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Harnessing big data analytics to revolutionize ESG reporting in clean energy initiatives

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Abstract

The integration of Big Data Analytics into Environmental, Social, and Governance (ESG) reporting holds significant potential to revolutionize clean energy initiatives. This paper examines the current challenges in ESG reporting, such as data collection and integration, data quality, regulatory compliance, transparency, and standardization. Big Data Analytics offers advanced techniques, including machine learning, artificial intelligence, predictive analytics, and real-time data processing, which can address these challenges. By leveraging diverse data sources—both structured and unstructured—clean energy projects can achieve more accurate environmental impact assessments, social impact evaluations, and governance analyses. The applications of Big Data Analytics are exemplified through various case studies, such as renewable energy projects, smart grids, and carbon offset programs. The benefits of these applications are vast, including enhanced data accuracy, improved decision-making, increased transparency, better stakeholder engagement, and cost efficiency. However, implementing Big Data Analytics in ESG reporting also presents challenges like data privacy, technological requirements, skills shortage, ethical considerations, and system integration. The future of Big Data Analytics in ESG reporting looks promising with emerging trends like blockchain for data transparency, IoT and sensor technologies, advanced machine learning models, and collaborative platforms. This paper concludes with a call to action for stakeholders to embrace these technologies, highlighting the transformative potential of Big Data Analytics in creating more effective and accountable clean energy initiatives.

Keywords: Big Data Analytics; ESG Reporting; Clean Energy; Environmental Impact; Social Impact; Governance; Machine Learning; Artificial Intelligence.

1. Introduction

Big Data Analytics refers to the process of examining large and varied datasets—commonly known as big data—to uncover hidden patterns, correlations, market trends, and other useful information (Vassakis et al., 2018). This analysis often involves the use of advanced statistical techniques and software tools that can handle the volume, velocity, and variety of data. Big data encompasses a broad spectrum of data types, including structured data (such as databases and spreadsheets) and unstructured data (such as text, images, and social media posts). The primary goal of Big Data Analytics is to extract actionable insights that can inform decision-making processes, optimize operations, and drive strategic initiatives (Simpa et al., 2024). Key components of Big Data Analytics include: Gathering data from diverse sources such as sensors, IoT devices, social media, transactional systems, and more. Utilizing robust storage solutions like data lakes and cloud storage to manage large datasets. Employing technologies like Hadoop and Spark to process data at scale. Applying machine learning algorithms, statistical models, and artificial intelligence to interpret data. Using

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visualization tools to present data insights in an understandable format, aiding in interpretation and decision-making (Simpa et al., 2024).

ESG Reporting is the disclosure of data covering an organization's operations in three key areas: environmental impact, social responsibility, and governance practices (Chouaibi, & Affes, 2021). ESG reporting provides stakeholders with a comprehensive view of how a company manages risks and opportunities related to sustainability and ethical impact. Environmental (E), This dimension addresses how a company performs as a steward of nature. It includes metrics on energy use, waste management, pollution, natural resource conservation, and the impact on ecosystems and climate change. Social (S), This focuses on a company's relationships with employees, suppliers, customers, and communities. It encompasses labor practices, diversity and inclusion, human rights, community engagement, and customer satisfaction. Governance (G), This pertains to the internal practices and policies that lead to effective decision-making and compliance with laws (Simpa et al., 2024). It includes board composition, executive compensation, audit practices, corruption, and shareholder rights. ESG reporting has become crucial for investors, regulators, and other stakeholders who are increasingly prioritizing sustainability and ethical practices. High-quality ESG reports enhance transparency, facilitate risk management, and can lead to better long-term financial performance (Raghavan, 2022).

Clean energy initiatives are pivotal in addressing the global challenges posed by climate change, resource depletion, and environmental degradation. These initiatives focus on promoting renewable energy sources such as solar, wind, hydro, and geothermal power, which generate energy without depleting natural resources or emitting greenhouse gases (Solomon et al., 2024). Transitioning to renewable energy helps mitigate the adverse effects of climate change by reducing carbon dioxide and other greenhouse gas emissions. Diversifying energy sources reduces dependence on fossil fuels, enhancing national security by lowering the risks associated with energy supply disruptions. Investment in clean energy technologies stimulates economic development, creates jobs, and fosters innovation in energy systems (Obasi et al., 2024). Reducing air and water pollution from fossil fuels leads to significant health benefits, including lower incidence of respiratory and cardiovascular diseases. Clean energy supports sustainable development goals by ensuring that energy production does not compromise the ability of future generations to meet their needs.

The primary purpose of this paper is to explore how Big Data Analytics can be leveraged to enhance ESG reporting in clean energy initiatives (Adenekan et al., 2024). The paper aims to address the following objectives: To highlight the existing challenges in ESG reporting within the clean energy sector, including issues related to data collection, quality, compliance, and transparency. Describe how Big Data Analytics can be applied to overcome these challenges and improve the accuracy, reliability, and comprehensiveness of ESG reports (Cruz & Matos, 2023). Provide practical examples and case studies that illustrate the successful implementation of Big Data Analytics in clean energy projects. Analyze the benefits of using Big Data Analytics in ESG reporting, such as improved decision-making and stakeholder engagement, as well as the challenges, including data privacy and technological requirements. Examine emerging trends and innovations in Big Data Analytics that could further transform ESG reporting and clean energy initiatives (Osimobi et al., 2023). In conclusion, this paper aims to underscore the transformative potential of Big Data Analytics in making ESG reporting more robust, reliable, and impactful, thereby supporting the broader goals of sustainability and ethical governance in the clean energy sector.

1.1. Current challenges in ESG reporting for clean energy

1.1.1. Data Collection and Integration

One of the primary challenges in ESG reporting for clean energy initiatives is the collection and integration of data. Clean energy projects often involve diverse and distributed sources of data, including physical sensors, smart meters, IoT devices, weather data, satellite imagery, and internal corporate systems (Onwuka et al., 2023). This variety of sources makes it difficult to gather comprehensive and consistent data. Different departments or partners may manage data separately, leading to silos that hinder comprehensive analysis. Integrating these disparate data sources is crucial for a holistic view but is often technically challenging. Clean energy projects generate vast amounts of data at high speeds (e.g., real-time data from smart grids), requiring advanced data processing capabilities to handle the volume and velocity effectively (Onwuka, & Adu, 2024). Data comes in various formats, including structured data (e.g., database records), semi-structured data (e.g., JSON or XML files), and unstructured data (e.g., text reports, images). Integrating these different formats into a cohesive dataset is complex. Accessing relevant data can be challenging due to proprietary systems, privacy concerns, or logistical issues, making it difficult to gather all necessary information for comprehensive ESG reporting.

