BIG DATA ANALYTICS AND DIGITAL TRANSFORMATION AND GROWTH IN INDONESIAN MSMES: A NARRATIVE REVIEW

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(Received 15th February 2026; revised 13th April 2026; accepted 25th April 2026)

Abstract. Research on Big Data Analytics (BDA) as a vehicle for digital transformation is particularly pertinent for Micro, Small, and Medium Enterprises (MSMEs), which continue to struggle in recovering from the COVID-19 pandemic. However, scholarly investigations addressing the utilization of BDA and potential solutions to the challenges faced by Indonesian MSMEs remain scarce. This study seeks to examine the role and impact of BDA adoption and to identify effective strategies for fostering MSME development in Indonesia. Employing a narrative review approach, the study provides a comprehensive understanding of how BDA enhances business processes, drives innovation, and generates both economic and social value for MSMEs. The findings demonstrate that the application of BDA enables MSMEs to make more informed decisions by offering deep insights into market trends, customer preferences, and operational efficiency. This, in turn, strengthens competitive advantage, fosters customer loyalty, and improves marketing effectiveness. Nevertheless, the adoption of BDA is hindered by several critical challenges, including knowledge gaps, limited IT infrastructure, financial constraints, and insufficient managerial support. Technical complexities, as well as concerns related to data security and privacy, further impede implementation. To address these barriers, MSMEs are advised to conduct thorough evaluations of their internal capacities, invest in training and education, and initiate small-scale BDA projects that may subsequently be scaled up. External support, including collaboration with service providers and consultants, together with government interventions in the form of financial incentives and the establishment of ethical data governance frameworks, is likewise essential to facilitate effective digital transformation. Overall, the strategic utilization of BDA constitutes a vital mechanism for enhancing competitiveness and promoting the sustainable growth of MSMEs in the digital era.
Keywords: *big data, MSMEs, data analytics, digital transformation, business decision*

Introduction

Micro, Small, and Medium Enterprises (MSMEs) play a pivotal role in the economy of any nation, particularly through their contributions to job creation, innovation, and inclusive economic growth (Maroufkhani et al., 2021). MSMEs not only serve as the backbone of the economy in many developing countries but also invigorate local markets by providing diverse goods and services. In the face of intensifying global competition, the role of MSMEs becomes increasingly strategic, as they are required to continuously innovate and enhance operational efficiency to remain relevant (Maroufkhani et al., 2021). The rapid advancement of digital transformation presents both opportunities and challenges for MSMEs to thrive in an increasingly data-driven environment. The development of digital technologies, particularly Big Data Analytics (BDA), has revolutionized business operations by enabling large-scale, real-time data analysis. Such technologies do not merely facilitate strategic decision-making but also allow MSMEs to better understand consumer behavior, optimize supply chains, and strengthen their competitive advantage (Aldossari et al., 2023). Through in-depth data analysis, MSMEs are able to identify market trends, anticipate shifts in demand, and design more effective marketing strategies. Moreover, the adoption of BDA paves the

way for more innovative products and services, aligned with efforts to accelerate digitalization in the MSME sector (Maroufkhani et al., 2021). By leveraging BDA, MSMEs can analyze consumer behavior and preferences, thereby enabling the development of more personalized marketing strategies and enhancing customer experience. Such targeted approaches hold the potential to increase sales and foster customer loyalty. In addition, BDA supports MSMEs in identifying operational inefficiencies and predicting potential risks before they occur, ultimately resulting in improved resource management and cost reduction.

The utilization of Big Data, which encompasses the collection, storage, and analysis of large volumes of data, empowers MSMEs to optimize business operations, formulate more accurate marketing strategies, and strengthen real-time interactions with customers (Mosbah, 2024). Within the MSME context, Big Data serves as a catalyst not only for operational efficiency but also for innovation, enabling smaller enterprises to compete with larger business entities by dynamically adjusting their strategies (Saraswathi, 2024). MSMEs hold an especially significant role in Indonesia's economic growth. According to data from Statistics Indonesia (BPS), MSMEs account for 99% of all business units, contribute 60.5% to the national Gross Domestic Product (GDP), and absorb 96.9% of total national employment (Juwitasari, 2023). As the driving force and backbone of Indonesia's economy, MSMEs have consistently demonstrated resilience, particularly during periods of global economic uncertainty and domestic economic downturns. *Figure 1* illustrates the progress of MSME digitalization in Indonesia, which has shown promising achievements. In 2020, approximately 12 million MSMEs had already undergone digital transformation, exceeding the initial target of 10 million. This success continued through 2023, with 27 million MSMEs adopting digital technologies. The Bangga Buatan Indonesia (Proudly Made in Indonesia) National Movement (Gernas BBI) contributed significantly to the increase in digitalized MSMEs, from 14% to 25% in 2020. Similarly, the MSME Program launched in August 2020 yielded positive results, recording transactions amounting to IDR 118.8 trillion across 10,412 MSMEs by September 2021. The digital transformation of MSMEs has made a substantial contribution to the growth of Indonesia's digital economy, as evidenced by a 22% increase in digital economic revenues in 2022, reaching USD 77 billion compared to the previous year. The e-commerce sector has emerged as the primary driver of this growth, as indicated by data from the Indonesian E-Commerce Association (idEa), which reported that 21.8 million MSMEs had gone digital by 2022 (Istamarina et al., 2025).

