FORECASTING DEMAND – UTILIZING BUSINESS ANALYTICS IN INDUSTRY 4.0 ENVIRONMENTS

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Purpose: The purpose of this publication is to present the applications of usage of business analytics in demand forecasting.

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 rise of Industry 4.0 has revolutionized the business landscape by creating a data-rich environment fueled by interconnected devices and digital systems throughout the supply chain. In this era, business analytics emerges as a crucial tool, leveraging the abundance of data to uncover intricate patterns and trends in consumer behavior, market dynamics, and product demand. By analyzing historical data and integrating external factors, business analytics enables more accurate demand forecasts, essential for effective inventory management, production planning, and overall business success. Advanced analytics techniques such as machine learning and predictive modeling thrive in Industry 4.0 environments, enabling businesses to process large datasets and predict future demand with precision. Moreover, business analytics facilitates the integration of demand forecasting with other supply chain components, optimizing resource allocation and enhancing efficiency. Industry 4.0 also fosters greater customization and personalization of products and services through market segmentation analysis and tailored forecasting, driving competitive advantage. This publication has explored the applications of business analytics in demand forecasting, emphasizing its importance, aspects, software applications, advantages, and challenges within the Industry 4.0 context. By addressing these aspects, organizations can harness the power of business analytics to optimize operations, foster growth, and stay competitive in today's dynamic business environment.

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; demand forecasting.

Category of the paper: literature review.

1. Introduction

Industry 4.0 generates a wealth of data from interconnected devices, sensors, and digital systems throughout the supply chain. Business analytics harnesses this data abundance to discern intricate patterns and trends in consumer behavior, market dynamics, and product demand. By analyzing vast datasets, businesses can derive actionable insights that inform more accurate demand forecasts. The real-time nature of Industry 4.0 operations necessitates agile and responsive forecasting capabilities. Business analytics enables organizations to conduct real-time analysis of incoming data streams, allowing for dynamic adjustments to demand forecasts in line with evolving market conditions. This agility ensures that businesses can swiftly adapt their production, inventory, and distribution strategies to meet fluctuating demand patterns.

Advanced analytics techniques such as machine learning and predictive modeling thrive in Industry 4.0 environments. These techniques excel at processing and analyzing large volumes of data to uncover hidden correlations and predict future demand with greater precision. By leveraging predictive models, businesses can anticipate demand variations, optimize resource allocation, and mitigate the risks associated with supply chain disruptions or market volatility. In addition, business analytics facilitates the integration of demand forecasting with other key components of the Industry 4.0 supply chain, such as inventory management, production planning, and logistics. By aligning demand forecasts with operational processes, businesses can optimize inventory levels, streamline production schedules, and enhance overall supply chain efficiency (Akundi et al., 2022).

Industry 4.0 enables greater customization and personalization of products and services to meet individual customer preferences. Business analytics enables businesses to segment markets, analyze customer behavior, and tailor demand forecasts to specific customer segments or product configurations. This customization enhances customer satisfaction, fosters brand loyalty, and drives competitive advantage in the marketplace.

The purpose of this publication is to present the applications of usage of business analytics in demand forecasting.

2. The selected aspects of business analytics usage in demand forecasting

Business analytics plays a crucial role in demand forecasting, serving as a cornerstone for strategic decision-making within organizations. Demand forecasting involves predicting future customer demand for products or services, which is essential for effective inventory management, production planning, and overall business success (Gajdzik, Wolniak, 2022;

Gajdzik et al., 2023). In the realm of demand forecasting, business analytics leverages historical data, statistical models, and advanced algorithms to analyze patterns, trends, and anomalies in past sales or demand data. By understanding historical demand patterns, businesses can identify seasonal fluctuations, cyclical trends, and other factors influencing consumer behavior (Zeng et al., 2022; Pech, Vrchota, 2022).

Business analytics also integrates external factors such as market trends, economic indicators, demographic shifts, and competitive intelligence into the forecasting process. This broader contextual understanding helps businesses anticipate changes in demand resulting from external factors, enabling proactive adjustments to production, inventory levels, and marketing strategies (Scappini, 2016). Moreover, advanced analytics techniques such as machine learning and predictive modeling enhance the accuracy of demand forecasts by identifying complex patterns and correlations within data sets (Sułkowski, Wolniak, 2015, 2016, 2018; Wolniak, Skotnicka-Zasadzień, 2008, 2010, 2014, 2018, 2019, 2022; Gajdzik, Wolniak, 2023; Swarnakar et al., 2023). These techniques enable businesses to develop more nuanced forecasts that account for various influencing factors and potential uncertainties (Bakir, Dahlan, 2022).

