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The importance of Big Data Analytics technology in business management

Abstract

Data processing, artificial intelligence and IoT technologies are on the rise. The role of data transfer security systems and databases, known as Big Data, is growing. The main cognitive aim of the publication is to identify the specific nature of Big Data management in an enterprise. The paper uses the bibliographic Elsevier and Springer Link databases, and the Scopus abstract database. The distribution of keywords, drawing attention to four main areas related to research directions, is indicated, i.e., Big Data and the related

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terms „human", „IoT" and „machine learning". The paper presents the specific nature of Big Data together with Kitchin and McArdle's research, indicating the need for a taxonomic ordering of large databases. The precise nature of Big Data management, including the use of advanced analytical techniques enabling managerial decision-making, was identified. The development of Cyber Production Systems (CPS), based on BD, integrating the physical world of an enterprise with the digitisation of information as the concept of Digital Twins (DTs), was also indicated. CPS offer the opportunity to increase enterprise resilience through increased adaptability, robustness and efficiency. With DTs, manufacturing costs are reduced, the product life cycle is shortened, and production quality increases.

Key words: Big Data management, Digital Twins, new technology management, Big Data Analytics, Scopus database

Introduction

Today, data processing, artificial intelligence, and IoT technologies are developing rapidly, and social media is growing in importance. With the development of technologies, at the same time, the role of data transfer security systems is increasing. The widespread implementation of information technologies in various spheres of life has caused enterprises to undergo intensive transformations. The growing importance of information technologies in business management should be pointed out. Enterprises develop their own, as well as implement external solutions. This is to ensure the security of data transmission and storage[1]. The organisational process of enterprises is mainly based on the combination of information and communication solutions and the development of new areas of knowledge[2]. The boundaries of existing industries and enterprises are not clear. This is because the boundaries between the competencies of enterprises are blurring. Business networks, modern IT tools and databases and, above all, creative people form the basis for new, highly flexible and efficient organisational solutions[3]. The literature

1 V. Prabhakaran, A. Kulandasamy, *Integration of recurrent convolutional neural network and optimal encryption scheme for intrusion detection with secure data storage in the cloud*, „Computational Intelligence" 2021, vol. 37, p. 344–370; R. Premkumar, S. Sathya Priya, *Service Constraint NCBQ trust orient secure transmission with IoT devices for improved data security in cloud using blockchain*, „Measurement: Sensors" 2022, vol. 24.

2 W. Pizło, A. Parzonko, *Virtual Organizations and Trust* [in:] *Trust, Organizations and the Digital Economy. Theory and Practice*, eds. J. Paliszkiewicz, K. Chen, New York 2022, p. 61–78.

3 L.C. Snellman, *Virtual teams: Opportunities and challenges for e-leaders*, „Procedia – Social and Behavioral Sciences" 2014, no. 110, p. 1251–1261.

indicates that high-tech companies are more inclined to cooperate[4], as are companies in the medical services sector (healthcare, due to the need for specialised procedures) and the entertainment sector (computer games). Organisations are being replaced by new relationships, which are often virtual[5]. Contemporary tools that support knowledge management[6] include database management systems, including Web 2.0[7], and support for innovation processes[8] and document management[9]. The tools indicated are examples of databases supporting managerial decisions.

The article was written as part of an international research project entitled „The Cross-Border Nature of Cybersecurity" implemented by the: War Studies University in Warsaw (Poland), Italian Team for Security, Terroristic Issues & Managing Emergencies – ITSTIME (Italy), National University of Life and Environmental Sciences of Kyiv (Ukraine), Technical University of Kosice, Faculty of Aeronautics (Slovakia), The John Paul II Catholic University of Lublin, Department of Theory of Politics and Eastern Studies (Poland), University of Bari Aldo Moro (Italy), University of Messina (Italy), University of Teramo (Italy), University of Udine (Italy), Warsaw University of Life Sciences (Poland).

