Carbon Footprint Integrated Climate Management Accounting Program (CMAP) Model Analysis to Improve Organization Sustainability Performance

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Abstract. The rapid development of industry, in addition to driving economic growth, has also caused negative impacts on the environment through increased CO_2 emissions. Therefore, this research aims to explore the potential implementation of a Climate Management Accounting Program (CMAP) based on blockchain and Artificial Intelligence (AI) to enhance transparency, accountability, and risk mitigation of carbon emissions. This research employs an exploratory qualitative method by collecting secondary data through a Systematic Literature Review (SLR) of relevant journals, books, and reports. The findings suggest that implementing CMAP can enhance the transparency and accountability of carbon footprint reporting, leveraging the support of blockchain, along with capabilities in predictive analysis, anomaly detection, ESG measurement, and the automation of an early warning system (EWS) through AI. In conclusion, the integration of CMAP based on blockchain and AI not only strengthens ESG reporting but also enhances corporate performance in developing carbon emission reduction strategies.

Keywords: CMAP, Blockchain, Artificial Intelligence (AI), Carbon Footprint

1. INTRODUCTION

As time passes, the industrial world continues to experience rapid development, which has a significant impact on the country's economic growth. On the other hand, studies in the Asia-Pacific region have found that corporate development is also accompanied by damage to the environment and society due to operational activities focused solely on profit (Hussain et al., 2024). In response to the challenge, the attention given to companies' sustainability performance by regulators, investors, and stakeholders through Environmental, Social, and Governance (ESG) disclosures is increasing (Shroff & Soni, 2024).

ESG measurement has become a benchmark to help business activities meet the needs of stakeholders focused on sustainable environmental well-being (Mardika et al., 2022). However, in its implementation, some shortcomings are still found, where according to Buallay (2019), several European banks with low ESG disclosure tend to face a decline in investor confidence, which ultimately affects their company value. This affects leaders in formulating risk mapping strategies to respond to business challenges.

Climate change is becoming one of the biggest global challenges facing businesses, with one of the main causes being the increased concentration of greenhouse gases, particularly carbon dioxide (CO_2). According to the International Energy Agency, there was a 0.8% increase in carbon emissions, reaching an all-time high of 37.8 Gt CO_2 in 2024 (IEA, 2025). Climate change will accelerate the depreciation of asset values, leading to high replacement costs (CFA Institute, 2020). This indicates an urgent need for an accurate and verifiable carbon footprint calculation and reporting system to support sustainable decision-making.

Previous research findings indicate that one of the main challenges in carbon footprint reporting lies in the still low availability and quality of data (Hettler & Graf-Vlachy, 2023). The data generated is often inconsistent, incomplete, and difficult to compare, which hinders the accuracy of calculations and reduces the credibility of reports. Additionally, the conventional approach to carbon footprint tracking and reporting is very limited because it still relies on centralized databases and manual record-keeping, making it prone to manipulation (Aurangzeb & Yoon, 2025). However, with the advancements of the Industrial Revolution 4.0 era, which brings technological developments such as blockchain and Artificial Intelligence (AI), new opportunities arise to improve organizational performance (Deniswara et al., 2021).

Blockchain acts as a secure and transparent decentralized ledger, enabling real-time carbon footprint tracking, verification of sustainability claims, and automation of emission reduction incentives through smart contracts and emission tokens (Mofatteh et al., 2024). On the other hand, AI has the ability in analytical and optimization technology capable of processing big data from carbon capture processes, detecting operational failures in real-time, and supporting strategic decision-making related to carbon emission reduction (Manikandan et al., 2024). Supporting this, the Artificial Intelligence and ESG Stakes report by EY (2023) found that company CEOs have developed strategies focused on integrating AI and sustainability, which impacts the acceleration of risk analysis. However, the implementation of AI needs to be considered because it consumes a large amount of energy with significant carbon emissions, so it needs to be included in ESG measurements based technology.

Several previous studies have developed the integration of blockchain and AI in carbon emission reduction (Wang et al., 2020; Hao, 2022; Hua et al., 2022). However, the large number of software developed requires in-depth analysis from data reception to data visualization, which aids in strategic decision-making for improving sustainability performance through ESG measurement. This research adapts from Dannouni et al. (2023) by implementing the Climate Management Accounting Program (CMAP), focusing on the modeling process that can enhance carbon emission risk mitigation and future alternatives that can be implemented by companies.

2. LITERATURE REVIEW

2.1 Diffusion of Innovative and Stakeholder Theory to Improve Sustainability Performance

The rapid growth of innovation has driven breakthroughs in various lines of business as solutions to problems, as demonstrated by Rogers in his Diffusion of Innovation Theory in 1962, particularly in the development of technology and business (Rogers, 2003). According to Rogers (2003), the diffusion of innovation occurs through five main stages, namely knowledge, persuasion, decision, implementation, and confirmation, which reflect the adoption process from introduction to established use. This is supported by the statement from Call and Herber (2022) that people will implement an innovation if they see positive results from the data analysis.

