International Business and Global Economy 2024, no. 43, pp. 19–32

Edited by the Institute of International Business, University of Gdańsk
ISSN 2300-6102
e-ISSN 2353-9496 https://doi.org/10.26881/ibage.2024.43.02

Grzegorz Kruk
Gdańsk Banking University

Big data in supply chain management – a case study of a printing enterprise

The aim of the article is to identify the benefits of applying the concept of big data as a significant tool for managing and optimizing the supply chain and logistic processes to gain a competitive advantage in the printing industry. The article explains the concept of big data and presents its main characteristics. Subsequently, it highlights the areas of application of big data and provides examples of its usage in the supply chain of printing enterprises. Research indicates that big data analysis can significantly contribute to the development of the printing industry and the functioning of its supply chain links.

Keywords: big data, supply chain management, logistics, analysis

JEL classification: D24, L69, O14

Introduction

Big data refers to vast or complex data sets that typically exceed the scale of exabytes. They surpass traditional systems in terms of storage, processing, monitoring, analysis, and data visualization capabilities [Kaisler et al., 2023]. Currently, the volume of data is growing exponentially, and it is predicted to reach several or even tens of zettabytes annually [Dragun, Kuczyńska, 2023].

Scientists and experts agree that the rapid growth of data opens up new, innovative possibilities. Companies worldwide are striving to develop and enhance their capabilities to analyse large datasets to gain a deeper understanding of their value. The concept of big data is constantly evolving, with most of its features now encapsulated in the "5 V" concept: variety, veracity, velocity, volume and value [Alsolbi et al., 2023]. The world of science has long emphasized that big data is a key factor influencing company performance [Kozłowska, 2020]. Thanks to advances in big data, businesses can better understand customer needs, improve service levels, enhance sales performance and revenue, and explore new markets.

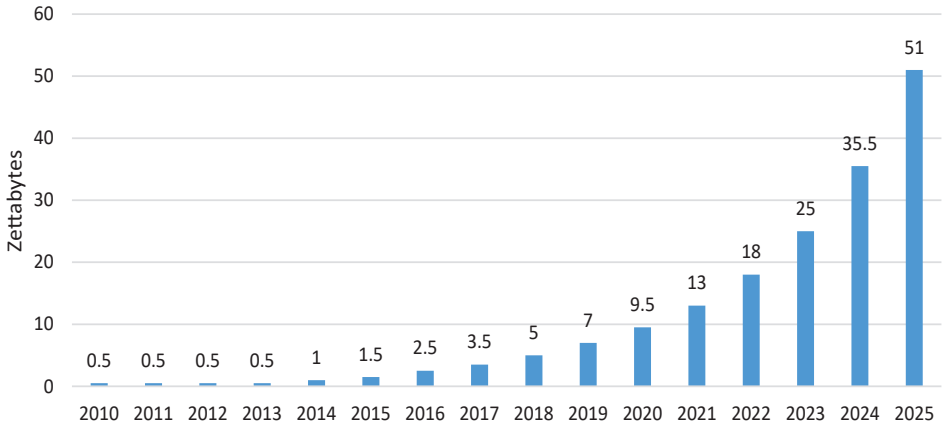

Figure 1. Annual data volume worldwide in zettabytes (trillions of gigabytes)
Source: [Statista].

Scientific research has shown that the utilization of big data in various sectors such as finance, marketing, banking, insurance, logistics and manufacturing can significantly contribute to their development [Tamym et al., 2020]. This article also presents the benefits of utilizing big data, but this time in the printing industry, focusing on creating new value and enhancing relationships in the supply chain. To achieve this goal, the article first defines key concepts related to big data and discusses their role in predicting the future in the supply chain. It then focuses on the importance of statistical analysis, simulation, and optimization in supply chain analytics. Finally, it presents specific applications of big data in various areas of the supply chain in the printing industry, followed by conclusions regarding the benefits of big data analysis in the supply chain in this industry.

1. Purpose and research methodology

The aim of the study was to identify the benefits of implementing the new concept of big data resulting from its characteristics. The analysis also aimed to assess the significance of this concept for supply chains and logistics in a printing company that has already adopted this solution. Data for the analysis were collected from literature on big data, company reports and information provided by employees involved in analysis, logistics and supply chain management within the discussed company. Additionally, information from articles published on platforms focusing on logistics, analysis and business, both in Polish and English, was included.

