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Utilization of Big Data Analytics to Improve Corporate Environmental Performance in Managerial and Organizational Dimensions

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ABSTRACT – This research aims to examine how Big Data Analytics (BDAC) capabilities can be utilized to improve corporate environmental performance, particularly within the framework of organizational management and human resources. This research was conducted using a literature-based qualitative approach, examining the contribution of BDAC to the formation of organizational capabilities in data-driven decision making. The findings show that BDAC can strengthen organizational learning, adaptive capabilities, and environmental policy innovation when supported by managerial factors such as leadership support, organizational readiness, and data literacy. In the SME and entrepreneurial sectors, managerial factors have a significant influence on the effectiveness of BDAC implementation in supporting environmental sustainability. This research also highlights the importance of integrating environmental analytics policies, data competency training, and strengthening data governance. BDAC, as a technological tool, also represents managerial transformation that requires the active involvement of all elements of the organization. These findings contribute to academic understanding and policy recommendations in efforts to strengthen data-based sustainable business practices.

Keywords: Big Data Analytics, environmental performance, organizational management, SMES, entrepreneurship, sustainability, human resources.

A. INTRODUCTION

The digital era has brought about a huge volume of data that represents strategic potential for organizations in various areas of management. Big Data Analytics (BDA) technology enables companies to collect, process, and analyze large amounts of data in order to make faster and more accurate decisions (Kalyar et al., 2024).

At the same time, demands on corporate environmental performance have increased significantly through regulations, customer expectations, and social pressure. For example, the application of big data analytics has been believed to improve corporate environmental performance by assisting in the identification and control of emissions and resource use efficiency (Le et al., 2024). This analytical capability is part of the broader phenomenon of big data, which has become a new thing that is transforming the way organisations and societies collect, analyse and act on information (Wahyudi et al., 2021).

In the realm of small and medium enterprises (SMEs) and entrepreneurship, environmental data management is often limited due to constraints in human resources and technology. In scientific terms, limitations in technical capacity and internal competence tend to hinder the establishment of a structured and reliable environmental information system. This challenge in human resource development is part of a broader discussion on the sustainability of human resource development in the industry 4.0 era, which is faced with a skills gap as well as opportunities for transformation through digitalisation (Oluwatoyin & Mardikaningsih, 2024). This creates the challenge of how management can utilize BDA to support environmental sustainability while strengthening managerial and organizational capabilities. Conceptually, these challenges require the simultaneous integration of analytical capability development, data governance practices, and organizational learning mechanisms to achieve consistent transformation towards sustainability (Putra & Arifin, 2021).

This research focuses on how the use of BDA in the framework of management, human resources, and entrepreneurship can systematically and measurably improve a

corporation's environmental performance. The expected contributions include the development of technology management theory and practical guidelines for SMEs and entrepreneurs in the field of sustainability.

One of the problems faced by corporations is the lack of use of analytical capabilities in the environmental decision-making process, where abundant data is often only used for routine reporting and has not been processed into strategic insights that can drive resource efficiency, emission reduction, or greener production process innovation. Several researches indicate that the implementation of BDA is not yet evenly distributed and there is still a gap between data potential and implementation in the field (Kalyar et al., 2024), which is reflected in the continued dominance of intuitive approaches, limited digital infrastructure, low managerial data literacy, and the absence of standard environmental data governance.

This low level of data literacy is closely related to the broader challenge of preparing a workforce capable of utilising the potential of big data, where employee competence and readiness are key determinants (Aisyah, 2023). Therefore, the approach to technology should be viewed not only as an analytical tool, but as a catalyst for sustainable human resource development, where digital innovation is deliberately designed to build competencies (Mardikaningsih & Wardoyo, 2024). As a result, corporations, especially SMEs and entrepreneurs, find it difficult to extract optimal environmental and economic added value from their technology and data investments.