1.1.2. Data Quality and Accuracy

Accurate ESG reporting depends on high-quality data, but ensuring data quality and accuracy presents significant challenges. Data collected from various sources may have inconsistencies in terms of format, units of measurement, or timeframes, complicating the process of standardizing and aggregating the data (Onwuka, & Adu, 2024). Incomplete data records due to equipment failure, human error, or data entry issues can lead to gaps that affect the accuracy and reliability of ESG reports. Using outdated or lagging data can result in reports that do not accurately reflect current conditions or performance, undermining the credibility of the reports (Onwuka, & Adu, 2024). Verifying the authenticity and accuracy of data from multiple sources is a significant challenge, particularly when dealing with third-party data providers or external stakeholders.

1.1.3. Regulatory Compliance

ESG reporting is subject to various regulations and standards, which can vary significantly across regions and industries. Ensuring compliance with these regulations is a critical challenge. Different countries and regions have their own ESG reporting requirements, which can be complex and constantly evolving (Bose, 2020). Companies operating in multiple jurisdictions must navigate these diverse regulatory landscapes. The lack of universally accepted standards for ESG reporting makes it difficult for companies to ensure compliance and comparability across different frameworks (e.g., GRI, SASB, TCFD). Ensuring compliance with ESG reporting regulations often involves significant costs related to data collection, verification, and reporting processes (Daramola et al., 2024). Non-compliance with ESG regulations can lead to legal penalties, reputational damage, and loss of investor confidence, making regulatory compliance a high-stakes challenge.

1.1.4. Transparency and Stakeholder Trust

Building and maintaining stakeholder trust through transparent ESG reporting is essential but challenging. Providing too much detailed information can overwhelm stakeholders, while too little can lead to perceptions of opacity or incomplete reporting. Striking the right balance is difficult (Daramola et al., 2024). Different stakeholders (e.g., investors, regulators, customers, communities) have varied interests and requirements for ESG information, making it challenging to address all stakeholder needs effectively. Companies may be accused of greenwashing if their ESG reports are perceived as misleading or exaggerated, undermining stakeholder trust and damaging reputations. Providing third-party verification or assurance of ESG reports can enhance transparency and trust but adds complexity and cost to the reporting process (Daramola et al., 2024).

1.1.5. Comparability and Standardization

Ensuring that ESG reports are comparable across companies and industries is a significant challenge due to the lack of standardization. The existence of multiple ESG reporting frameworks (e.g., GRI, SASB, TCFD) with different metrics and methodologies makes it difficult to compare ESG performance across companies (Oduro et al., 2024). Clean energy projects may have unique ESG metrics that are not easily comparable to those of other industries, complicating cross-sector comparisons. Without standardized benchmarks, it is challenging for stakeholders to assess relative performance and progress in ESG initiatives. ESG reporting standards are continually evolving, which can create moving targets for companies trying to maintain consistency and comparability in their reports (Uzougbo et al., 2024). In conclusion, ESG reporting for clean energy initiatives faces numerous challenges related to data collection and integration, data quality and accuracy, regulatory compliance, transparency and stakeholder trust, and comparability and standardization (Uzougbo et al., 2024). Addressing these challenges requires a concerted effort to adopt advanced technologies, improve data management practices, and engage with stakeholders to create robust and reliable ESG reports.

1.2. Role of big data analytics in ESG reporting

1.2.1. Data Sources and Types

Structured data is highly organized and easily searchable by basic algorithms. It resides in fixed fields within records or files, typically stored in relational databases and spreadsheets. In the context of ESG reporting, structured data can include: Balance sheets, profit and loss statements, and other financial documents (Pesqueira, & Sousa, 2024). Energy consumption records, production data, and efficiency metrics. Records related to environmental regulations, labor laws, and corporate governance standards. Structured responses from employee satisfaction surveys, community feedback forms, and stakeholder questionnaires. Structured data allows for straightforward querying and analysis, providing a foundation for quantitative ESG metrics.

Unstructured data does not follow a specified format, making it more challenging to process and analyze (Uzougbo et al., 2024). This type of data is typically textual or multimedia in nature and can come from a wide range of sources, such as: Tweets, Facebook updates, and LinkedIn articles discussing a company's ESG activities. Videos, images, and audio recordings from events, inspections, or community meetings. Reports, emails, policy documents, and news articles (Ikegwu, 2022). Unstructured data streams from IoT devices, including environmental sensors and smart meters. Analyzing unstructured data requires sophisticated tools and techniques, such as natural language processing (NLP) and machine learning, to extract meaningful insights.

1.2.2. Advanced Analytics Techniques

Machine learning (ML), Machine learning involves algorithms that allow computers to learn from and make predictions based on data. In ESG reporting, ML can be used for: Identifying trends in energy usage, waste generation, and other environmental metrics (Daramola et al., 2024). Detecting irregularities in compliance data or operational performance that could indicate potential risks. Forecasting future environmental impacts, social outcomes, and governance performance based on historical data.

Artificial Intelligence, Artificial intelligence (AI) encompasses a broad range of technologies designed to simulate human intelligence (Daramola et al., 2024). AI in ESG reporting can facilitate: Generating comprehensive ESG reports by aggregating and analyzing data from various sources. Providing recommendations for improving ESG performance based on data-driven insights (Daramola et al., 2024). Analyzing stakeholder sentiments from social media and other unstructured data sources to gauge public perception and identify areas of concern.

Predictive Analytics, Predictive analytics uses statistical techniques and algorithms to forecast future events based on historical data. Applications in ESG reporting include: Predicting future emissions, resource consumption, and environmental impacts to inform sustainability strategies (Daramola et al., 2024). Estimating the likelihood of regulatory breaches, labor disputes, or reputational damage. Anticipating the effects of operational changes on ESG metrics and optimizing practices for better outcomes.

Real-Time Data Processing, Real-time data processing involves analyzing data as it is generated, enabling immediate insights and actions. In ESG reporting, real-time processing can be applied to: Monitoring energy consumption in real time to identify inefficiencies and implement corrective measures promptly (Ibe et al., 2018). Tracking emissions and pollutant levels continuously to ensure compliance with environmental standards. Using real-time data from sensors and IoT devices to enhance workplace safety and quickly address hazards.