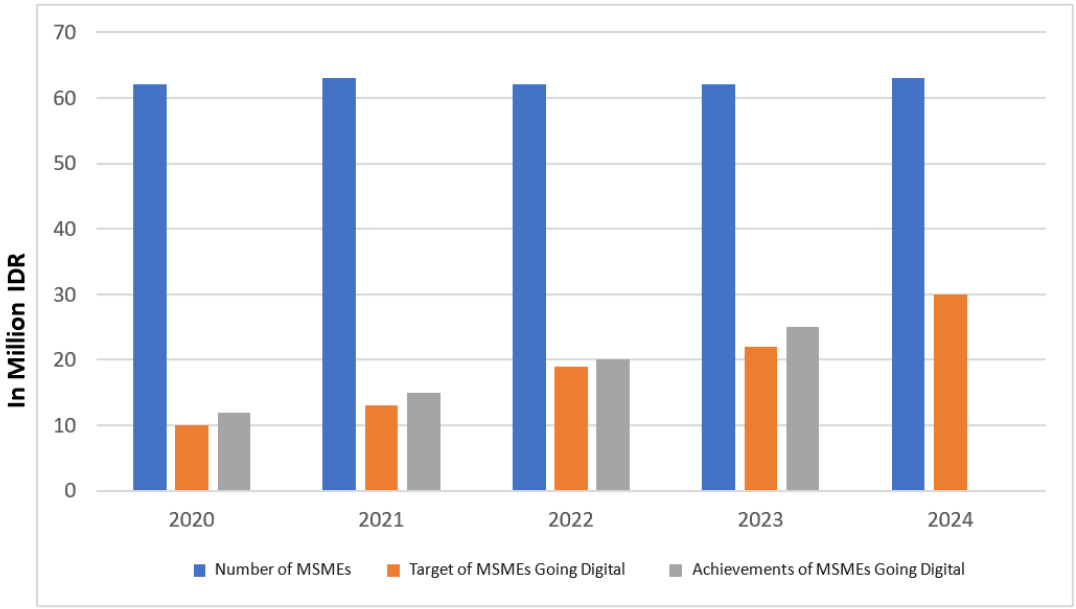

Figure 1. *Number of Digitalized MSMEs (Millions).*

Despite its significant potential benefits, the adoption of BDA among MSMEs continues to encounter various challenges. Financial constraints, the lack of skilled professionals with expertise in digital technologies, and internal resistance to change represent major obstacles commonly faced (Maroufkhani et al., 2021). Concerns over data security and privacy further exacerbate the risks associated with Big Data implementation, given the potential for data breaches that could severely harm businesses (Maroufkhani et al., 2021). Similarly, the adoption of BDA technologies among MSMEs in developing countries, including Indonesia, is frequently impeded by technological infrastructure limitations, low levels of digital literacy, high implementation costs, and insufficient government support (Godwin et al., 2024; Putra and Santoso, 2020). The 2022 National MSME Survey indicated that only 17% of Indonesian MSMEs used digital platforms for marketing, and merely 10% employed digital management information systems (BPS, 2022). This demonstrates that a large proportion of MSMEs have yet to maximize digital technologies to enhance their performance and competitiveness.

The majority of existing literature on BDA adoption and its associated benefits for MSMEs, as well as the factors influencing its implementation, primarily focuses on Europe (Ardito et al., 2024; Willetts and Atkins, 2024; Chernova et al., 2023; Ciacci and Penco, 2023; Skare et al., 2023; Hansen and Bøgh, 2021) Asia (Escolano et al., 2025; Al-Shanableh et al., 2024; Asiri et al., 2024; Babalghaith and Aljarallah, 2024; Soomro et al., 2024; Maroufkhani et al., 2021), Afrika (Telukdarie et al., 2022) and the United States (Kasiri et al., 2024). Meanwhile, journal publications investigating the opportunities and challenges of big data analytics for MSME performance in the Indonesian context remain limited and predominantly emphasize technical aspects of digital technology utilization (Ratnaningtyas et al., 2025; Hariyanti and Kristanti, 2024; Chusumastuti et al., 2023; Putra et al., 2023; Zahiroh, 2022; Fadillah and Fasa, 2021) along with strategies to address these challenges (Kuleh et al., 2023; Zahara et al., 2023; Ausat and Peirisal, 2021). Accordingly, the present study seeks to explore the factors influencing BDA adoption among Indonesian MSMEs and to identify effective

strategies that may help overcome such barriers. The findings are expected to provide practical insights that support MSME digital transformation and improve business performance through the optimal application of big data analytics.

