

Big Data Analytics for Data Intelligence and SME Transformation

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ARTICLE INFORMATION	ABSTRACT
<i>Section</i> Research Results Articles	This study examines the role of Industry 4.0 Big Data Analytics (BDA) in promoting corporate sustainability among SMEs, particularly in emerging markets. Using the PRISMA 2020 framework, this systematic literature review analyzes the effects of Big Data (BD) on business and economic outcomes and its contribution to sustainability in Industry 4.0-enabled SMEs, especially in manufacturing. The findings indicate that BD adoption improves operational efficiency and revenue generation while supporting quality control, predictive maintenance, and manufacturing process optimization. These findings provide an integrated perspective on BD’s contribution to SME sustainability and offer practical insights for managers and policymakers in developing effective technology adoption strategies.
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INTRODUCTION

Digitalization represents a major strategic factor for economic development and the growth of small and medium-sized enterprises (SMEs), as it redefines the way they operate, compete, and create value (Bouwman, Nikou and de Reuver, 2019). Moreover, Data intelligence denotes set of tools and processes inside a cloud platform which show data experts to collect, curate, and manage data across their transactional databases, warehouses, analytical tools and AI and machine learning (ML) assets.

This provides the building blocks for an integrated system for data governance, data quality management, and data integration. The goal is to ensure that the entire data lifecycle is managed effectively before data is fed to AI models or data analysis and visualization tools.



Data analytics primarily focuses on examining data and drawing conclusions. Data analytics tools and techniques are used to perform statistical analysis, generate reports, and create models that help to understand the lessons contained in historical data and even predict future outcomes (Ojo, 2025).

They do this by identifying patterns, trends, and relationships within data and displaying their findings in visualizations that can inform decision-making. Big data analytics plays a crucial role in Data intelligence too. In this context, analytics and artificial intelligence (AI) have become relevant tools for transforming information into decision-making support and, thus, influence financial performance. SMEs must should attract and retain customers during thrive in a competitive market. To personalize businesses' marketing efforts, big data (BD) may enable quicker and broader engagement (Zong *et al.*, 2025).

Digital economy is expanding continuously; SMEs must be encouraged to focus on decision-making to maintain competitiveness. Existing investigation emphasizes large enterprises, leaving limited focus in describing factors influencing BDA within SMEs. This knowledge gap is particularly concerning because SMEs often operate under resource constraints while facing increasing pressure to undergo digital transformations (Lutfi *et al.*, 2022; Kgakatsi *et al.*, 2024).

This study fills the gap on the acculturation of large-scale analytics on SME. It specifically highlights the key drivers and impedance assimilation of BDA including cost constraints. Moreover, the review discusses the perturbation of BDA adoption through enhancement of operational efficiency, competitiveness and dynamic response to market environments (de Vries, 1994; Kgakatsi *et al.*, 2024).

The result expresses literature on information systems and digital innovation by overviewing the outcomes of big data adoption in SMEs. However, this review provides a more SME-specific perspective on the digital transformation journey, highlighting the distinctive challenges and opportunities associated with big data adoption in SMEs. Finally, this review identifies unexplored research directions and insights into the need for more empirical studies to validate the existing findings in various industries contexts. Boosting up the empirical evidence will advance theoretical understanding and support the development of practical frameworks that enable SMEs to successfully leverage Big Data for sustainable growth.

RQ1: How do AI, Big Data Analytics, and digital technologies enhance SME competitiveness and performance in Industry 4.0?

RQ2: What barriers hinder SMEs from adopting digital technologies in Industry 4.0?

RQ3: How does digital transformation support SME sustainability and innovation in Industry 4.0?

LITERATURE REVIEW

Industry 4.0

Three earlier industrial revolutions—mechanization, electrification, and information—have shaped the development of industrialized economies (de Vries, 1994). The advent of electricity in 20th century brought about a second revolution in the industry by enabling industrial automation through the use of electrical assembly lines and conveyors. This allowed for mass production to meet the rapidly increasing population following World War II.

Industry 4.0 represents fourth industrial revolution, digital transformation of manufacturing by integrating cyber-physical systems (Vaidya, Ambad and Bhosle, 2018). Its primary objective is to establish intelligent and interconnected manufacturing systems in which

humans, machines, and products communicate continuously, enabling autonomous, real-time decision-making throughout the production process (Albers *et al.*, 2016).

The features of Industry 4.0 is interconnection, integration and Big Data (Albers *et al.*, 2016; Ghasemaghaei and Calic, 2020). Interconnection enables smooth communication between machines, products and stakeholders across the manufacturing ecosystem, creating intelligent value chains that support automated production and information exchange. Industry 4.0 is integrated on different levels like horizontal, vertical, end-to-end. Horizontal integration is a forward-to-backward (customer-to-supplier) approach that is carried out across the value chain.

The industrial environment became more collaborative from development to production thanks to horizontal integration, which led to more effective, dependable, and efficient manufacturing. Vertical integration is the process of replacing the current traditional fixed manufacturing system with contemporary web-controlled procedures (Khan *et al.*, 2017). When these technologies and processes are fully integrated, they create a decentralized manufacturing system that enables all stakeholders to access information rapidly while shifting decision-making and operational control closer to the manufacturing floor (Ghasemaghaei and Calic, 2020). This transformation is driven by advancements across multiple technical and industrial domains and the convergence of emerging technologies, including mobile technologies and neuro-technologies.

