE OF INVENTORY MANAGEMENT IN INDUSTRY 4.0 CONDITIONS

Radosław WOLNIAK[1*], Wies GREBSKI[2]

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

Purpose: The purpose of this publication is to present the applications of usage of business analytics in inventory management.
Design/methodology/approach: Critical literature analysis. Analysis of international literature from main databases and polish literature and legal acts connecting with researched topic.
Findings: Industry 4.0 has ushered in a transformative era of technological innovation, particularly in inventory management. Business Analytics has emerged as a crucial tool for optimizing inventory control and supply chain management in this context. This integration of digital technologies, the Internet of Things, artificial intelligence, and big data has made inventory management more complex yet highly efficient. Business Analytics, driven by machine learning and predictive analytics, empowers organizations to make data-driven decisions, improve demand forecasting, and enhance supplier relationships, resulting in cost reduction, increased customer satisfaction, and sustainability efforts. Industry 4.0 has also introduced various software solutions that streamline inventory management, albeit with challenges. Overcoming these challenges, businesses leverage the advantages to adapt to a dynamic market, reduce costs, and enhance sustainability, solidifying the critical role of Business Analytics in inventory management in an evolving landscape.

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

Category of the paper: literature review.

1. Introduction

The advent of Industry 4.0 has ushered in a new era of technological innovation and transformation across various industries (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). One of the most critical areas that has seen significant changes is inventory management. In this context, Business Analytics plays a pivotal role in optimizing inventory control and supply chain management. This article delves into the implications and applications of Business Analytics in the context of inventory management within the framework of Industry 4.0.

Industry 4.0, often referred to as the Fourth Industrial Revolution, is characterized by the integration of digital technologies, the Internet of Things (IoT), artificial intelligence, machine learning, and big data into the manufacturing processes. In this highly connected and automated environment, inventory management becomes more complex, but also more efficient.

The purpose of this publication is to present the applications of usage of business analytics in inventory management.

2. The selected aspects of business analytics usage in inventory management

One of the key aspects of Industry 4.0 is the massive amount of data generated by various sensors, devices, and systems. This data can be harnessed through Business Analytics to make informed decisions about inventory (Ghibakholl et al., 2022). Businesses can analyze historical data, real-time data, and predictive analytics to optimize stock levels, demand forecasting, and reorder points. Business Analytics, powered by machine learning algorithms, can predict future demand patterns with high accuracy. This enables companies to reduce excess inventory and avoid stockouts, ultimately saving costs and improving customer satisfaction. The predictive models can adapt to changing market conditions, making the supply chain more agile (Bakir, Dahlan, 2022).

With the integration of IoT sensors and connected devices, businesses can monitor their inventory in real-time. Analytics tools can interpret this data, helping managers make instant decisions, such as rerouting shipments, reordering stock, or optimizing production schedules. Business Analytics can optimize inventory levels by considering multiple factors such as lead times, carrying costs, and demand variability. This optimization leads to cost reduction and working capital efficiency (Olsen, 2023).

In Industry 4.0 conditions, the relationship between suppliers and manufacturers has evolved (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; Stecuła, Wolniak, 2022; Olkiewicz et al., 2021). Business Analytics helps in supplier evaluation, risk assessment, and performance monitoring, ensuring a smooth supply chain. This reduces lead times and enhances overall inventory management. Advanced analytics can segment inventory into different categories

based on their demand patterns, lead times, and other factors. This allows for more focused management and allocation of resources. By using predictive maintenance, companies can reduce the risk of machine breakdowns that can disrupt the supply chain and increase holding costs. Analytics tools can help identify when equipment needs servicing or replacement, thereby reducing unforeseen downtime and costs (Wolniak, Grebski, 2018; Wolniak et al., 2019, 2020; Wolniak, Habek, 2015, 2016; Wolniak, Skotnicka, 2011; Wolniak, Jonek-Kowalska, 2021; 2022).