There is uncertainty in the relationship between increased BDA capabilities and improved environmental performance, as not all analytical investments automatically translate into operational decisions that can reduce emissions, reduce waste, or improve resource efficiency in a measurable way. Le et al. (2024) found varying results among international corporates regarding the impact of BDA on environmental performance, indicating that data quality, organizational readiness, evidence-based decision-making culture, and leadership support are important mediating factors in determining the extent to which BDA actually has a significant environmental impact. The culture of evidence-based decision-making and organisational readiness is greatly influenced by the local context, where the effectiveness of sustainability policies depends on their relevance to the cultural values embraced by the local community (Mardikaningsih & Darmawan, 2023).

At the SME and entrepreneurial level, managerial and human resource challenges are major barriers to adopting BDA for the environment, as owners and managers often have to divide their focus between short-term operational needs and investments in digital capabilities whose environmental benefits are more long-term and less immediately apparent. This human resource challenge stems from the quality of individual human resources reflected in employee performance and loyalty as the foundation that determines an organisation's capacity to adapt and adopt new capabilities (Darmawan et al., 2020). Issues such as limited analytical competence, technological inclusion, and integration with sustainability management strategies often pose obstacles. Without adequate training, clear guidelines on data usage, and alignment of BDA with sustainability vision and performance indicators, environmental data risks remaining at the administrative level and failing to develop into a basis for strategic decision-making that can improve both competitiveness and corporate environmental performance.

In an era of globalization and increasingly stringent environmental regulations, corporations are compelled to respond with management innovations that leverage data technology, not only to ensure compliance with standards and regulations, but also to identify opportunities for operational efficiency, market differentiation, and sustainable value creation through more precise and real-time utilization of environmental information (Darmawan & Gardi, 2024). This process of creating sustainable value is further strengthened by an approach that deliberately integrates green principles and technologies into the core of the company's management system, so that environmental efforts become structured and systemic (Mardikaningsih & Wardoyo, 2024). Research on BDA within the framework of environmental management provides important insights for the development of theory and practice relevant to contemporary challenges, as it explains how environmental big data can be integrated into strategic planning processes, management control systems, and performance measurement mechanisms so that companies do not merely react to external pressures but also proactively build dynamic

capabilities that enable them to anticipate environmental risks, design adaptive green business models, and strengthen institutional legitimacy in the eyes of regulators, consumers, and other stakeholders.

As a result, for the SME and entrepreneurship sector, which is the backbone of the national economy, understanding how BDA can be integrated with management and human resources to support sustainability is very strategic, because the application of data analytics in small and medium-sized businesses requires adjustments in organizational structure, leadership patterns, cross-functional work mechanisms, and employee competency development so that environmental data is not only collected but also processed into a basis for systematic and consistent decision-making. The findings of this research are expected to have direct implications for decision makers at the operational and strategic levels, for example in designing environmental data literacy training programs, developing protocols for monitoring and evaluating green performance based on measurable indicators, and integrating the use of BDA into long-term business planning so that SMEs and entrepreneurs can strengthen their competitiveness, minimize regulatory risks, and gradually internalize sustainability principles as part of the organization's core capabilities.

Efforts to strengthen competitiveness are in line with findings that the competitive advantage of SMEs is largely determined by technological orientation and entrepreneurial competence, where BDA can play a key enabling role (Putra & Darmawan, 2022). Understanding this regulatory landscape is becoming increasingly critical for entrepreneurs in the digital sector, especially for startups developing platform models, where legal implications related to data, consumers, and business competition directly affect their sustainability and growth strategies (Marsal & Hardyansah, 2025).

This research aims to examine the effect of Big Data Analytics capabilities on corporate environmental performance within the framework of management and human resources, as well as to identify managerial factors that facilitate or hinder its utilization in the SME and entrepreneurial sectors. The theoretical contribution includes the development of a conceptual framework for sustainable technology management, while the practical contribution is aimed at developing implementation guidelines for SMEs and entrepreneurs.