2. Characteristics of big data

To fully understand the impact and application of big data, we must first have a solid understanding of what this concept entails. Put simply, big data refers to a massive amount of data. This term specifically refers to datasets of such a large size that they no longer fit into computer memory. These data can be captured, stored, transmitted, aggregated and analysed. As the volume of data has grown, there has been a need to modernize the tools used for their analysis. Accordingly, these data do not fit into the traditional model where they are organized in columns and rows. Big data comes from various sources and encompasses diverse types of data: structured, semi-structured and completely unstructured. According to a different approach, these data can include numbers, images, sound, text and discourse. They can originate from technologies such as radio frequency identification (RFID), global positioning system (GPS), point of sale (POS), as well as from social media platforms like Twitter, Instagram, Facebook, call centres or customer blogs. Today's advanced analytical technologies allow for knowledge extraction from various types of data. Analytics is the combination of mathematics and statistics with large datasets. Big data analysis involves using statistics and mathematics to analyse large datasets. Big data without analytics is simply a vast amount of data. Over the years, individuals and companies have amassed huge amounts of data. On the other hand, analytics without large datasets is simply mathematical or statistical tools and applications. Nowadays, companies can extract insights from massive datasets thanks to the enormous computational power available at lower costs than ever before. The combination of big data and analytics allows for the creation of various tools that assist decision-makers in gaining valuable, meaningful insights and transforming information into business analysis.

3. Supply chain analytics

A supply chain is a collection of firms, from raw material suppliers to manufacturers or central organization, wholesalers, retailers, customers and end-users. In addition to physical flows such as material and product transfers, the supply chain also includes flows of information and finances. Supply chain analytics involves the use of big data analysis techniques to extract hidden, valuable knowledge from this process [Wamba, 2018a]. This analytics can be divided into descriptive, predictive and prescriptive analysis [Johnson, Bohle, 2019]. Well-planned and implemented decisions have a direct impact on financial outcomes by reducing costs of procurement, transportation, storage, inventory depletion and disposal. The use of big data

analytics techniques in solving supply chain management problems contributes to improving its efficiency. Managers and researchers have long applied statistical and operational research techniques to balance supply and demand [Johnson, Bohle, 2019]. However, recent developments in analytics have opened up new opportunities for managers and researchers. Figure 2 also shows the relationships between descriptive, predictive and prescriptive analytics in decision-making or actions.

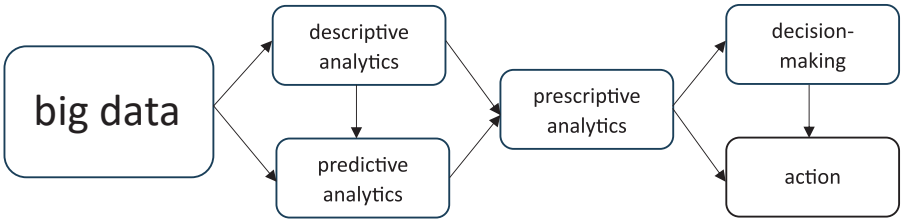

Figure 2. Utilizing descriptive, predictive and prescriptive analytics in decision-making and actions

Source: [Wyrembek, 2022].

The diverse potential benefits of data-driven decision-making have led researchers and scholars to explore the integration of large datasets in supply chains. As a result, the number of scholarly articles on this topic has increased in recent years. The significance of employing big data analytics techniques in supply chains is particularly crucial because organizations cannot succeed in today's competitive markets without utilizing these tools. Since 2010, many articles have been published emphasizing the importance of big data analytics in supply chains and the achievements in this field [Barbosa et al., 2018; Lamba, Singh, 2017; Nguyen et al., 2018; Wamba, 2018b]. Mishra et al. [2017] also identified influential researchers and articles with the highest number of citations by conducting a bibliometric analysis of large datasets. The results showed an increase in the number of articles related to big data analysis. Barbosa et al. [2018] conducted a systematic literature review examining the application of big data analytics in the supply chain area. They demonstrated that analytical techniques typically employ predictive and normative approaches, rather than descriptive ones. Dubey et al. [2018] conducted a study to identify the impact of large datasets and predictive analytics on aspects of sustainable development. Data were collected from 205 manufacturing firms and analysed using partial least squares structural equation modelling. The results showed a positive and significant impact of big data on the social and environmental aspects of sustainable development. Gupta et al. [2017] conducted a systematic literature review based on 28 articles in journals, examining the impact of big data analytics techniques on humanitarian supply chains. They proposed several important research directions based on key organizational theories. Zhao et al. [2017] proposed a green supply

chain optimization model using big data analytics, considering three different optimization scenarios. They utilized a data-driven approach for data acquisition and management. Song et al. [2018] investigated issues and challenges related to big data in the context of environmental performance evaluation, summarizing the latest achievements in environmental management based on big data technologies.