In Industry 4.0, sustainability is a growing concern. Analytics can be used to minimize waste, optimize shipping routes to reduce emissions, and make environmentally conscious decisions about inventory management (Wolniak, Skotnicka-Zasadzień, 2008, 2010, 2014, 2018, 2019, 2022; Wolniak, 2011, 2013, 2014, 2016, 2017, 2018, 2019, 2020, 2021, 2022; Gajdzik, Wolniak, 2023; Wolniak, 2013, 2016; Hys, Wolniak, 2018). The use of Business Analytics in inventory management within Industry 4.0 conditions is an iterative process. Companies continually refine their models and strategies based on historical data and real-time feedback, adapting to the ever-changing market dynamics (Greasley, 2019).

In Industry 4.0, Business Analytics has emerged as a game-changer in the realm of inventory management. It empowers businesses to make data-driven decisions, optimize supply chains, reduce costs, enhance customer satisfaction, and contribute to sustainability goals. As technology continues to advance, the role of Business Analytics in inventory management will only become more critical, helping companies stay competitive in the evolving landscape of Industry 4.0 (Nourani, 2021).

Table 1 contains descriptions of how business analytics is used in inventory management. This table provides a concise overview of how Business Analytics is applied to various aspects of inventory management. It showcases the diverse ways in which analytics can be used to enhance efficiency, reduce costs, and make data-driven decisions in the management of inventory.

Table 1.
The usage of business analytics in inventory

Aspect of Inventory Management	Application of Business Analytics
Demand Forecasting	Predicting future demand patterns using historical and real-time data. Implementing machine learning models for accuracy.
Real-time Inventory Monitoring	Utilizing IoT sensors for real-time tracking of inventory. Interpreting data to make instant decisions for rerouting shipments or reordering stock.
Inventory Optimization	Balancing stock levels to minimize carrying costs while ensuring demand fulfillment. Considering lead times and demand variability for optimization.
Supplier Relationship Management	Evaluating supplier performance and risk through analytics. Monitoring supplier data for supply chain efficiency and risk management.
Inventory Segmentation	Categorizing inventory based on demand patterns and other relevant factors. Efficient allocation of resources and management.

Cont. table 1.

Cost Reduction	Predictive maintenance to prevent machine breakdowns and reduce downtime. Identifying opportunities for cost savings and efficiency improvements.
Sustainability and Environment	Optimizing shipping routes for reduced emissions and environmental impact. Minimizing waste through data-driven inventory management decisions.
Continuous Improvement	Iterative process of refining models and strategies based on historical data and real-time feedback. Adaptation to changing market dynamics and ongoing improvements.
Safety Stock Management	Analyzing historical data and variability to determine optimal safety stock levels. Setting parameters for automated reordering when safety stock thresholds are met.
Lead Time Management	Analyzing historical lead time data to optimize procurement and production schedules. Predicting lead time variations for proactive inventory management.
Inventory Turnover	Monitoring inventory turnover ratios and identifying slow-moving or obsolete items. Recommending actions to reduce excess inventory or promote fast-moving items.
Seasonal and Trend Analysis	Identifying seasonal demand patterns and trends in product categories. Adapting inventory management strategies to align with seasonal fluctuations.
ABC Analysis	-Categorizing inventory items based on value or importance. Allocating more resources and attention to high-value items using data-driven insights.
Multi-Location Inventory	Managing inventory across multiple locations efficiently. Optimizing stock transfer between locations based on demand patterns and cost considerations.
Demand Volatility	Assessing the volatility of demand for various products. Implementing dynamic pricing or stocking strategies to respond to fluctuations.
Compliance and Regulation	Ensuring inventory management practices align with industry regulations and standards. Implementing analytics to monitor and maintain compliance.
Excess and Obsolete Inventory	Identifying excess or obsolete items through data analysis. Implementing strategies to minimize excess inventory and reduce write-offs.

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).

3. Software used in inventory management in Industry 4.0 conditions

Inventory management in Industry 4.0 conditions has evolved significantly with the integration of advanced software solutions. Industry 4.0, also known as the Fourth Industrial Revolution, is characterized by the extensive use of automation, data exchange, and smart technologies (Scappini, 2016). These changes have led to a fundamental transformation in how inventory is managed, making it more efficient, accurate, and responsive. IMS (Inventory Management Systems) software has been upgraded to incorporate real-time data tracking and analysis. These systems allow for the continuous monitoring of stock levels, order history, and demand forecasting. They enable companies to optimize their inventory levels, reduce

carrying costs, and prevent stockouts or overstock situations. IMS can also be integrated with other systems, such as Enterprise Resource Planning (ERP) and Customer Relationship Management (CRM) software (Aslam et al., 2020).