B. METHOD

This research uses a qualitative literature study approach with a thematic synthesis design to examine the relationship between Big Data Analytics (BDA) capabilities and improved corporate environmental performance within the framework of management and entrepreneurship. This strategy was chosen because it allows for systematic exploration of concepts, variables, and interconnections between theories that have been developed in various reputable academic publications. This approach refers to the integrative model developed by Torraco (2005), which emphasizes the importance of building new theoretical contributions through critical integration of existing literature.

The literature search strategy was conducted systematically by accessing academic databases such as Scopus, Web of Science, ScienceDirect, and SpringerLink. Inclusion criteria included publications in the last two decades (2004–2024), written in English, and originating from reputable peer-reviewed journals. The articles reviewed must contain an explicit link between BDA, environmental performance, and managerial or entrepreneurial aspects. Exclusion criteria included opinion articles, unindexed publications, and studies that were not substantially relevant to the focus of the research. The search results were filtered through abstracts, keywords, and methodological content to ensure topic relevance.

The coding process was conducted manually and assisted by reference management software to organize citations. Data were analyzed using Braun and Clarke's (2006) thematic framework to identify patterns of argumentation, research gaps, and central themes emerging in the literature. The reliability of the synthesis results was maintained through source triangulation and cross-validation between articles to avoid interpretive bias. Content validity was strengthened by aligning the analysis results with a theoretical framework that has been tested in the fields of technology management and sustainability. The entire analysis process was carried out with an emphasis on the principles of academic transparency and replicability.

C. RESULTS AND DISCUSSION

Big Data Analytics Capabilities and Corporate Environmental Performance

Big Data Analytics Capability (BDAC) is a collection of resources, technologies, and organizational competencies that enable the collection, processing, and analysis of large volumes of data from various sources. As a strategic capacity, BDAC supports rapid and informed decision-making and can strengthen an organization's response to environmental challenges (Mikalef et al., 2019). Empirical research shows that BDAC development correlates positively with better environmental performance; Mikalef et al. (2019) found that corporations with high BDAC achieved more significant performance impacts than those with low capabilities. This capability functions not only as a technological instrument but also as a catalyst for improving operational efficiency in resource management and emissions reduction. Organizations that are able to systematically implement BDAC tend to have an advantage in identifying inefficient energy consumption patterns, enabling them to design data-driven interventions that have a direct impact on reducing environmental burdens.

BDAC also enables real-time monitoring of environmental indicators, accelerating responses to potential pollution and regulatory non-compliance. Within this framework, organizations gain clarity on the relationship between internal activities and their ecological impact, ultimately strengthening the company's environmental accountability system. Corporations with robust BDAC can integrate data from the supply chain to map environmental risks more accurately, creating advantages in risk management and compliance. The implementation of BDAC is also closely related to increased operational transparency, which is a crucial element in building stakeholder trust, especially on sustainability issues. When BDAC is structured within a corporate governance framework, it has the potential to become the foundation for building a long-term, highly competitive business model. The development of a competitive and sustainable business model can be supported by various strategic approaches, as reflected in efforts to improve the competitiveness of SMEs through the application of principles that emphasise fairness, transparency, and responsibility (Mardikaningsih et al., 2024). Optimal utilization of BDAC can support more accurate sustainability reporting, accelerate the environmental audit process, and provide strategic feedback for continuous improvement.

Within the framework of organizational management, BDAC does not function solely as information technology, but rather as a dynamic element that connects environmental strategy with operational practices. Singh (2019) notes that BDAC functions through managerial modules such as data-driven decision making, process agility, and continuous organizational learning. The use of BDAC enables organizations to create a continuous information cycle between strategic planning and the operationalization of environmental policies, which has direct implications for the efficiency and accuracy of interventions. The availability of accurate and relevant data provides a solid basis for policymakers to systematically evaluate environmental performance without having to rely solely on estimates or assumptions.