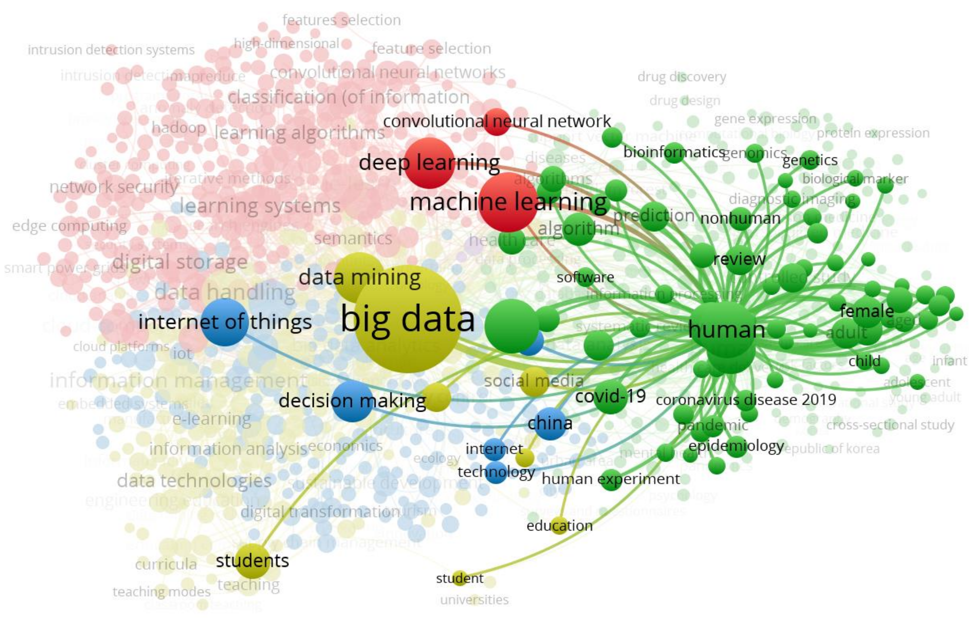
Aim and research methodology

The main cognitive aim of the publication is to identify the specific nature of Big Data management in an enterprise. Big Data issues are an interdisciplinary research field discussed in technical, medical, and social sciences, and especially in business and management. The aim of the research is to 1) identify Big Data

4 O. Gassmann, *Opening up the innovation process: towards an agenda*, „R&D Management" 2006, no. 3, p. 223–228.
5 P. Chamoso, S. Rodriguez F. de la Prieta, J. Bajo, *Classification of retinal vessels using a collaborative agent-based architecture*, „AI Communications" 2018, vol. 31, p. 427–444.
6 K. Le-Nguyen, R. Dyerson, G. Harindranath, *Exploring knowledge management software implementation from a knowing-in-practice perspective*, „Information Systems Frontiers" 2018, vol. 20, p. 1117–1133.
7 S. Orenga-Roglá, R. Chalmeta, *Methodology for the Implementation of Knowledge Management Systems 2.0*, „Business & Information Systems Engineering" 2019, vol. 61, p. 195–213.
8 S. Schmidt, D. von der Oelsnitz, *Innovative business development: identifying and supporting future radical innovators*, „Leadersh Educ Personal Interdiscip J" 2020, vol. 2, p. 9–21.
9 J. Sun et al., *Text visualization for construction document information management*, „Automation in Construction Volume" 2020, vol. 111.

as a tool for obtaining a new value and 2) build a model based on Big Data Analytics in the new enterprise model – 4.0.

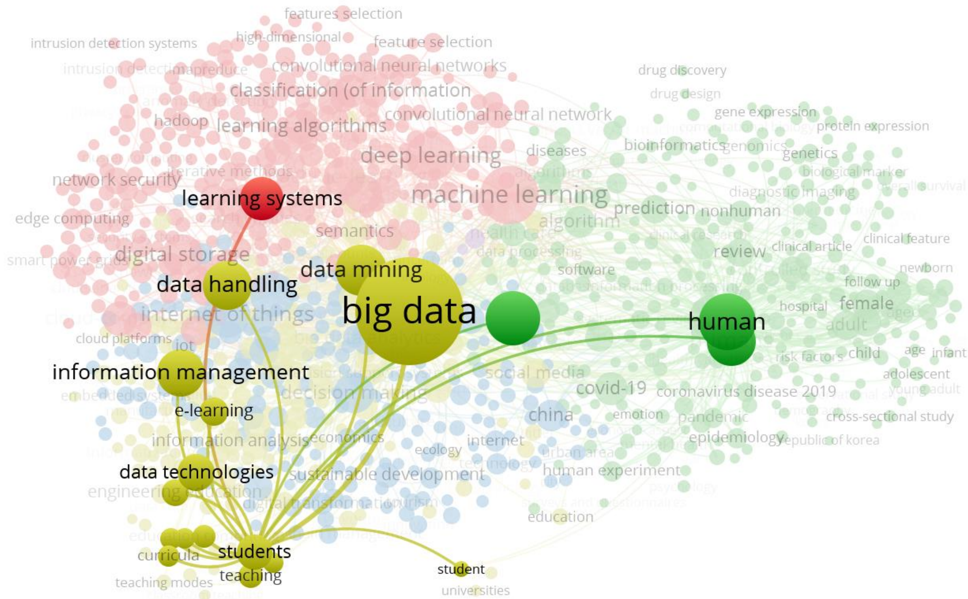
The paper identifies existing research by performing a literature review. The subject of the assessment included articles released in scientific journals published in English. These publications were mainly sourced from the Elsevier and Springer Line databases, and abstracts from the Scopus database. The indicated databases were searched for scientific, peer-reviewed papers published between 2020 and 2022 by querying the quantitative distribution of texts and any declared issues. The research is a review. In the largest Scopus database available, more than 140 thousand papers contained the term „Big Data during the period in question. To present the research directions, the keywords Big Data" from 19 497 publications in 2022 and early (March) 2023 were taken into account. VOSviewer software was used to visualise the linking of the keywords. Based on this, four areas relating to „Big Data", „human", „IoT" and „machine learning" can be identified (Fig. 1).