1.3. Applications of big data analytics in ESG reporting

1.3.1. Environmental Impact Assessment

Big Data Analytics can significantly enhance carbon footprint analysis by integrating data from various sources, including energy consumption records, transportation logs, and production data (Blomberg, 2023). Advanced analytics can: Calculate greenhouse gas emissions from multiple activities and processes. Pinpoint areas of high emissions within operations and supply chains. Model the impact of different strategies (e.g., switching to renewable energy) on carbon footprints. Accurate tracking of resource usage (e.g., water, raw materials) is crucial for sustainability. Big Data Analytics enables: Continuously monitor resource usage across different sites and processes (Osuagwu et al., 2023). Analyze data to identify inefficiencies and opportunities for resource conservation. Compare resource usage against industry standards and best practices to set improvement targets. Monitoring pollution levels in real time can help ensure compliance with environmental regulations and protect public health. Big Data Analytics supports: Aggregate data from air and water quality sensors to monitor pollutant levels. Detect long-term trends in pollution data to assess the effectiveness of mitigation efforts (Adanma, & Ogunbiyi, 2024). Identify and respond to pollution incidents quickly to minimize environmental damage.

1.3.2. Social Impact Evaluation

Big Data Analytics can improve the monitoring and evaluation of labor practices and conditions by: Analyzing structured survey responses and unstructured feedback to assess worker satisfaction and identify areas for improvement (Adanma, & Ogunbiyi, 2024). Tracking compliance with labor laws and standards using data from HR systems and external audits. Examining workforce demographics to measure progress on diversity and inclusion goals. Effective community engagement is crucial for social sustainability. Big Data Analytics can enhance this by: Analyzing social media and other unstructured data to gauge community sentiment and identify concerns. Monitoring participation in community programs and initiatives to assess their impact and effectiveness (Adanma, & Ogunbiyi, 2024). Aggregating

and analyzing feedback from community meetings and surveys to inform decision-making. Ensuring the health and safety of employees and communities is a key component of ESG reporting. Big Data Analytics can be used to: Analyze data from health and safety incidents to identify patterns and root causes. Use historical data to predict potential safety risks and implement preventative measures (Abati et al., 2024). Leverage IoT devices and sensors to monitor environmental conditions and employee health metrics in real time.

1.3.3. Governance Analysis

Big Data Analytics can enhance the evaluation of corporate governance practices by: Analyzing data on board member demographics, skills, and experience to ensure diversity and effectiveness. Examining compensation data to ensure alignment with performance and stakeholder interests. Identifying governance risks through data on board activities, meeting attendance, and decision-making processes (Adebajo et al., 2024). Ensuring compliance with regulatory requirements is critical for governance. Big Data Analytics facilitates this by: Continuously track compliance with relevant laws and regulations using integrated data sources. Automate the audit process by analyzing financial records, operational data, and compliance reports. Use predictive models to forecast potential compliance issues and take proactive measures (Adanma, & Ogunbiyi, 2024). Ethical Business Practices, Promoting ethical business practices is essential for good governance. Big Data Analytics can support this by: Identify suspicious transactions and activities through anomaly detection algorithms. Analyze data from suppliers to ensure adherence to ethical standards and identify risks. Provide detailed and transparent reports on ethical practices and initiatives to build trust with stakeholders (Adanma, & Ogunbiyi, 2024).

In summary, Big Data Analytics plays a crucial role in enhancing ESG reporting by leveraging diverse data sources, employing advanced analytics techniques, and applying these insights to assess environmental impact, social responsibility, and governance practices. This approach not only improves the accuracy and reliability of ESG reports but also supports better decision-making and more sustainable business practices.

1.4. Case studies and examples

1.4.1. Renewable Energy Projects

Wind Energy Projects, In wind energy projects, Big Data Analytics can be leveraged to optimize turbine performance and increase energy output. By analyzing data from sensors installed on turbines, companies can monitor wind speed, direction, and turbine efficiency in real time (Adebayo et al., 2021). For example, GE Renewable Energy uses its Predix platform to collect and analyze data from wind farms worldwide. The platform enables predictive maintenance, reducing downtime and operational costs by forecasting potential failures before they occur. Additionally, the platform's analytics help optimize turbine settings to maximize energy production based on real-time wind conditions.

Solar Energy Projects, Solar energy projects benefit from Big Data Analytics by improving the efficiency and placement of solar panels. Companies like SolarCity (now part of Tesla) use advanced analytics to analyze weather patterns, solar irradiance, and panel performance data. This analysis helps in determining the optimal placement of panels and predicting energy production (Oyinkansola, 2024). By monitoring and analyzing data from solar installations, companies can also detect performance issues and maintenance needs, ensuring that panels operate at peak efficiency.

1.4.2. Smart Grids and Energy Efficiency Programs

Smart Grids, Smart grids use Big Data Analytics to enhance the efficiency, reliability, and sustainability of electricity distribution. For instance, the use of smart meters generates vast amounts of data on energy consumption patterns. Utilities can analyze this data to balance supply and demand, detect outages, and improve grid stability. The Pacific Gas and Electric Company (PG&E) implemented a smart grid program that uses data analytics to optimize energy distribution and integrate renewable energy sources (Adelakun, 2023). By analyzing consumption data, PG&E can offer dynamic pricing, encouraging consumers to shift their usage to off-peak times, thus reducing overall energy demand.

Energy Efficiency Programs, Energy efficiency programs leverage Big Data Analytics to identify opportunities for reducing energy consumption. For example, the Energy Star program uses data from building sensors to assess energy use in commercial buildings. By analyzing this data, building managers can identify inefficiencies, such as outdated HVAC systems or poor insulation, and implement targeted improvements (Adelakun, 2023). The program provides benchmarks and recommendations based on the analyzed data, helping businesses achieve significant energy savings.

1.4.3. Carbon Offset Programs

Forest Conservation Projects, Big Data Analytics plays a crucial role in monitoring and verifying carbon offset projects, such as forest conservation. Satellites and drones collect high-resolution images of forested areas, which are then analyzed using machine learning algorithms to assess forest health and measure carbon sequestration. Companies like Pachama use AI and remote sensing technologies to monitor reforestation and conservation projects accurately (Adeusi et al., 2024). The analyzed data ensures that carbon credits are based on actual, verifiable carbon absorption, providing transparency and credibility to carbon offset programs.