In descriptive analytics, the following issues are examined: what happened, what is currently happening, and why. This process utilizes visualization tools and online analytical processing systems, supported by reporting technology (e.g. RFID, GPS, transactional barcode), and real-time data to identify new opportunities and problems. Descriptive statistics are used to collect, describe and analyse raw data related to past events. This allows for the analysis and description of past events, enabling their interpretation and understanding by humans. Descriptive analytics enables organizations to draw conclusions from the past and understand the relationships between variables and their impact on future outcomes. It can be applied, for example, to present average amounts of money, inventory levels and annual changes in sales. Descriptive analytics is also useful in financial reporting, sales, operations and production within organizations

Predictive analytics techniques are used to answer the question of what may happen in the future by examining data trends from the past using statistical techniques, programming and simulation. The aim of these techniques is to discover the causes of events and phenomena and to accurately predict the future or supplement data or information that no longer exists. Statistical techniques do not provide predictions of the future with 100% accuracy. Predictive analytics is used to forecast purchasing patterns, customer behaviours, and sales trends to identify and forecast future sales actions. These techniques are also used to predict customer needs and manage inventory and operations.

Prescriptive analytics deals with the question of what should be done and how to achieve it. It is based on predictive and descriptive analysis, utilizing descriptive and predictive techniques, simulation, mathematical optimization, or multi-criteria decision-making techniques. The use of prescriptive analytics is complex, and most companies still struggle to apply it in their daily business operations. Proper use of prescriptive analytics techniques can lead to optimal and effective decision-making. Many large companies use data analysis to optimize production and inventory management. Key scenarios that prescriptive analytics allows companies to address include, but are not limited to:

- What offer should be proposed to each end customer?
- What should be the shipping strategy for each retail location?
- Which product should be introduced to the market and when?

In making decisions in the supply chain, statistical analysis, simulation, optimization and various techniques are utilized [Wyrembek, 2022].

4. Application of big data and supply chain management in a printing enterprise

There are numerous potential applications of big data analysis in various areas of enterprises. Virtually every area within a company can benefit from big data analysis. A literature review also indicates that big data analysis can be applied in many areas of enterprise supply chains [Nowakowska, 2023].

In the case of the discussed printing enterprise, data analysis is primarily used in areas such as supplier relationship management, product design and development, demand forecasting, procurement management, customization of products for customers, inventory management and broadly defined logistics. Data comes from both external channels and internal networks. A particular emphasis is placed on customer data, which enables precise determination of their needs and effective adaptation of offerings. This allows for selling them appropriate solutions, and analysing their purchasing behaviours helps predict their needs. Combining various data sources, such as demand and customer data, seasonality, historical data and trends in goods flow, enables demand forecasting. This, in turn, facilitates planning and optimizing distribution processes. Data is also generated in the production department, where it includes a network of sensors, devices on the production floor and production-supporting software updated by employees with various required data in real-time. Thanks to machine learning algorithms, inventory management devices can predict the completion date of new orders, facilitating planning and optimizing logistics processes. By using big data for more precise analysis and integration of all these data, the efficiency of the production, distribution, and sales processes is regularly monitored, and processes and devices are constantly observed. The enterprise consistently utilizes large data sets and analytical techniques to develop its supply chain areas, thereby reducing analytical errors or uncertainties in strategic decision-making to less than 5%.