Radio-Frequency Identification (RFID) is a crucial element in Industry 4.0 inventory management. RFID tags and readers enable the automatic and real-time tracking of inventory items, reducing the need for manual input and minimizing errors. This technology improves accuracy, reduces labor costs, and allows for more precise control over the movement of products throughout the supply chain. IoT devices, such as sensors and beacons, are used to monitor the condition and location of inventory items. These devices provide valuable data, such as temperature, humidity, and handling conditions. By collecting and analyzing this data in real-time, businesses can ensure the quality and safety of their products while reducing waste due to spoilage or damage (Charles et al., 2023).

Machine learning algorithms and artificial intelligence are employed for demand forecasting and predictive analytics. These technologies analyze historical data, market trends, and other variables to anticipate future inventory needs accurately. They also optimize reorder points, lead times, and safety stock levels, which is especially valuable in just-in-time inventory systems (Javaid, Haleem, 2020). Cloud-based inventory management software offers several benefits in Industry 4.0. It allows for remote access, collaboration, and scalability, making it easier for businesses to adapt to changing market conditions and expand their operations. Cloud solutions also provide secure data storage and backup, essential in a digital and data-driven environment (Peter et al., 2023).

Blockchain can be used to create transparent and tamper-proof supply chain records. It provides end-to-end visibility, enabling businesses to trace the origin and journey of each product (Akundi et al., 2022). This is particularly valuable in industries where traceability and compliance are critical, such as pharmaceuticals and food. RPA (Robotic Process Automation) software automates routine and rule-based tasks in inventory management. It can handle data entry, order processing, and even autonomous decision-making for restocking and routing inventory. RPA not only reduces human error but also speeds up the overall process. Data analytics software is used to gain insights from the vast amount of data generated in Industry 4.0. Advanced reporting and visualization tools help organizations make informed decisions and identify areas for improvement in their inventory management processes (Cillo et al., 2022).

The software solutions mentioned above play a pivotal role in improving efficiency, accuracy, and adaptability in inventory management, helping businesses thrive in a rapidly changing and highly competitive environment (Adel, 2022).

Table 2 highlighting examples of software and applications used in inventory management, along with descriptions of their usage. These software and applications play aa important role in energy management, enabling organizations to monitor, analyze, and optimize their energy

usage, reduce costs, and meet sustainability objectives in an increasingly data-driven and interconnected world.

Table 2.
The usage of business analytics in inventory

Aspect of Energy Management	Usage of Business Analytics
Energy Consumption Analysis	1. Real-time monitoring and analysis of energy consumption patterns. 2. Identifying energy usage trends and anomalies. 3. Predictive analytics to forecast future consumption.
Demand Forecasting	1. Using historical data and predictive models to anticipate energy demand. 2. Optimizing energy generation, distribution, and storage based on forecasts.
Cost Optimization	1. Identifying cost drivers in energy consumption. 2. Implementing cost-saving strategies based on analytics insights.
Sustainability Monitoring	1. Tracking and reporting on greenhouse gas emissions and energy efficiency. 2. Setting and monitoring sustainability targets. 3. Assessing the environmental impact of energy usage.
Equipment Efficiency	1. Real-time monitoring of equipment performance and energy usage. 2. Predictive maintenance to reduce downtime and improve efficiency.
Energy Procurement	1. Analyzing energy market data for strategic procurement decisions. 2. Evaluating energy supplier contracts and pricing structures. 3. Identifying opportunities for cost savings.
Renewable Energy Integration	1. Evaluating the feasibility of incorporating renewable energy sources. 2. Assessing the economic benefits of renewable energy adoption. 3. Monitoring the performance of renewable energy systems.
Energy Policy Compliance	1. Ensuring compliance with energy regulations and standards. 2. Generating reports and documentation for regulatory purposes.
Risk Management	1. Identifying and mitigating risks associated with energy supply and consumption. 2. Using analytics to respond to unforeseen events, such as power outages or supply disruptions.

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).