Source: Scopus database www.scopus.com [access: 6.03.2023].

Fig. 1. Linking the keywords „human" and „IoT" to the term „Big Data" in the Scopus database for 2022–2023

The expression „Big Data" is also linked to the terms „IoT", „human" and „machine learning" and „students". This demonstrates the interconnectedness of research covering many descriptors indicated (Fig. 2).



Source: Scopus database www.scopus.com [access: 6.03.2023].

Fig. 2. Linking the keywords „students" to the term „Big Data" in the Scopus database for 2022–2023

In the Elsevier database, the number of publications on Big Data issues exceeded 79 thousand as the sum of publications released between 2001 and 2023. In 2022, the number of publications on this topic increased by more than 16,2 thousand (representing more than 20% of publications), and the year before, by 14,1 thousand (17,8%). In the case of the Springer Line database, for the same criteria as the Elsevier database, there were more than 43 thousand scientific papers on Big Data between 2001 and 2023. And in 2022 alone, there were more than 10 thousand publications on Big Data (representing 23% of publications).

The specific nature of Big Data and Big Data Analytics

The decrease in costs associated with storing and processing data has led to increased information comprised of Big Data covering various areas of social and economic life. Public institutions and private entities both collect data. In the latter case, collected data comes mainly from digital applications, through which we optimise our social and market behaviour, and which also have their impact on most areas of our daily lives. The information we leave behind on social media and other applications used to track our movements[10] and purchases or used for entertainment makes Amazon, Apple, Facebook, Google, Microsoft and other IT players the holders of this information. Having large databases at their disposal forces these entities to look for analytical tools so they can make broad use of them. These tools enable companies to build vast data resources. Big Data represents the technologies being developed and improved for processing information. The expression Big Data refers to large data sets whose size exceeds the capacity of the software tools utilised and are used to acquire, select and manage them in addition to processing the data at a given time. The distinctive feature of BD is large data sets, repeatedly used for changing research purposes. In reviewing the literature on Big Data issues, Kitchin and McArdle[11] in 2016 identified the following key characteristics of BD, such as (abbreviated as the 3Vs): volume consisting of enormous quantities of data; velocity created in real-time; and variety consisting of structured, semi-structured and unstructured data. These authors taxonomically organised the DB characteristics described in the literature[12] by distinguishing the following Big Data characteristics, namely: 1) exhaustivity, covering an entire system, i.e., all data instead of sampling; 2) resolution and exceptional indexicality; 3) relationality, containing common fields that enable the conjoining of different data sets; 4) extensionality, involving the easy addition/changing of new fields in the database; 5) scalability, capable of rapidly expanding the size of the database; 6) veracity, the data can be messy and contain false data or errors, and have value, as many insights can be extracted from the data, and the data itself can be repurposed; 7) data variability can shift constantly depending on the context in which it is considered.

In practice, as the BD research[13] showed, a significant proportion of the databases did not meet the definitional requirement as the dominant descriptive features appeared to be the exhaustivity and veracity of the data. The authors[14] indicate that only a negligible proportion of BD contained all

10 I. Sbai, S. Krichen, *A real-time Decision Support System for Big Data Analytic: A case of Dynamic Vehicle Routing Problems*, „Procedia Computer Science" 2020, vol. 176, p. 938–947.
11 R. Kitchin, G. McArdle, *What makes Big Data, Big Data? Exploring the ontological characteristics of 26 datasets*, „Article in Big Data & Society" 2016, vol. 3, no. 1, p. 1–10.
12 V. Mayer-Schonberger, K. Cukier, *Big Data: A Revolution that will Change How We Live, Work and Think*, London 2013.
13 R. Kitchin, G. McArdle, op. cit.
14 Ibidem.

seven identified characteristics. In other words, the acronym 3Vs, which purports to describe the individualities of BD, is false and misleading as well as creates confusion regarding the definitional boundaries of the term Big Data.