5. Big data analysis and supplier relationship management in a printing enterprise

Supplier relationship management involves establishing discipline in strategic planning and managing all interactions with the organization's suppliers to mitigate the risk of failures and maximize the value of these interactions. For the discussed printing enterprise, building close relationships with key suppliers and strengthening cooperation with them is a key factor in discovering and creating new value, as well as reducing the risk of failures in supplier relationship

management. Strategic resources and supplier relationship management are critical success factors for the enterprise, which focuses on relationship management and collaboration [Nowakowska, 2023]. The big data analysis techniques used by the enterprise provide precise information on organizational spending patterns, which helps in supplier relationship management. For example, big data provides the enterprise with accurate data on the return on investment of any investment and supports in-depth analysis of a potential supplier. In the process of evaluating and selecting suppliers in the discussed enterprise, fuzzy synthetic evaluation and analytic hierarchy process are also utilized, considering the effectiveness of processing large data sets as one of the evaluated factors. Through big data analysis with the aforementioned indicators, the enterprise maintains a very stable position in the market, ensuring continuity of supplies to its customers. The aim of conducting big data analyses is to select a supplier partner who will be able to adapt, among other things, to future challenges related to large data sets [Wang et al., 2018].

6. Designing a big data analytics and supply chain network in a printing enterprise

In every enterprise, the design of the supply chain network constitutes a strategic decision that encompasses all aspects related to selecting supply chain partners and establishes the policies and programs of the enterprise aimed at achieving long-term strategic objectives [Prasad et al., 2018].

In the context of a printing enterprise, designing the supply chain network involved determining the physical configuration of the supply chain that impacts most business units and functional areas of the enterprise. In this context, a key element was also considering customer satisfaction and supply chain efficiency. The primary goal of supply chain design was to create a network of members capable of meeting the long-term strategic objectives of the enterprise. The following steps were applied in supply chain design:

- defining long-term strategic goals,
- determining the scope of the project,
- choosing the form of analysis to be conducted,
- selecting the tools to be utilized.

Ultimately, the optimal supply chain project was chosen, which entailed appropriate planning to gain significant competitive advantage. This project proposed a nonlinear mixed-integer model for the location of distribution centres, utilizing large datasets and randomly generated data for warehouse operations, customer demand forecasting, and transportation planning. It was also assumed that behavioural data would be analysed using marketing analytics tools, and large datasets

would provide essential information regarding costs, penalties, and service levels. It was deemed to be a powerful tool for designing complex distribution networks.

In selecting the appropriate project, consideration was also given to the application of big data analysis in project interventions, such as healthcare, disaster relief and education in the supply chain. The chosen project fully met the expectations of the enterprise, significantly contributing to its development and operational improvement.

7. Big data analysis and product design and development

One of the main challenges in the analysed printing company is ensuring that their products align with customer preferences. As customer preferences and expectations change throughout a product's lifecycle, those responsible for sales and distribution need tools to predict and measure these preferences and expectations. Insufficient information about customer preferences and expectations has always been a significant issue in the product design and sales process. However, with ongoing monitoring of customer behaviours and access to real-time data on customer preferences, sales representatives can now effectively meet customer expectations, achieving a prediction accuracy level exceeding 90%, which is a significant improvement compared to the pre-big data analysis tool implementation, which was around 60%. Through continuous monitoring of customer behaviours, sales representatives, along with the team responsible for production processes, generate vast amounts of data, considered as big data. Collecting and managing this vast data, as well as applying modern data analysis methods to derive valuable insights and information, and then translating them into actions, have significantly reduced the level of uncertainty.

Product design and development are often defined as the process of transforming customer needs into design specifications. Although there are various approaches to product design [Labbi et al., 2015], all these methods are applicable in the context of data science. The general outline of the design process is depicted in Figure 3.

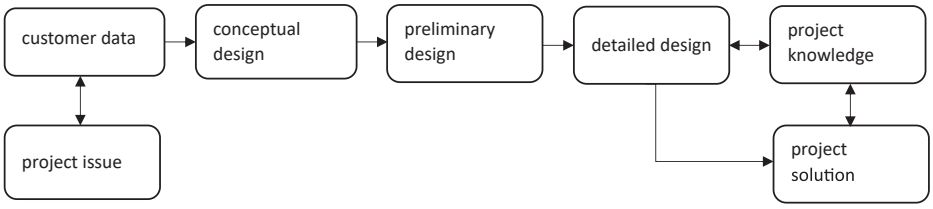

Figure 3. The design process from an analytics perspective
Source: [Suh, 2001].