Big Data Analytics

Big data is extraordinarily large and diverse collections of semi-structured, unstructured, and organized data that continue to expand quickly over time (Ghasemaghaei and Calic, 2020). People, businesses, and robots are fundamental of big data. Some scholars have used the concept of “Vs” (volume, velocity, variety, veracity, and value) (Ghasemaghaei, 2020). Variety comprises of data models in terms of structured, semi-structured, unstructured to collect data such as RFID, Blockchain, cloud computing or AI (Mohapatra and Mohanty, 2020). In real-time data analytics, velocity refers to the pace at which data is generated and gathered. Big data is expanding at an exponential rate. Veracity refers to the truthfulness of data, i.e. whether the data comes from a reputable, trustworthy source (Shukla *et al.*, 2020).

Big Data Analytics and Small and Medium Enterprises

Recently, SMEs are essential for innovation and economic growth, thus being able to use Big Data effectively is particularly critical for them. SMEs may improve their overall performance, raise competitiveness, improve marketing efficacy, and optimize company strategy by implementing Big Data, which transforms massive datasets into useful insight. BDA can be commonly applied through three major analytical approaches: descriptive, predictive, and prescriptive analytics (Kamble, Gunasekaran and Gawankar, 2020). The adoption of BDA supports SMEs in transforming their organizations by minimizing uncertainty and the time needed for the implementation of structural changes. BDA helps in informed strategic choice-making (Iranmanesh *et al.*, 2022; Sanchez-Huguet, Aramendia-Muneta and Erro-Garcés, 2022) by providing more reliable forecasts of customer behavior and market trends.

Additionally, it can be used to lower production costs, increase operational efficiency and reduce production lead times. Previous studies by Sanchez-Huguet, Aramendia-Muneta and Erro-Garcés (2022) have also found that BDA improves both market performance and financial performance of SMEs. SMEs become more capable of implementing BDA found that, BDA influences SMEs in digitization of internal operations and procedures, performance effectiveness and efficiency, business model transformation, and providing corporate

sustainability. Jalali *et al.* (2023) recognized Big Data Analysis (BDA) as a vital technology for SMEs.

High expenses and complexity of data administration, BDA use has historically been mostly restricted to large enterprises. However, thanks to technological advances such as cloud computing, AI, and machine learning, BDA solutions are now more accessible to SMEs giving them the opportunity to use data-driven strategies to increase operational efficiency and decision making (Sanchez-Hughet, Aramendia-Muneta and Erro-Garcés, 2022; Kateryna and Ivan, 2024). SMEs can estimate demand, spot trends, and streamline supply chains by analyzing large datasets through BDA. These skills are essential for staying competitive in ever-changing marketplaces (Iranmanesh *et al.*, 2022; Jalali *et al.*, 2023).

BDA adoption in SMEs is not without difficulties, despite its promise. The current study identifies knowledge gaps on the precise processes by which BDA affects the resilience and performance of SMEs. Although a number of studies have found a positive correlation between BDA and performance outcomes, the underlying processes and contextual factors governing these relationships remain little understood.

Notable shortcomings are also present in earlier systematic literature reviews (SLR) on BDA in SMEs. Without exploring the particular difficulties SMEs have while using BDA technology, many assessments concentrate on general trends (Coleman *et al.*, 2016; Aldossari, Mokhtar and Abdul Ghani, 2023). Although some studies draw attention to technological obstacles, they frequently ignore important organizational and cultural elements that affect the adoption of BDAs (Maroufkhani, Iranmanesh and Ghobakhloo, 2022). Additionally, current assessments typically present static viewpoints that fail to sufficiently take into consideration how BDA technologies are developing and how they are used in real-world scenarios in SMEs (Coleman *et al.*, 2016; Chuah and Thirusamry, 2021).

Table 1. The Existing SME-BDA Adoption Published Literature

Study	Theoretically Background	Methodology	Major Findings
(Verma and Bhattacharyya, 2017)	Technical Organization	Interview with 22 small - structured semi - structured semi - structured small and large companies.	Various organizational, technical and ecological factors such as: BDA strategic values. This will determine whether Indian companies will implement BDA.
(Yuan and Wang, 2019)	Knowledge management literature	Qualitative analysis of 8 studies.	Analyzing interconnectedness (big data with SMEs)
(Yadegaridehkordi <i>et al.</i> , 2020)	Technology-organization: Environment structure and theory of fit.	A survey conducted using questionnaires was administered to 418 small and SMEs in the hotel industry in Malaysia.	Several factors influence the intention to adopt BDA. BDA implementation, consequently, affects enterprise performance:
(Maroufkhani, Iranmanesh and Ghobakhloo, 2022)	Diffusion of innovation, rbv, and technology organization-environment framework.	Survey of 171 Iranian firms.	BDA implementation results in business performance enhancement.
(Lei, Chen and Lim, 2021)	Technology-organization environment.	A survey conducted using questionnaires, consisting of 320 managers from SMEs in UK.	The adoption of BDA is influenced by perceived benefits, technological complexity, and management support.

