

BUSINESS ANALYTICS IN THE CASE OF PROCESS OPTIMALIZATION IN INDUSTRY 4.0 CONDITIONS

Radosław WOLNIAK^{1*}, Wies GREBSKI²

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; wvg3@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 process optimization.

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

Findings: In the era of Industry 4.0, the intersection of data-driven technologies and manufacturing processes underscores the indispensable role of business analytics in process optimization. This transformative landscape redefines business operations, highlighting data analytics as the cornerstone of operational excellence. Business analytics offers a multitude of advantages, including data-driven decision-making, efficiency enhancements, predictive capabilities, and cost reduction, ultimately ensuring a competitive edge. Nevertheless, it also presents a set of challenges, such as data quality, integration, and resistance to change. Overcoming these obstacles is essential to fully unlock the potential of business analytics in Industry 4.0. In doing so, organizations can navigate this dynamic landscape and secure their position in the ever-evolving industrial ecosystem.

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

Category of the paper: literature review.

1. Introduction

In today's rapidly evolving industrial landscape, the convergence of data-driven technologies and manufacturing processes has given rise to what is commonly known as Industry 4.0 (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 transformative shift has redefined how businesses

operate and has created an environment where data analytics plays a pivotal role in optimizing processes and enhancing productivity. Among the many applications of data analytics in this context, process optimization stands out as a critical aspect of achieving operational excellence.

Industry 4.0, characterized by the integration of the Internet of Things (IoT), artificial intelligence, machine learning, and automation, has led to an unprecedented influx of data within industrial settings. This data includes real-time sensor readings, production logs, supply chain information, and customer feedback. Leveraging this wealth of data through business analytics is instrumental in fine-tuning operations for efficiency and competitiveness (Ghibakholl et al., 2022).

Business analytics has become a cornerstone of process optimization in Industry 4.0 conditions. By harnessing the power of data, companies can drive efficiency, quality, and innovation in their operations, ultimately ensuring their competitiveness in an increasingly digitized and interconnected industrial landscape. Those who embrace these analytical tools and methodologies are better positioned to thrive in this new era of manufacturing and commerce.

The purpose of this publication is to present the applications of usage of business analytics in process optimization.

2. The selected aspects of business analytics usage in process optimization

The first step in any analytics-driven process optimization initiative is to gather relevant data from various sources, such as sensors, machines, and enterprise software systems. This data is then integrated into a centralized platform for analysis, ensuring that it is both accessible and structured for meaningful insights. Industry 4.0 environments thrive on real-time decision-making. With the help of analytics, businesses can monitor processes as they happen, enabling quick responses to deviations, anomalies, and bottlenecks. Real-time insights are particularly crucial for industries like manufacturing, where even small delays can have significant consequences (Bakir, Dahlan, 2022).

One of the most valuable applications of analytics is in predicting equipment failures before they occur. By analyzing historical data and sensor readings, predictive maintenance can be implemented, reducing downtime and increasing the lifespan of machinery. Analytics identifies areas of inefficiency in production and supply chain processes. By analyzing historical and real-time data, businesses can optimize workflows, reduce waste, and minimize energy consumption. In Industry 4.0, maintaining high-quality standards is critical. Analytics can be used to continuously monitor product quality, detect defects, and provide immediate feedback to production lines, ensuring that only high-quality products reach the market (Wolniak,

Grebski, 2018; Wolniak et al., 2019, 2020; Wolniak, Habek, 2015, 2016; Wolniak, Skotnicka, 2011; Wolniak, Jonek-Kowalska, 2021; 2022).

Through data analysis, companies can better manage their inventories by predicting demand and optimizing stocking levels. This leads to cost savings and a more responsive supply chain. Analytics enables businesses to pinpoint areas of unnecessary expenditure and optimize resource allocation. By reducing operational costs, companies can improve their bottom line.

