International Journal of Global Tech Management (IJGTM)
Volume 2, Issue 1, January-June, 2025
Available online at: https://pgrpublication.com/index.php/ijgtm

# The Role of Big Data Analytics in Business Risk Management

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**Article history:** Received: 25 February 2025, Accepted: 17 March 2025, Published online: 04 April 2025

**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 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.**

**Keywords: Big Data management, Digital Twins, new technology management, Big Data Analytics, Scopus database**

## INTRODUCTION

In today's rapidly evolving digital environment, the proliferation of artificial intelligence, the Internet of Things (IoT), and advanced data analytics has reshaped the operational landscape across sectors. Simultaneously, the rising prominence of social media has introduced new dynamics in data exchange and communication, making the protection of transmitted and stored information a critical concern. As technological innovations permeate nearly every aspect of professional and personal life, enterprises are undergoing significant structural and functional transformations to adapt to these changes.

A notable shift is the integration of in-house and externally sourced digital solutions to safeguard sensitive information. Business operations now rely heavily on interconnected digital platforms that merge communication systems with expanding fields of expertise. The distinction between sectors and the functions within organizations is becoming increasingly fluid due to overlapping competencies and collaborative frameworks. Today's flexible organizational structures are built upon interconnected business ecosystems, sophisticated IT solutions, expansive data repositories, and—importantly—innovative human capital.

Scholarly work suggests that enterprises engaged in high-technology fields are particularly open to collaboration. Similar trends are observed in healthcare, where precision and procedural complexity drive specialized partnerships, and in the entertainment industry, especially in interactive media like video games. These shifts indicate a move away from rigid institutional boundaries toward dynamic, often virtual, alliances.

Modern enterprises rely on various technologies to streamline knowledge sharing and innovation. These include intelligent database platforms, tools aligned with Web 2.0 architecture, systems that enhance ideation processes, and applications designed for efficient documentation control. Such digital resources are indispensable for executives aiming to make informed strategic choices.

This text synthesizes findings derived from a transnational academic collaboration under the umbrella of the research project titled The Cross-Border Nature of Cybersecurity. This initiative is spearheaded by multiple academic institutions, including the War Studies University in Warsaw, ITSTIME (Italy), the National University of Life and Environmental Sciences of Kyiv, the Technical University of Kosice's Faculty of Aeronautics, The John Paul II Catholic University of Lublin, and several Italian universities such as Bari Aldo Moro, Messina, Teramo, and Udine.

Additionally, the Warsaw University of Life Sciences also contributes to this multinational effort aimed at exploring cybersecurity challenges that transcend national boundaries.

