

## ANALYZING CUSTOMER BEHAVIOR – EMPLOYING BUSINESS ANALYTICS WITHIN INDUSTRY 4.0 ECOSYSTEMS

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**Purpose:** The purpose of this publication is to present the applications of usage of business analytics in customer behaviour analysis.

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

**Findings:** The integration of business analytics with customer behavior analysis in Industry 4.0 environments offers businesses a transformative opportunity to gain profound insights into customer preferences, trends, and behaviors. Through the utilization of state-of-the-art technologies and data-driven methodologies, organizations can attain unprecedented levels of precision and detail in understanding customer behavior. Real-time data collection and analysis facilitate agile responses to evolving market dynamics, enabling personalized customer experiences across various channels. Additionally, advanced analytics tools such as predictive modeling and sentiment analysis empower businesses to forecast future trends, address churn, and enhance customer satisfaction. However, businesses may encounter challenges like data quality issues, privacy concerns, and resource limitations. Overcoming these obstacles necessitates a comprehensive approach, involving investments in data governance, talent acquisition, and technology infrastructure. By surmounting these challenges, businesses can harness the full potential of business analytics to drive strategic decisions, refine marketing strategies, and elevate overall business performance within Industry 4.0 environments.

**Originality/Value:** Detailed analysis of all subjects related to the problems connected with the usage of business analytics in the case of smart manufacturing.

**Keywords:** business analytics, Industry 4.0, digitalization, artificial intelligence, real-time monitoring; customer behavior analysis.

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

### 1. Introduction

At its core, customer behavior analysis in Industry 4.0 environments involves leveraging cutting-edge technologies and data-driven approaches to gain actionable insights into customer preferences, trends, and behaviors. By harnessing the power of business analytics, businesses

can sift through vast volumes of customer data generated by interconnected devices, sensors, social media platforms, and digital touchpoints.

One of the key benefits of employing business analytics in customer behavior analysis within Industry 4.0 environments is the ability to achieve unprecedented levels of granularity and precision in understanding customer behavior. Through advanced analytics techniques such as predictive modeling, machine learning, and natural language processing, businesses can uncover hidden patterns, correlations, and trends within their customer data. Moreover, Industry 4.0 technologies enable real-time data collection and analysis, allowing businesses to gain insights into customer behavior instantaneously. This real-time visibility into customer interactions empowers businesses to respond promptly to changing preferences, market dynamics, and competitive pressures. By leveraging real-time analytics, businesses can personalize customer experiences, optimize marketing campaigns, and drive customer engagement in ways that were previously unimaginable.

Another significant advantage of integrating business analytics with Industry 4.0 environments is the ability to achieve seamless omni-channel customer experiences. With customers interacting with businesses through a myriad of channels, including websites, mobile apps, social media platforms, and physical stores, it is essential for businesses to have a unified view of customer behavior across these channels. Business analytics enables businesses to aggregate and analyze data from disparate sources, allowing for a holistic understanding of the customer journey and facilitating personalized, omni-channel experiences (Bakir, Dahlan, 2022).

The purpose of this publication is to present the applications of usage of business analytics in customer behavior analysis.

## **2. The selected aspects of business analytics usage in customer behavior analysis**

Business analytics has emerged as a pivotal tool in deciphering and understanding customer behavior, offering businesses invaluable insights into consumer preferences, tendencies, and trends. Through the strategic application of data analysis techniques, businesses can unlock a wealth of information that shapes marketing strategies, enhances customer experiences, and drives revenue growth. One primary application of business analytics in customer behavior analysis is customer segmentation. By leveraging demographic, psychographic, and transactional data, businesses can categorize their customer base into distinct segments with similar characteristics and behaviors (Akundi et al., 2022). This segmentation allows for targeted marketing efforts, personalized communication, and tailored product offerings, thereby maximizing customer engagement and satisfaction. Furthermore, business analytics enables

businesses to delve deep into purchase patterns and trends. By analyzing historical transaction data, businesses can identify correlations between product purchases, seasonal fluctuations, and customer preferences. Such insights empower organizations to optimize inventory management, pricing strategies, and product placements, ensuring that offerings resonate with customer needs and preferences (Zeng et al., 2022; Pech, Vrchota, 2022).