Study	Theoretically Background	Methodology	Major Findings
(Lei, Chen and Lim, 2021)	Information system theories are commonly studied here.	Survey of 54 BDA platforms in China.	The adoption rate of business databases among Chinese companies, regardless of their size, is typically low
(Mangla <i>et al.</i> , 2020)	BDA and project management literature.	Survey of 106 Indian manufacturing firms.	The adoption of BDA technology results in enhanced project performance for manufacturing SMEs.
(Park and Kim, 2021)	A Model for Analyzing implication of Technological Factors on Project Performance.	Study involved interviewing 50 experts and surveying 226 Korean SMEs.	Various organizational, technological, and environmental factors, including government policies or system simplicity, influence the adoption of BDA within. Korean SMEs.
(Youssef, Eid and Agag, 2022)	Diffusion of innovation, institutional theory and technology-organization environment framework.	Investigation conducted using questionnaires collected responses from 2,278 organizations.	The adoption of business databases varies among companies and locations.
(Sim, Seo and Yang, 2025)	Digital strategy, supported by big data analytics capability and data-driven insight, helps SMEs achieve successful digital transformation.	Survey of 192 Korean SMEs, analyzed using PLS-SEM to examine mediation and serial mediation.	Digital strategy positively affects digital transformation.
(Klimeck a-Tatar and Krynke, 2026)	3D scanning, integrated with Total Productive Maintenance, can support smart manufacturing in SMEs.	A structured survey of manufacturing SMEs was conducted to examine factors influencing 3D scanning adoption, including financial, technical, infrastructure, and cybersecurity factors.	3D scanning combined with TPM improves driven maintenance planning.
(Ratanac haroench ai and Jantapoon, 2026)	Dynamic Capabilities Theory (DCT) and Resource-Based View (RBV) explain how AI enhances SMEs' sensing, seizing, and reconfiguring capabilities.	Survey of 327 Thai manufacturing SMEs using AI, analyzed through PLS-SEM with SmartPLS 4.0 and 5,000 bootstrap samples.	AI capabilities positively affect supply chain resilience and environmental sustainability.
(Shaikh <i>et al.</i> , 2024)	GHRMP and BDAC are organizational resource that can help SMEs develop green competitive advantage and improve environmental performance.	A quantitative survey of 467 manufacturing SME managers and directors was analyzed using SEM with SmartPLS 4.0.9.6.	GHRMP and BDAC positively contribute to green competitive advantage and environmental performance.
(Sarıışık, Göncü and Ögütlü, 2026)	Industry 4.0 technologies such as IoT, AI, and advanced analytics can help SMEs reduce carbon emissions.	A mixed-methods study of 120 SMEs in Türkiye, using surveys, operational records, statistical analysis, forecasting, and machine-learning models.	I4.0 adoption significantly reduced electricity, natural gas, and waste emissions, with higher adoption projected to achieve greater cumulative emission reductions.
(Yli-Viitala and Helo, 2026)	Organisational Learning Theory is used to explain how SMEs' learning processes influence Industry 4.0 and perceived obstacles.	95 Finnish manufacturing SMEs using hierarchical clustering and multivariate analysis.	R&D spending significantly influence technology adoption, while obstacle clusters reflect different stages of organizational learning.

Study	Theoretically Background	Methodology	Major Findings
(Demir, Sarıışık and İlhan, 2026)	The study focuses on Big Data Analytics (BDA) adoption in Indian companies.	Data were collected through semi-structured interviews with 22 small and large companies in India.	The adoption of BDA is determined by various organizational, technical, and environmental factors. The perceived strategic value of BDA plays an important role in determining whether Indian companies implement BDA.
(Zarea <i>et al.</i> , 2026)	Industry 4.0 technologies (AI, ML, IIoT) can improve productivity and sustainable development, but their adoption involves technical, organizational, financial, social, and environmental risks, especially for SMEs.	Survey of 307 professionals from mining, automotive manufacturing, and construction (May–July 2020). Risks were assessed across three adoption stages using the Fuzzy Analytical Hierarchy Process (FAHP).	Technical risks dominated across industries and adoption stages. SMEs experienced higher organizational and financial risks, whereas social and environmental risks were systematically undervalued.
(Jamwal <i>et al.</i> , 2026)	Industry 4.0 adoption in SMEs in emerging economies is linked to sustainability, resource efficiency, and competitiveness. The study emphasizes organizational, technological, supply-chain, environmental, and social enablers.	A survey of 233 Indian manufacturing SMEs employe EFA to classify into five categories, following by Fuzzy-AHP prioritized them and Fuzzy-DEMATEL to analyze their interrelationships. Sensitivity analysis also utilizes validated the results.	Digital technologies and environmental strategies were found to depend strongly on organizational and policy support.
(Abu-Lail <i>et al.</i> , 2025)	Industry 4.0 (I4.0) adoption strategies in SMEs were evaluated from technology and Technology–Organization–Environment (TOE) perspectives, addressing criteria importance, data variability, and expert uncertainty	A three-phase Circular-Fermatean Fuzzy Sets–Fuzzy Weighted Zero-Inconsistency (C-FFS–FWZIC) framework evaluated 30 technology and 114 TOE-ecosystem criteria, supported by sensitivity and comparative analyses	Rankings varied substantially across perspectives: I4.0AS23 ranked first technologically but 26th under TOE, whereas I4.0AS1 ranked first under TOE but 15th technologically. I4.0AS25 ranked sixth in both, indicating balanced performance.
(Venkatesh <i>et al.</i> , 2025)	Data analytics capabilities are increasingly important for operational efficiency, resilience, and sustainability.	Editorial synthesis of research contributions on the interplay between analytics and operations in MSMEs, highlighting key research trends and emerging applications of analytics and Industry 4.0 technologies.	Analytics and Industry 4.0 may improve the operational efficiency, resilience, and sustainability of the MSMEs and future research should investigate the challenges to the implementation of business intelligence and dynamic capabilities for digital transformation.