At the organizational level, BDAC improves adaptive capabilities to changes in environmental regulations and encourages more proactive updates to operational procedures. BDAC also contributes to strengthening internal monitoring systems that enable companies to detect potential deviations from environmental targets early on. When integrated with quality and sustainability management systems, BDAC facilitates cross-departmental connectivity through a uniform and open data platform. This creates a more efficient coordination structure for collectively and purposefully managing environmental issues. Organizations that successfully strategically organize the role of BDAC tend to experience a work culture transformation that is more oriented towards speed, accuracy, and collaboration in achieving sustainability goals. This transformation of work culture and improvement in adaptive capabilities requires the right leadership approach, where situational leadership strategies can be applied to effectively manage change and improve team performance in a new data-driven context (Mardikaningsih & Darmawan, 2022). The participatory leadership model supported by BDAC can also strengthen employee engagement in the environmental innovation process, accelerate feedback flow, and foster a sense of collective responsibility for ecological performance achievements.

In the field of human resources (HR), big data analytics capabilities are changing the demands on workforce competencies (Aisyah, 2023). Organizations that develop BDAC need to provide data literacy training, cross-functional collaboration, and encourage an evidence-based culture for these capabilities to function optimally (Garmaki et al., 2023). This transformation requires updating the role of HR from an administrative function to a strategic function that supports real-time data-driven decision making (Ali & Darmawan, 2023). Employees can no longer rely solely on conventional technical skills but are required to understand the interpretive logic of data to develop applicable and relevant solutions. The success of BDAC integration in HR management is greatly influenced by the organization's readiness to design career development paths that are adaptive to analytical competency needs. The establishment of this development pathway must deliberately lead to the development of green skills specific skills that support sustainable economic transition in the workplace as a tangible result of improved analytical competence (Mardikaningsih & Hariani, 2025). Strengthening BDAC in the HR sector also encourages the creation of a more objective performance evaluation system through verifiable quantitative indicators. The basic principles for an objective and fair evaluation system include data consistency, clear criteria, and process optimisation (Seran & Kurniawan, 2025).

In work environments that actively implement BDAC, the HR policy-making process becomes more transparent because it is based on measurable data patterns, rather than mere intuition or seniority. Organizations that place data mastery as part of HR competency standards have a greater opportunity to maintain consistent operational excellence. With this foundation, HR involvement in the development of data-driven sustainability policies becomes increasingly strategic because the process is focused, responsive, and measurable (Mardikaningsih & Wardoyo, 2024). Ultimately, this approach strengthens the position of human resources as drivers of innovation and guardians of sustainability values articulated through data-driven corporate policies. This strategic transformation of HR functions is an important prerequisite for companies to implement sustainable enterprise strategies, which aim to maintain continuous innovation and consistent product quality in a competitive market (Eddine & Fared, 2024).

The direct link between BDAC and environmental performance was revealed in a recent research study that positioned BDAC as the primary stimulus in the Organism Response Stimulation (ORS) model for environmental outcomes (Xinqi et al., 2025). This finding confirms that large-scale data processing and utilization not only creates internal process efficiency, but also shapes perceptions, assessments, and strategic responses to complex environmental issues. Within the S O R model framework, BDAC encourages the formation of an organizational perceptual system towards environmental threats and opportunities through systematically calibrated real-time data. Organisms in this model refer to organizational actors who actively process information and then respond to it through policies or actions that lead to improved environmental performance.

Stimuli in the form of structured and unstructured data will shape the organization's interpretation of the sustainability priorities that need to be implemented. The accuracy of these interpretations determines the quality of the responses, whether in the form of green technology investments, energy efficiency, emission reductions, or the development of environmentally friendly operational strategies. This model provides an analytical framework that can explain the dynamics between data capabilities and sustainability actions without relying solely on technocratic assumptions. In this case, BDAC serves as a source of validation and catalysis for transforming environmental strategies into measurable work processes. The existence of BDAC also strengthens the corporate public accountability because it enables digitally-based sustainability reporting that can be audited externally. Mechanisms such as this make transparency not a passive requirement, but an integral part of an information-based environmental management system. Ultimately, the integration of BDAC into the S O R framework is not merely a response to regulatory pressure, but rather creates a competitive advantage based on trust, predictability, and adaptability.