Predictive analytics plays a crucial role in customer behavior analysis by forecasting future trends and outcomes (Gajdzik, Wolniak, 2022; Gajdzik et al., 2023). Through sophisticated modeling techniques, businesses can predict customer churn, anticipate future purchasing behavior, and identify opportunities for cross-selling or upselling. Armed with this foresight, organizations can proactively implement retention strategies, personalized marketing campaigns, and targeted promotions to mitigate churn and maximize customer lifetime value (Ghibakholl et al., 2022).

Sentiment analysis, another facet of business analytics, mines customer feedback, reviews, and social media interactions to gauge consumer sentiment towards products or services (Wolniak, Grebski, 2018; Wolniak et al., 2019, 2020; Wolniak, Habek, 2015, 2016; Wolniak, Skotnicka, 2011; Wolniak, Jonek-Kowalska, 2021; 2022). By analyzing language patterns and sentiment scores, businesses can identify areas of strength and weakness, address customer concerns, and refine their offerings to better align with customer expectations (Scappini, 2016). Recommendation systems powered by business analytics leverage machine learning algorithms to deliver personalized product recommendations to customers (Sułkowski, Wolniak, 2015, 2016, 2018; Wolniak, Skotnicka-Zasadzień, 2008, 2010, 2014, 2018, 2019, 2022; Gajdzik, Wolniak, 2023; Swarnakar et al., 2023). By analyzing past behavior, preferences, and similarities with other customers, recommendation engines enhance the customer shopping experience, increase conversion rates, and foster brand loyalty (Cillo et al., 2022).

Finally, business analytics facilitates the evaluation of campaign effectiveness by measuring key performance indicators such as click-through rates, conversion rates, and return on investment. By assessing the impact of marketing initiatives on customer behavior and sales outcomes, businesses can optimize marketing spend, refine targeting strategies, and improve overall marketing efficiency. Table 1 contains descriptions of how business analytics is used in the case of customer behavior analysis.

**Table 1.**

*The usage of business analytics in customer behavior analysis*

Aspect of Customer Behavior Analysis	Description of Usage of Business Analytics
Customer Segmentation	Business analytics is utilized to segment customers based on various attributes such as demographics, purchasing behavior, and psychographics. Analytics tools help in identifying distinct customer groups with similar characteristics, enabling targeted marketing strategies and personalized offerings.

Cont. table 1.

Purchase Patterns Analysis	Business analytics examines historical transaction data to identify patterns in customer purchases. This analysis helps in understanding which products or services are frequently bought together, seasonal trends, and customer preferences. By leveraging this insight, businesses can optimize their inventory, pricing strategies, and product recommendations.
Churn Prediction	Through predictive analytics, businesses forecast the likelihood of customers churning or discontinuing their relationship with the company. By analyzing factors such as usage patterns, engagement metrics, and customer feedback, businesses can proactively implement retention strategies to prevent churn, such as personalized offers, loyalty programs, or improved customer service.
Customer Lifetime Value (CLV) Analysis	Business analytics calculates the CLV of customers by estimating the net profit attributed to the entire relationship with a customer. By analyzing past behavior and spending patterns, businesses can predict future revenue potential from each customer, guiding decisions related to customer acquisition, retention, and resource allocation.
Sentiment Analysis	Utilizing text mining and natural language processing techniques, business analytics extracts insights from customer feedback, reviews, and social media conversations. Sentiment analysis helps in understanding customer perceptions, opinions, and emotions towards products or services. By identifying sentiment trends, businesses can address issues, improve products, and enhance customer satisfaction.
Recommendation Systems	Business analytics powers recommendation engines that suggest relevant products or services to customers based on their past behavior, preferences, and similarities with other customers. By employing machine learning algorithms, businesses can deliver personalized recommendations through various channels such as websites, emails, or mobile apps, thereby increasing sales and enhancing customer experience.
Campaign Effectiveness Analysis	Business analytics evaluates the performance of marketing campaigns by analyzing metrics such as click-through rates, conversion rates, and return on investment (ROI). By measuring the impact of different campaigns on customer behavior and sales, businesses can optimize marketing strategies, allocate resources effectively, and improve overall marketing efficiency.