Agricultural Carbon Offsets, In agricultural carbon offset programs, Big Data Analytics helps measure and verify the carbon sequestration potential of sustainable farming practices. By analyzing soil health data, crop yields, and farming practices, companies can quantify the carbon sequestered by different agricultural techniques (Jejeniwa et al., 2024). For instance, Indigo Agriculture uses data analytics to support farmers in adopting regenerative agriculture practices that increase soil carbon storage. The platform tracks and verifies carbon sequestration, enabling farmers to earn carbon credits for their sustainable practices.

1.4.4. Successful Implementation Examples

Google's Environmental Insights Explorer, Google's Environmental Insights Explorer (EIE) uses Big Data Analytics to provide cities with actionable insights into their carbon emissions and potential for renewable energy adoption (Jejeniwa et al., 2024). The platform analyzes data from Google Maps and other sources to estimate emissions from buildings and transportation. Cities like Dublin and Melbourne have used EIE to develop strategies for reducing their carbon footprints and promoting renewable energy projects. The platform's insights help cities identify high-impact areas for intervention, track progress, and report on their sustainability efforts.

Schneider Electric's EcoStruxure Platform, Schneider Electric's EcoStruxure platform uses IoT and Big Data Analytics to enhance energy efficiency and sustainability in industrial operations. The platform collects data from connected devices and systems, analyzes it in real time, and provides actionable insights to improve energy management (Jejeniwa et al., 2024). For example, the platform has been implemented in several manufacturing facilities, resulting in significant energy savings and reduced carbon emissions. By optimizing energy usage and improving operational efficiency, EcoStruxure helps companies meet their ESG goals.

1.4.5. Benefits of using big data analytics in ESG reporting

Big Data Analytics improves the accuracy and reliability of ESG reporting by integrating data from multiple sources and using advanced algorithms to validate and cleanse the data. This ensures that the reported data is comprehensive and free from errors (Jejeniwa et al., 2024). Accurate data is essential for credible ESG reports, as stakeholders rely on these reports to make informed decisions. By leveraging Big Data Analytics, companies can provide precise and verifiable information, enhancing the trustworthiness of their ESG reports. Big Data Analytics enables organizations to make data-driven decisions by providing insights into ESG performance. By analyzing historical data and identifying trends, companies can forecast future outcomes and develop strategies to improve their ESG metrics. For example, predictive analytics can help companies anticipate regulatory changes and adjust their practices accordingly (Jejeniwa et al., 2024). With better data insights, organizations can prioritize initiatives that have the most significant impact on sustainability and social responsibility. Using Big Data Analytics in ESG reporting enhances transparency and accountability by providing detailed and real-time insights into a company's operations. Analytics platforms can generate comprehensive reports that include data on environmental impact, social initiatives, and governance practices. This transparency allows stakeholders to hold companies accountable for their ESG performance. Additionally, third-party verification of data through advanced analytics increases the credibility of ESG reports, building stakeholder trust. Big Data Analytics facilitates better engagement with stakeholders by providing relevant and timely information (Joel, & Oguanobi, 2024). Companies can use analytics to understand stakeholder concerns and preferences, enabling more effective communication and collaboration. For example, sentiment analysis of social media data can reveal public opinion on a company's ESG initiatives, allowing the company to address concerns proactively. Engaging stakeholders with transparent and data-driven reports helps build stronger relationships and enhances corporate reputation. Big Data Analytics can lead to cost savings and resource optimization by identifying inefficiencies and areas for improvement (Joel, & Oguanobi, 2024). By analyzing energy consumption data, companies can implement measures to reduce energy usage and lower operational costs. Similarly, analytics can help optimize supply chain operations, reducing waste and improving resource management. Cost-efficient operations not only enhance profitability but also contribute to sustainability goals by minimizing environmental impact. In conclusion, the integration of Big Data Analytics into ESG reporting offers numerous benefits, including enhanced data accuracy, improved decision-making, increased transparency, better stakeholder engagement, and cost efficiency (Joel, & Oguanobi, 2024). By leveraging advanced

analytics techniques and diverse data sources, companies can provide more robust and reliable ESG reports, supporting their sustainability and ethical governance objectives.

1.5. Challenges and considerations

1.5.1. Data Privacy and Security

Data privacy and security are critical concerns when leveraging Big Data Analytics for ESG reporting. The large volumes of data collected from various sources often include sensitive information about employees, customers, and business operations. Ensuring the protection of this data is paramount to avoid breaches and maintain trust. Companies must adhere to data protection regulations such as GDPR in Europe and CCPA in California (Joel, & Oguanobi, 2024). These laws require robust measures to protect personal data and grant individuals rights over their data. Implementing advanced cybersecurity measures, including encryption, access controls, and intrusion detection systems, is essential to safeguard data from unauthorized access and cyberattacks. To protect individual privacy, companies can use techniques such as data anonymization and aggregation. These methods allow the use of data for analysis without exposing personal information (Joel, & Oguanobi, 2024). Establishing clear data governance policies and practices ensures that data is managed responsibly throughout its lifecycle, from collection to disposal.

1.5.2. Technological and Infrastructure Requirements

The adoption of Big Data Analytics requires significant technological and infrastructural investments. Companies must build and maintain systems capable of handling large volumes of diverse data. Investing in scalable storage solutions and high-performance computing infrastructure is necessary to store and process big data efficiently (Joel, & Oguanobi, 2024). Cloud platforms offer flexible and cost-effective solutions for big data storage and processing, enabling companies to scale their resources based on demand. Companies need robust integration frameworks to aggregate data from various sources, including IoT devices, sensors, and legacy systems. Implementing real-time analytics requires infrastructure capable of handling continuous data streams and providing immediate insights.

1.5.3. Skills and Expertise

The effective use of Big Data Analytics in ESG reporting requires specialized skills and expertise. Hiring skilled data scientists and analysts who can interpret complex data sets and develop advanced models is crucial for extracting actionable insights. IT teams must possess the knowledge to implement and manage big data infrastructure, ensuring smooth operation and integration of various technologies. Investing in ongoing training and development programs helps employees stay updated with the latest tools and techniques in data analytics. Encouraging collaboration between data experts and ESG professionals ensures that analytics initiatives are aligned with sustainability goals and business objectives.