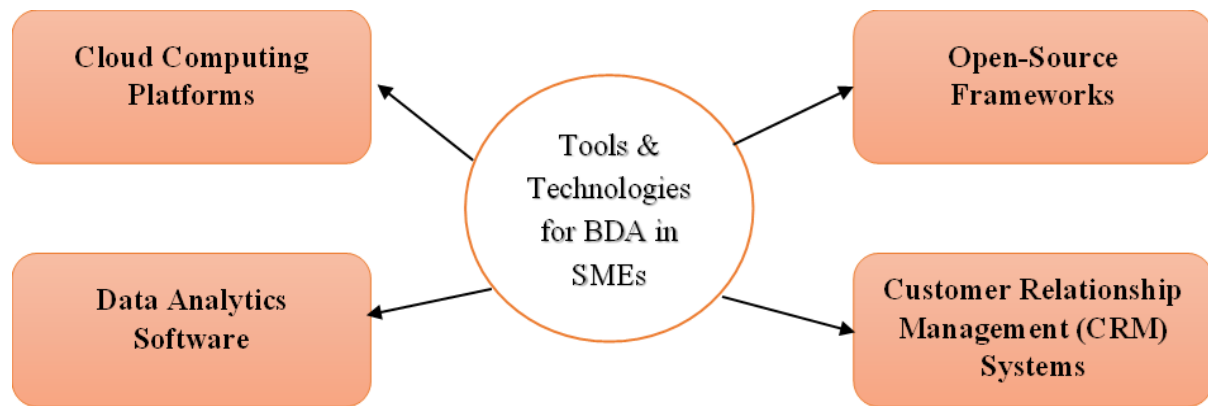


Figure 1. Application of Big Data Analysis on SMEs

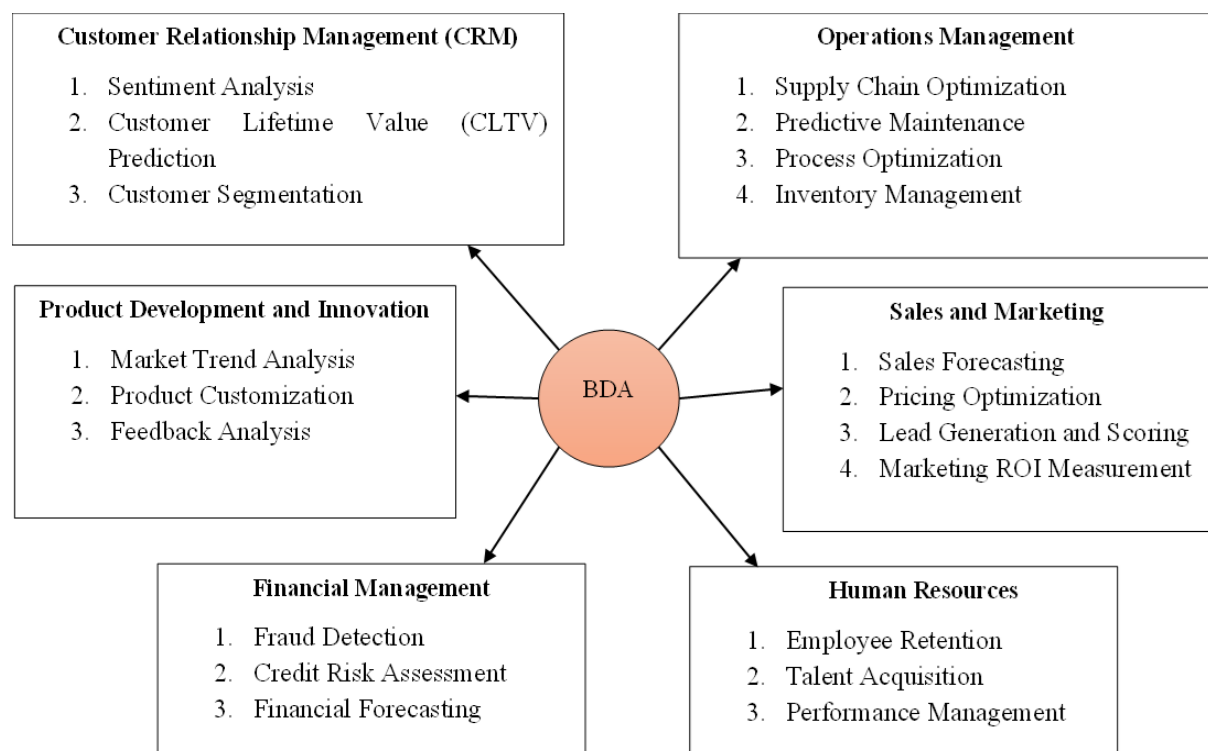


Figure 2. Application of Big Data Analysis on SMEs

Source: Author's Own

METHODS

Research Design

The review follows PRISMA 2020 guidelines to ensure a rigorous, transparent, and reproducible research process, supported by structured reporting recommendations, checklists, and flow diagrams for systematic reviews (PRISMA Executive, 2026).

Search Strategy

A structured published evidence search was performed across Web of Science, Scopus, Google Scholar, Elsevier, Taylor & Francis, Springer, and Wiley, to find studies relevant to objectives (Google Scholar, no date; Clarivate, 2026; Elsevier, 2026b, 2026a; Informa UK Limited, 2026; John Wiley & Sons Inc, 2026; Springer Nature, 2026). The retrieval of relevant publications was performed by means of predefined keywords and Boolean operators. Search

string representatives: “Big Data Analysis” AND “SMEs”, “Big Data” AND “Industry 4.0”, “Data Analytics” AND “Small and Medium Enterprises” and “Data Mining” AND “-written4.0”. English written publications, peer-reviewed articles published between 2021 to 2026, were included to ensure consistency in data extraction and analysis.