Literature review

Big Data Analytics (BDA) has gained increasing recognition as a critical component for organizations seeking to enhance decision-making processes and operational efficiency, particularly within the context of Industry 4.0 (Maroufkhani et al., 2021). With its capacity to process vast amounts of both structured and unstructured data, BDA facilitates the extraction of valuable insights that can inform strategic initiatives. The perceived relative advantages of BDA, such as improved financial and market performance, serve as strong motivators for organizations to invest in analytical technologies. BDA refers to the process of analyzing large and complex datasets to uncover patterns, correlations, and insights that support decision-making and strategic planning (Thanabalan et al., 2025). This process involves the application of advanced analytical techniques, including data mining, predictive analytics, and machine learning, to extract meaningful information from structured as well as unstructured data (Aldossari et al., 2023; Maroufkhani et al., 2021). Through these capabilities, BDA enables organizations to process and comprehend data holistically, thereby generating new ideas that can foster operational efficiency, enhance customer experience, and promote innovation in products and services. BDA is typically characterized by three primary dimensions: volume (the massive amount of data generated), velocity (the speed at which data is produced and processed), and variety (the diversity of data types, such as text, images, and videos) (Thanabalan et al., 2024; Maroufkhani et al., 2021). The effective utilization of BDA is critical for organizations to remain competitive in the digital era, as it supports real-time data-driven decision-making. Successful implementation, however, requires adequate IT infrastructure, competent human resources, and an organizational culture that embraces data-driven approaches. Only under such conditions can BDA be optimally integrated into business processes.

Theoretical framework of digital transformation

The integration of digital technology into all facets of organizational operations is known as "digital transformation," and it radically alters how businesses operate and provide value to their clients. Cloud computing, big data, the Internet of Things (IoT), and artificial intelligence (AI) are just a few of the many technologies that are part of this shift. According to Westerman et al. (2011), digital transformation extends beyond the mere adoption of technology; it requires a holistic approach involving cultural change and continuous adaptation to evolving technologies. For MSMEs, digital transformation provides opportunities to improve efficiency, broaden market reach, and enhance customer service. Previous research indicates that a successful digital transformation may greatly enhance corporate performance, but it also highlights the necessity of a strategic strategy customized to each firm's unique skills and circumstances (Trushkina et al., 2020).

Micro, Small, and Medium Enterprises (MSMEs)

Micro, small, and medium enterprises are forms of small-scale economic activities owned by the people that meet the criteria of net assets or annual sales revenue and

ownership as regulated in the law. Small enterprises can be defined as follows (Al Farisi, 2022): (1) Development of the four primary economic sectors: manufacturing, human resources, agriculture, and marine business; that operate as the engine of development; (2) Development of priority areas to accelerate economic recovery through regional approaches, by selecting certain regions to accommodate priority programs and to develop sectors and potential industries; (3) Enhancement of community empowerment efforts. Based on Law No. 20 of 2008 concerning Micro, Small, and Medium Enterprises (MSMEs), the government classifies enterprises according to asset and turnover criteria (Khasanah et al., 2022): (1) "Micro Enterprises are productive businesses owned by individuals and/or individual business entities that meet the criteria of maximum net assets of IDR 50 million, excluding land and buildings of the business premises. In addition, they have an annual turnover of a maximum of IDR 300 million; (2) Small Enterprises are independent productive businesses owned and managed by individuals or business entities. Such enterprises are neither subsidiaries nor branches of medium or large enterprises, whether directly or indirectly owned or controlled. The criteria for small enterprises include net assets ranging from more than IDR 50 million up to IDR 500 million, excluding land and buildings of the business premises. Furthermore, they have annual sales revenue of more than IDR 300 million and up to a maximum of IDR 2.5 billion; (3) Medium Enterprises are independent productive businesses that are not subsidiaries or branches of other companies. The criteria for medium enterprises include net assets exceeding IDR 500 million and up to a maximum of IDR 10 billion, excluding land and buildings. In addition, they have annual turnover ranging from more than IDR 2.5 billion up to a maximum of IDR 50 billion."

Syafnur et al. (2023) says that digital transformation in micro, small, and medium enterprises (MSMEs) refers to the application of digital technologies and the use of data to optimize operations, enhance efficiency, and expand business reach. The objectives of digital transformation are as follows: (1) Improving competitiveness: The main objective of training for MSME actors in designing online businesses is to improve their competitiveness in the digital marketplace. By understanding and adopting contemporary strategies and technologies, MSMEs can compete more effectively with larger enterprises and other competitors in the digital market; (2) Business development: Such training aims to assist MSME actors in developing their businesses from conventional models into online businesses that are more efficient and effective. This includes aspects of promotion, sales, inventory management, and customer service; (3) Enhancing the local economy: Through MSME development, it is expected to contribute more significantly to the local economy. By optimizing their business potential, MSMEs can create new jobs, increase household income, and stimulate the overall local economy.