**AIM AND RESEARCH METHODOLOGY**

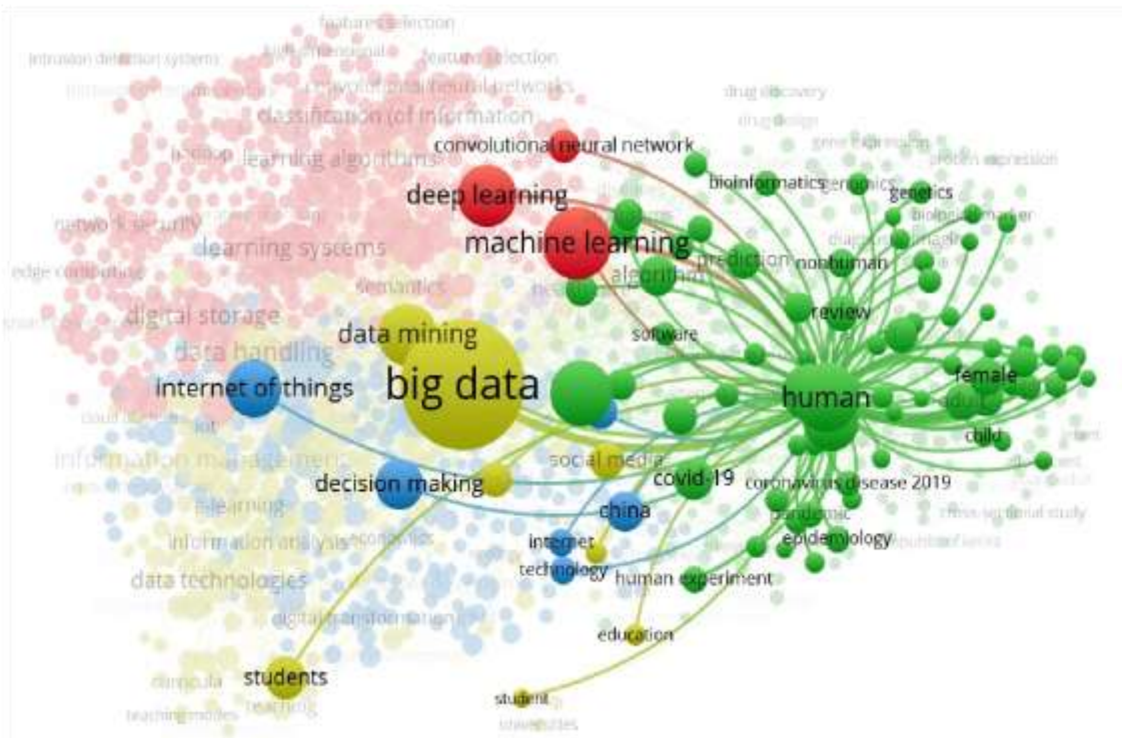
The core intellectual objective of this study is to explore the unique characteristics of managing extensive datasets within contemporary business environments. The topic of large-scale data handling represents a multifaceted academic domain that intersects various disciplines, including engineering, healthcare, social science, and—most prominently—enterprise operations and strategic management. The research pursues two key goals: first, to understand how vast data resources can be leveraged as a source of organizational advantage; and second, to formulate a conceptual framework for integrating advanced data analytics into the architecture of next-generation enterprises, commonly referred to as Industry 4.0 models.

To achieve these objectives, the study undertakes a comprehensive synthesis of existing academic work through a methodical review of scholarly articles. The evaluated literature includes English-language studies from peer-reviewed journals, primarily obtained from the Elsevier and SpringerLink repositories, with supplementary data drawn from Scopus-indexed abstracts. These platforms were systematically searched for works published between 2020 and 2022, focusing on the frequency and thematic distribution of publications addressing the subject.

The investigation follows a review-based methodology. During the designated period, over 140,000 entries containing the term "Big Data" were identified in the Scopus database alone, the largest academic source of its kind. To identify prevailing scholarly trends and directions, the study examined keyword data from 19,497 documents published throughout 2022 and the initial months of 2023.

To map the interrelation of key concepts within this vast body of research, the visualization tool VOSviewer was utilized. Through this analytical process, the study delineated four major thematic clusters: data-centric processes, human factors, the integration of interconnected smart devices (IoT), and the application of intelligent algorithmic systems such as machine learning.