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 customer behavior analysis in Industry 4.0 conditions

Business analytics software plays a crucial role in understanding and analyzing customer behavior, offering businesses valuable insights to drive strategic decision-making and enhance customer experiences (Adel., 2022). These software applications leverage advanced analytics techniques to process vast amounts of data, enabling businesses to uncover patterns, trends, and correlations within their customer base. By utilizing these insights, organizations can segment customers based on various attributes, such as demographics, behaviors, and preferences, allowing for targeted marketing efforts and personalized communication (Jonek-Kowalska, Wolniak, 2021, 2022, 2023; Rosak-Szyrocka et al., 2023; Gajdzik et al., 2023; Jonek-Kowalska et al., 2022; Kordel, Wolniak, 2021, Orzeł, Ponomarenko et al., 2016; Stawiarska et al., 2020, 2021; Stecula, Wolniak, 2022; Olkiewicz et al., 2021). Moreover,

predictive analytics capabilities enable businesses to forecast customer behavior, anticipate churn, and identify opportunities for upselling or cross-selling. Real-time analytics functionality provides businesses with up-to-date insights into customer interactions across multiple channels, enabling prompt responses and tailored engagement strategies. Additionally, advanced data visualization tools allow businesses to create interactive dashboards and reports, facilitating the exploration and communication of insights derived from customer data. By harnessing the power of business analytics software, organizations can gain a deeper understanding of their customers, optimize marketing strategies, improve customer satisfaction, and drive sustainable business growth (Du et al., 2023; Fjellström, Osarenkhoe, 2023; Castro et al., 2014; Wang et al., 2023).

Table 2 highlighting examples of software and applications used in customer behavior analysis, along with descriptions of their usage.

**Table 2.**

*The usage of business analytics software in customer behavior analysis*

Software/ Application	Description	Key Features
IBM Watson Analytics	IBM Watson Analytics is a cloud-based analytics platform that offers advanced analytics capabilities for businesses. It allows users to explore and analyze data through intuitive visualizations and predictive analytics tools.	<ul style="list-style-type: none"> <li>• Advanced data visualization: Interactive dashboards and visualizations facilitate the exploration of customer data and trends.</li> <li>• Predictive analytics: Enables businesses to forecast customer behavior, identify patterns, and make data-driven decisions.</li> <li>• Natural language processing (NLP): Allows users to ask questions in natural language and receive insights, making data analysis more accessible to non-technical users.</li> </ul>
Salesforce Einstein Analytics	Salesforce Einstein Analytics is an AI-powered analytics platform integrated with Salesforce CRM, designed to provide actionable insights and recommendations to improve customer experiences.	<ul style="list-style-type: none"> <li>• Integration with CRM data: Seamlessly integrates with Salesforce CRM to analyze customer data, including sales, service, and marketing interactions.</li> <li>• Predictive analytics: Utilizes machine learning algorithms to forecast customer behavior, predict churn, and identify cross-selling opportunities.</li> <li>• AI-driven insights: Generates automated insights and recommendations to guide sales and marketing strategies, enhancing customer engagement and retention.</li> </ul>
Google Analytics	Google Analytics is a web analytics service offered by Google that tracks and reports website traffic and user interactions. While primarily used for website analysis, it also provides valuable insights into customer behavior.	<ul style="list-style-type: none"> <li>• Website traffic analysis: Tracks customer interactions on websites, including page views, session durations, and conversion rates, to understand user behavior and preferences.</li> <li>• E-commerce tracking: Provides insights into online purchase behavior, including product performance, transaction values, and shopping cart abandonment rates.</li> <li>• Audience segmentation: Allows businesses to segment website visitors based on demographics, interests, and behaviors, enabling targeted marketing and personalized content delivery.</li> </ul>

Cont. table 2.