Materials and Methods

This study systematically examines and synthesizes previous research on the digital transformation of Indonesian MSMEs using a narrative review methodology. Peer-reviewed journals, industry reports, government publications, and case studies released in the last five years, from 2020 to 2025, are the main sources of analysis. The literature was gathered using keywords like "Big Data Analytics," "Technology Adoption," "Digital Transformation," and "Small and Medium Enterprises Indonesia" from

extensive databases like Scopus and Web of Science. Refined search criteria identified 9 studies from Web of Science and 14 from Scopus, which formed the analytical foundation of this study. Each selected article was critically examined to identify relevant themes, including the benefits of digital transformation, the challenges faced by MSMEs, the factors influencing technology adoption, and effective strategies for digital integration. The findings from these sources were subsequently categorized and analyzed to delineate current phenomena in MSME digital transformation, highlight significant research gaps, and establish a context for further investigation. This study is intended to assess the relevance of and identify journals that examine the development, challenges, and opportunities of Big Data Analytics adoption among MSMEs. By utilizing recent literature, this review aims to provide a comprehensive overview of digital trends and innovations, as well as to present in-depth insights that can serve as a strategic foundation for digital transformation in the micro, small, and medium enterprise sector.

Results and Discussion

The author conducted an exploration of scientific literature to analyze the significance of BDA adoption in MSMEs. The journals reviewed are presented in *Table 1*.

***Table 1**. Journals analyzed.*

No.	Journals
1.	Al-Shanableh, N., Alzyoud, M., Alomar, S., Kilani, Y., Nashnush, E., Al-Hawary, S., Al-Momani, A. (2024): The adoption of big data analytics in Jordanian SMEs: An extended technology-organization-environment framework with diffusion of innovation and perceived usefulness. – International Journal of Data and Network Science 8(2): 753-764.
2.	Ardito, L., Filieri, R., Raguseo, E., Vitari, C. (2025): Artificial intelligence adoption and revenue growth in European SMEs: Synergies with IoT and big data analytics. – Internet Research 35(4): 1508-1534.
3.	Asiri, A.M., Al-Somali, S.A., Maghrabi, R.O. (2024): The integration of sustainable technology and big data analytics in Saudi Arabian SMEs: A path to improved business performance. – Sustainability 16(8): 1-28.
4.	Ausat, A.M.A., Peirisal, T. (2021): Determinants of e-commerce adoption on business performance: A study of MSMEs in Malang City, Indonesia. – Jurnal Optimasi Sistem Industri 20(2): 104-114.
5.	Babalghaith, R., Aljarallah, A. (2024): Factors affecting big data analytics adoption in small and medium enterprises. – Information Systems Frontiers 26(6): 2165-2187.
6.	Chernova, O.A., Mitrofanova, I.V., Pleshakova, M.V., Batmanova, V.V. (2023): Use of big data analytics for small and medium-sized businesses. – Serbian Journal of Management 18(1): 93-109.
7.	Chusumastuti, D., Zulfikri, A., Rukmana, A.Y. (2023): Pengaruh digital marketing dan kompetensi wirausaha terhadap kinerja pemasaran: Studi pada UMKM di Jawa Barat. – Jurnal Bisnis dan Manajemen West Science 2(2): 83-93.
8.	Ciacci, A., Penco, L. (2023): Business model innovation: Harnessing big data analytics and digital transformation in hostile environments. – Journal of Small Business and Enterprise Development 31(8): 22-46.
9.	Escolano, V.J.C., Shiang, W.J., Hernandez, A.A., Cardaña, D.A. (2025): Predicting big data analytics adoption intention among small and medium enterprises in the Philippines. – TELKOMNIKA (Telecommunication Computing Electronics and Control) 23(1): 192-200.
10.	Fadillah, R., Fasa, M.I. (2021): Digital economic transformation: Optimalisasi ekonomi digital pascapandemi COVID-19 pada pelaku UMKM. – Jurnal Manajemen dan Organisasi Review 3(2): 123-135.
11.	Hansen, E.B., Bøgh, S. (2021): Artificial intelligence and internet of things in small and medium-sized enterprises: A survey. – Journal of Manufacturing Systems 58(B): 362-372.
12.	Kuleh, Y., Kadafi, M.A., Ilmi, Z. (2023): Prospects of digitalization of MSMEs business expansion in Sepakat Village. – International Journal of Social Science and Business 7(3): 678-687.
13	Maroufkhani, P., Tseng, M.L., Iranmanesh, M., Ismail, W.K.W., Khalid, H. (2021): Big data analytics adoption: Determinants and performances among small- to medium-sized enterprises. – International Journal of Information Management 54: 1-15.
14.	Kasiri, N., Cirino, C., Nasim, C. (2024): The patterns of business analytics adoption in US SMEs: A qualitative approach. – Small Business Institute Journal 20(1): 1-11.
15.	Putra, T.W.A., Solechan, A., Hartono, B. (2023): Transformasi digital pada UMKM dalam meningkatkan daya saing pasar. – Jurnal Informatika Upgris 9(1): 7-12.
16.	Ratnaningtyas, H., Wicaksono, H., Irfal, I. (2025): Barriers and opportunities for MSME development in Indonesia: Internal and external perspectives. – International Journal of Multidisciplinary Approach Research and Science 3(1): 1-8.