4. Advantages and problems of business analytics usage in inventory management

Utilizing business analytics in inventory management offers a multitude of advantages, transforming the way businesses handle their stock levels and supply chains. Business analytics empowers organizations to make informed decisions based on real-time and historical data. This helps in optimizing inventory levels, supplier relationships, and order management, leading to more accurate forecasting and better strategic planning. Through data analysis and tracking, businesses can minimize the risk of stockouts and overstock situations. This leads to better inventory accuracy, reduced carrying costs, and the elimination of dead or obsolete inventory (Di Marino et al., 2023).

Table 3 contains the advantages of using business analytics in inventory management within Industry 4.0 conditions, along with descriptions for each advantage.

Table 3.
The advantages of using business analytics in inventory management

Advantages	Description
Improved Demand Forecasting	Accurate prediction of customer demand, reducing stockouts and overstock situations.
Cost Reduction	Lower holding and carrying costs, leading to minimized costs related to rush orders and excess inventory.
Optimized Inventory Levels	Right-sized inventory, minimizing overstock and ensuring efficient capital allocation for strategic investments.
Enhanced Supplier Performance	Evaluation and selection of reliable suppliers, leading to improved negotiation leverage and better terms.
Reduced Working Capital	Reduced capital tied up in inventory, freeing up funds for other investments and growth.
Increased Customer Satisfaction	Consistent product availability and on-time delivery, resulting in higher customer loyalty and positive word-of-mouth.
Streamlined Supply Chain	Identification and elimination of bottlenecks, reducing lead times and enhancing operational efficiency.
Risk Mitigation	Early identification and mitigation of supply chain risks, with the development of effective contingency plans.
Support for Strategic Growth	Allocation of resources to support expansion and identification of new market opportunities.
Compliance and Regulatory Support	Ensuring adherence to industry regulations and generating necessary reports and documentation.
Environmental Sustainability	Assessment of the environmental impact of inventory management and support for sustainability initiatives.

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).

Table 4 contains the problems of using business analytics in inventory management within Industry 4.0 conditions, along with descriptions for each advantage. It's important to note that while these problems are associated with the use of business analytics in inventory management, many can be addressed through careful planning, proper training, and ongoing maintenance. The benefits of improved inventory management through analytics often outweigh the challenges, but organizations must be prepared to address these issues.

Table 4.
The problems of using business analytics in energy management

Problems	Description
Data Quality Issues	Inaccurate or incomplete data can lead to flawed analysis and incorrect decisions. Data must be clean and consistent for analytics to be effective.
High Implementation Costs	Setting up business analytics systems can be expensive, particularly for small businesses with limited budgets.
Complex Implementation	Implementing business analytics solutions can be technically challenging, requiring expertise in data management and analytics tools.
Staff Training Requirements	Employees may require training to effectively use and interpret analytics tools, adding to the implementation costs.
Data Security Concerns	Storing and handling sensitive inventory data can pose security risks, and protecting data is paramount.

Cont. table 4.

Integration Challenges	Integrating business analytics with existing inventory management systems and other enterprise software can be complex and time-consuming.
Overemphasis on Historical Data	Relying solely on historical data may not account for sudden changes or external factors that impact inventory management.
Complexity of Interpretation	Complex analytics models and data can make it challenging to extract actionable insights, particularly for non-technical staff.
Lack of Scalability	Inventory data and analytics needs may outgrow the capabilities of existing systems, requiring costly upgrades.
Maintenance and Updates	Regular maintenance and updates are essential to keep analytics systems running efficiently and securely.
Resistance to Change	Employees and management may resist changes to traditional inventory management methods, hindering adoption.
Misinterpretation of Data	Misunderstanding or misinterpretation of analytics results can lead to erroneous decisions.
Data Overload	A surplus of data can overwhelm decision-makers, making it challenging to focus on the most critical information.
Incompatibility with Legacy Systems	Older inventory management systems may not be compatible with advanced analytics tools.
Unforeseen Implementation Delays	Unexpected issues or challenges during implementation can delay the rollout of analytics solutions.
Vendor Reliability Issues	Depending on third-party vendors for analytics tools can introduce reliability concerns if the vendor experiences issues or goes out of business.