Tableau	Tableau is a powerful data visualization tool that allows businesses to create interactive and shareable dashboards for analyzing customer behavior.	<ul style="list-style-type: none"> <li>• Interactive dashboards: Enables users to visualize and explore customer data through interactive charts, graphs, and maps, facilitating deeper insights into customer behavior.</li> <li>• Data blending: Integrates data from multiple sources, such as CRM systems, social media platforms, and transactional databases, to provide a comprehensive view of customer interactions.</li> <li>• Predictive analytics: Offers predictive modeling capabilities to forecast customer behavior, identify trends, and make data-driven decisions.</li> </ul>
SAS Customer Intelligence	SAS Customer Intelligence is a comprehensive suite of analytics solutions designed to help businesses understand and engage with customers effectively.	<ul style="list-style-type: none"> <li>• Customer segmentation: Utilizes advanced analytics techniques to segment customers based on demographics, behaviors, and preferences, enabling targeted marketing campaigns and personalized communications.</li> <li>• Real-time analytics: Provides real-time insights into customer interactions across multiple channels, allowing businesses to respond promptly to customer needs and preferences.</li> <li>• Campaign optimization: Optimizes marketing campaigns by analyzing campaign performance, identifying the most effective channels and messages, and optimizing marketing spend to maximize ROI.</li> </ul>
Adobe Analytics	Adobe Analytics is a web analytics solution that provides businesses with insights into customer interactions across digital channels, including websites, mobile apps, and social media platforms.	<ul style="list-style-type: none"> <li>• Omnichannel analytics: Tracks customer interactions across multiple digital touchpoints, allowing businesses to understand the customer journey and identify opportunities for engagement and conversion.</li> <li>• Segmentation and targeting: Enables businesses to segment customers based on behavior, demographics, and other attributes, and target them with personalized content and offers.</li> <li>• Attribution modeling: Provides insights into the effectiveness of marketing channels and campaigns, helping businesses allocate resources effectively and optimize marketing ROI.</li> </ul>
Microsoft Power BI	Microsoft Power BI is a business analytics tool that allows businesses to visualize and analyze data from various sources, including databases, spreadsheets, and cloud services.	<ul style="list-style-type: none"> <li>• Data visualization: Offers a range of visualization options, including charts, graphs, and maps, to help businesses explore and communicate insights from customer data effectively.</li> <li>• Natural language queries: Allows users to ask questions in natural language and receive insights from the data, making it easier for non-technical users to analyze and understand customer behavior.</li> <li>• Integration with Microsoft products: Seamlessly integrates with other Microsoft products, such as Excel, SharePoint, and Dynamics 365, to provide a unified analytics platform for businesses.</li> </ul>

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 customer behavior analysis**

Utilizing business analytics in customer behavior analysis offers a multitude of advantages for businesses seeking to thrive in today's competitive landscape. By harnessing the power of data-driven insights, organizations can gain a deeper understanding of their customers, optimize their marketing strategies, and enhance overall business performance. One of the primary advantages of leveraging business analytics in customer behavior analysis is the ability to enhance customer segmentation. By analyzing vast amounts of customer data, businesses can segment their customer base more accurately based on demographics, behaviors, preferences, and purchasing patterns. This allows for targeted marketing efforts, personalized communication, and tailored product offerings, ultimately leading to higher customer engagement and satisfaction. Furthermore, business analytics enables data-driven decision-making processes. Instead of relying on guesswork or intuition, businesses can make informed decisions backed by empirical evidence and insights derived from customer behavior analysis. This results in more effective strategies, better allocation of resources, and improved business outcomes (Charles et al., 2023).

Predictive analytics capabilities offered by business analytics tools allow businesses to forecast future trends and behaviors. By analyzing historical data and using sophisticated algorithms, businesses can anticipate customer needs, predict churn, identify cross-selling opportunities, and optimize pricing strategies. This proactive approach helps businesses stay ahead of the competition and capitalize on emerging opportunities in the market. Moreover, business analytics facilitates personalized marketing campaigns. By analyzing customer behavior data, businesses can create targeted marketing campaigns tailored to the preferences and interests of specific customer segments. This not only increases the effectiveness of marketing efforts but also enhances customer engagement and loyalty.

Real-time insights provided by business analytics tools enable businesses to respond promptly to changing market conditions and customer preferences. By monitoring customer interactions in real-time, businesses can identify trends, detect anomalies, and take immediate action to address issues or capitalize on opportunities. This agility gives businesses a competitive edge in today's fast-paced business environment (Nourani, 2021).