The essence of management in a new technology environment

Big data management (Big Data Analytics, BDA) covers the use of advanced analytical techniques to extract valuable knowledge from large data sets, thereby facilitating the decision-making process. A good example is supply chain management[15] (SCM), where a wide range of technologies such as sensors, barcodes, RFID and the Internet of Things (IoT) are used extensively to integrate and coordinate every link in the supply chain[16]. It could be argued that big data management (BDA) has revolutionised supply chains, as is confirmed by many specialist publications[17]. Big data management (BDA) is regarded as the game changer in the supply chain, enabling companies to achieve a certain level of excellence in a rapidly changing market environment.

The implementation of Big Data Analytics projects in the case of production companies, for example, involves the following series of activities: the definition of the business problem, an exploration of the scope of the data, the creation of a cross-functional team, a plan of the individual activities in the project, the collection and selection of data, data analysis and modelling, data visualisation, generation of the report, integration into information systems, and training of specialists. Big Data management (BDA) provides an opportunity to transform business models and impact staffing. By analogy, the knowledge derived from BD Analytics makes it possible to compare the automation process and its effect on the production workforce, as it was decades ago with the mechanisation of

15 Z. Dong et al., *Blockchained supply chain management based on IoT tracking and machine learning*, „Journal Wireless Computer Network" 2022, vol. 127.
16 X. Chen, C. He, Y. Chen, Z. Xie, *Internet of Things (IoT) – blockchain-enabled pharmaceutical supply chain resilience in the post-pandemic era*, „Frontiers of Engineering Management" 2022, vol. 10, p. 82–95.
17 J.R. Basu, M.D. Abdulrahman, M. Yuvaraj, *Improving agility and resilience of automotive spares supply chain: The additive manufacturing enabled truck model*, „Socio-Economic Planning Sciences" 2023, vol. 85; J. Xie, C. Chen, *Supply chain and logistics optimization management for international trading enterprises using IoT-based economic logistics model*, „Oper Manag Res" 2022, vol. 15, p. 711–724.

production processes. Big Data Analytics enables timely and accurate insights to make better production decisions using machine learning, predictive analytics or MapReduce-like tools[18]. By connecting companies or individual systems of an organisation, new uses of data resources are enabled by public databases. Employees are becoming 'data generators' in much the same way that the IoT is, with IP addresses and various types of sensors generating data both within the enterprise and collaborating with other organisations. Increasingly sophisticated software supports machine interpretation of data enabling largely autonomous decision-making and deeper integration of Big Data applications combined with traditional value-creation activities. Digitalisation and Big Data Analytics are challenging business models in many industries.

There are companies, even those with a strong market position, that do not take advantage of the full opportunities offered by the process of digitisation and Big Data Analytics and may also find it tough to adapt their business models to the new conditions. The ongoing digitisation process significantly reduces the transaction costs associated with information gathering[19], communication and control. Facilitated access to an up-to-date pool of information and advanced Big Data Analytics allows companies, for example, to analyse the interdependence of purchasing behaviour to fit advertising content better, which can be reflected in increased overall consumer demand. Consequently, gradual improvements in established business models through increased digitisation and data analytics can replace less efficient business models in the long term. However, with increasing levels of standardisation, deployed and standardised big data solutions may not be good enough when providing a sustainable competitive advantage. Analytical solutions that explore structured and unstructured data can help organisations gain insights, not only from privately sourced data but also from large datasets publicly available on the web. The ability to link information on consumer preferences and product features with information from blogs, product rating platforms and social network data provides companies with a wide range of opportunities to understand the needs of their customers, anticipate their needs and requirements and, above all, optimise the use of resources. The willingness of companies to use analytics technology generally involves the purchase of

18 T.H. Sardar, Z. Ansari, *Distributed Big Data Clustering using MapReduce-based Fuzzy C-Medoids*, „Journal of Institution of Engineers (Indie). Ser. B" 2022, vol. 103, p. 73–82.
19 D.F. Li, P. Liu, K.W. Li, *Big Data and Intelligent Decisions: Introduction to the Special Issue*, „Group Decision and Negotiation" 2021, vol. 30, p. 1195–1200.

expensive software licences, the use of a sizable computing infrastructure, and high consultancy fees for analysts who work with the company to better understand operations, organise data and integrate it for analytical purposes. The ability to mine data to understand the processes taking place, the relationships between employees and devices, and the offering of tailored services and insights from data from multiple sources – all these are crucial for the competitive advantage of businesses. Making sense of data, extracting non-obvious patterns and using these patterns to predict future behaviour is nothing new. Knowledge Discovery in Data (KDD) aims to remove non-obvious information through careful, detailed analysis and interpretation.