In addition to being profit-oriented, companies see technological advances as having a positive impact on data collection, analysis, and decision-making through analytical data visualization to determine future performance, particularly in achieving sustainability (Ragulina, 2022). According to Grover et al. (2019) and Dzuranin et al. (2023), the spread of blockchain technology shows different diffusion patterns across industries, with some being successful in the implementation process. Therefore, companies need to get to know their stakeholders thoroughly to

help meet their needs adequately. The significant growth of organizations, accompanied by increased business complexity, prompted the development of stakeholder theory by Freeman (2010) in 1984 as a response to the limitations of the traditional view, which emphasized only the company's responsibility to shareholders. This became relevant to the world's need to address environmental and social issues, with external pressure from stakeholders playing a significant role in encouraging companies to adopt environmentally friendly strategies that are in line with market demands and regulations (Zhu et al., 2023).

2.2 Integration of Artificial Intelligence and Blockchain - Climate Management Accounting Platform

The presence of advanced technology has increasingly improved decision-making with a reliable risk mapping scale to maintain organizational stability (Kurniawan & Mulyawan, 2023). Blockchain functions as a decentralized ledger for transactions, managed and authenticated by a network of computers around the world (Sarmah, 2018). However, Saberi et al. (2019) reveal that blockchain still faces many challenges that require AI intervention to resolve. Nevertheless, it is projected to provide several significant benefits (Odekanle et al., 2022).

Alotaibi et al. (2024) show that blockchain can strengthen accountability by providing an audit trail that cannot be manipulated, thereby increasing the verifiability of carbon emissions reporting. Meanwhile, Ragulina (2022) emphasizes that the development of AI within the framework of the environmental AI economy has the potential to drive decarbonization and waste reduction, thereby supporting the sustainability agenda. The results support the implementation of software developed by integrating AI and Blockchain, namely CMAP, which also refers to the standards and frameworks of the Greenhouse Gas Protocol (GHGP), Task Force for Climate-Related Disclosure (TCFD), and Partnership for Carbon Accounting Financials (PCAF) to improve calculation accuracy (Persefoni, 2023; Dannouni et al., 2023).

3. RESEARCH METHOD

This research uses an exploratory qualitative method aimed at exploring and analyzing the success of ESG measurement by companies thru the integrated implementation of CMAP with the use of Artificial Intelligence and Blockchain in achieving sustainability aspects, as stated by Saunders et al. (2019) in their book "Research Methods For Business Students" Eighth Edition, which explains that qualitative research is exploratory in nature with an inductive thought pattern, aiming to delve deeper into information from the target parties to obtain broader and more reliable answers to be presented to those in need regarding the current conditions and situations faced.

To enhance data analysis and the solutions developed, this research utilizes secondary data collection with a Systematic Literature Review approach on several international journals, books, and reports that are analyzed and developed to generate information for future readers (Saunders et al., 2019). The SLR methodology allows researchers to identify and analyze all relevant previous studies on sustainability integrated with technologies.

4. RESULT AND DISCUSSION

4.1. The Role of Blockchain and Artificial Intelligence in Improving Supply Chains and Reducing Negative Environmental Impacts

Blockchain functions as an inter-organizational connectivity layer by providing security, integrity, and transparency in data flows across supply chains. Its decentralized networks and distributed ledger technology help address traceability issues and enhance supply chain oversight. Through smart contracts, resource management and transportation operator scheduling become more efficient, as demonstrated by Maersk's TradeLens platform, which connects multiple stakeholders in managing approximately 10% of global container cargo while accounting for factors such as cost and carbon emissions.

The integration of AI technologies, such as machine learning and predictive analytics, into blockchain further supports both strategic and tactical resource optimization in supply chains. Studies indicate that the combination of blockchain and AI enhances accuracy, transparency, and the speed of real-time carbon footprint analysis, thereby contributing to improved corporate ESG projections (Puschmann & Quattrocchi, 2023). This aligns with the *Artificial Intelligence Ethics Regulation* issued by Indonesia's Ministry of Communication and Information Technology (Kominfo, 2023), which emphasizes transparency, sustainable development, security, and inclusivity.

Metric	Traditional Supply Chain	Supply Chain with Blockchain	Supply Chain with AI	Supply Chain with Blockchain and AI
Efficiency (Time to Process Orders)	3 days	1 day	2 days	1 hour
Transparency (Visibility of Data)	Low	High	Medium	High
Traceability (Product Tracking)	Limited	Full	Limited	Full
Accuracy (Reducing Errors)	Moderate	High	Moderate	High

Table 1. Comparison of supply chain performance using traditional approaches, blockchain technology, AI, and the integration of blockchain with AI

Table 1 presents the performance of each approach in terms of efficiency, measured by the time required to process orders. The table also evaluates the level of transparency, which reflects the visibility of data across the supply chain. Additionally, it assesses traceability, which refers to the ability to track and trace products or components.