The advantages of using business analytics in customer behavior analysis are manifold. From enhanced customer segmentation and data-driven decision-making to predictive analytics and personalized marketing campaigns, businesses can leverage analytics to gain a deeper understanding of their customers, drive business growth, and maintain a competitive edge in the market. Table 3 contains the advantages of using business analytics in customer behavior analysis within Industry 4.0 conditions, along with descriptions for each advantage. This table showcases how business analytics in smart manufacturing offer various advantages across

different facets of operations, ultimately driving efficiency, reducing costs, and enhancing competitiveness (Greasley, 2019).

**Table 3.**

*The advantages of using business analytics in customer behavior analysis*

<b>Advantage</b>	<b>Description</b>
Enhanced Customer Segmentation	Business analytics allows for more accurate and detailed segmentation of customers based on demographics, behaviors, and preferences. This enables targeted marketing efforts and personalized experiences.
Data-Driven Decision Making	By analyzing customer behavior data, businesses can make informed decisions backed by data rather than relying on assumptions or intuition. This leads to more effective strategies and better outcomes.
Improved Customer Retention	Business analytics helps in identifying churn patterns and predicting which customers are at risk of leaving. By implementing targeted retention strategies, businesses can improve customer retention rates and loyalty.
Personalized Marketing Campaigns	With insights gained from customer behavior analysis, businesses can create personalized marketing campaigns tailored to the preferences and interests of specific customer segments. This increases engagement and conversion rates.
Optimal Resource Allocation	By understanding customer preferences and behaviors, businesses can allocate resources more effectively, whether it's marketing budgets, product development efforts, or customer service initiatives. This ensures maximum return on investment (ROI).
Enhanced Customer Experience	Analyzing customer behavior helps businesses identify pain points, preferences, and opportunities to enhance the overall customer experience. By addressing these areas, businesses can improve satisfaction and loyalty.
Competitive Advantage	Businesses that leverage business analytics to analyze customer behavior gain a competitive edge by understanding market trends, customer preferences, and emerging opportunities better than their competitors.
Real-Time Insights	Business analytics provides real-time insights into customer interactions and behaviors, allowing businesses to respond promptly to changing market conditions, customer needs, and competitive threats.
Increased Revenue Generation	Ultimately, the insights gained from customer behavior analysis lead to increased revenue generation through improved targeting, higher conversion rates, increased customer lifetime value, and better overall business performance.

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 customer behavior analysis within Industry 4.0 conditions, along with descriptions for each advantage. These problems highlight some of the key challenges that businesses may encounter when using business analytics for customer behavior analysis. Overcoming these challenges requires a holistic approach, including addressing data quality issues, investing in talent and technology, and ensuring alignment with strategic objectives.

**Table 4.**

*The problems of using business analytics in customer behavior analysis*

<b>Problem</b>	<b>Description</b>
Data Quality Issues	One of the primary challenges in using business analytics for customer behavior analysis is poor data quality. Inaccurate or incomplete data can lead to erroneous insights and flawed decision-making processes.
Data Integration Challenges	Businesses often struggle with integrating data from various sources such as CRM systems, social media platforms, and transactional databases. Incompatible data formats and structures can hinder the analysis process.



Cont. table 4.

Privacy and Compliance Concerns	With the increasing focus on data privacy regulations such as GDPR and CCPA, businesses must ensure that they handle customer data ethically and comply with relevant regulations. This can limit the scope of data available for analysis.
Complexity of Analytics Tools	Business analytics tools often come with a steep learning curve and require specialized skills to use effectively. This can pose a challenge for businesses lacking in-house expertise or resources to implement and manage these tools.
Interpretation and Actionability	While business analytics can provide valuable insights into customer behavior, interpreting these insights and translating them into actionable strategies can be challenging. Businesses may struggle with prioritizing initiatives and implementing changes based on analytics findings.
Lack of Alignment with Business Goals	Another common problem is the disconnect between analytics initiatives and broader business goals. Without clear alignment with strategic objectives, analytics efforts may fail to deliver meaningful outcomes or drive tangible business results.
Overreliance on Historical Data	Business analytics often relies on historical data to analyze customer behavior and make predictions. However, relying solely on past data may not accurately capture changing market dynamics or emerging trends, leading to suboptimal decision-making.
Resource Constraints	Implementing and maintaining business analytics solutions requires significant investment in terms of time, money, and resources. Small and medium-sized businesses may face challenges in allocating sufficient resources to support analytics initiatives.
Technology Limitations	Rapid advancements in technology can outpace businesses' ability to adopt and leverage the latest analytics tools and techniques. Legacy systems and outdated infrastructure may limit the capabilities of business analytics solutions.