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

The advent of Industry 4.0 has brought about a transformative era of technological innovation, particularly in the realm of inventory management. Business Analytics has emerged as a pivotal tool for optimizing inventory control and supply chain management within the context of Industry 4.0. The integration of digital technologies, the Internet of Things, artificial intelligence, and big data has led to a more complex yet efficient inventory management environment. Business Analytics, driven by machine learning and predictive analytics, allows organizations to make data-driven decisions, accurately forecast demand, monitor inventory in real-time, and enhance supplier relationships. This leads to reduced costs, increased customer satisfaction, and improved sustainability efforts.

Furthermore, Industry 4.0 has given rise to an array of software solutions that streamline inventory management, including Inventory Management Systems (IMS), Radio-Frequency Identification (RFID), IoT devices, machine learning algorithms, and cloud-based systems. These software tools provide real-time data tracking, enhanced demand forecasting, and increased automation, making inventory management more efficient and adaptable to changing market conditions.

While the advantages of employing Business Analytics in inventory management are evident, challenges also exist. Issues such as data quality, implementation costs, staff training, and data security must be addressed. Furthermore, integrating Business Analytics with legacy systems and overcoming resistance to change can be complex. However, with the right strategies, these challenges can be mitigated, and the benefits far outweigh the drawbacks.

In the evolving landscape of Industry 4.0, Business Analytics is undeniably a game-changer in the field of inventory management. It empowers businesses to adapt to changing market dynamics, reduce costs, enhance customer satisfaction, and contribute to sustainability goals. As technology continues to advance, the role of Business Analytics in inventory management will only become more critical, ensuring that companies remain competitive in this dynamic environment.

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. In: *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. Dutta, J., Roy, S., Chowdhury, C. (2019). Unified framework for IoT and smartphone based different smart city related applications. *Microsystem Technologies, 25(1),* 83-96.
13. 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.
14. 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.
15. 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.
16. 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.
17. Gajdzik, B., Wolniak, R. (2021). Transitioning of steel producers to the steelworks 4.0 - literature review with case studies. *Energies, 14(14),* 1-22.
18. 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.
19. 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.
20. 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.
21. 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.
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. 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.
24. Gębczyńska, A., Wolniak, R. (2018). *Process management level in local government.* Philadelphia: CreativeSpace.
25. 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.
26. 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.
27. 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".
28. Grabowska, S., Grebski, M., Grebski, W., Wolniak, R. (2019). *Introduction to engineering concepts from a creativity and innovativeness perspective.* New York: KDP Publishing.
29. Grabowska, S., Grebski, M., Grebski, W., Wolniak, R. (2020). *Inżynier – zawód przyszłości. Umiejętności i kompetencje inżynierskie w erze Przemysłu 4.0.* Warszawa: CeDeWu.
30. Greasley, A. (2019). *Simulating Business Processes for Descriptive, Predictive, and Prescriptive Analytics.* Boston: deGruyter.
31. 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.
32. 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.
33. 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.
34. Hąbek, P., Wolniak, R. (2016). Relationship between management practices and quality of CSR reports. *Procedia – Social and Behavioral Sciences, 220,* 115-123.
35. Herdiansyah, H. (2023). Smart city based on community empowerment, social capital, and public trust in urban areas. *Glob. J. Environ. Sci. Manag., 9,* 113-128.
36. Hurwitz, J., Kaufman, M., Bowles, A. (2015). *Cognitive Computing and Big Data Analytics.* New York: Wiley.
37. Hurwitz, J., Kaufman, M., Bowles, A. (2015). *Cognitive Computing and Big Data Analytics,* New York: Wiley.
38. Hys, K., Wolniak, R. (2018). Praktyki przedsiębiorstw przemysłu chemicznego w Polsce w zakresie CSR. *Przemysł Chemiczny, 9,* 1000-1002.

39. 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.
40. 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 Entrepreneurship, 5(4),* 507-530, doi: 10.1142/S2424862220500220.
41. Jonek-Kowalska, I., Wolniak, R. (2021). Economic opportunities for creating smart cities in Poland. Does wealth matter? *Cities, 114,* 1-6.
42. 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.
43. 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.
44. 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
45. 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.
46. 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.
47. 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.
48. 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.
49. Nourani, C.F. (2021). *Artificial Intelligence and Computing Logic: Cognitive Technology for AI Business Analytics (Innovation Management and Computing).* New York: CRC Press.
50. 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.