17. Skare, M., De Las Mercedes De Obesso, M., Ribeiro-Navarrete, S. (2023): Digital transformation and European small and medium enterprises: A comparative study using digital economy and society index data. – International Journal of Information Management 68: 16p.
18. Soomro, R.B., Memon, S.G., Dahri, N.A., Al-Rahmi, W.M., Aldriwish, K., Salameh, A.A., Al-Adwan, A.S., Saleem, A. (2024): The adoption of digital technologies by small and medium-sized enterprises for sustainability and value creation in Pakistan: The application of a two-staged hybrid SEM-ANN approach. – Sustainability 16(17): 1-27.
19. Hariyanti, S., Kristanti, D. (2024): Digital transformation in MSMEs: An overview of challenges and opportunities in adopting digital technology. – Jurnal Manajemen Bisnis, Akuntansi dan Keuangan 3(1): 37-46.
20. Telukdarie, A., Dube, T., Matjuta, P., Philbin, S. (2022): The opportunities and challenges of digitalization for SMEs. – Procedia Computer Science 217: 689-698.
21. Willetts, M., Atkins, A.S. (2024): Evaluation of a software positioning tool to support SMEs in adoption of big data analytics. – Journal of Electronic Science and Technology 22(1): 1-13.
22. Zahara, Z., Ikhsan, I., Santi, I.N., Farid, F. (2023): Entrepreneurial marketing and marketing performance through digital marketing capabilities of SMEs in post-pandemic recovery. – Cogent Business and Management 10(2): 1-17.
23. Zahiroh, M.Y. (2022): Peluang dan tantangan transformasi digital UMKM di Indonesia pascapandemi COVID-19. – Journal of Economics and Social Sciences 1(2): 124-133.

The role of big data analytics for MSMEs

Big Data Analytics enables MSMEs to make well-informed decisions by providing profound insights into market trends, customer preferences, and operational efficiency (Willetts and Atkins, 2024). This data-driven approach assists MSMEs in rapidly adapting to shifting market conditions and consumer demand. By leveraging big data, MSMEs can identify unique opportunities and potential threats in their markets, thereby formulating strategies to strengthen competitive advantage (Aldossari et al., 2023; Maroufkhani et al., 2021). This capability is particularly critical amid intensifying competition. In addition, MSMEs can utilize big data to analyze customer behavior and preferences, resulting in more personalized marketing strategies. This targeted approach significantly enhances customer experience and reinforces consumer loyalty (Maroufkhani et al., 2021). Big data also contributes to streamlining operations by identifying inefficiencies and optimizing resource allocation, ultimately improving productivity and reducing operational costs. The analytical capacity of big data in processing large datasets enables MSMEs to forecast market trends and consumer behavior more accurately. These insights provide opportunities for MSMEs to innovate and tailor products or services that better align with future demand. Furthermore, big data supports the implementation of sustainability practices by enabling the monitoring of resource utilization and environmental impact. Such practices not only assist MSMEs in complying with applicable regulations but also attract environmentally conscious consumers. By integrating sustainability strategies into their operations, MSMEs can enhance their reputation and market positioning. Overall, the effective use of big data provides substantial competitive advantages within dynamic market environments. Big data utilization constitutes a key driver of sustainable growth and long-term competitiveness for MSMEs.

Challenges and barriers

Digital transformation offers numerous benefits to MSMEs, including reduced transaction costs, lower operational expenses compared to conventional business infrastructure, improved efficiency in the delivery and exchange of goods and services, and increased integration with wider and more interactive markets (Telukdarie et al., 2022). Collectively, these advantages contribute to the sustainable development of MSMEs. This is reinforced by Skare et al. (2023), who emphasized that digital transformation enhances MSME business activities through the acquisition of new customers, improved competitiveness, reduced input costs via efficiency and resource

allocation, easier access to external financing, and adaptability to changing policy frameworks.

Nonetheless, behind these advantages, digital transformation also presents distinct challenges for MSMEs. These include a shortage of skilled labor in operating digital technologies, insufficiently experienced managers, and the potential loss of existing competitive capabilities due to the need to transition to new digital business processes (Skare et al., 2023). Chernova et al. (2023) confirmed similar issues in Russia, where a lack of understanding of the benefits of big data analytics posed a primary barrier for MSMEs. In Indonesia, only 18% of MSMEs utilized digital data in their business strategies, with the majority relying on intuition. Additionally, the high costs of professional analytics software, such as Tableau or Power BI, present another barrier.