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 integration of business analytics with customer behavior analysis in Industry 4.0 environments presents a transformative opportunity for businesses to gain deeper insights into customer preferences, trends, and behaviors. By leveraging cutting-edge technologies and data-driven approaches, businesses can achieve unprecedented levels of granularity and precision in understanding customer behavior. Real-time data collection and analysis enable businesses to respond promptly to changing market dynamics and deliver personalized experiences across multiple channels. Moreover, advanced analytics techniques such as predictive modeling and sentiment analysis empower organizations to anticipate future trends, mitigate churn, and enhance customer satisfaction.

Despite the numerous advantages offered by business analytics in customer behavior analysis, businesses may encounter challenges such as data quality issues, privacy concerns, and resource constraints. Addressing these challenges requires a holistic approach, including investment in data governance, talent development, and technology infrastructure. By overcoming these obstacles, businesses can unlock the full potential of business analytics to drive strategic decision-making, optimize marketing strategies, and improve overall business performance in Industry 4.0 environments.

## 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. 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.
11. Gajdzik, B., Jaciow, M., Wolniak, R., Wolny, R., Grebski, W. (2024). Diagnosis of the development of energy cooperatives in Poland - a case study of a renewable energy cooperative in the upper Silesian region. *Energies*, 17(3), 1-27, 647.
12. Gajdzik, B., Jaciow, M., Wolniak, R. (2024). Gastronomic curiosity and consumer behavior: the impact of television culinary programs on choices of food services. *Foods*, 13(1), 1-16, 115.
13. Gajdzik, B., Wolniak, R. (2021a). 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.

14. Gajdzik, B., Wolniak, R. (2021b). 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.
15. Gajdzik, B., Wolniak, R. (2021c). Transitioning of steel producers to the steelworks 4.0 - literature review with case studies. *Energies*, 14(14), 1-22.
16. 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.
17. Gajdzik, B., Wolniak, R. (2022a). 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. (2022b). 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. (2022c). 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. (2023a). 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., Nagaj, R., Žuromskaitė-Nagaj, B., Grebski, W. (2024). The influence of the global energy crisis on energy efficiency: a comprehensive analysis. *Energies*, 17(4), 1-49, 947.
22. Gajdzik, B., Wolniak, R., Grebski, W. (2023b). 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. (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. Gajdzik, B., Wolniak, R., Nagaj, R., Grebski, W., Romanyshyn, T. (2023). Barriers to Renewable Energy Source (RES) Installations as Determinants of Energy Consumption in EU Countries. *Energies*, 16(21), 7364.
25. Gębczyńska, A., Wolniak, R. (2018). *Process management level in local government*. Philadelphia: CreativeSpace.
26. 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.

27. 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>.
28. 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".
29. Grabowska, S., Grebski, M., Grebski, W., Wolniak, R. (2019). *Introduction to engineering concepts from a creativity and innovativeness perspective*. New York: KDP Publishing.
30. Grabowska, S., Grebski, M., Grebski, W., Wolniak, R. (2020). *Inżynier – zawód przyszłości. Umiejętności i kompetencje inżynierskie w erze Przemysłu 4.0*. Warszawa: CeDeWu.
31. Greasley, A. (2019). *Simulating Business Processes for Descriptive, Predictive, and Prescriptive Analytics*. Boston: deGruyter.
32. 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.
33. 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.
34. 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.
35. Hąbek, P., Wolniak, R. (2016). Relationship between management practices and quality of CSR reports. *Procedia – Social and Behavioral Sciences*, 220, 115-123.
36. 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.
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. (2021a). Economic opportunities for creating smart cities in Poland. Does wealth matter? *Cities*, 114, 1-6.

42. Jonek-Kowalska, I., Wolniak, R. (2021b). 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. (2023). *Towards sustainability and a better quality of life?* 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. Nagaj, R., Gajdzik, B., Wolniak, R., Grebski, W. (2024). The impact of deep decarbonization policy on the level of greenhouse gas emissions in the European Union. *Energies*, 17(5), 1-23, 1245.
50. Nourani, C.F. (2021). *Artificial Intelligence and Computing Logic: Cognitive Technology for AI Business Analytics (Innovation Management and Computing)*. New York: CRC Press.
51. 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.
52. 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.
53. 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.
54. 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.