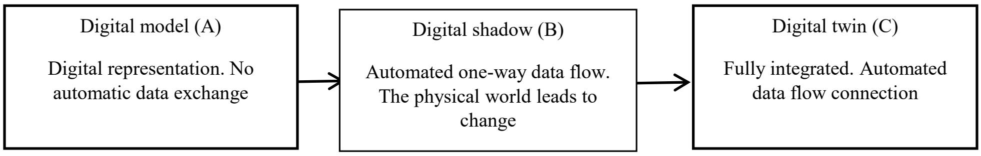
From the Cyber Production System to Digital Twins

Through IT services, companies can increase productivity. Machines, equipment and employees receive stimuli and collect them in the form of data, which is then used to build Big Data and applied to the cyber part of the company, analysed and processed. The information obtained in this way is used to make decisions using the interface. Cyber Production Systems (CPS) are defined as integrating the physical world and computational processes identified with digitising information and its use, taking the form of Digital Twins (DTs)[20]. The use of new technologies is transforming the physical world into a digitalised one, using decision support tools[21]. The ongoing changes in the industry are taking the form of Cyber-Physical systems (CPS). Research on CPS focuses on theoretical issues, including discussions on terminology, system architecture and technologies, among others, and practical issues concerning the application of CPS in engineering practice. When making comparisons[22] between CPS and, for example, IoT-based technologies, it is indicated that CPS considerations are more foundational and scientific[23]. The Cyber Production System consists

20 F. Tao, Q. Qi, L. Wang, A.Y.C. Nee, *Digital Twins and Cyber–Physical Systems toward Smart Manufacturing and Industry 4.0: Correlation and Comparison*, „Engineering" 2019, vol. 5, p. 653–661.
21 T. Ruppert, J. Abonyi, *Integration of real-time locating systems into digital twins*, „Journal of Industrial Information Integration" 2020, vol. 20; C. Zhang, Y. Chen, *A review of research relevant to the emerging industry trends: industry 4.0, IoT, block chain, and business analytics*, „Journal of Industrial Integration and Management" 2016, vol. 5, no. 1, p. 165–180.
22 F. Tao, Q. Qi, L. Wang, A.Y.C. Nee, op. cit., p. 653–661.
23 L. Monostori et al., *Cyber–physical systems in manufacturing*, „CIRP Annals" 2016, vol. 65, no. 2, p. 621–641.

of the physical dimension, namely machines, equipment, materials, the working environment and the processes between, without and with them; the organisational dimension consisting of, among other things, adopted strategies, project management and conflict resolution systems. In the literature, modern production systems are described as those that use Cyber-Physical Systems (CPS)[24]. These systems offer the possibility of increasing the resilience of enterprises, including their manufacturing parts. The concept of an organisation's resilience is understood as its adaptability, robustness and efficiency. The notion of DTs, in turn, uses digital copies of physical systems so that they could be optimised in real-time. Through their implementation, the simulation of the production system contributes to reducing manufacturing costs, shortening the product life cycle and increasing production quality[25]. Smart manufacturing is an emerging form of manufacturing rooted in the concept of cyber-physical systems[26]. The possible integration of the physical parts and their representation in the digital world can influence the material processes, through their optimisation, in line with the management objective. Integrating these two worlds provides users with intuitive decision-making and remote control of manufacturing processes. In the case of modern production systems, the Digital Twins (DTs) model consists of[27] a model for visualising the shop floor, which is used to monitor the quality of the manufacturing process, and a model for visualising future quality and identification. This subsystem can be used for calculations and as a decision support tool. The interface, based on DTs, visualises data and information from the shop floor, allowing current activity to be easily monitored and anomalies to be spotted. The literature indicates using the Grey-Markov model to predict future qualitative data values[28]. Identifying the causes of lower-than-expected quality must be based on a rational risk assessment – in particular, on the analysis of information from the shop floors.