Additionally, business analytics facilitates scenario analysis and "what-if" simulations, allowing organizations to assess the impact of different scenarios on future demand (Cillo et al., 2022). By modeling various scenarios, businesses can evaluate the potential outcomes of different strategies and make informed decisions to optimize their operations and resources (Wolniak, Grebski, 2018; Wolniak et al., 2019, 2020; Wolniak, Habek, 2015, 2016; Wolniak, Skotnicka, 2011; Wolniak, Jonek-Kowalska, 2021; 2022). Furthermore, the integration of real-time data sources and technologies like Internet of Things (IoT) devices and social media analytics enhances the agility and responsiveness of demand forecasting processes. Real-time data enables businesses to adapt quickly to changing market dynamics and consumer preferences, thereby improving forecast accuracy and reducing the risk of stockouts or excess inventory (Ghibakholl et al., 2022).

Table 1 contains descriptions of how business analytics is used in the case of demand forecasting.

Table 1.
The usage of business analytics in demand forecasting

Aspect of demand forecasting	Description of Usage of Business Analytics
Historical Data Analysis	Utilizes past sales or demand data to identify patterns, trends, and anomalies, providing insights into historical demand behavior. Historical data analysis forms the foundation for building statistical models and forecasting algorithms.
Integration of External Factors	Incorporates external factors such as market trends, economic indicators, demographic shifts, and competitive intelligence into the forecasting process. By considering these factors, businesses can anticipate changes in demand influenced by external variables.

Cont. table 1.

Advanced Analytics Techniques	Leverages advanced analytics techniques such as machine learning, predictive modeling, and data mining to enhance the accuracy of demand forecasts. These techniques identify complex patterns and correlations within data sets, enabling more nuanced and precise forecasting.
Scenario Analysis and What-If Simulations	Conducts scenario analysis and "what-if" simulations to assess the impact of different scenarios on future demand. By modeling various scenarios, organizations can evaluate the potential outcomes of different strategies and make informed decisions to optimize operations.
Real-Time Data Integration	Integrates real-time data sources and technologies like IoT devices and social media analytics to enhance the agility and responsiveness of demand forecasting processes. Real-time data enables businesses to adapt quickly to changing market dynamics and consumer preferences.
Forecasting Accuracy Improvement	Aims to improve forecasting accuracy by continuously refining models, incorporating new data sources, and evaluating the performance of forecasting algorithms. Enhanced forecasting accuracy minimizes the risk of stockouts or excess inventory, leading to optimized resource allocation.
Demand Sensing and Dynamic Demand Forecasting	Utilizes demand sensing techniques and dynamic demand forecasting models to capture short-term demand fluctuations and respond quickly to changes in consumer behavior. These approaches enable businesses to adapt their operations in real-time to meet evolving demand patterns.
Inventory Optimization	Applies business analytics to optimize inventory levels by balancing supply and demand, reducing carrying costs, and minimizing the risk of stockouts or overstock situations. Inventory optimization ensures efficient allocation of resources and enhances overall supply chain performance.
Market Segmentation Analysis	Conducts market segmentation analysis using business analytics to identify distinct customer segments with unique demand patterns and preferences. By tailoring marketing strategies and product offerings to specific segments, businesses can optimize demand forecasting and enhance customer satisfaction.

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 demand forecasting analysis in Industry 4.0 conditions

Business analytics software plays a crucial role in demand forecasting by leveraging advanced data analysis techniques to predict future customer demand. These software solutions enable businesses to analyze large volumes of historical sales data, market trends, and external factors to generate accurate forecasts. By employing statistical models, machine learning algorithms, and time-series analysis, business analytics software identifies patterns, trends, and correlations within the data, allowing organizations to anticipate changes in demand and optimize resource allocation accordingly (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; Stecuła, Wolniak, 2022; Olkiewicz et al., 2021). Furthermore, business analytics software offers features such as interactive dashboards, data visualization tools, and scenario analysis capabilities, enabling

users to explore data insights, communicate forecasting results, and assess the impact of different scenarios on future demand. With the ability to integrate with other enterprise systems and collaborate in real-time, these software solutions facilitate cross-functional collaboration and alignment of demand forecasting processes across the organization (Adel, 2022).