The analysis of big data has an impact on numerous industries, and product design is no exception. This stems from the fact that an increasing number of businesses are leveraging various tools for designing manufacturing processes, which also integrate communication technologies. Consequently, it is essential to consider the specificities of a company's product during supply chain design and to integrate all partners and constraints of this chain. Designing the supply chain according to the product design allows for the creation of competitive advantage and flexibility in supply chain operations [Labbi et al., 2015].

The introduction of big data analysis into the product design process at the discussed printing company has led to the creation of new, unique products that perfectly align with customer preferences, effectively meeting their expectations. Utilizing big data analysis in product design has enabled the company to fully understand customer preferences and expectations, resulting in the creation of tailor-made products that meet their needs and preferences. Sales representatives continuously leverage available online data regarding customer behaviours and purchase histories to anticipate and understand their needs. Through constant access to data, they can identify product features and forecast future trends, continuously monitoring customer behaviours and needs and gathering insights from their feedback.

8. Big data analysis and demand forecasting in a printing enterprise

Many managers from various enterprises aim to improve demand forecasting and production planning using large datasets. Accurate demand forecasting has always been a crucial issue in supply chain management [Feng, Shanthikumar, 2018]. Current access to big data analytics in the printing enterprise allows for determining customer loyalty, predicting demand, and presenting optimal pricing data. Access to analytics also enables the identification of new market trends and the determination of root causes of issues, failures and defects.

Data analytics also enables predicting customer preferences and needs by analysing their behaviours, thereby stimulating creativity and innovation. Through the utilization of big data analysis tools, the enterprise manages to achieve over 90% accuracy in forecasting the demand of its loyal customers each year. Prior to the introduction of big data analysis tools, such high accuracy in demand forecasting was not achievable.

9. Big data analysis and procurement management in a printing enterprise

As tactical and operational decisions, procurement involves a range of mechanisms and contracting processes [Johnson, Bohle, 2019]. In a given printing enterprise, procurement planning encompasses a large volume of widely distributed data generated across various operations, systems, and geographic regions. The enterprise utilizes advanced analytical systems to manage this vast data and a team of skilled specialists capable of analysing the data and deriving valuable insights and knowledge from it.

In the past, the enterprise struggled with difficulties in manually collecting and analysing data. Such an approach would take many days or even weeks to obtain internal and structural data regarding the company's operations and transactions, as well as those of its partners. However, nowadays, with the utilization of big data analytics programs, diverse structural, unstructured, internal, and external data generated as a result of automated processes are analysed in real-time or in a very short period.

Additionally, by utilizing big data analytics tools, the enterprise analyses supplier performance and continuously evaluates supply chain risks, which was previously impossible. Such predictive analysis of large datasets has enabled the identification, assessment, mitigation, and management of risks within the supply chain. Through the utilization of this analysis, the enterprise achieves a procurement planning accuracy level of over 90% each year, whereas prior to the implementation of analytics, the enterprise achieved a maximum procurement planning accuracy of 60%.

10. Big data analysis and customized production in a printing enterprise

Thanks to big data analysis, manufacturers have the opportunity to discover new information and identify patterns that allow them to streamline processes, increase supply chain efficiency, and recognize factors influencing production. In today's global and highly complex environment, supply chains and production processes involve lengthy and intricate procedures. There is also the possibility of thoroughly examining all elements of each process and link in the supply chain to simplify processes and optimize the supply chain. Data analysis programs used in the discussed printing enterprise enable precise determination of actions and tasks for each employee on the production line through timely and accurate analysis of data from every part of the production process and detailed examination

of the entire supply chain. This capability enables the identification of bottlenecks and reveals poorly functioning processes and production components. In the past, centralized and large-scale production was not rational, as it focused solely on the needs of a small group of strategic clients. However, today's big data analysis used in the printing enterprise allows for very accurate prediction of requirements and preferences of all customers, including especially preferences for non-standard products, enabling the enterprise to create products perfectly tailored to customer needs.

11. Big data analysis and inventory management in a printing enterprise

Inventory control encompasses processes of demand forecasting, inventory management, procurement, and supply synchronization. Key objectives of inventory control project include:

- monitoring inventory levels and required stock quantities,
- facilitating timely replenishment of inventory through automatic recording and handling of pending orders,
- minimizing inventory levels through analysis of past purchasing and consumption patterns,
- utilizing automated inventory management, handling, and procurement tools,
- improving financial control through regular inventory checks and physical counts.