In Industry 4.0, mass customization is a reality. Analytics helps companies understand customer preferences and tailor products and services accordingly, increasing customer satisfaction and loyalty. With the increasing emphasis on sustainability, analytics can help industries minimize their environmental footprint by optimizing processes to reduce waste, energy consumption, and emissions. Business analytics in Industry 4.0 facilitates a culture of continuous improvement. By regularly analyzing data and performance metrics, companies can adapt to changing market conditions and stay ahead of the competition (Olsen, 2023).

Table 1 contains descriptions of how business analytics is used in process optimization. This table provides a concise overview of the various ways business analytics is employed for process optimization in Industry 4.0 conditions. Each application serves to enhance efficiency, quality, and sustainability while promoting a culture of continuous improvement in industrial operations (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 empowers organizations to make informed decisions based on data rather than intuition. Through the collection and analysis of data from various sources, including IoT sensors, production logs, and supply chain records, companies gain a deeper understanding of their operations. Industry 4.0 emphasizes real-time operations. Analytics tools provide the capability to monitor processes as they occur, allowing for immediate detection of issues, performance deviations, and bottlenecks. This real-time visibility enables swift responses and adjustments (Nourani, 2021).

By leveraging historical data and machine learning algorithms, predictive maintenance models can forecast equipment failures before they happen. This proactive approach reduces downtime and extends the life of critical machinery. Analytics helps identify inefficiencies in production and supply chain processes. It provides the means to continuously analyze historical and real-time data to pinpoint areas for improvement (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). Optimization efforts can lead to increased efficiency, reduced waste, and energy savings. Maintaining product quality is paramount. Business analytics is instrumental in continuously monitoring quality parameters and quickly identifying defects or deviations from quality standards. This ensures that only high-quality products reach the market (Greasley, 2019).

Analytics tools help in managing inventory more efficiently. They forecast demand patterns, enabling organizations to optimize stock levels and reduce carrying costs while ensuring product availability. Businesses can identify and eliminate unnecessary expenses through data analysis. By optimizing resource allocation and reducing operational costs, they can enhance profitability and competitiveness.

Table 1.
The usage of business analytics in process optimization

Aspect of process optimization	Description
Data Collection and Integration	Gather data from various sources, such as sensors, machines, and enterprise software systems, and integrate it for analysis.
Real-Time Monitoring	Monitor processes in real time, allowing for quick responses to deviations, anomalies, and bottlenecks.
Predictive Maintenance	Predict equipment failures using historical data and sensor readings, reducing downtime and extending machinery lifespan.
Process Optimization	Analyze historical and real-time data to identify inefficiencies, optimize workflows, reduce waste, and minimize energy consumption.
Quality Control	Continuously monitor product quality, detect defects, and provide immediate feedback to production lines.
Inventory Management	Predict demand and optimize stocking levels for efficient inventory management, reducing costs and improving the supply chain.
Cost Reduction	Identify areas of unnecessary expenditure and optimize resource allocation to reduce operational costs.
Customization and Personalization	Use analytics to understand customer preferences and tailor products and services, increasing customer satisfaction and loyalty.
Sustainability	Optimize processes to reduce waste, energy consumption, and emissions, contributing to sustainability goals.
Continuous Improvement	Establish a culture of continuous improvement by regularly analyzing data and performance metrics, adapting to changing market conditions.

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 process optimization in Industry 4.0 conditions

Inventory management is a vital aspect of business operations, and numerous software and applications have been developed to streamline and optimize this crucial function. These solutions offer a wide range of features and capabilities to meet the diverse needs of businesses, whether they are large enterprises or small and mid-sized companies (Aslam et al., 2020).

SAP's inventory management software is an integral part of its ERP suite. It provides comprehensive tools for tracking and optimizing inventory. Key features include real-time visibility, demand forecasting, and replenishment planning. Oracle's inventory management solution is designed to work seamlessly with its suite of business software. It offers features such as multi-location support, lot and serial tracking, and cycle counting.

Microsoft's cloud-based Dynamics 365 offers end-to-end inventory and supply chain management. It provides real-time visibility, supports demand forecasting, and allows for vendor collaboration. QuickBooks Commerce is a cloud-based platform suitable for small to mid-sized businesses. It offers multi-channel sales, order management, and robust reporting and analytics (Scappini, 2016).