Eligibility Criteria

Eligibility criteria established emphasizing objectives relevancy. They Passed conformity when they investigated the adoption or application of BDA in SMEs, particularly in relation to organizational performance and Industry 4.0. Inclusion of conceptual and empirical studies on the relationship between BDA implementation and SME performance. Publications were excluded if they were not focused on BDA or SMEs, did not have a clear theoretical or methodological framework.

Study Selection Process

The study selection procedure followed PRISMA 2020 framework (PRISMA Executive, 2026). From seven academic sources, 539 records were initially retrieved, comprising 420 articles from Google Scholar, 30 from Scopus, 30 from Springer, 26 from Web of Science, 16 from Taylor & Francis, 9 from Elsevier, and 8 from Wiley (Google Scholar, no date; Clarivate, 2026; Elsevier, 2026b, 2026a; Informa UK Limited, 2026; John Wiley & Sons Inc, 2026; Springer Nature, 2026).

After removing duplicates based on screening titles and abstracts, 162 studies remained for further evaluation based on the predefined inclusion criteria. Following the full-text assessment, 142 studies were excluded due to insufficient theoretical support or limited relevance to the impact of BDA on SME performance. Consequently, 20 studies satisfied all eligibility requirements which illustrated in the PRISMA flow diagram (Figure 3).

Data Extraction and Management

Researchers systematically extracted the data to ensure accuracy and reduce bias. Each researcher independently reviewed assigned articles and entered relevant information into a shared Excel database. The data extracted included author(s), year of publication, theoretical framework used, research methodology, and main findings related to the topic. Any issues were resolved through discussion between the researchers, and corrections were made when necessary.

Table 2. Eligibility Criteria

Criteria	Inclusion	Exclusion
Topic	Big Data in SME assuring Industry 4.0	Articles unrelated to BD on SME
Framework	Research framework for Big Data in SME with Industry 4.0	Not adequate framework in the articles
Language	English	Not English
Time Frame	From 2021 to 2026	Outside 2021 to 2026

Strings

To identify relevant studies addressing the role of Big Data in the Industry 4.0 context, a set of search strings was developed using key terms related to Big Data, data analytics, and data mining. The search strings applied in this systematic literature review are presented in figure 3 below:

“Big Data”, “Data Analytics”, and “Data Mining”, “Big Data in Industry 4.0”

Figure 3. Search Strings Utilized in The Review

Data Collection

Data collected using seven academic databases: Google Scholar, Springer, Scopus, Web of Science, Tylor & Francis, Wiley and Elsevier. A total of 539 records were initially retrieved, comprising 420 articles from Google Scholar, 30 from Scopus, 30 from Springer, 26 from Web of Science, 16 from Taylor & Francis, 9 from Elsevier, and 8 from Wiley (Google Scholar, no date; Clarivate, 2026; Elsevier, 2026b, 2026a; Informa UK Limited, 2026; John Wiley & Sons Inc, 2026; Springer Nature, 2026).

These records were subsequently screened, and duplicate records were removed before the title and abstract screening stage. The collected studies were resourced to the two researchers. Prevention of redundancy and guarantee comprehensive literature coverage, each researcher was designated a particular publication feasible to review autonomously. Information from the chosen studies was designed into a communal spreadsheet for mutual examination and instantaneous modifications. Following the development of the search strings, the study employed the PRISMA 2020 framework to systematically identify, screen, and select relevant studies for the review. The overall data collection and study selection process is illustrated in figure 4:

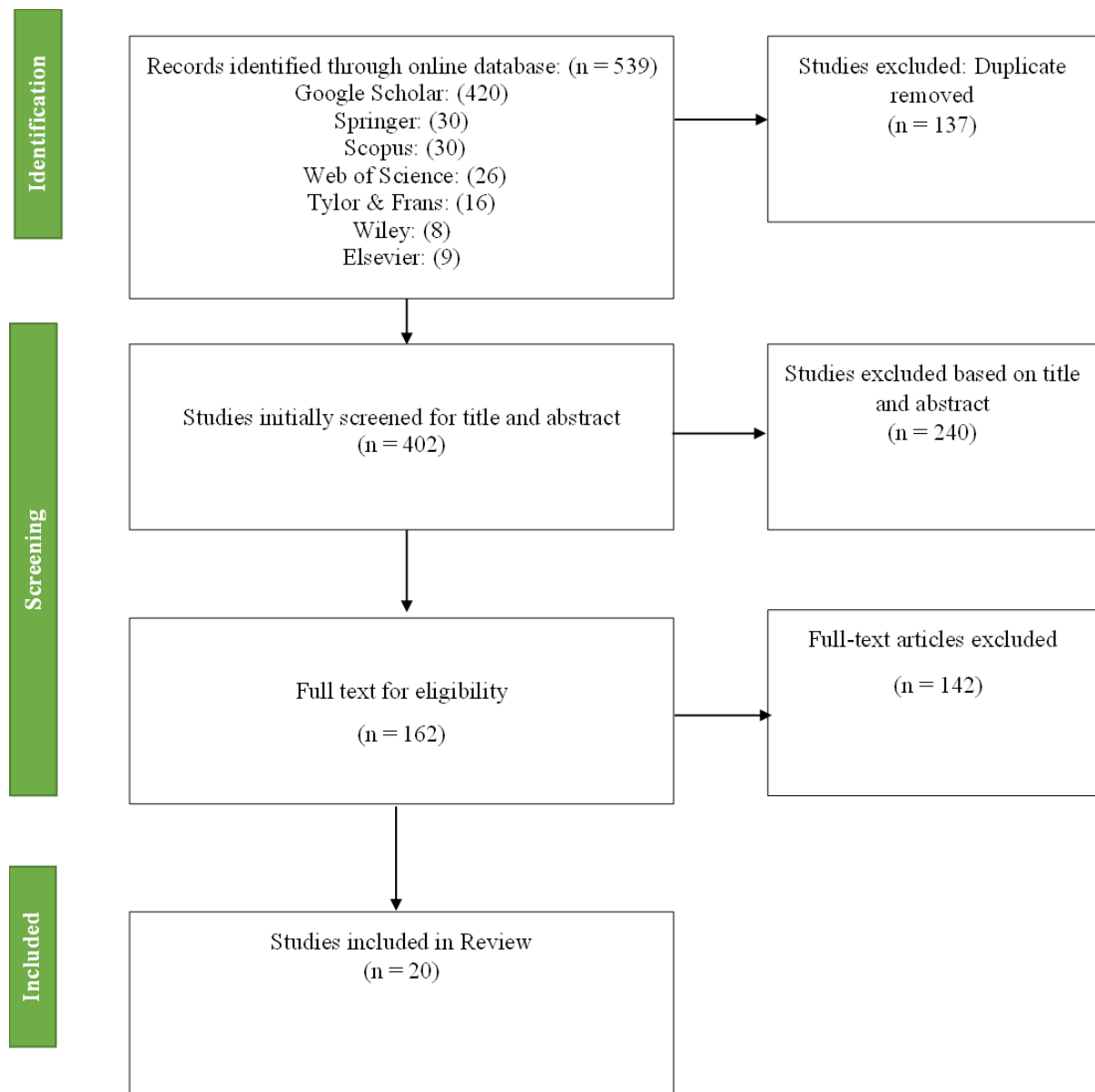


Figure 4. Data Collection Process Flowchart using PRISMA 2020 Framework

RESULTS AND DISCUSSION

Advantages of BDA in SMEs Aligned with Industry 4.0

The systematic literature review identifies several key benefits associated with Big Data Analytics (BDA) adoption among SMEs within the Industry 4.0 context. These benefits extend beyond operational improvements, encompassing decision-making, risk management, innovation, customer-oriented quality improvement, cost reduction, revenue growth, pricing optimization, and competitive advantage. Figure 5 illustrates the main advantages of BDA in SMEs, particularly in relation to Quality 4.0:

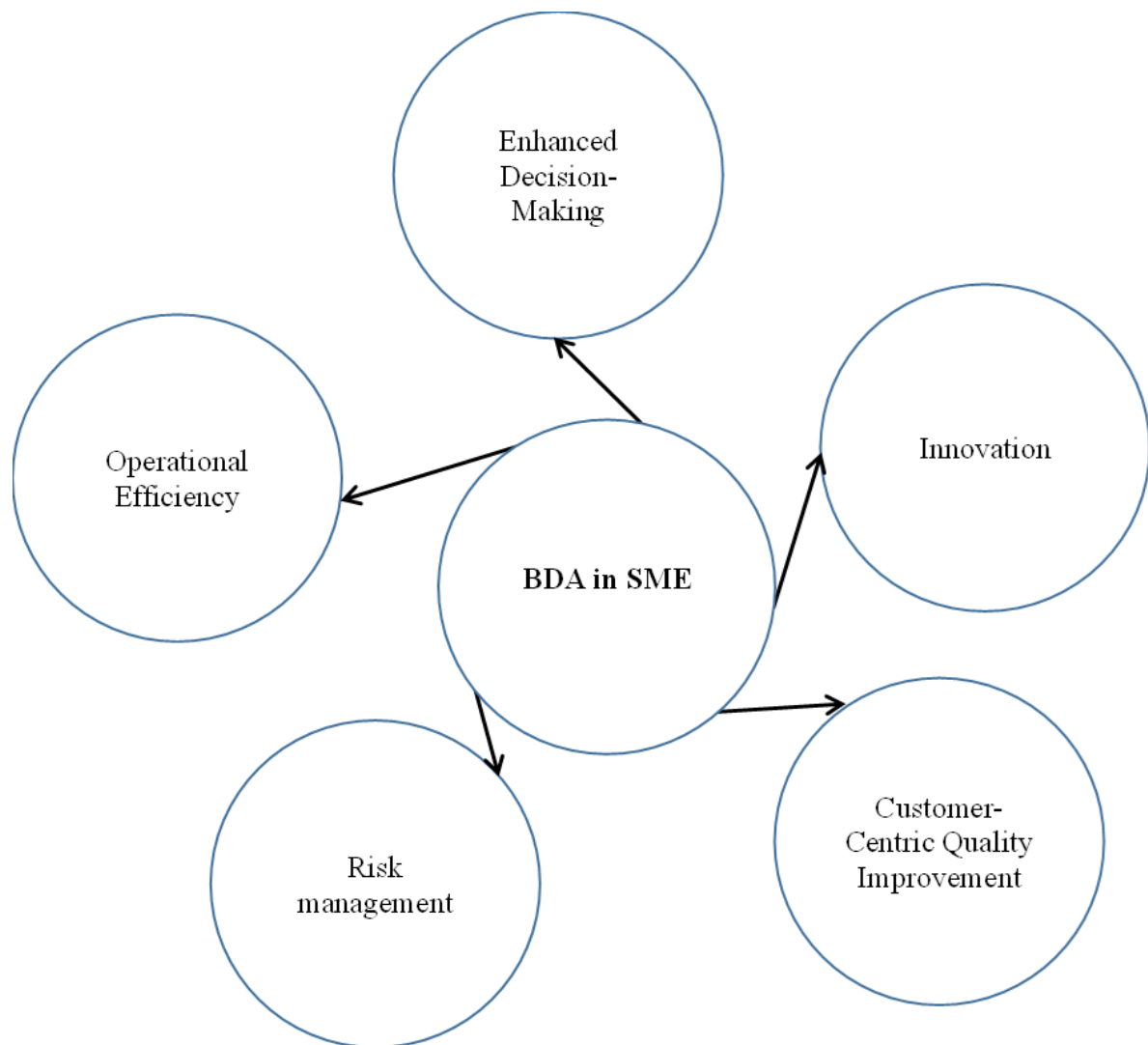


Figure 5. Advantages of BDA in SMEs Aligned with Quality 4.0

The finding presented in figure 5 indicates that BDA contributes to SME performance through multiple interconnected mechanisms. By transforming large volumes of data into actionable insights, BDA enables SMEs to identify operational inefficiencies, improve resource utilization, understand customer preferences, manage risks, and support continuous innovation. These benefits suggest that BDA functions not only as a technological tool but also as a strategic capability that can support SMEs in responding to increasingly data-driven business environments. To further synthesize the evidence identified across the reviewed studies, table 3 summarizes the principal applications of Big Data in the SME sector:

Table 3. Application of Big Data in The SME Sector

Segments	Description	Reference
Operational Efficiency	Big data analytics helps SMEs streamline operations by identifying inefficiencies, automating routine tasks, and optimizing supply chains. Examining workflow and utilization of resources can assist businesses in cutting costs, reducing delays and boosting overall productivity.	(Choi, Chan and Yue, 2017; Choi, Wallace and Wang, 2018)

Segments	Description	Reference
Enhanced Decision-Making	Big data provides insights into customer behavior and business performance, reducing guesswork and enabling faster, more accurate planning.	(Nasrollahi, Ramezani and Sadraei, 2020)
Risk Management	BD tools detect patterns, anomalies, and financial instability. This allows SMEs to proactively address threats and ensure compliance, protecting both assets and reputation.	(Yuan and Wang, 2019)
Innovation	Analyzing large datasets uncovers unmet needs, emerging trends, and customer preferences.	(Saura, Palacios-Marqués and Ribeiro-Soriano, 2023)
Customer-Centric Quality Improvement	BD enables SMEs to gain a deep understanding of customer feedback, behavior, and preferences. This leads to personalized experiences, targeted marketing, and improvements in product and service quality, ultimately increasing customer satisfaction and loyalty.	(Sharma <i>et al.</i> , 2023)

The evidence in table 3 demonstrates that BDA applications span both internal and market-oriented activities. Internally, BDA supports operational efficiency by identifying inefficiencies and optimizing processes, while externally it facilitates a better understanding of customer behavior and market needs. In addition, BDA contributes to risk management and innovation by enabling SMEs to identify anomalies, emerging trends, and unmet customer needs.

Customer-centric quality improvement further demonstrates how data-driven insights can be translated into more personalized products, services, and marketing strategies. Beyond these applications, the literature also identifies several direct business benefits associated with Big Data adoption. Table 4 presents the potential benefits of Big Data for SMEs:

Table 4. The Potential Benefits of SME by BD

Big Data Application	Description	Reference
Reduces Overall Costs	The main key of reducing overall costs is efficiency. SMEs can use BD to identify their inefficiencies and BDA to address this problem. For example, consumers uninterest buy gift wrap when they check out. This provision can be terminated by a small firm and as a result they can stop stocking present wrapping materials which would save operating expenses.	(Maroufkhani, Iranmanesh and Ghobakhloo, 2022)
Boosts Revenue and Sales	By BDA, SMEs gain a great deal about the preferences of their customers. Companies can utilize this information to boost sales.	(Lahoti and Panse, 2022)
Optimizes Pricing Decisions	Pricing is a crucial factor for SMEs to thrive in business. A businessman cannot succeed in	(GANUSHCHAK-YEFIMENKO, 2025)

Big Data Application	Description	Reference
	business if he set good's price without analysis rival's supply and demand.	
Competitive Advantage	Big data allows small businesses to focus on the needs of local customers. Data tools offer insight into purchasing patterns and eliminate the need for guessing when examining the local market. If small businesses have a solid understanding of their clients' opinions and preferences, they may be able to add a personal touch and get a competitive advantage. By sifting through the digital activity of their customers, data technologies reduce the significant amount of human labor that small businesses must conduct.	(Hernandez <i>et al.</i> , 2021)
Increases Efficiency in Decision-Making (use Hybrid Data)	SOCIAL SOMAINTEINING entails gathering and evaluating user data, and understanding key aspects of their buying behavior, interests and responses to promotions. Social media and big data worked together for social media mining. Small companies may analyze their social media accounts more effectively with the use of data-based tools and procedures. By collecting data on business practices, this method frees up small firms from having to spend additional time or effort manually searching through multiple social media networks.	(Injadat, Salo and Nassif, 2016)

As shown in Table 4, the benefits of BD extend to financial and strategic dimensions. BDA can help SMEs reduce costs by identifying inefficient activities, increase revenue by analyzing customer preferences, and support pricing decisions through the analysis of market conditions. Moreover, access to customer and social media data can strengthen SMEs' understanding of local markets and improve decision-making. These capabilities may enable SMEs to respond more effectively to customer needs while reducing reliance on intuition or manual analysis.