Cloud-based business analytics software provides the flexibility and scalability needed to adapt to dynamic market conditions and evolving business requirements. By harnessing the power of business analytics software, organizations can make informed decisions, minimize risks, and capitalize on market opportunities, ultimately driving growth and competitiveness in today's rapidly changing business landscape (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 demand forecasting, along with descriptions of their usage.

Table 2.
The usage of business analytics software in demand forecasting

Software/Application	Description	Key Features
Tableau	Tableau is a data visualization software that allows businesses to analyze and visualize large datasets to uncover insights relevant to demand forecasting. It enables users to create interactive dashboards and reports, making it easier to explore data trends and patterns. With Tableau, businesses can visualize historical demand data, identify correlations, and communicate forecasting results effectively to stakeholders.	• Interactive dashboards and reports • Visualization of historical demand data • Data exploration tools
SAS Forecast Server	SAS Forecast Server is a forecasting software solution that utilizes advanced analytics techniques to generate accurate demand forecasts. It employs statistical models, machine learning algorithms, and time-series analysis to predict future demand based on historical data and relevant factors. SAS Forecast Server offers automated forecasting capabilities, enabling businesses to streamline the forecasting process and achieve greater accuracy in demand predictions.	• -Statistical models and machine learning algorithms • Time-series analysis • Automated forecasting
IBM Planning Analytics	IBM Planning Analytics is a comprehensive planning and forecasting software platform that integrates business analytics with performance management capabilities. It enables businesses to create demand forecasting models, scenario analysis, and predictive modeling to optimize resource allocation and decision-making. IBM Planning Analytics offers collaborative features, allowing teams to collaborate on forecasting projects and share insights across the organization.	• Demand forecasting models - Scenario analysis • Predictive modelling • Collaboration features
Oracle Demand Planning	Oracle Demand Planning is a cloud-based demand forecasting solution that helps businesses optimize inventory levels, production schedules, and supply chain operations. It leverages historical sales data, market trends, and external factors to generate accurate demand forecasts. Oracle Demand Planning offers advanced analytics capabilities, such as predictive analytics and what-if analysis, enabling businesses to anticipate demand fluctuations and make data-driven decisions.	• Cloud-based demand forecasting • Predictive analytics • What-if analysis

Cont. table 2.

Microsoft Power BI	Microsoft Power BI is a business intelligence platform that enables businesses to analyze data, create visualizations, and share insights across the organization. It provides tools for data preparation, visualization, and interactive reporting, making it suitable for demand forecasting applications. With Microsoft Power BI, businesses can analyze historical demand data, identify trends, and generate forecasts to support decision-making processes.	• Data preparation tools • Data visualization • Interactive reporting
SAP Integrated Business Planning	SAP Integrated Business Planning (IBP) is an end-to-end planning solution that encompasses demand planning, supply chain planning, and inventory optimization. It leverages advanced analytics and machine learning algorithms to generate accurate demand forecasts and optimize inventory levels. SAP IBP offers real-time collaboration capabilities, enabling cross-functional teams to collaborate on demand forecasting projects and align planning processes across the organization.	• End-to-end planning solution • Advanced analytics and machine learning • Real-time collab

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 demand forecasting

Utilizing business analytics in demand forecasting offers a multitude of advantages that contribute to improved decision-making, operational efficiency, and overall business performance. One significant advantage is the enhancement of forecast accuracy. By leveraging advanced analytics techniques such as statistical models and machine learning algorithms, businesses can analyze historical data and identify patterns, trends, and correlations. This leads to more precise predictions of future demand, enabling better resource allocation, reduced stockouts, and ultimately, enhanced customer satisfaction. Furthermore, business analytics facilitates better decision-making by providing decision-makers with actionable insights derived from data analysis (Charles et al., 2023). Visualizing trends, identifying opportunities, and assessing the impact of different scenarios enable organizations to make informed decisions that optimize inventory levels, production schedules, and marketing strategies. This strategic approach leads to more efficient operations, cost savings, and a competitive advantage in the market.

Real-time monitoring and adaptation are also key benefits of using business analytics in demand forecasting. With the ability to analyze data streams in real-time, businesses can identify emerging trends, respond to fluctuations in demand promptly, and adjust forecasting models dynamically. This agility enables organizations to minimize inventory costs, reduce excess inventory, and capitalize on opportunities in the market. Integration with supply chain

processes is another advantage of business analytics in demand forecasting. By aligning forecasting with inventory management, production planning, and logistics, businesses can optimize resource allocation, streamline operations, and improve supply chain efficiency. This integration ensures better coordination across the supply chain, reduces lead times, and enhances overall operational performance (Nourani, 2021).