The results show that big data analytics capabilities (BDAC) directly affect environmental performance and partially through the mediation of supply chain innovation, decision-making quality, and risk-

taking behavior. The successful implementation of BDAC depends on the synergy between technology, business processes, and human resource capabilities (Xinqi et al., 2025). Innovative human resource capabilities, developed to enhance organisational competitiveness in the global era, are the foundation that enables such synergy (Abdulah et al., 2021). In an organization with a developed learning culture and change management, BDAC can improve resource efficiency and significantly reduce environmental impact. BDAC is therefore a key component for corporations seeking to improve environmental performance within a modern management framework.

BDAC enables organizations to identify high-environmental-intensity operational areas and target interventions through predictive analytics that can measurably reduce emissions or waste. Integrating these capabilities with green supply chain systems enables corporations to pursue environmental effectiveness while maintaining profitability. BDAC also strengthens evidence-based decision-making structures so that corporations can produce responsive, adaptive, and innovative environmental policies (Ali & Darmawan, 2023). Developing analytical capabilities creates a workforce capable of utilizing data as a basis for environmental action and encourages the emergence of internal initiatives that support sustainability. Strengthening synergies between departments through an integrated data platform accelerates the implementation of environmental strategies and ensures that the entire organization is involved in achieving targets. Finally, the use of BDAC as part of corporate governance signifies that environmental performance can be a real part of an organization's competitive advantage, not just regulatory compliance or reputation.

Big data analytics capabilities facilitate the development of advanced environmental decision-making systems, strengthen internal organizational processes, and enhance human resource competencies in facing the challenges of the data era. This confirms that BDAC is not just an additional technology, but rather a core asset in a company's sustainability strategy that is integrated with organizational and human resource management. The existence of BDAC enables organizations to build accurate prediction mechanisms for future environmental trends and risks, allowing for preventive and structured planning. BDAC-based decision-making systems encourage corporations to develop measurable environmental performance indicators that are evaluated on an ongoing basis. The integration of BDAC into operational management systems accelerates the automation of environmental monitoring and reporting processes, which were previously carried out manually and inefficiently.

In complex organizational structures, BDAC enables cross-unit coordination to be more synchronized because all decisions are based on consistent data sources. In the context of human resource development, the existence of BDAC requires the emergence of new competency profiles that combine technical, analytical, and ethical understanding, creating human resources capable of responding to long-term sustainability challenges. This ethical understanding is crucial to ensure that the use of powerful technologies and data such as BDAC is carried out with consideration for social responsibility and principles of fairness, so that innovation truly leads to inclusive sustainability (Da Silva & Gani, 2022). The implementation of BDAC also encourages companies to make long-term investments in digital infrastructure and continuous training, strengthening the resilience of organizational transformation as a whole. BDAC not only improves managerial effectiveness, but also emphasizes that the achievement of corporate sustainability now relies on integrated information excellence and technological capabilities.

Managerial Factors in the Use of Big Data Analytics to Improve Environmental Performance in SMEs and Entrepreneurship

The implementation of big data analytics capabilities (BDAC) in small and medium-sized enterprises (SMEs) and entrepreneurs is greatly influenced by managerial factors, including leadership support, organizational readiness, data-driven culture, and allocation of skilled human resources. Several researches indicate that within the framework of BDA adoption, managerial factors have a more dominant influence than technological or external environmental factors. For example, a study of 233 SMEs in Saudi Arabia found that top management support, organizational readiness, and a data-driven culture had a significant impact on BDA adoption (Babalghaith & Aljarallah, 2024). These managerial factors determine whether BDAC will develop to a high level of capability or remain at an experimental level within SME organizations. When leaders

provide strategic direction for big data analytics, resources can be shifted from ad hoc projects to a sustainable operational framework.