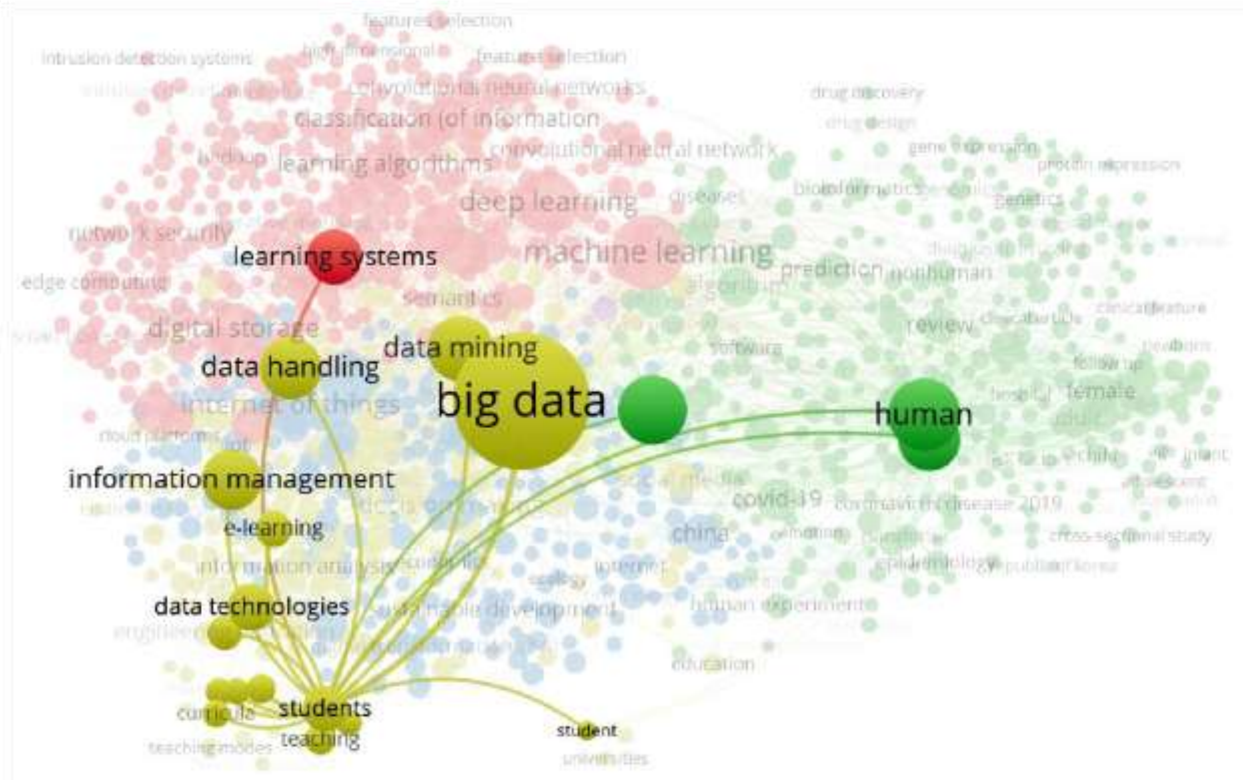
This conceptual categorization not only clarifies the scope of Big Data applications across industries but also serves as a foundation for designing strategic enterprise models that harness these emerging technologies to drive value creation, operational agility, and competitive differentiation in the digital age.




**Source:** Scopus database www.scopus.com

**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

**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 reduced expenditure related to data storage and computational capabilities has significantly expanded the availability of massive datasets that touch nearly every facet of society and the economy. Both governmental organizations and corporate bodies actively gather digital information. In the private sector, much of this data is sourced through online platforms and mobile applications, which individuals use to streamline their lifestyle and purchasing decisions—ultimately influencing their personal routines and market activities.

Our interactions—ranging from posts on social networking sites to digital traces left through entertainment apps, location tracking tools, and e-commerce behavior—are constantly collected and analyzed. Technology giants such as Google, Apple, Amazon, Facebook, Microsoft, and similar corporations accumulate enormous volumes of this user-generated information. Managing these extensive repositories requires the use of sophisticated analytic frameworks to effectively extract meaningful insights and support strategic decision-making.

The concept of large-scale data refers to immense digital collections that exceed the processing limitations of conventional software. It involves not only the acquisition and organization of data but also advanced methods for interpreting it within limited timeframes. A defining attribute of these datasets is their capacity for multifaceted reuse, supporting evolving investigative objectives.

In a pivotal scholarly contribution from 2016, Kitchin and McArdle outlined core traits of these large data systems—initially summarized using the "3Vs" framework: volume (enormity), velocity (real-time generation), and variety (ranging from structured to unstructured formats). Their refined taxonomy went further to include:

1. **Comprehensiveness**, representing entire populations rather than subsets;
2. **Precision and detailed referencing**;
3. **Interconnectivity**, allowing datasets to be merged using shared identifiers;
4. **Flexibility**, offering seamless integration or alteration of data fields;
5. **Expandability**, allowing databases to grow rapidly;
6. **Inaccuracy and potential**, acknowledging that raw data may be flawed yet still useful;
7. **Fluidity**, recognizing context-driven changes in interpretation.