Moreover, business analytics contributes to improved customer satisfaction by enabling businesses to anticipate customer demand more accurately and align their offerings with customer preferences. By analyzing customer behavior, market trends, and sentiment analysis, organizations can tailor products, promotions, and pricing strategies to meet customer needs effectively. This leads to increased brand loyalty and higher revenue generation. Additionally, cost savings and resource optimization are achieved through the use of business analytics in demand forecasting. By generating accurate demand forecasts, businesses can minimize excess inventory, reduce carrying costs, and avoid stockouts or overproduction. This leads to improved cash flow and a more efficient use of resources across the supply chain. Table 3 contains the advantages of using business analytics in demand forecasting within Industry 4.0 conditions, along with descriptions for each advantage. This table outlines the advantages of using business analytics in demand forecasting, including improved forecast accuracy, enhanced decision-making, real-time monitoring and adaptation, integration with supply chain processes, improved customer satisfaction, cost savings and resource optimization, and scalability and flexibility. Each advantage highlights how business analytics empowers organizations to optimize operations, drive growth, and gain a competitive edge in today's dynamic business environment (Greasley, 2019).

Table 3.
The advantages of using business analytics in demand forecasting

Advantage	Description
Improved Forecast Accuracy	Business analytics enhances forecast accuracy by analyzing historical data, identifying patterns, and utilizing advanced algorithms to generate more precise predictions. By leveraging statistical models, machine learning, and predictive analytics, businesses can anticipate changes in demand more accurately, leading to better resource allocation, reduced stockouts, and improved customer satisfaction.
Enhanced Decision-Making	Business analytics provides decision-makers with actionable insights derived from data analysis, enabling informed decision-making in demand forecasting. By visualizing trends, identifying opportunities, and assessing the impact of different scenarios, businesses can make strategic decisions to optimize inventory levels, production schedules, and marketing strategies. This leads to more efficient operations, cost savings, and a competitive advantage in the market.
Real-Time Monitoring and Adaptation	Business analytics enables real-time monitoring of demand patterns and market trends, allowing businesses to adapt quickly to changing conditions. With the ability to analyze data streams in real-time, organizations can identify emerging trends, respond to fluctuations in demand, and adjust forecasting models dynamically. This agility enables businesses to minimize inventory costs, reduce excess inventory, and capitalize on opportunities in the market.

Cont. table 3.

Integration with Supply Chain Processes	Business analytics integrates demand forecasting with other supply chain processes such as inventory management, production planning, and logistics. By aligning forecasting with these processes, businesses can optimize inventory levels, streamline production schedules, and improve supply chain efficiency. This integration ensures better coordination across the supply chain, reduces lead times, and enhances overall operational performance.
Improved Customer Satisfaction	Business analytics enables businesses to anticipate customer demand more accurately and align their offerings with customer preferences. By analyzing customer behavior, market trends, and sentiment analysis, organizations can tailor products, promotions, and pricing strategies to meet customer needs effectively. This leads to improved customer satisfaction, increased brand loyalty, and higher revenue generation.
Cost Savings and Resource Optimization	Business analytics helps businesses optimize resource allocation and reduce costs associated with inventory holding, stockouts, and production inefficiencies. By generating accurate demand forecasts, organizations can minimize excess inventory, reduce carrying costs, and avoid stockouts or overproduction. This leads to cost savings, improved cash flow, and a more efficient use of resources across the supply chain.
Scalability and Flexibility	Business analytics software offers scalability and flexibility to adapt to changing business requirements and accommodate growth. Whether it's scaling up to handle larger datasets or customizing forecasting models to specific business needs, analytics solutions provide the agility needed to meet evolving demands. This scalability ensures that businesses can continue to leverage analytics effectively as they expand operations, enter new markets, or introduce new products and services.

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 demand forecasting 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 demand forecasting

Problem	Description
Data Quality Issues	One of the primary challenges in using business analytics for demand forecasting is the quality of data. Inaccurate, incomplete, or inconsistent data can lead to unreliable forecasts and erroneous decision-making. Data quality issues may arise from various sources, including errors in data entry, discrepancies between systems, and missing or outdated information. Addressing data quality issues requires robust data governance processes, data cleaning techniques, and continuous monitoring to ensure the accuracy and reliability of forecasting models.
Complexity of Analysis	Another challenge is the complexity of analysis involved in business analytics for demand forecasting. Analyzing large volumes of data, applying advanced statistical models, and interpreting complex algorithms require specialized skills and expertise. Organizations may face difficulties in hiring and retaining qualified data analysts or data scientists capable of conducting sophisticated analysis. Moreover, the complexity of analysis may result in longer processing times, making it challenging to generate timely forecasts and respond quickly to changes in demand.