Organizational readiness includes selecting processes, structures, and policies that enable BDAC to function effectively and generate insights relevant to environmental decisions. A data-driven culture encourages the transformation of organizational behavior from reactive to proactive in response to operational environmental management challenges (Darmawan & Marsal, 2025). The allocation of skilled human resources increases the probability that the data collected will be utilized to its fullest potential and interpreted with high quality into actions that improve environmental performance. In the realm of SMEs and entrepreneurship, management that understands the importance of BDAC will integrate big data analytics into risk management systems, environmental performance measurement, and operational innovation. These managerial factors facilitate external partnerships, for example with technology providers or analytics consultants, which accelerate the effective adoption of BDAC in organizations with limited resources.

Top management support is considered a critical prerequisite for ensuring that major data initiatives are strategically legitimized within an organization. This support creates an internal legitimacy structure that allows organizational resources to be allocated appropriately to data initiatives. Without commitment from top leadership, such initiatives tend to be limited to pilot projects and do not lead to impactful operational changes. The absence of strategic legitimacy makes these initiatives prone to misalignment of objectives and lack of continuity. This is also evident in a study of large companies which found that managerial commitment strengthens the influence of BDAC on organizational performance (Mikalef et al., 2019). Leadership commitment has a positive correlation with the diffusion of strategic information technology into day-to-day managerial processes. Top management support is positively related to the assimilation of AI BDA systems and improves environmental performance, especially when managerial commitment is high (Gallo et al., 2023).

In the realm of SMEs and entrepreneurship, where financial and technological resources may be limited, organizational readiness which includes the readiness of systems, processes, and human resources capable of supporting analytical capabilities is an essential managerial factor. This readiness marks an organization's capacity to internalize digital transformation in a sustainable manner. The readiness of human resources needs to be driven by digital-based development policies, which can serve as drivers of collaborative and sustainable product and service innovation (Mardikaningsih et al., 2024). Research by Setyawan et al. (2024) on SMEs in the culinary and fashion sectors shows that SMEs with data infrastructure, employee training, and supply chain integration practices have higher environmental performance results. This achievement shows that structural readiness and functional competencies contribute significantly to successful technology adaptation. The impact of digitalization on product and process innovation varies in scale (micro, small, and medium), and its influence is limited and depends on the form of digitalization used. This research confirms that involvement in digitalization has a positive impact only on SMEs that do not perform internal machining, but on SMEs that do perform internal machining (Radici & Petkovic, 2023).

A data-driven organizational culture is an important managerial factor that enables BDAC to be implemented effectively. A shared understanding of the strategic value of data accelerates the conversion of information into impactful decisions. Organizations need to develop attitudes, values, and practices that support the use of data as the basis for daily decisions (Ali & Darmawan, 2023). The internalization of this culture strengthens analytical discipline and reduces reliance on intuition alone. Garmaki et al. (2023) emphasize that data literacy training and the formation of an analytical culture encourage the achievement of analytical capabilities that impact performance. An organization's analytical acuity is determined by the extent to which data is accepted as the primary reference in daily work processes. The analytical acuity of an organization is determined by the extent to which data is accepted as the main reference in daily work processes. Digital organizational culture significantly improves organizational performance by instilling values that support data-oriented decision making (Pradana et al., 2022).

Managers must also formulate strategies for developing big data analytical capabilities within a clear and measurable framework (Grover et al., 2018; Tabesh et al., 2019). A structured approach to analytical capabilities

enables organizations to convert data into sustainable performance advantages. This includes setting environmental goals, determining environmental performance indicators, and establishing mechanisms for reporting analytical results. Formalizing objectives and performance indicators strenghes the consistency of data-driven decision-making in environmental management. Research by Le & Vu (2024) indicates that when BDA strategies are explicitly directed at environmental performance, corporate environmental outcomes tend to improve. The integration of strategic orientation and data analytics tends to result in more systematic improvements in environmental performance (Afifa & Nguyen, 2022).