Fishbowl Inventory is a popular QuickBooks add-on that enhances inventory control. It features capabilities like barcoding, multi-location support, and order management. Zoho Inventory is a cloud-based solution tailored for small businesses. It offers tools for order management, multi-channel sales, and batch tracking.

TradeGecko is designed for e-commerce businesses, providing inventory and order management solutions. Key features include sales and purchase order management, demand forecasting, and a B2B e-commerce portal. inFlow Inventory is designed for small businesses and offers customization options. It supports barcoding, provides detailed reporting, and manages sales and purchase orders (Javaid, Haleem, 2020).

Odoo Inventory is part of the open-source Odoo ERP suite. It offers real-time inventory updates, batch and serial tracking, and robust warehouse management features. Wasp Inventory Control is a software solution ideal for small and medium-sized businesses. It supports barcoding, automated alerts, and provides reporting and analytics capabilities (Charles et al., 2023).

Table 2 highlighting examples of software and applications used in inventory management, along with descriptions of their usage. These software and applications offer a range of features and functionalities to cater to the diverse needs of businesses when it comes to inventory management. Depending on the size of the business, the complexity of operations, and specific requirements, organizations can select the most suitable solution to efficiently manage their inventory and streamline supply chain operations.

Table 2.

The usage of business analytics software in process optimization

Software/Application	Description	Key Features
SAP Inventory Management	Part of the SAP ERP suite, it offers comprehensive inventory tracking and optimization.	Real-time visibility, demand forecasting, replenishment planning.
Oracle Inventory	Integrated with Oracle's broader suite of business software for end-to-end inventory control.	Multi-location support, lot and serial tracking, cycle counting.
Microsoft Dynamics 365	A cloud-based solution for inventory and supply chain management.	Real-time visibility, demand forecasting, vendor collaboration.
QuickBooks Commerce	A cloud-based inventory and order management platform for small to mid-sized businesses.	Multi-channel sales, order management, reporting, and analytics.
Fishbowl Inventory	A popular QuickBooks inventory add-on for enhanced inventory control.	Barcoding, multi-location support, order management.
Zoho Inventory	A cloud-based inventory management solution for small businesses.	Order management, multi-channel sales, batch tracking.

Cont. table 2.

TradeGecko	Inventory and order management software designed for e-commerce businesses.	Sales and purchase order management, demand forecasting, B2B e-commerce portal.
inFlow Inventory	A small business-focused inventory software with various customization options.	Barcode support, reporting, sales and purchase orders.
Odoo Inventory	Part of the open-source Odoo ERP suite, it provides a wide range of inventory management tools.	Real-time inventory updates, batch and serial tracking, warehouse management.
Wasp Inventory Control	A software solution offering asset and inventory tracking for small and medium-sized businesses.	Barcode support, automated alerts, reporting, and analytics.

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 process optimization

Business analytics empowers organizations to make informed decisions based on concrete data and insights. It reduces the reliance on gut feelings or intuition, leading to more accurate and strategic choices. Analytics scrutinizes processes, uncovering inefficiencies, redundant tasks, and bottlenecks. By addressing these issues, organizations can optimize their operations, resulting in increased productivity and substantial cost savings (Peter et al., 2023).

Business analytics enables organizations to forecast future trends, demands, and potential issues. This forecasting capability allows businesses to plan proactively, mitigate risks, and seize opportunities before their competitors do. Through process optimization, analytics helps organizations contain costs. It identifies areas where resources are misallocated or overallocated, effectively reducing waste and minimizing operational expenses (Cillo et al., 2022).

Business analytics provides insights into the optimal allocation of resources, including manpower, time, and equipment. This leads to improved resource utilization, reduced underutilization, and ultimately greater efficiency. Leveraging analytics for process optimization enables companies to respond swiftly to market changes and evolving customer preferences. This agility provides a competitive edge, helping businesses stay ahead in their industries (Adel., 2022).