1.5.4. Ethical and Legal Considerations

The use of Big Data Analytics in ESG reporting raises ethical and legal considerations that companies must address. Ensuring that data analytics models are free from bias and do not reinforce existing inequalities is essential for fair and ethical decision-making. Companies should be transparent about their data collection and analytics practices, providing clear information on how data is used and the purposes it serves (Oguanobi, & Joel, 2024). Obtaining informed consent from individuals whose data is being collected and used is a fundamental ethical requirement. Ensuring compliance with all relevant laws and regulations governing data usage, environmental reporting, labor practices, and corporate governance is essential to avoid legal repercussions.

1.5.5. Integration with Existing Systems

Integrating Big Data Analytics with existing systems poses significant challenges that must be addressed for seamless operation. Many companies rely on legacy systems that may not be compatible with modern analytics platforms (Oguanobi, & Joel, 2024). Upgrading or integrating these systems can be complex and costly. Breaking down data silos to enable seamless data flow across departments and systems is essential for comprehensive analysis. Ensuring interoperability between different data sources, platforms, and tools is crucial for effective data integration and analysis. Implementing new technologies and processes requires careful change management to minimize disruptions and ensure user adoption.

1.6. Future trends and innovations

Blockchain technology offers promising solutions for enhancing data transparency and integrity in ESG reporting. Blockchain's immutable ledger ensures that ESG data is tamper-proof and verifiable, enhancing trust in reported

information. Blockchain can provide a transparent and traceable record of sustainability practices across supply chains, ensuring accountability. Using smart contracts, companies can automate compliance and verification processes, ensuring adherence to ESG standards (Oguanobi, & Joel, 2024). The Internet of Things (IoT) and sensor technologies are transforming data collection for ESG reporting. IoT devices enable real-time monitoring of environmental parameters, such as air and water quality, energy usage, and emissions. Sensors can predict equipment failures and maintenance needs, reducing downtime and improving efficiency. IoT expands the scope and granularity of data collection, providing detailed insights into various aspects of operations. Advancements in machine learning models are driving more accurate and insightful ESG analysis. Deep learning techniques can analyze complex and unstructured data, such as images and texts, providing deeper insights into ESG metrics. Natural Language Processing, NLP enables the analysis of textual data from reports, social media, and other sources, helping gauge public sentiment and identify emerging issues (Simpa et al., 2024). Automated Insights, Advanced models can automate the extraction of actionable insights from large data sets, supporting more informed decision-making. Collaborative platforms and open data initiatives are fostering greater transparency and cooperation in ESG reporting. Platforms that facilitate data sharing among companies, regulators, and stakeholders promote collaborative efforts to address ESG challenges (Simpa et al., 2024). Open data initiatives provide access to publicly available data sets, enabling broader analysis and innovation in ESG reporting. Collaborative platforms enhance stakeholder engagement by providing accessible and transparent information on sustainability practices. Evolving regulations are shaping the future of ESG reporting and the role of Big Data Analytics (Simpa et al., 2024). Regulatory bodies are imposing stricter ESG reporting standards, necessitating more comprehensive and accurate data collection and analysis. Increasing mandates for ESG disclosures require companies to adopt advanced analytics to meet regulatory requirements. Efforts to harmonize ESG reporting standards globally will drive the adoption of standardized analytics practices and technologies.

2. Conclusion

Big Data Analytics plays a pivotal role in revolutionizing ESG reporting by enhancing data accuracy, improving decision-making, increasing transparency, and optimizing resource use. Despite the significant benefits, companies face challenges related to data privacy, technological requirements, skills, ethical considerations, and system integration. Addressing these challenges requires strategic investments and a commitment to ethical practices. The transformative potential of Big Data Analytics lies in its ability to provide detailed, real-time insights into environmental, social, and governance performance. By leveraging advanced technologies, companies can enhance their sustainability practices, meet regulatory requirements, and build stronger relationships with stakeholders. Big Data Analytics not only improves the quality of ESG reporting but also supports the development of more sustainable and socially responsible business models. Stakeholders, including businesses, regulators, investors, and the public, must collaborate to harness the full potential of Big Data Analytics in ESG reporting. Companies should invest in the necessary technologies and skills, adhere to ethical standards, and strive for transparency in their reporting practices. Regulators should promote standardized reporting frameworks and support the adoption of advanced analytics. Investors and consumers should demand greater transparency and accountability from companies, driving the shift towards more sustainable and responsible business practices. By working together, stakeholders can ensure that Big Data Analytics significantly contributes to the global sustainability agenda.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Abati, S. M., Bamisaye, A., Adaramaja, A. A., Ige, A. R., Adegoke, K. A., Ogunbiyi, E. O., ... & Saleh, T. A. (2024). Biodiesel production from spent vegetable oil with Al2O3 and Fe2O3-biobased heterogenous nanocatalysts: Comparative and optimization studies. *Fuel*, *364*, 130847.

[2] Adanma, U. M., & Ogunbiyi, E. O. (2024). A comparative review of global environmental policies for promoting sustainable development and economic growth. *International Journal of Applied Research in Social Sciences*, *6*(5), 954-977.

[3] Adanma, U. M., & Ogunbiyi, E. O. (2024). A comparative review of global environmental policies for promoting sustainable development and economic growth. *International Journal of Applied Research in Social Sciences*, *6*(5), 954-977.

[4] Adanma, U. M., & Ogunbiyi, E. O. (2024). Artificial intelligence in environmental conservation: evaluating cyber risks and opportunities for sustainable practices. *Computer Science & IT Research Journal*, *5*(5), 1178-1209.

[5] Adanma, U. M., & Ogunbiyi, E. O. (2024). Artificial intelligence in environmental conservation: evaluating cyber risks and opportunities for sustainable practices. *Computer Science & IT Research Journal*, *5*(5), 1178-1209.

[6] Adanma, U. M., & Ogunbiyi, E. O. (2024). Assessing the economic and environmental impacts of renewable energy adoption across different global regions. *Engineering Science & Technology Journal*, *5*(5), 1767-1793.

[7] Adanma, U. M., & Ogunbiyi, E. O. (2024). Assessing the economic and environmental impacts of renewable energy adoption across different global regions. *Engineering Science & Technology Journal*, *5*(5), 1767-1793.