Taken together, the findings from Tables 3 and 4 indicate that the benefits of BDA are not generated solely by the availability of data or analytical technologies. Their realization also depends on organizational capabilities, technological readiness, and the external business environment. Therefore, the identified factors were further synthesized into organizational, technological, and environmental dimensions, as presented in Table 5.

Table 5. Synthesis of Organizational, Technological, and Environmental Factors Influencing BDA Benefits in SMEs

Dimension	Key Factors Identified Across Studies	Mechanism	Main SME Outcomes
Organizational	Managerial capability, knowledge management, analytical skills, customer orientation, resource availability	Converts analytical insights into decisions and actions	Better decision-making, innovation, customer retention
Technological	Data availability, analytics tools, automation, social media/hybrid data, data integration	Enables collection, processing and analysis of complex data	Efficiency, cost reduction, risk management, pricing optimization
Environmental	Competition, changing customer preferences, market uncertainty, digitalization, Industry 4.0	Creates pressure and opportunities for data-driven responses	Competitive advantages, innovation, responsiveness, customer-centric quality
Interaction	Alignment of organizational, technological and environmental capabilities	Convert external pressure and data resources into actionable business intelligence	Sustainable performance and competitive advantage

Overall, the reviewed literature suggests that BDA can strengthen SME performance by connecting data resources with organizational capabilities and external market demands. BDA provides SMEs with valuable insights into consumer preferences, purchasing patterns, and retention behavior, enabling them to better understand customer needs and identify behavioral patterns. These insights allow SMEs to develop more targeted marketing strategies, personalize customer interactions, improve customer engagement, and encourage repeat purchases and customer loyalty. By transforming customer data into actionable information, BDA also supports more informed and timely business decision-making, reducing reliance on assumptions in marketing and operational planning.

Furthermore, BDA assists SMEs in evaluating customer lifetime value and customer acquisition costs, enabling them to distinguish between high-value and low-value customers. Understanding the relationship between customer acquisition costs and customer profitability allows SMEs to allocate marketing resources more effectively and prioritize customer segments that generate greater long-term value. This capability can improve marketing effectiveness, optimize investment decisions, and enhance the efficiency of resource allocation. Consequently, the integration of customer analytics, data-driven decision-making, and strategic resource allocation can contribute to improved operational efficiency, customer retention, innovation, revenue generation, and sustainable business growth.

Implications

For SME managers, this study emphasizes their responsibility regarding the adoption of BDA as it relates to their position within the organizational hierarchy. Due to the sheer size of SMEs, management is simpler, almost always an owner-manager who doubles as the CEO, making decisions unilaterally. Moreover, managers in SMEs are more persuasive than in larger

firms because SMEs lack formally defined processes. Therefore, as advocates of new technologies, managers must proactively work to cultivate this acceptance. The study explains that a manager's decision to accept BDA will depend on the level of integration with existing systems, the compatibility with organizational culture, adoption complexity, and funding, skilled personnel available, and required IT infrastructure.

The policy makers could accelerate SMEs' to promote investment in big data analytics by providing some incentives. They should spearhead the process by rolling out programs that offer technical assistance and training on data analytics to help these small enterprises resolve the resources and skills shortage challenges they experience, therefore, encouraging them to use the BDA for their efficiency and performance.

In addition to AI and machine learning, the cloud provides the infrastructure that is essential for managing massive volumes of data. The key to providing organizations with the tools and techniques they need to mine and analyze data from many sources is BDA. Additionally, it's possible that there aren't enough highly skilled employees who understand how to properly manage and use these technologies. Finally, the implementation of such systems may be subject to some budgetary limitations, in SMEs businesses.

CONCLUSION

Conclusion

This systematic literature review expresses that how BDA can optimize SME's competitiveness and performance by improving decision-making, operational efficiency, customer relationship management, and innovation. However, several deterrents that continue to hinder widespread adoption include financial constraints, limited technological expertise, and low levels of digital literacy, particularly among SMEs in developing and economically disadvantaged contexts. This research provides theoretical insights on digital transformation and circular innovation in a framework of sustainable and cutting-edge computational production. It offers important implications for policy and practice.

Policy makers should strengthen digital infrastructure, foster digital inclusion and promote cross-sector collaboration to create an enabling environment for SMEs. In contrast, Industry practitioners should strategically leverage AI, BD, and related digital technologies to improve operational efficiency, foster creativity, and advance sustainability within Industry 4.0 transformation. Future research can stroke in different economic contexts to scrutinize the long-term ramification of digital circular innovation on SME competitiveness and sustainability. By integrating technological intelligence such as BDA with circular innovation, SMEs can leverage regenerative growth while balancing economic viability and eco-sustainability.

Limitations and Future Directions

Findings suggest that using BDA in the world of Industry 4.0 works well when there is money, when employees have the right technical skills and when data analytics projects match what the company wants to achieve. Researcher has contributed nowadays but not properly proved in some areas especially in countries that are digitalized. Future research should be conducted in different geo-locations and on different types of businesses so that the results can be used more widely. Policymakers and companies should work together to create policies, build better systems and offer training so that BDA can be used better and so that small and medium businesses can digitalize faster.

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Conflict of Interest

The authors declare that they have no conflicts of interest related to the research, authorship, or publication of this article. The authors confirm that there are no financial, professional, personal, or institutional relationships that could have influenced the research process, interpretation of the findings, or preparation of the manuscript.

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