51. 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.
52. 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.
53. 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.
54. 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.
55. 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.
56. 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.
57. 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.
58. 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.
59. 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.
60. 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.
61. 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.
62. Wolniak, R., Skotnicka-Zasadzień, B. (2014). The use of value stream mapping to introduction of organizational innovation in industry. *Metalurgija, 53(4),* 709-713.
63. Wolniak, R. (2011). *Parametryzacja kryteriów oceny poziomu dojrzałości systemu zarządzania jakością.* Gliwice: Wydawnictwo Politechniki Śląskiej.
64. Wolniak, R. (2013). Projakościowa typologia kultur organizacyjnych. *Przegląd Organizacji, 3,* 13-17.
65. Wolniak, R. (2014). Korzyści doskonalenia systemów zarządzania jakością opartych o wymagania normy ISO 9001:2009. *Problemy Jakości, 3,* 20-25.

66. Wolniak, R. (2016). Kulturowe aspekty zarządzania jakością. *Etyka biznesu i zrównoważony rozwój. Interdyscyplinarne studia teoretyczno-empiryczne, 1,* 109-122.
67. Wolniak, R. (2016). *Metoda QFD w zarządzaniu jakością. Teoria i praktyka*. Gliwice: Wydawnictwo Politechniki Śląskiej.
68. 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.
69. Wolniak, R. (2016). The role of QFD method in creating innovation. *Systemy Wspomagania Inżynierii Produkcji, 3*, 127-134.
70. 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.
71. 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.
72. 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.
73. Wolniak, R. (2017). The Design Thinking method and its stages. *Systemy Wspomagania Inżynierii Produkcji, 6*, 247-255.
74. 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.
75. Wolniak, R. (2018). Functioning of social welfare on the example of the city of Łazy. *Zeszyty Naukowe Wyższej Szkoły, Humanitas. Zarządzanie, 3,* 159-176.
76. 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.
77. Wolniak, R. (2019). Context of the organization in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *133*, 121-136.
78. Wolniak, R. (2019). Downtime in the automotive industry production process - cause analysis. *Quality, Innovation, Prosperity*, *2*, 101-118.
79. Wolniak, R. (2021). Performance evaluation in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *151*, 725-734.
80. Wolniak, R. (2022). Engineering ethics – main principles. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *155*, 579-594.

81. Wolniak, R. (2023). Analiza danych w czasie rzeczywistym. *Zarządzanie i Jakość*, *2(5),* 291-312.
82. 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.
83. Wolniak, R. (2023). Design thinking and its use to boast innovativeness. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *170,* 647-662.
84. 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.
85. Wolniak, R., Grebski, M.E. (2018). Innovativeness and creativity as nature and nurture. *Zeszyty Naukowe Politechniki Ślaskiej. Seria Organizacja i* Zarządzanie, *116*, 215-226.
86. 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.
87. 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.
88. Wolniak, R., Hąbek, P. (2015). Quality management and corporate social responsibility. *Systemy Wspomagania w Inżynierii Produkcji*, *1*, 139-149.
89. Wolniak, R., Hąbek, P. (2016). Quality assessment of CSR reports – factor analysis. *Procedia – Social and Behavioral Sciences*, *220*, 541-547.
90. 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.
91. 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.
92. 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.
93. 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.
94. Wolniak, R., Skotnicka, B. (2011). *Metody i narzędzia zarządzania jakością – Teoria i praktyka, cz. 1.* Gliwice: Wydawnictwo Naukowe Politechniki Śląskiej.
95. Wolniak, R., Skotnicka-Zasadzień, B. (2008). *Wybrane metody badania satysfakcji klienta i oceny dostawców w organizacjach.* Gliwice: Wydawnictwo Politechniki Śląskiej.
96. Wolniak, R., Skotnicka-Zasadzień, B. (2010). *Zarządzanie jakością dla inżynierów.* Gliwice: Wydawnictwo Politechniki Śląskiej.

97. 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.
98. Wolniak, R., Skotnicka-Zasadzień, B. (2022). Development of photovoltaic energy in EU countries as an alternative to fossil fuels. *Energies, 15(2),* 1-23.
99. 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.
100. 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.