These objectives aim to enhance operational efficiency, optimize inventory levels, reduce costs and ensure smooth supply chain operations in the printing enterprise.

The integration of business systems supported by big data has significantly increased operational efficiency in the printing enterprise, simultaneously bringing greater profitability. Through continuous monitoring and analysis of operational data, sales representatives have better access to metrics, resulting in increased efficiency and the elimination of bottlenecks. Big data analysis has also improved the performance of the entire supply chain, with real-time data access enabling immediate response to changes in demand and consumer trends. Directors, including those in finance, can constantly monitor and analyse data, enabling them to make better investment decisions, thereby increasing profitability. Sales representatives have the ability to adjust inventory levels to current orders and customer preferences, contributing to increased customer satisfaction. Additionally, data analysis is used to predict increases and decreases in demand as well as seasonal trends, allowing for more accurate inventory planning in different periods.

12. Big data analysis and logistics in a printing enterprise

In recent years, every industry has experienced significant transformation driven by the increasing volume of data, growing emission concerns, complex regulatory requirements, evolving business models, and limitations related to human resources, infrastructure, and technological development. In the discussed printing enterprise, a priority has been the standardization of data exchange structure and content to streamline communication and collaboration across various logistics sectors, such as freight forwarders, manufacturers, logistics companies, distributors, and end customers, for example, printing houses. Cost reduction through inventory optimization, real-time event response, and resource sharing has become crucial for effective supply chain management and big data analysis in the enterprise.

Currently, due to the vast amount of data from various sources and the integration of business intelligence and data, advanced systems are being used to enable rapid data analysis and provide real-time information for quick decision-making. With the exponential growth in the number of orders, the enterprise requires huge datasets and real-time analysis methods to manage orders and maintain high-quality production. Through the daily generation of large amounts of data related to shipped parcels, such as size, weight, origin and destination, the enterprise utilizes the best available system solutions for data analysis and improving operational efficiency and customer service.

The data platforms and data analysis processes in the discussed enterprise have been designed to translate insights into actions and adapt them dynamically in line with the company's strategic vision, which emphasizes the aspiration to be a progressive enterprise leveraging comprehensive analysis to gain valuable insights and invest in advanced analytical systems and tools.

The discussed enterprise actively strives to stay ahead of market changes in the printing industry by leveraging advanced management and data analysis technologies and transitioning to modern, sophisticated data management and analysis techniques. It aims to be a knowledge-based enterprise, utilizing the latest analytical systems to acquire valuable insights and continuously analysing various observations in both internal processes and relationships with customers and business partners.

The company also aims to embrace the concept of "information without borders" in communication among customers, business partners, and suppliers in the printing industry, with whom it maintains strategic alliances. The vast array of data generated by these entities is integrated into logistics technologies, such as supply chain management solutions and IoT devices, enabling data sharing and access for all involved parties.

The supply chain platform of the enterprise manages and integrates diverse data originating from various internal and external systems, while also ensuring

appropriate validation and management to enhance data reliability. It also provides business users with suitable tools for conducting exploratory analyses and generating insights independently.

Conclusions

Big data analysis has become a critical practical issue in today's enterprises, offering a wide range of development opportunities through the appropriate utilization of analytical techniques. This article attempts to illustrate both basic and latest applications of big data analysis using a printing enterprise as a case study. Special attention is given to key techniques used in supply chain management, which are significant from a managerial perspective.

The article demonstrates the importance of proper data analysis in the context of the entire supply chain, including areas such as supplier relationship management, product design, demand planning, inventory management, logistics network design, production, procurement, logistics, and distribution. The utilization of large datasets and advanced analytical techniques in the discussed printing enterprise has led to significant improvements in supply chain processes, enabling the achievement of over 90% accuracy in predicting customer demand each year.

Furthermore, big data analysis supports sustainable development of the supply chain in the enterprise, aiding in the management and integration of diverse data in the global supply chain. These innovative approaches have contributed to the establishment of a significant competitive advantage for the printing enterprise in the market.

References

Alsolbi I., Shavaki F.H., Agarwal R., Bharathy G.K., Prakash S., Prasad S., 2023, *Big data optimisation and management in supply chain management: A systematic literature review*, Artificial Intelligence Review, no. 56.

Barbosa M.W., Vicente A.D., Ladeira M.B., Oliveira M.P., 2018, *Managing supply chain resources with big data analytics: A systematic review*, International Journal of Logistics Research and Applications, no. 3.