One of the managerial obstacles for SMEs in utilizing BDA is the limited number of human resources with analytical and data management competencies (Haylemariam et al., 2025). This competency gap highlights the importance of strengthening internal capacity as a prerequisite for the effective use of analytical technology. This strengthening of internal capacity is one of the key factors that can distributedly improve the overall effectiveness of the organisation (Darmawan, 2024). Ramp up human resource competencies or internal talent development is the responsibility of managers. The active role of management in building human resource capabilities determines the success of data-driven transformation at the organizational level. Research by Khan et al. (2024) states that for SMEs, barriers related to human resource competencies and access to technology hinder the adoption of BDA, which impacts operational sustainability. Limited competencies and technological infrastructure tend to reduce an organization's ability to achieve sustainable operational performance through the use of data analytics (Saeed, 2024).

The allocation of internal resources such as budget, hardware, software, and analytics investments must be managed strategically by management. Strategic management of internal resources ensures that analytics investments are aligned with the organization's performance priorities and sustainability goals. Without adequate allocation, BDA projects will stall at the pilot stage and not progress to the environmental performance measurement stage. Limited resource allocation tends to hinder the scalability and integration of analytics into environmental performance monitoring systems. A research study by Babalghaith and Aljarallah (2024) revealed that financial and technological constraints are major barriers to BDA adoption in SMEs. Financial and technological barriers generally reduce the ability of small organizations to integrate big data analytics into their operational processes and strategic decision-making. Chernova et al. (2022) also found that a lack of financial resources and qualified employees capable of managing analytics strategies are major obstacles for SMEs in adopting BDA.

Change management is also a managerial factor that is often overlooked. Neglecting aspects of change management shows that social and structural readiness within an organization is an important prerequisite for the success of data analytics initiatives. The application of BDA for environmental sustainability requires process changes, cross-functional involvement (management, production, environment), and cultural adaptation. Process transformation supported by cross-functional collaboration and changes in work culture tends to increase the effectiveness of analytics utilization for sustainability purposes (Darmawan & Marsal, 2025). Singh (2019) states that an organization's ability to learn and adapt quickly (organizational learning) is an important mediator between BDAC and performance outcomes. Organizational learning capabilities in general serve as a critical link between analytical capabilities and superior performance.

In order to improve environmental performance, management must establish a data governance model that includes data policies, privacy protection, and data quality. Privacy protection should be viewed not only as a technical necessity, but as an integral part of human rights in the digital space, where the protection of personal data is a prerequisite for individual autonomy and dignity (Issalillah & Hardyansah, 2024). The emphasis on protection is not an option, but rather a strategic necessity in the digital age, where cyber vulnerability and personal data protection have become global challenges that require collaboration and the highest standards (Gardi & Eddine, 2023). The consequences of negligence in data protection are very serious, as companies can face significant legal liability in cases of personal data breaches, including compensation and reputational damage (Dirgantara et al., 2025). The implementation of these privacy protection principles can be supported by cutting-edge technology, such as the use of

blockchain in HR departments to maintain the security and integrity of employee personal data, which forms the foundation of trust in an organisation's data ecosystem (Costa et al., 2023). The application of blockchain for employee data management specifically serves to improve data transparency and security, creating immutable records that strengthen accountability a principle that is also vital for environmental data (Khairi & Darmawan, 2025).

Comprehensive data governance design generally strengthens accountability and consistency in the use of data in environmental decision-making. Accurate and reliable data is a prerequisite for credible analytics. The reliability of analytical results is essentially determined by the validity, integrity, and consistency of the data used as input. Research by Mikalef et al. (2020) shows that data quality and information systems affect the impact of BDAC on organizational performance. The synergy between data quality and information system infrastructure is often a determining factor in the contribution of analytical capabilities to improving organizational performance.