[8] Adanma, U. M., & Ogunbiyi, E. O. (2024). Evaluating the effectiveness of global governance mechanisms in promoting environmental sustainability and international relations. *Finance & Accounting Research Journal*, *6*(5), 763-791.

[9] Adanma, U. M., & Ogunbiyi, E. O. (2024). Evaluating the effectiveness of global governance mechanisms in promoting environmental sustainability and international relations. *Finance & Accounting Research Journal*, *6*(5), 763-791.

[10] Adanma, U. M., & Ogunbiyi, E. O. (2024). The public health benefits of implementing environmental policies: A comprehensive review of recent studies. *International Journal of Applied Research in Social Sciences*, *6*(5), 978-1004.

[11] Adanma, U. M., & Ogunbiyi, E. O. (2024). The public health benefits of implementing environmental policies: A comprehensive review of recent studies. *International Journal of Applied Research in Social Sciences*, *6*(5), 978-1004.

[12] Adebajo, S. O., Ojo, A. E., Bankole, P. O., Oladotun, A. O., Akintokun, P. O., Ogunbiyi, E. O., & Bada, A. (2023). Degradation of paint and textile industrial effluents by indigenous bacterial isolates. *Bioremediation Journal*, *27*(4), 412-421.

[13] Adebayo, A. O., Ogunbiyi, E. O., Adebayo, L. O., & Adewuyi, S. (2021). Schiff Base Modified Chitosan Iron (III) Complex as new Heterogeneous Oxidative Catalyst. *Journal of Chemical Society of Nigeria*, *46*(2).

[14] Adelakun, B. O. (2023). How Technology Can Aid Tax Compliance in the Us Economy. *Journal of Knowledge Learning and Science Technology ISSN: 2959-6386 (online)*, *2*(2), 491-499.

[15] Adelakun, B. O. (2023). Tax Compliance in the Gig Economy: The Need for Transparency and Accountability. *Journal of Knowledge Learning and Science Technology ISSN: 2959-6386 (online)*, *1*(1), 191-198.

[16] Adenekan, O. A., Solomon, N. O., Simpa, P., & Obasi, S. C. (2024). Enhancing manufacturing productivity: A review of AI-Driven supply chain management optimization and ERP systems integration. *International Journal of Management & Entrepreneurship Research*, *6*(5), 1607-1624.

[17] Adeusi, K. B., Jejeniwa, T. O., & Jejeniwa, T. O. (2024). Advancing financial transparency and ethical governance: innovative cost management and accountability in higher education and industry. *International Journal of Management & Entrepreneurship Research*, *6*(5), 1533-1546.

[18] Blomberg, N. (2023). Environmental, Social and Governance (ESG) Reporting frameworks and standards used in wind power operations: case OX2 Technical and Commercial Management customer sampling.

[19] Bose, S. (2020). Evolution of ESG reporting frameworks. *Values at work: Sustainable investing and ESG reporting*, 13-33.

[20] Chouaibi, S., & Affes, H. (2021). The effect of social and ethical practices on environmental disclosure: evidence from an international ESG data. *Corporate Governance: The International Journal of Business in Society*, *21*(7), 1293-1317.

[21] Cruz, C. A., & Matos, F. (2023). ESG maturity: A software framework for the challenges of ESG data in investment. *Sustainability*, *15*(3), 2610.

[22] Daramola, G. O., Adewumi, A., Jacks, B. S., & Ajala, O. A. (2024). CONCEPTUALIZING COMMUNICATION EFFICIENCY IN ENERGY SECTOR PROJECT MANAGEMENT: THE ROLE OF DIGITAL TOOLS AND AGILE PRACTICES. *Engineering Science & Technology Journal*, *5*(4), 1487-1501.

[23] Daramola, G. O., Adewumi, A., Jacks, B. S., & Ajala, O. A. (2024). NAVIGATING COMPLEXITIES: A REVIEW OF COMMUNICATION BARRIERS IN MULTINATIONAL ENERGY PROJECTS. *International Journal of Applied Research in Social Sciences*, *6*(4), 685-697.

[24] Daramola, G. O., Adewumi, A., Jacks, B. S., & Ajala, O. A. (2024). CONCEPTUALIZING COMMUNICATION EFFICIENCY IN ENERGY SECTOR PROJECT MANAGEMENT: THE ROLE OF DIGITAL TOOLS AND AGILE PRACTICES. *Engineering Science & Technology Journal*, *5*(4), 1487-1501.

[25] Daramola, G. O., Adewumi, A., Jacks, B. S., & Ajala, O. A. (2024). NAVIGATING COMPLEXITIES: A REVIEW OF COMMUNICATION BARRIERS IN MULTINATIONAL ENERGY PROJECTS. *International Journal of Applied Research in Social Sciences*, *6*(4), 685-697.

[26] Daramola, G. O., Jacks, B. S., Ajala, O. A., & Akinoso, A. E. (2024). ENHANCING OIL AND GAS EXPLORATION EFFICIENCY THROUGH AI-DRIVEN SEISMIC IMAGING AND DATA ANALYSIS. *Engineering Science & Technology Journal*, *5*(4), 1473-1486.

[27] Daramola, G. O., Jacks, B. S., Ajala, O. A., & Akinoso, A. E. (2024). AI APPLICATIONS IN RESERVOIR MANAGEMENT: OPTIMIZING PRODUCTION AND RECOVERY IN OIL AND GAS FIELDS. *Computer Science & IT Research Journal*, *5*(4), 972-984.

[28] Daramola, G. O., Jacks, B. S., Ajala, O. A., & Akinoso, A. E. (2024). ENHANCING OIL AND GAS EXPLORATION EFFICIENCY THROUGH AI-DRIVEN SEISMIC IMAGING AND DATA ANALYSIS. *Engineering Science & Technology Journal*, *5*(4), 1473-1486.

[29] Daramola, G. O., Jacks, B. S., Ajala, O. A., & Akinoso, A. E. (2024). AI APPLICATIONS IN RESERVOIR MANAGEMENT: OPTIMIZING PRODUCTION AND RECOVERY IN OIL AND GAS FIELDS. *Computer Science & IT Research Journal*, *5*(4), 972-984.