Dragun Ł., Kuczyńska K., 2023, *Wykorzystanie potencjału Big Data jako narzędzia innowacyjnego w dziedzinie logistyki*, Akademia Zarządzania, no. 3.

Dubey R., Altay N., Gunasekaran A., Blome C., Papadopoulos T., Childe S.J., 2018, *Supply chain agility, adaptability and alignment: Empirical evidence from the Indian auto components industry*, International Journal of Operations & Production Management, no. 1.

Feng Q., Shanthikumar J.G., 2018, *How research in production and operations management may evolve in the era of big data*, Production and Operations Management, no. 9.

Gupta S., Altay N., Luo Z., 2017, *Big data in humanitarian supply chain management: A review and further research directions*, Annals of Operations Research, no. 283.

Johnson L., Bohle A., 2019, *Supply chain analytics implications for designing supply chain networks*, Master's thesis, Jönköping University.

Kaisler S., Espinosa J.A., Armour F., Money W.H., 2023, *Big data and analytics: Issues and challenges for the past and next ten years* [in:] *Proceedings of the 56th Hawaii International Conference on System Sciences*, University of Hawaii, Mānoa.

Kozłowska J., 2020, *Metodyka analizy strategicznej przedsiębiorstwa na potrzeby integracji produktowo-usługowej*, Oficyna wydawnicza Politechniki Białostockiej, Białystok.

Lamba K., Singh S.P., 2017, *Big data in operations and supply chain management: Current trends and future perspectives*, Production Planning and Control, nos. 11–12.

Labbi O., Ouzizi L., Douimi M., 2015, *Simultaneous design of a product and its supply chain integrating reverse logistic operations: An optimization model*, Xème Conférence Internationale: Conception et Production Intégrées, Tanger, Morocco.

Mishra D., Luo Z., Jiang S., Papadopoulos T., Dubey R., 2017, *A bibliographic study on big data: Concepts, trends and challenges*, Business Process Management Journal, no. 3.

Suh P.N., 2001, *Axiomatic design: Advances and applications*, Oxford University Press, New York.

Nguyen T., Li Z.H., Spiegler V., Ieromonachou P., Lin Y., 2018, *Big data analytics in supply chain management: A state-of-the-art literature review*, Computers and Operations Research, no. 98.

Nowakowska P., 2023, *Nowe technologie w rozwoju i zarządzaniu przedsiębiorstwem*, Zarządzanie Innowacyjne w Gospodarce i Biznesie, no. 1.

Prasad S., Zakaria R., Altay N., 2018, *Big data in humanitarian supply chain networks: A resource dependence perspective*, Annals of Operations Research, nos. 1–2.

Song M.L., Fisher R., Wang J.L., Cui L.B., 2018, *Environmental performance evaluation with big data: Theories and methods*, Annals of Operations Research, nos. 1–2.

Statista, n.d., *Annual size of real time data in the global datasphere from 2010 to 2025*, https://www.statista.com/statistics/949144/worldwide-global-datasphere-real-time-data-annual-size [access: 2.01.2025].

Tamym L., Benyoucef L., Nait Sidi Moh A., *Big data for supply chain management in industry 4.0 context: A comprehensive survey*, 13th International Conference on Modeling, Optimization and Simulation – MOSIM.

Wamba S.F., Gunasekaran A., Papadopoulos T., Ngai E., 2018a, *Big data analytics in logistics and supply chain management*, The International Journal of Logistics Management, no. 2.

Wamba S.F., Gunasekaran A., Dubey R., Ngai E., 2018b, *Big data analytics in operations and supply chain management*, Annals of Operations Research, nos. 1–2.

Wang G., Gunasekaran A., Ngai E., 2018, *Distribution network design with big data: Model and analysis*, Annals of Operations Research, nos. 1–2.

Wyrembek M., 2022, *Wykorzystanie technologii Big Data do predykcji ryzyka opóźnień w łańcuchu dostaw*, Gospodarka Materiałowa i Logistyka, no. 6.

Zhao R., Liu Y., Zhang N., Huang T., 2017, *An optimization model for green supply chain management by using a big data analytic approach*, Journal of Cleaner Production, no. 142.

G. Kruk (✉) grzegorz.kruk@mmrgroup.pl