Many MSMEs face significant knowledge gaps concerning big data analytics, which can hinder their ability to effectively adopt and leverage the technology (Chernova et al., 2023). This lack of understanding may lead to underutilized BDA investments, as business owners may fail to grasp its potential benefits or applications. Furthermore, MSMEs often lack adequate IT infrastructure to support big data initiatives. This includes inadequate hardware, software, and data management systems, all of which impede adoption and limit the effectiveness of BDA efforts (Chernova et al., 2023). Financial resource constraints represent another common challenge, restricting MSMEs' capacity to invest in big data technologies and related training necessary for effective implementation (Escolano et al., 2025). These limitations can prevent them from fully benefiting from BDA advantages.

Previous studies have discussed the challenges and barriers of digital transformation in Indonesian MSMEs, such as several journal publications conducted by Ratnaningtyas et al. (2025), Hariyanti et al. (2024), Anagusti et al. (2023), Putra et al. (2023), Zahiroh (2022) as well as Kurniawati et al. (2021). A comprehensive identified four main obstacles in the implementation of MSME digitalization policies, namely disparities in digital infrastructure across regions, low levels of digital literacy among business actors, limited access to financing, and complex regulations that are not yet harmonized. Similar findings were also emphasized by Fadillah and Fasa (2021) who highlighted the widening digital divide between urban and rural MSMEs after the COVID-19 pandemic. In addition, the document "Report on the Development of Indonesia's Digital Economy 2022–2023" issued by the Coordinating Ministry for Economic Affairs showed that the government's target of encouraging 30 million MSMEs to go digital by 2024 was still far from being achieved. By the end of 2023, only 12.5 million MSMEs had utilized digital platforms.

Recent statistical data released by the Indonesian Internet Service Providers Association (APJII) indicates that Indonesia's digital ecosystem actually holds great potential. With internet penetration reaching 77% of the total population and e-commerce transaction values reaching IDR 476 trillion in 2022, Indonesia's digital market has emerged as one of the leading markets in Southeast Asia. A study even predicts that Indonesia's digital economy will reach a value of USD 130 billion by 2025, a projection that illustrates the vast opportunities available to MSMEs that succeed in digitally transforming (Zahiroh, 2022).

The development of digital technology also becomes a challenge for MSMEs in Indonesia; although technology provides excellent opportunities for marketing and distributing products, many MSMEs find it difficult to adapt to these changes (Ikhwan and Himawati, 2024). Most MSMEs are still accustomed to traditional ways of running

their businesses, thus being hampered in fully utilizing digital technology. Furthermore, this article refers to the barriers of digital transformation primarily in the growth of MSMEs as put forward by (Zahiroh, 2022) as follows: (1) Digital Infrastructure Gap. One of the main challenges in the development of the digital economy, particularly for MSMEs in Indonesia, is the digital infrastructure gap across regions. Although national internet penetration continues to increase, there remains significant inequality between urban and rural areas, especially in Eastern Indonesia. The availability of fast and stable internet access is an absolute prerequisite for MSMEs to utilize digital platforms for marketing, transactions, and business management. Without adequate infrastructure, MSMEs in marginalized regions risk being left behind in digital transformation; (2) Low Digital Literacy. A number of MSME actors still do not optimally understand how to leverage digital technology to support their businesses, such as using e-commerce, digital marketing, or cloud-based accounting applications. Most of them still operate conventionally and have not developed awareness of the potential market expansion offered by digital platforms; (3) Limited Access to Digital Financing. In the context of the digital economy, access to financing remains a classic yet relevant challenge. Although financial technology (fintech) has expanded alternative financing schemes, not all MSMEs can utilize such services. Many MSME actors do not yet have digitized credit histories or do not meet the administrative requirements of fintech lending. In addition, a lack of understanding of digital financial products also becomes an obstacle; (4) High Competition in Digital Markets. The digital economy opens wide market access but at the same time brings MSMEs into direct competition with large competitors, both domestic and foreign. Open e-commerce platforms allow foreign products to enter easily, often at competitive prices. Local MSMEs that lack production efficiency or large-scale capacity are at risk of losing in this competition; (5) Data Security and Consumer Trust. Another challenge concerns data security and consumer protection in digital transactions. Many MSME actors have not yet implemented adequate cybersecurity systems, leaving them vulnerable to cyberattacks, data theft, and online fraud. Consumer trust strongly depends on assurances of personal data security and transaction safety; (6) Fragmentation of the Digital Ecosystem. The current digital ecosystem of Indonesian MSMEs remains fragmented. Numerous e-commerce platforms, marketplaces, fintech services, and digital solutions operate independently without adequate integration. This fragmentation makes it difficult for MSMEs to manage their businesses efficiently, as they must adapt to diverse systems and procedures; (7) Non-Adaptive Regulations. The rapid development of the digital economy is often not accompanied by adaptive and responsive regulations. Many regulations still refer to conventional business patterns, resulting in legal uncertainty in digital transactions. For example, aspects of taxation, digital labor, and consumer protection in online transactions remain gray areas that frequently confuse MSME actors; (8) Disparities in Human Resource Quality and Innovation. Digital transformation requires MSME actors to possess not only basic technological skills but also the ability to innovate in products and services. Unfortunately, disparities in the quality of human resources constitute a serious obstacle. Most MSME actors still struggle to access training in innovation, product design, or advanced digital business development. Without innovation, MSME products will find it difficult to compete in rapidly changing markets; (9) Lack of Continuous Mentorship. MSME digitalization programs are often sporadic and unsustainable. One-time training or socialization is insufficient to ensure that MSMEs can independently achieve digital transformation.