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

Table 3.*The advantages of using business analytics in process optimization*

Advantage	Description
Data-Driven Decisions	Utilizing historical and real-time data, organizations can make well-informed decisions, reducing reliance on guesswork and intuition. This leads to more accurate and strategic choices.
Improved Efficiency	Business analytics identifies inefficiencies, redundant tasks, and bottlenecks within processes. By addressing these issues, organizations can optimize their operations, leading to increased productivity and cost savings.
Enhanced Predictive Capabilities	Analytics enables organizations to forecast future trends, demand, and potential issues. This forecasting ability empowers businesses to plan proactively, mitigate risks, and seize opportunities ahead of competitors.
Cost Reduction	Through process optimization, analytics helps in cost containment. It identifies areas where resources are overallocated or misallocated, thereby reducing waste and minimizing operational expenses.
Better Resource Allocation	Business analytics provides insights into resource allocation, ensuring that resources like manpower, time, and equipment are assigned optimally. This leads to improved resource utilization and reduced underutilization.
Competitive Advantage	Leveraging analytics for process optimization allows companies to respond quickly to market changes and evolving customer preferences. This agility provides a competitive edge, helping businesses stay ahead in their industries.
Improved Customer Experience	By analyzing data on customer behavior and feedback, organizations can refine their processes to better meet customer needs and expectations. This leads to higher customer satisfaction and loyalty, enhancing the overall experience.
Enhanced Risk Management	Business analytics helps in identifying potential risks and vulnerabilities within processes. By addressing these issues, organizations can minimize the impact of unexpected events and maintain operational stability.
Scalability and Growth	Process optimization using analytics ensures that operations are scalable. As businesses grow, they can adapt and expand their processes more efficiently, accommodating increased demand without significant disruptions.
Regulatory Compliance	Analytics can assist in monitoring and ensuring compliance with industry regulations and standards. This reduces the risk of non-compliance, penalties, and reputational damage, promoting a culture of accountability.

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).

The quality of the data used in analytics is paramount. Inaccurate, incomplete, or inconsistent data can lead to erroneous conclusions and misguided optimization efforts. Data cleansing and validation are necessary to ensure that the analytics process is built on a solid foundation. Many organizations store data in disparate systems and formats. Integrating this data into a unified dataset can be complex and time-consuming. Data integration challenges often require significant technical resources and expertise.

The shortage of qualified data analysts and data scientists can hinder optimization efforts. Skilled professionals are needed to operate analytics tools, interpret results, and effectively communicate insights to stakeholders. Recruitment and continuous training are essential to address this problem. Acquiring and implementing analytics tools, infrastructure, and training personnel can be costly. This financial burden can be a significant barrier for smaller businesses or organizations with limited budgets.

Employees may resist changes suggested by data-driven insights. This resistance can stem from concerns about job displacement, lack of trust in the technology, or the perceived threat to established processes. Convincing the workforce to embrace change is a significant challenge. Relying solely on historical data may lead to optimization strategies that are ill-suited for current conditions. The analytics process must account for evolving market dynamics and emerging trends to remain relevant and effective (Di Marino et al., 2023).

Table 4 contains the problems of using business analytics in process optimization within Industry 4.0 conditions, along with descriptions for each advantage.

Table 4.