[30] Ibe, G. O., Ezenwa, L. I., Uwaga, M. A., & Ngwuli, C. P. (2018). Assessment of challenges faced by non-timber forest products (NTFPs) dependents' communities in a changing climate: a case of adaptation measures Inohafia LGA, Abia State, Nigeria. *Journal of Research in Forestry, Wildlife and Environment*, *10*(2), 39-48.

[31] Ikegwu, C. (2022) GOVERNANCE CHALLENGES FACED BY THE BITCOIN ECOSYSTEM: THE WAY FORWARD.

[32] Jejeniwa, T. O., Mhlongo, N. Z., & Jejeniwa, T. O. (2024). A COMPREHENSIVE REVIEW OF THE IMPACT OF ARTIFICIAL INTELLIGENCE ON MODERN ACCOUNTING PRACTICES AND FINANCIAL REPORTING. *Computer Science & IT Research Journal*, *5*(4), 1031-1047.

[33] Jejeniwa, T. O., Mhlongo, N. Z., & Jejeniwa, T. O. (2024). AI SOLUTIONS FOR DEVELOPMENTAL ECONOMICS: OPPORTUNITIES AND CHALLENGES IN FINANCIAL INCLUSION AND POVERTY ALLEVIATION. *International Journal of Advanced Economics*, *6*(4), 108-123.

[34] Jejeniwa, T. O., Mhlongo, N. Z., & Jejeniwa, T. O. (2024). CONCEPTUALIZING E-GOVERNMENT INITIATIVES: LESSONS LEARNED FROM AFRICA-US COLLABORATIONS IN DIGITAL GOVERNANCE. *International Journal of Applied Research in Social Sciences*, *6*(4), 759-769.

[35] Jejeniwa, T. O., Mhlongo, N. Z., & Jejeniwa, T. O. (2024). Diversity and inclusion in the workplace: a conceptual framework comparing the USA and Nigeria. *International Journal of Management & Entrepreneurship Research*, *6*(5), 1368-1394.

[36] Jejeniwa, T. O., Mhlongo, N. Z., & Jejeniwa, T. O. (2024). SOCIAL IMPACT OF AUTOMATED ACCOUNTING SYSTEMS: A REVIEW: ANALYZING THE SOCIETAL AND EMPLOYMENT IMPLICATIONS OF THE RAPID DIGITIZATION IN THE ACCOUNTING INDUSTRY. *Finance & Accounting Research Journal*, *6*(4), 684-706.

[37] Jejeniwa, T. O., Mhlongo, N. Z., & Jejeniwa, T. O. (2024). THE ROLE OF ETHICAL PRACTICES IN ACCOUNTING: A REVIEW OF CORPORATE GOVERNANCE AND COMPLIANCE TRENDS. *Finance & Accounting Research Journal*, *6*(4), 707-720.

[38] Jejeniwa, T. O., Mhlongo, N. Z., & Jejeniwa, T. O. (2024). THEORETICAL PERSPECTIVES ON DIGITAL TRANSFORMATION IN FINANCIAL SERVICES: INSIGHTS FROM CASE STUDIES IN AFRICA AND THE UNITED STATES. *Finance & Accounting Research Journal*, *6*(4), 674-683.

[39] Joel O. T., & Oguanobi V. U. (2024). Data-driven strategies for business expansion: Utilizing predictive analytics for enhanced profitability and opportunity identification. International Journal of Frontiers in Engineering and Technology Research, 2024, 06(02), 071–081.

[40] Joel O. T., & Oguanobi V. U. (2024). Entrepreneurial leadership in startups and SMEs: Critical lessons from building and sustaining growth. International Journal of Management & Entrepreneurship Research P-ISSN: 2664-3588, E-ISSN: 2664-3596 Volume 6, Issue 5, P.No.1441-1456, May 2024 DOI: 10.51594/ijmer.v6i5.1093. www.fepbl.com/index.php/ijmer

[41] Joel O. T., & Oguanobi V. U. (2024). Future Directions in Geological Research Impacting Renewable Energy and Carbon Capture: A Synthesis of Sustainable Management Techniques. International Journal of Frontiers in Science and Technology Research, 2024, 06(02), 071–083 .

[42] Joel O. T., & Oguanobi V. U. (2024). Geological Data Utilization in Renewable Energy Mapping and Volcanic Region Carbon Storage Feasibility. Open Access Research Journal of Engineering and Technology, 2024, 06(02), 063–074.

[43] Joel O. T., & Oguanobi V. U. (2024). Geological Survey Techniques and Carbon Storage: Optimizing Renewable Energy Site Selection and Carbon Sequestration. Open Access Research Journal of Engineering and Technology, 2024, 11(01), 039–051. https://doi.org/10.53022/oarjst.2024.11.1.0054

[44] Joel O. T., & Oguanobi V. U. (2024). Geotechnical Assessments for Renewable Energy Infrastructure: Ensuring Stability in Wind and Solar Projects. Engineering Science & Technology Journal P-ISSN: 2708-8944, E-ISSN: 2708-8952 Volume 5, Issue 5, P.No. 1588-1605, May 2024 DOI: 10.51594/estj/v5i5.1110.

[45] Joel O. T., & Oguanobi V. U. (2024). Leadership and management in high-growth environments: effective strategies for the clean energy sector. International Journal of Management & Entrepreneurship Research, P-ISSN: 2664-3588, E-ISSN: 2664-3596, Volume 6, Issue 5, P.No.1423-1440, May 2024. DOI: 10.51594/ijmer.v6i5.1092. www.fepbl.com/index.php/ijmer

[46] Joel O. T., & Oguanobi V. U. (2024). Navigating business transformation and strategic decision-making in multinational energy corporations with geodata. International Journal of Applied Research in Social Sciences P-ISSN: 2706-9176, E-ISSN: 2706-9184 Volume 6, Issue 5, P.No. 801-818, May 2024 DOI: 10.51594/ijarss.v6i5.1103. www.fepbl.com/index.php/ijarss

[47] Obasi, S. C., Solomon, N. O., Adenekan, O. A., & Simpa, P. (2024). Cybersecurity's role in environmental protection and sustainable development: Bridging technology and sustainability goals. *Computer Science & IT Research Journal*, *5*(5), 1145-1177.

[48] Oduro, P., Uzougbo, N.S. and Ugwu, M.C., 2024. Navigating legal pathways: Optimizing energy sustainability through compliance, renewable integration, and maritime efficiency. Engineering Science & Technology Journal, 5(5), pp.1732-1751.