Many business actors require intensive and continuous mentorship, particularly during the implementation stage of technology in their daily business operations; (10) Gender Gaps and Social Inclusion. Finally, the development of the digital economy for MSMEs also faces challenges in terms of social inclusion, particularly gender disparities. Many women-led MSMEs, especially in the informal sector, face double barriers in accessing technology, training, and digital financing. Digital economy development policies must take into account the principle of social inclusion so that vulnerable groups, such as women, persons with disabilities, and indigenous communities, can also benefit equally from digital transformation.

Factors influencing the successful adoption of big data analytics

The success of BDA adoption often depends on strong leadership and commitment from top management (Soomro et al., 2024). On the other hand, Babalghaith and Aljarallah (2024) argue that among the three organizational factors (top management support, data-driven culture, and organizational readiness), a data-driven culture is one of the most important factors for the successful adoption of BDA, followed by organizational readiness, and then top management support. A lack of support from management can significantly affect the success of big data initiatives, potentially leading to failure. The complex nature of big data technology, including sophisticated algorithms and large datasets, can also pose difficulties and obstacles for MSMEs (Falahat et al., 2023). This complexity may discourage them from pursuing BDA adoption, as they may feel overwhelmed by the technical requirements.

Issues of data security and privacy may create reluctance among MSMEs to adopt BDA, as observed in Russia, a country with relatively high levels of information security (Chernova et al., 2023). Concerns about potential data breaches and associated risks can inhibit their willingness to fully embrace BDA. Furthermore, a lack of external support (such as guidance from big data service providers or government initiatives) can hinder MSMEs in their efforts to adopt and integrate BDA into their work processes (Falahat et al., 2023). These barriers can make it difficult for MSMEs to navigate the complexities of big data adoption.

There are several solutions that may be used to alleviate these issues. First, improving digital technology education and training. Training initiatives run by Indonesia's Ministry of Cooperatives and MSMEs have been successful in raising small and medium-sized business owners' digital proficiency, speeding up their acceptance of new technology, and assisting them in utilizing digital tools to boost productivity and competitiveness. These training courses frequently cover practical instruction in the use of digital tools, advice on integrating the newest technology, and assistance in creating successful digital strategy. These programs' goal is to assist them close current knowledge and skill gaps by giving them practical abilities and understanding on how to use digital technologies related to their company demands. With adequate training, MSMEs can be better prepared to face technological challenges and utilize digital tools to improve overall business performance, including aspects such as inventory management, digital marketing, and customer relationship management (Zahara et al., 2023).

Second, financial incentives from the government or financial institutions play an important role in reducing the cost burden borne by MSMEs, especially in the adoption of digital technologies (Ausat and Peirisal, 2021). Programs for software and hardware subsidies, like the Yogyakarta local government's "SME Digitalization Program," have

greatly aided MSMEs in overcoming financial obstacles. MSMEs benefit from this initiative by receiving funding for equipment purchases, training subsidies, and technical assistance required to enable the adoption of new technologies. MSMEs may obtain the technology they want without incurring unaffordable expenses thanks to these advantages. This speeds up the adoption of technology, allowing MSMEs to maintain their competitiveness in a market that depends more and more on digital technologies. This kind of funding is essential to enabling MSMEs to benefit from digital prospects without having to make significant upfront expenses, which are sometimes a key barrier for many small and medium-sized businesses.

Third, infrastructural development initiatives are essential for facilitating MSMEs' use of digital technology, especially in rural regions. As seen by the "Digital Village" initiative in West Nusa Tenggara (NTB), investments in more reasonably priced technology and improved internet connection have had a major beneficial impact. This initiative has effectively decreased the digital divide between urban and rural areas and improved access to digital technology. MSMEs in distant locations can boost their operational efficiency and reach a wider audience thanks to better digital infrastructure. Additionally, improved technological access makes it possible for businesses to take advantage of commercial possibilities that were previously unattainable, increasing their competitiveness in larger markets. Such investments not only benefit MSMEs but also contribute to local economic development by providing access to technologies that foster growth and innovation (Kuleh et al., 2023).