The problems of using business analytics in process optimization

Problem	Description
Data Quality Issues	Inaccurate, incomplete, or inconsistent data can lead to faulty analysis and unreliable optimization recommendations. Data cleansing and quality assurance are essential to mitigate this problem.
Data Integration Challenges	The integration of data from diverse sources, which may use different formats and structures, can be arduous and time-consuming. This may require significant resources and specialized tools to achieve a unified dataset for analysis.
Lack of Skilled Analysts	A shortage of qualified data analysts and data scientists who can effectively utilize analytics tools, interpret results, and communicate insights can hamper optimization efforts. Continuous training and recruitment may be necessary.
High Implementation Costs	The cost of acquiring, implementing, and maintaining analytics tools, as well as the necessary infrastructure, can strain a company's budget. Additionally, ongoing licensing fees, hardware expenses, and personnel costs should be considered.
Resistance to Change	Employees may resist changes suggested by data-driven insights due to fear of job displacement, lack of trust in the technology, or concerns about the impact on established processes. This resistance can impede the implementation of optimization recommendations.
Over-Reliance on Historical Data	Relying solely on historical data may not account for changing market dynamics, emerging trends, and future uncertainties. An overreliance on past data can lead to optimization strategies that are outdated or ill-suited for current conditions.
Lack of Clear Objectives	Undefined or unclear optimization goals can result in unfocused analytics efforts, causing wasted resources and confusion among the team. Having a well-defined, strategic roadmap is essential for successful optimization.
Privacy and Security Concerns	Analyzing sensitive data can pose significant privacy and security risks. Ensuring compliance with data protection regulations, maintaining data encryption, and implementing strict access controls are imperative to address these concerns.
Scalability Issues	As the business grows, the analytics infrastructure may face challenges in terms of scalability. The system may not easily accommodate increased data volumes and complex analyses, resulting in performance bottlenecks and escalating costs.
Misalignment with Business Strategy	If the optimization goals do not align with the overall business strategy, it can lead to misguided efforts and suboptimal results. It's crucial to ensure that analytics initiatives are closely linked to the broader business objectives and priorities.
Tool Selection and Vendor Lock-In	Selecting the right analytics tools can be challenging, and businesses may inadvertently become locked into a particular vendor's ecosystem. This can limit flexibility, hinder innovation, and increase dependency on a single supplier.
Lack of Real-Time Analytics	Some optimization processes require real-time or near-real-time insights. If the analytics infrastructure cannot provide this, decision-makers may not be able to respond quickly to changing conditions or emerging opportunities.
Difficulty in Measuring ROI	Quantifying the return on investment (ROI) of business analytics for process optimization can be complex. Measuring the direct impact of analytics on profitability and efficiency may require sophisticated tracking and analysis.

Cont. table 4.

Cultural and Organizational Challenges	Transforming a company's culture to embrace data-driven decision-making can be challenging. Resistance to change, a lack of data-driven mindset, and siloed organizational structures can hinder the adoption of analytics for process optimization.
Inadequate Data Governance	Poor data governance practices can lead to data inconsistency, lack of data lineage, and data ownership issues. Effective data governance is crucial for maintaining data quality and integrity throughout the analytics process.

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

In the dynamic realm of Industry 4.0, where data-driven technologies and manufacturing processes intersect, the role of business analytics in process optimization cannot be overstated. This transformative landscape has redefined the way businesses operate, emphasizing the pivotal role of data analytics in achieving operational excellence. From real-time monitoring to predictive maintenance, from quality control to sustainability, business analytics is the cornerstone upon which organizations build their path to success in this new era.

The advantages of leveraging business analytics are numerous. It empowers organizations to make data-driven decisions, leading to more accurate and strategic choices. Through efficiency improvements, predictive capabilities, cost reduction, and better resource allocation, businesses can enhance their operations and maintain a competitive edge. It also fosters improved customer experiences, better risk management, scalability, and regulatory compliance.

However, it's vital to recognize the challenges that come hand-in-hand with integrating business analytics into process optimization. Data quality issues, data integration challenges, and the scarcity of skilled analysts are common hurdles that need to be addressed. The high implementation costs, resistance to change, and over-reliance on historical data can pose significant roadblocks. Misalignment with business strategy, vendor lock-in, and a lack of real-time analytics also require careful consideration. Measuring ROI, tackling cultural and organizational challenges, and establishing effective data governance further add to the complexity.

In conclusion, the transformative potential of business analytics in process optimization within Industry 4.0 conditions is substantial. While it offers a multitude of benefits, it is not without its challenges. To harness the full potential of business analytics for process optimization, organizations must acknowledge and address these obstacles diligently. By doing so, they can unlock the power of data-driven decision-making and stay at the forefront of their respective industries, ultimately ensuring their competitiveness in a rapidly evolving and interconnected industrial landscape.

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