[49] Oduro, P., Uzougbo, N.S. and Ugwu, M.C., 2024. Renewable energy expansion: Legal strategies for overcoming regulatory barriers and promoting innovation. International Journal of Applied Research in Social Sciences, 6(5), pp.927-944.

[50] Oguanobi V. U. & Joel O. T., (2024). Geoscientific research's influence on renewable energy policies and ecological balancing. Open Access Research Journal of Multidisciplinary Studies, 2024, 07(02), 073–085.

[51] Oguanobi V. U. & Joel O. T., (2024). Scalable Business Models for Startups in Renewable Energy: Strategies for Using GIS Technology to Enhance SME Scaling. Engineering Science & Technology Journal, P-ISSN: 2708- 8944, E-ISSN: 2708-8952, Volume 5, Issue 5, P.No. 1571-1587, May 2024. DOI: 10.51594/estj/v5i5.1109.

[52] Onwuka, O. U., & Adu, A. (2024). Eco-efficient well planning: Engineering solutions for reduced environmental impact in hydrocarbon extraction. *International Journal of Scholarly Research in Multidisciplinary Studies*, *4*(01), 033-043.

[53] Onwuka, O. U., & Adu, A. (2024). Technological synergies for sustainable resource discovery: Enhancing energy exploration with carbon management. *Engineering Science & Technology Journal*, *5*(4), 1203-1213.

[54] Onwuka, O., Obinna, C., Umeogu, I., Balogun, O., Alamina, P., Adesida, A., ... & Mcpherson, D. (2023, July). Using High Fidelity OBN Seismic Data to Unlock Conventional Near Field Exploration Prospectivity in Nigeria's Shallow Water Offshore Depobelt. In *SPE Nigeria Annual International Conference and Exhibition* (p. D021S008R001). SPE.

[55] Osimobi, J. C., Ifeanyi, E., Onwuka, O., Deborah, U., & Kanu, M. (2023, July). Improving Velocity Model Using Double Parabolic RMO Picking (ModelC) and Providing High-End RTM (RTang) Imaging for OML 79 Shallow Water, Nigeria. In *SPE Nigeria Annual International Conference and Exhibition* (p. D021S008R003). SPE.

[56] Osuagwu, E. C., Uwaga, A. M., & Inemeawaji, H. P. (2023). Effects of Leachate from Osisioma Open Dumpsite in Aba, Abia State, Nigeria on Surrounding Borehole Water Quality. In *Water Resources Management and Sustainability: Solutions for Arid Regions* (pp. 319-333). Cham: Springer Nature Switzerland.

[57] Oyinkansola, A. B. (2024). THE GIG ECONOMY: CHALLENGES FOR TAX SYSTEM. *Journal of Knowledge Learning and Science Technology ISSN: 2959-6386 (online)*, *3*(3), 1-8.

[58] Pesqueira, A., & Sousa, M. J. (2024). Exploring the role of big data analytics and dynamic capabilities in ESG programs within pharmaceuticals. *Software Quality Journal*, 1-34.

[59] Raghavan, K. (2022). ESG reporting impact on accounting, finance. *Journal of Global Awareness*, *3*(1), 9.

[60] Simpa, P., Solomon, N. O., Adenekan, O. A., & Obasi, S. C. (2024). Nanotechnology's potential in advancing renewable energy solutions. *Engineering Science & Technology Journal*, *5*(5), 1695-1710.

[61] Simpa, P., Solomon, N. O., Adenekan, O. A., & Obasi, S. C. (2024). Strategic implications of carbon pricing on global environmental sustainability and economic development: A conceptual framework. *International Journal of Advanced Economics*, *6*(5), 139-172.

[62] Simpa, P., Solomon, N. O., Adenekan, O. A., & Obasi, S. C. (2024). Innovative waste management approaches in LNG operations: A detailed review. *Engineering Science & Technology Journal*, *5*(5), 1711-1731.

[63] Simpa, P., Solomon, N. O., Adenekan, O. A., & Obasi, S. C. (2024). Environmental stewardship in the oil and gas sector: Current practices and future directions. *International Journal of Applied Research in Social Sciences*, *6*(5), 903-926.

[64] Simpa, P., Solomon, N. O., Adenekan, O. A., & Obasi, S. C. (2024). Sustainability and environmental impact in the LNG value chain: Current trends and future opportunities.

[65] Simpa, P., Solomon, N. O., Adenekan, O. A., & Obasi, S. C. (2024). The safety and environmental impacts of battery storage systems in renewable energy. *World Journal of Advanced Research and Reviews*, *22*(2), 564-580.

[66] Solomon, N. O., Simpa, P., Adenekan, O. A., & Obasi, S. C. (2024). Sustainable nanomaterials' role in green supply chains and environmental sustainability. *Engineering Science & Technology Journal*, *5*(5), 1678-1694.

[67] Solomon, N. O., Simpa, P., Adenekan, O. A., & Obasi, S. C. (2024). Circular Economy Principles and Their Integration into Global Supply Chain Strategies. *Finance & Accounting Research Journal*, *6*(5), 747-762.

[68] Uzougbo, N. S., Ikegwu, C. G., & Adewusi, A. O. (2024). Cybersecurity compliance in financial institutions: A comparative analysis of global standards and regulations.

[69] Uzougbo, N. S., Ikegwu, C. G., & Adewusi, A. O. (2024). Enhancing consumer protection in cryptocurrency transactions: Legal strategies and policy recommendations.

[70] Uzougbo, N. S., Ikegwu, C. G., & Adewusi, A. O. (2024). International enforcement of cryptocurrency laws: Jurisdictional challenges and collaborative solutions. *Magna Scientia Advanced Research and Reviews*, *11*(1), 068-083.

[71] Uzougbo, N. S., Ikegwu, C. G., & Adewusi, A. O. (2024). Legal accountability and ethical considerations of AI in financial services. *GSC Advanced Research and Reviews*, *19*(2), 130-142.

[72] Uzougbo, N. S., Ikegwu, C. G., & Adewusi, A. O. (2024). Regulatory Frameworks for Decentralized Finance (DeFi): Challenges and opportunities. *GSC Advanced Research and Reviews*, *19*(2), 116-129.

[73] Vassakis, K., Petrakis, E., & Kopanakis, I. (2018). Big data analytics: applications, prospects and challenges. *Mobile big data: A roadmap from models to technologies*, 3-20.