Conclusion

The implementation of Big Data Analytics (BDA) in MSMEs can significantly enhance decision-making capabilities by utilizing data to identify market trends, customer preferences, and operational efficiency. The application of BDA not only contributes to strengthening competitive advantage but also supports innovation, sustainability, and improved business performance. Nevertheless, several factors hinder the adoption of BDA by MSMEs, such as knowledge gaps, limited IT infrastructure, financial constraints, insufficient managerial support, as well as technical complexities and concerns related to data security. To address these challenges, MSMEs are advised to conduct a thorough evaluation of their existing data management capabilities and IT infrastructure, as well as to invest in training and educational programs aimed at improving employees' skills in utilizing Big Data technologies. Collaboration with external service providers or consultants can assist in overcoming the complexities of technology implementation, while a gradual approach through small-scale pilot projects can serve as an effective initial step. On the other hand, the government is expected to introduce supportive policies, such as financial incentives, grants, and the development of ethical data governance frameworks, to encourage investment in Big Data. With strong internal support and enabling external policies, MSMEs can optimize the utilization of BDA to achieve sustainable growth and enhance competitiveness in the marketplace.

Recommendation and implication

To address the challenges in adopting Big Data Analytics (BDA), Micro, Small, and Medium Enterprises (MSMEs) should begin by assessing their existing data management capabilities and IT infrastructure to identify deficiencies that need to be

addressed (Aldossari et al., 2023). This step helps to understand the specific needs and resources available for BDA implementation. Investment in employee training and education on BDA tools and techniques is crucial for enhancing their skills, thereby enabling them to effectively leverage big data for better decision-making and innovation (Maroufkhani et al., 2021). In addition, MSMEs can collaborate with big data service providers or consultants to obtain guidance and support in implementing BDA strategies, assisting them in navigating the complexities of big data technologies and ensuring successful integration (Soomro et al., 2024).

The digital transformation strategies of MSMEs must be tailored to the needs and capacities of each business actor. A one-size-fits-all model is less effective. Therefore, a segmentation-based approach is required (for example, the digitalization of manufacturing MSMEs differs from that of culinary or service enterprises) (Chusumastuti et al., 2023). It is recommended that MSMEs begin with small-scale BDA projects targeting specific business challenges, enabling managed implementation and providing opportunities to learn before scaling up to larger initiatives (Aldossari et al., 2023). A focus on data quality and the integration of various data sources is essential for BDA effectiveness. Hence, efforts to clean and integrate data must be prioritized to create a comprehensive dataset capable of generating valuable insights (Soomro et al., 2024). stablishing clear and measurable objectives for BDA initiatives will help MSMEs remain focused and assess the impact of their efforts, ensuring that BDA strategies contribute to business growth and competitiveness (Al-Shanableh et al., 2024; Asiri et al., 2024). The government also needs to build a data-based evaluation system to assess the success of these strategies and adjust them periodically (Putra & Santoso, 2020). Regular monitoring and evaluation of BDA initiative outcomes are also important to understand their effectiveness, with metrics established to assess performance and adjustments made to strategies based on insights gained.

Supportive policies for the use of Big Data technologies in business include awareness and education initiatives, financial incentives, and data governance frameworks (Falahat et al., 2023). The government is expected to implement socialization and managerial training, product innovation, and simplification of financing access, which are necessary to promote MSME growth, strengthen policy dissemination, and ensure equal implementation across Indonesia, so that MSMEs understand the benefits of Big Data for achieving competitive advantage (Ratnaningtyas et al., 2025; Asiri et al., 2024). Furthermore, the provision of grants and tax incentives is essential to encourage investment in Big Data, particularly for MSMEs lacking capital, along with the implementation of data governance policies that ensure ethical and responsible data management (Maroufkhani et al., 2021). Policies should also support collaboration between businesses and technology providers to facilitate access to Big Data tools and resources. Support for research and development through government funding can foster innovation in data analytics and processing. The development of centralized data-sharing platforms will enhance collaboration between companies and government institutions, resulting in more optimal data utilization (Escolano et al., 2025). In addition, the implementation of training and skills development programs in the field of BDA is essential to equip employees, particularly in MSMEs that may lack adequate internal expertise (Al-Shanableh et al., 2024). The implementation of such policies is expected to encourage the adoption of Big Data by optimizing data accessibility and security, thereby generating positive effects that promote the advancement of MSMEs.

Acknowledgement

Danang Bambang Irawan conducted data collection and wrote the article under the supervision of Andy Wijayanto, who handled the conceptualization, review and editing. All authors have read and agreed to the final manuscript. This research was independently funded by the researchers themselves.

Conflict of interest

The authors state that they have no competing financial interests or personal relationships that could affect this research.

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