Tabel 1. Key Managerial Factors for Utilizing BDAC in SMEs/Entrepreneurial Firms

No	Key Factor	Core Idea	Practical Example in SMEs/Entrepreneurial Firms
1	**Top management support**	Commitment of top leaders to make BDA part of strategy and operations, including environmental performance.	Leaders include environmental analytics in the business plan, approve budgets, and regularly request data reports on emissions, waste, and energy use.
2	**Organizational readiness**	Readiness of systems, processes, and human resources to manage and use data in decision making.	Simple data collection procedures exist, basic staff training is provided, and there is minimal data infrastructure (e.g., structured spreadsheets or POS data being used).
3	**Data-driven culture**	Habit of making decisions based on data, not merely intuition.	Production and operations meetings use figures on energy use, waste, and materials as the basis for adjusting processes.
4	**Analytical HR competencies**	Employees' skills in reading, processing, and interpreting data.	Basic Excel/BI training, data literacy workshops, and appointing a "data champion" to support other team members.
5	**Resource allocation**	Provision of sufficient budget, time, and technology for BDA initiatives.	Allocating a small portion of the budget for simple analytics tools, hardware upgrades, or subscriptions to cloud-based software.
6	**Data governance & change management**	Rules for managing data + managing work process changes caused by BDA use.	Setting standards for data input and access rights, and communicating SOP changes based on data to employees gradually and clearly.

While much of the literature focuses on large companies, studies specifically examining SMEs and entrepreneurs in the realm of environmental sustainability and BDA are still limited. The limited empirical studies on SMEs indicate an important knowledge gap that needs to be filled in order to understand the dynamics of data analytics utilization in smaller businesses. Setyawan et al. (2024) state that the application of BDAC in SMEs can improve environmental performance when supported by appropriate managerial practices such as human resource training, green supply chain management, and circular economy practices. The combination of analytical capabilities with targeted managerial interventions tends to strengthen the integration of environmental objectives into SME operational processes in a sustainable manner. The combination of analytical capabilities with these targeted managerial interventions tends to strengthen the integration of environmental objectives into SME operational processes in a sustainable manner.

The following managerial factors are key to utilizing BDAC to improve environmental performance in SMEs and entrepreneurship: leadership support, organizational readiness, data culture, human resource competencies, resource allocation, change management, and data governance. In particular, human resource competencies and engagement focused on sustainability initiatives have been shown to improve organisational performance and the achievement of sustainable social goals (Hariani & Mardikaningsih, 2024; Rehman & Singh, 2025). Entrepreneurial organizations that successfully manage these factors can convert analytical capabilities into higher environmental performance.

The research further emphasizes that management in SMEs and entrepreneurs must apply a strategic approach to BDAC. Practical steps include developing an environmental analytics roadmap, providing data literacy training for managers and staff, integrating environmental goals into performance metrics,

and forming cross-functional teams that combine management, production, and analytics. Clear internal policies and regular monitoring and evaluation mechanisms will strengthen the transformation of technology into tangible environmental performance. The use of BDAC is not merely a technology upgrade, but a managerial transformation that requires the active involvement of all elements of the organization.

D. CONCLUSIONS

Big Data Analytics Capabilities (BDAC) provide strategic opportunities for companies to improve environmental performance, particularly through the optimization of responsive and sustainable data-driven decision-making. In organizational and human resource management, BDAC contributes to strengthening organizational learning, adaptive capabilities, and innovation in corporate environmental policies. The results of the research show that the successful implementation of BDAC is highly dependent on managerial support, organizational readiness, and adequate human resource competencies, especially in the SME and entrepreneurial sectors that face structural challenges.

These findings have theoretical and practical implications. Theoretically, the research enriches the sustainability management literature by integrating the analytical technology perspective into the organizational framework and dynamic capabilities. Practically, corporations, especially SMEs, need to design clear and structured data-driven policies, improve data literacy at the managerial level, and establish measurable environmental indicators to support long-term sustainability.

It is recommended that the government and entrepreneurship support institutions strengthen the digital mentoring ecosystem through big data training, data infrastructure financing, and facilitation of cross-sector collaboration platforms. For academics, further studies can be directed at longitudinal measurements of the impact of BDAC on specific environmental indicators, as well as exploration of collaborative models between technology startups and SMEs in transforming data-based management systems.

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