Despite this complex framework, empirical analysis of real-world datasets revealed that most did not fully align with these theoretical definitions. Predominant attributes were limited mainly to data breadth and reliability. Researchers noted that very few instances genuinely displayed all seven elements, calling into question the adequacy of the original "3Vs" model. As a result, it has been argued that the popularized definition of massive datasets is overly simplistic and may obscure the term's true scope and boundaries.

**The essence of management in a new technology environment**

Advanced data handling, often referred to as Big Data Analytics (BDA), entails leveraging cutting-edge analytical tools to derive actionable insights from enormous volumes of information. This, in turn, supports strategic and operational decision-making across industries. A notable illustration of BDA's practical application lies in logistics and resource distribution systems, where technologies like RFID, barcoding, sensors, and Internet of Things (IoT) devices work together to streamline operations across various nodes of the value chain. Numerous studies highlight how BDA has reshaped supply systems, making them more responsive and agile in a fluctuating business landscape.

When implemented within manufacturing firms, such initiatives typically follow a structured roadmap: identifying core challenges, evaluating the data landscape, assembling a multidisciplinary team, outlining specific project milestones, gathering and curating relevant datasets, conducting modelling and analytics, generating visual outputs, reporting, integrating insights into digital platforms, and upskilling internal teams. These digital transformations are not merely about technology—they signify a broader shift in organizational structures and talent deployment. Much like past industrial revolutions altered labour through mechanization, the rise of analytics and machine intelligence is transforming decision-making and operations through tools like predictive modelling, machine learning, and distributed computing systems.

Through digital interconnectivity, businesses now exploit both proprietary and shared datasets to create novel services and operational efficiencies. Employees, in many cases, act as data contributors—akin to smart devices—feeding continuous streams of operational data from within and beyond the organisation. Intelligent software systems now interpret such inputs with minimal human intervention, enabling decentralized decisions and enhanced integration with traditional operations. These advancements pose fundamental challenges to legacy business frameworks across sectors.
Despite these developments, some firms—even dominant ones—struggle to adapt to the accelerating pace of digital evolution. The transformation process notably cuts down the costs of acquiring, transmitting, and monitoring information. Access to real-time intelligence, paired with advanced analytics, empowers companies to align marketing with observed buying patterns, driving greater engagement and ultimately influencing consumer habits. Over time, firms adopting such innovations may outpace those clinging to outdated methods. Still, as analytics tools become increasingly uniform, achieving long-term differentiation requires more than just off-the-shelf solutions.

Utilizing insights from both structured databases and non-traditional sources like user reviews, forums, or social platforms opens up dynamic possibilities for anticipating client expectations and managing resources effectively. However, deploying these technologies demands significant investment—in infrastructure, software, and expert consultancy. Decoding complex relationships within internal operations, revealing hidden trends, and customizing offerings based on comprehensive data exploration are vital strategies for sustaining competitiveness. The practice of uncovering subtle patterns and forecasting behaviours—central to Knowledge Discovery in Data (KDD)—remains a foundational technique in today's digital economy.

**From the Cyber Production System to Digital Twins**

Leveraging information technology services enables organizations to enhance efficiency by converting inputs from machines, tools, and personnel into actionable insights. These inputs, captured as data, contribute to the formation of expansive analytical systems, which are subsequently embedded within the digital infrastructure of the enterprise for interpretation and strategic deployment. This transformation fuels decision-making through advanced human-computer interfaces.

One critical advancement in this domain is the emergence of Cyber Production Systems (CPS), which blend tangible industrial components with algorithmic and computational intelligence. A prominent aspect of this evolution is the concept of Digital Twins (DTs)—virtual replicas of real-world systems—designed to replicate and simulate performance for continuous refinement. These digital technologies are steadily redefining traditional industrial environments by facilitating the transition to smart operations, supported by decision-enhancing software tools.