Cont. table 4.

Lack of Integration with Business Processes	Business analytics solutions for demand forecasting may face challenges in integrating with existing business processes and systems. Siloed data sources, disparate software platforms, and organizational barriers may hinder seamless integration, leading to inefficiencies and data discrepancies. Without proper integration, businesses may struggle to leverage the full potential of analytics insights in decision-making and fail to realize the benefits of demand forecasting. Overcoming integration challenges requires alignment between IT and business stakeholders, investment in interoperable systems, and a cohesive data strategy.
Uncertainty and Volatility in the Market	Market uncertainty and volatility pose significant challenges to demand forecasting using business analytics. External factors such as economic conditions, regulatory changes, and geopolitical events can have unpredictable impacts on consumer behavior and demand patterns. Moreover, sudden shifts in market trends, emergence of new competitors, or disruptive technologies may invalidate existing forecasting models and render forecasts inaccurate. Addressing market uncertainty and volatility requires robust risk management practices, scenario planning techniques, and the flexibility to adapt forecasting models in response to changing market dynamics.
Overreliance on Historical Data	An inherent challenge in demand forecasting using business analytics is the overreliance on historical data. While historical data provides valuable insights into past demand patterns, it may not always capture emerging trends, market disruptions, or changes in consumer preferences. Relying solely on historical data without considering external factors or qualitative insights can lead to biases in forecasting models and missed opportunities. To mitigate the risk of overreliance on historical data, businesses need to complement quantitative analysis with qualitative inputs, market research, and expert judgment to capture the full spectrum of demand drivers.
Technology and Infrastructure Limitations	Technology and infrastructure limitations can impede the effectiveness of business analytics in demand forecasting. Legacy systems, outdated software, and inadequate IT infrastructure may lack the capabilities to handle large datasets, perform complex analytics, or support real-time forecasting. Moreover, scalability issues, data security concerns, and compatibility issues with emerging technologies can hinder the adoption and deployment of advanced analytics solutions. Addressing technology and infrastructure limitations requires investment in modernizing IT infrastructure, adopting cloud-based solutions, and leveraging emerging technologies such as artificial intelligence and edge computing to enhance analytics capabilities.
Interpretation and Communication Challenges	Effective interpretation and communication of analytics insights pose challenges in demand forecasting. Complex statistical models and technical jargon may be difficult for non-specialists to understand, leading to misinterpretation or mistrust of forecasting results. Moreover, presenting forecasts in a meaningful and actionable format to decision-makers requires effective communication skills and data visualization techniques. Overcoming interpretation and communication challenges requires fostering a data-driven culture, providing training and education on analytics concepts, and utilizing visualization tools to convey insights in a clear and concise manner.

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 ushered in a data-rich environment where interconnected devices and digital systems generate vast amounts of data across the supply chain. Leveraging this data abundance, business analytics emerges as a powerful tool for discerning intricate patterns and trends in consumer behavior, market dynamics, and product demand. Through the

analysis of historical data and integration of external factors, business analytics facilitates more accurate demand forecasts, crucial for effective inventory management, production planning, and overall business success. In the realm of demand forecasting, advanced analytics techniques such as machine learning and predictive modeling thrive in Industry 4.0 environments. These techniques enable businesses to process large datasets, uncover hidden correlations, and predict future demand with greater precision. Moreover, business analytics facilitates the integration of demand forecasting with other key components of the supply chain, optimizing resource allocation, streamlining production schedules, and enhancing overall efficiency.

Industry 4.0 also enables greater customization and personalization of products and services to meet individual customer preferences. Through market segmentation analysis and tailored forecasting, businesses can optimize demand forecasting and drive competitive advantage in the marketplace. This publication has presented the applications of business analytics in demand forecasting, highlighting its importance, selected aspects, software applications used, advantages, and challenges within the Industry 4.0 context. By understanding and addressing these aspects, organizations can harness the power of business analytics to optimize operations, drive growth, and gain a competitive edge in today's dynamic business landscape.

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