55. 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.
56. 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.
57. 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.
58. 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.
59. Stawiarska, E., Szwajca, D., Matuszek, M., Wolniak, R. (2020). *Wdrażanie rozwiązań przemysłu 4.0 w wybranych funkcjonalnych obszarach zarządzania przedsiębiorstw branży motoryzacyjnej: próba diagnozy*. Warszawa: CeDeWu.
60. Stawiarska, E., Szwajca, D., Matuszek, 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.
61. 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.
62. 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.
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. (2016a). Kulturowe aspekty zarządzania jakością. *Etyka biznesu i zrównoważony rozwój. Interdyscyplinarne studia teoretyczno-empiryczne*, 1, 109-122.
68. Wolniak, R. (2016b). *Metoda QFD w zarządzaniu jakością. Teoria i praktyka*. Gliwice: Wydawnictwo Politechniki Śląskiej.
69. Wolniak, R. (2016c). 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. (2016d). The role of QFD method in creating innovation. *Systemy Wspomagania Inżynierii Produkcji*, 3, 127-134.
71. Wolniak, R. (2017a). 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. (2017b). 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. (2017c). 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. (2017d). The Design Thinking method and its stages. *Systemy Wspomagania Inżynierii Produkcji*, 6, 247-255.
75. Wolniak, R. (2021). Performance evaluation in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series*, 151, 725-734.
76. Wolniak, R. (2022a). Innovations in Industry 4.0 conditions. *Silesian University of Technology Scientific Papers. Organization and Management Series*, 169, 725-741.
77. Wolniak, R. (2022b). Functioning of real-time analytics in business. *Silesian University of Technology Scientific Papers. Organization and Management Series*, 172, 659-677.
78. Wolniak, R. (2023a). Deskryptywna analiza danych. *Zarządzanie i Jakość*, 5(2), 282-290.
79. Wolniak, R. (2023b). Smart biking w smart city. *Zarządzanie i Jakość*, 5(2), 313-328.
80. Wolniak, R. (2023c). Analiza w czasie rzeczywistym. *Zarządzanie i Jakość*, 5(2), 291-312.
81. Wolniak, R. (2023d). Smart mobility jako element koncepcji smart city. *Zarządzanie i Jakość*, 5(2), 282-290.
82. Wolniak, R., Jonek-Kowalska, I. (2021a). The level of the quality of life in the city and its monitoring. *Innovation (Abingdon)*, 34(3), 376-398.
83. Wolniak, R., Jonek-Kowalska, I. (2021c). The quality of service to residents by public administration on the example of municipal offices in Poland. *Administration Management Public*, 37, 132-150.
84. 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.
85. 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.
86. Wolniak, R., Skotnicka, B. (2011). *Metody i narzędzia zarządzania jakością – Teoria i praktyka, cz. 1*. Gliwice: Wydawnictwo Naukowe Politechniki Śląskiej.
87. Wolniak, R., Skotnicka-Zasadzień, B. (2008). *Wybrane metody badania satysfakcji klienta i oceny dostawców w organizacjach*. Gliwice: Wydawnictwo Politechniki Śląskiej.

88. Wolniak, R., Skotnicka-Zasadzień, B. (2010). *Zarządzanie jakością dla inżynierów*. Gliwice: Wydawnictwo Politechniki Śląskiej.
89. Wolniak, R., Skotnicka-Zasadzień, B. (2018). Developing a model of factors influencing the quality of service for disabled customers in the conditions of sustainable development, illustrated by an example of the Silesian Voivodeship public administration. *Sustainability*, 7, 1-17.
90. Wolniak, R., Skotnicka-Zasadzień, B. (2022). Development of photovoltaic energy in EU countries as an alternative to fossil fuels. *Energies*, 15(2), 1-23.
91. 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.
92. 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.
93. Wolniak, R., Sułkowski, M. (2015). Motywy wdrażanie certyfikowanych Systemów Zarządzania Jakością. *Problemy Jakości*, 9, 4-9.
94. 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.
95. 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.