24 R. Schmitt et al., *Enhancing Resiliency in Production Facilities Through Cyber Physical Systems*, Berlin 2017, p. 287–313.
25 B. Rodič, *Industry 4.0 and the new simulation modelling paradigm*, „Organizacija" 2017, vol. 50, no. 3, p. 193–207.
26 R. Schmitt et al., op. cit. p. 287–313.
27 C. Zhuang et. al., *Digital Twin-based Quality Management Method for the Assembly Process of Aerospace Products with the Grey-Markov Model and Apriori Algorithm*, „Chinese Journal of Mechanical Engineering" 2022, vol. 35.
28 Ibidem.



Key: At the first level (A), the „offline model" is connected to the system via manual data flow; at level B, the „digital level", the shadow model automatically collects data from the shop floor; at the „digital twin" level (C), the model is fully synchronised through real-time communication.

Source: T. Ruppert, J. Abonyi, op. cit.

Fig. 3. Three levels of digitisation of production according to Tamas Ruppert, Janos Abonyi

Conclusion

The development of IoT data collection and processing technologies, as well as the growing importance of artificial intelligence, is driving the need to re-engineer production systems. The emergence of new sub-systems of cyber management is increasing the significance of cyber security. The process of reorganising business should also be pointed out, where the axis of change is IT solutions that change the scope and manner of data collection and change the basis of decision-making, where the support of the decision-maker can be an artificial intelligence algorithm. Big Data issues were initiated more than twenty years ago. In the Scopus database, database issues comprise more than 140 thousand papers. As of 2022 and the first days of March 2023, there were 19 497 publications in the Scopus database. The number of publications on this topic is increasing. The keywords occurring along with the term Big Data in the period under consideration include „human", „IoT" and „machine learning". The term Big Data, as an analytical category, is too broad, so its proper etymologisation and, consequently, the identification of its different types is necessary.

New technologies are contributing to the emergence of Cyber Production Systems (CPS). These systems represent the integration of the physical world and the digitalisation of design and manufacturing processes. Changes in the industry are taking the form of cyber-physical systems (CPS), focusing on theoretical and design issues, on the one hand, regarding the architecture of the emerging systems, and on the other, the technology and application of these systems in practice. Cyber-physical systems provide opportunities for companies to increase resilience, understood as the speed of adapting to changing conditions, and increasing company efficiency. In the case of Digital Twins (DTs), digital copies of physical systems are used. The Digital Twins Model consists of 1. a model for visualising the shop floor and 2. a model for visualising future quality and identification. Big Data has become a permanent part of the economic system. Companies must learn to use this data rationally, systematically and creatively.

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Znaczenie technologii Big Data Analytics w zarządzaniu przedsiębiorstwem

Streszczenie

W zarządzaniu przedsiębiorstwem na popularności zyskuje m.in. przetwarzanie dużych zbiorów danych, zastosowanie sztucznej inteligencji i technologie IoT. Rośnie rola systemów bezpieczeństwa przesyłania danych oraz baz danych określanych jako Big Data. Głównym celem poznawczym publikacji jest identyfikacja specyfiki zarządzania Big Data w przedsiębiorstwie. W pracy wykorzystano bibliograficzne bazy danych Elsevier i Springer Link oraz bazę abstraktów Scopus. Wskazano rozkład słów kluczowych, zwracając uwagę na główne obszary dotyczące kierunków badań Big Data i związanych z nimi terminów „człowiek", „IoT" oraz „uczenie maszynowe". Artykuł przedstawia specyfikę Big Data, wskazuje m.in. badania Kitchina i McArdle'a opisujące potrzebę uporządkowania taksonomicznego dużych baz danych. W artykule zidentyfikowano charakter zarządzania Big Data, w tym wykorzystanie zaawansowanych technik analitycznych umożliwiających podejmowanie decyzji zarządczych. Wskazano również rozwój Cyber Production Systems (CPS), opartych na BD, integrujących fizyczny świat przedsiębiorstwa z digitalizacją informacji jako koncepcję Digital Twins (DTs). CPS oferują możliwość zwiększenia odporności przedsiębiorstwa poprzez zwiększoną zdolność adaptacji, solidność i wydajność. Dzięki DT koszty produkcji są zmniejszone, cykl życia produktu jest skrócony, a jakość produkcji wzrasta.

Słowa kluczowe: zarządzanie Big Data, Digital Twins, zarządzanie nowymi technologiami, Big Data Analytics, baza Scopus