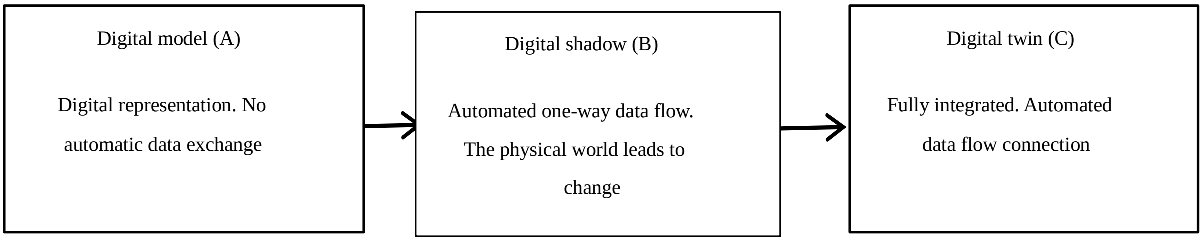
Ongoing developments under the umbrella of CPS address both academic discourse, including discussions on systemic models, digital architectures, and foundational concepts, and hands-on implementation in engineering settings. In contrast to Internet of Things (IoT) applications, CPS is viewed as encompassing deeper theoretical roots and more sophisticated research frameworks.

The structure of CPS comprises two primary facets. The physical aspect includes machinery, raw materials, tools, workflows, and operational environments. The organizational aspect encompasses managerial strategies, workflow design, team coordination, and resolution methodologies. Scholarly research portrays modern production ecosystems as reliant on these cyber-integrated frameworks, which bolster organizational robustness, adaptability, and operational sustainability.

Digital Twins play a pivotal role by creating simulated environments that mirror actual production systems. These allow for real-time assessments, helping companies reduce operational expenses, accelerate product development, and boost overall manufacturing quality. Smart factories, an evolving paradigm in industrial production, are intrinsically connected to CPS and reflect a sophisticated merger between mechanical processes and their digital counterparts.

This dual integration empowers stakeholders with intuitive monitoring tools and remote command capabilities over production workflows. The DTs model, specifically, includes modules for visualizing current shop floor activities as well as predictive analytics tools that assess future outcomes and potential irregularities. These modules support process optimization and early anomaly detection, thereby facilitating proactive management.

Predictive models such as the Grey-Markov technique are cited in scholarly discourse as effective in estimating future quality indicators. Determining reasons for diminished quality output hinges on thorough risk evaluation, especially through systematic analysis of manufacturing floor data.




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

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

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.

## CONCLUSION

The rapid evolution of smart sensor technologies and artificial intelligence has made it essential to overhaul existing industrial operations. With this transformation, digital supervisory components are becoming more prevalent, placing greater emphasis on safeguarding information systems. At the same time, businesses are undergoing structural changes driven by advanced computing platforms that reshape how information is acquired and fundamentally alter the decision-making landscape. Increasingly, machine-driven intelligence is supporting executive judgment.

The exploration of expansive digital datasets began over two decades ago. According to records from the Scopus index, more than 140,000 scholarly contributions have addressed this domain. Specifically, by the end of 2022 and into the early months of 2023, nearly 19,500 relevant entries were noted. This growing body of literature reflects the mounting interest in the subject. Alongside the principal term often appear associated concepts like connected devices, machine learning processes, and human-centric analysis. Given the conceptual breadth of this field, a clearer understanding and categorization of its sub-domains is now essential.

Cutting-edge developments have given rise to advanced digital-manufacturing hybrids, known as Cyber Production Systems (CPS). These new frameworks embody the fusion of tangible operations with virtual modeling across design and production functions. Industrial modernization is increasingly shaped by such interactive structures, which focus on both theoretical blueprints and real-world application. These hybrid systems offer enterprises an avenue to enhance adaptability—responding swiftly to disruptions—and improve operational performance.

A particularly notable application is the concept of Digital Twins: virtual counterparts of real-world machinery and workflows. These replicas are composed of two distinct yet interconnected frameworks—one simulates the present operational environment, while the other predicts potential outcomes and quality issues. The widespread integration of massive digital repositories into economic operations has become irreversible. Thus, companies must not only accumulate these resources but also utilize them with strategy, discipline, and innovation.

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