4.2. Implementation of CMAP Integrated with Blockchain and AI for Analyzing Carbon Footprints in the Corporate Value Chain

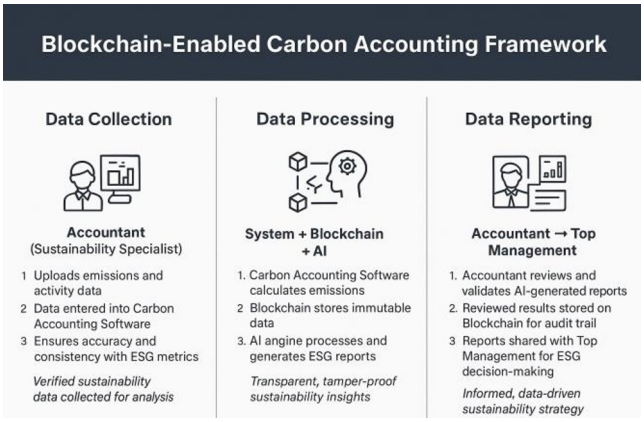

Fig 2. ***Framework of CMAP integrated with Blockchain-AI.*** **(Researcher, 2024)**

Figure 2 illustrates the stages of CMAP implementation, which are designed to enhance the efficiency of carbon utilization. All carbon footprint data are input into CMAP, which adopts a blockchain-based data storage system. AI then utilizes the data stored within the blockchain to collect, interpret, process, and project it into valuable information for periodic decision-making. AI generates guidelines for mitigation, monitoring, and measurement, while also serving as a detection and long-term projection by identifying trends derived from the data.

Through the implementation of CMAP to track carbon footprints in real time, an Early Warning System (EWS) can be developed to analyze the impact of carbon emissions on corporate operations (Li et al., 2024). The design of an EWS for carbon footprints plays an effective role in identifying and monitoring risks related to abnormal carbon footprint patterns and providing dynamic, real-time alerts (Agbehadji et al., 2024). This enables company management to issue directives and make decisions promptly through a system intended to anticipate and control potential performance deviations with significant impacts.

4.3 Projection of CMAP Implementation in Addressing Challenges in Carbon Footprint

Table 2. Changes Before and After CMAP Integration with Blockchain and AI

Categories	**AI-Blockchain Adoption to Reduce Carbon Footprint**		**SGDs 2030**
	Previously	**After**	
Business Operations	Tracking carbon emissions through conventional techniques, such as reporting, monitoring, and verification of carbon emissions.	Automation of carbon footprint tracking.	SDGs 8.1 SDGs 8.2
Carbon Consumption	Issues of transparency and accuracy.	Effectiveness and transparency of carbon management.	SDGs 8.4
Risk Management	No way to confirm authenticity and protect against fraud.	Providing immutable and transparent records across the entire value chain (traceable and verifiable).	SDGs 9.5
Efficiency	Carbon footprint calculation processes are costly and inefficient.	Automation reduces costs and increases efficiency.	SDGs 8.4

Source: (Pierre, 2023; P27 Team, 2023; Wang *et al*., 2020)

With the implementation of CMAP to track carbon footprints in real time, an Early Warning System (EWS) can be developed to analyze the impact of carbon emissions on corporate operations (Li et al., 2024). The design of an EWS for carbon footprints plays an effective role in identifying and monitoring risks associated with abnormal carbon footprint patterns and in providing dynamic, real-time alerts(Agbehadji et al., 2024). This enables corporate management to issue directives and make timely decisions through a system designed to anticipate and control potential performance deviations with significant impacts.

A limitation of this technological advancement lies in the absence of regulations governing the use of blockchain, given that it is still in its early stages of development. This creates potential vulnerabilities that could be exploited by hackers, thereby requiring companies to maximize cybersecurity within their organizational structures.

5. CONCLUSION

By adopting integrated technology in business operations, users are assisted in conducting risk analysis through ESG measurement, which impacts improved organizational performance in line with the sustainability agenda, namely carbon emission reduction actions with blockchain and AI-based decision-making. The accuracy of information helps users effectively evaluate operational performance and expand the development of relevant strategies to reduce their carbon footprint in accordance with investor and regulator demands, as well as national developments in improving community and environmental well-being.

The research can be further developed by collecting data comparing performance across various business lines to identify organizational needs and the steps taken in accordance with applicable standards. This research can expand the diffusion of innovation theory supported by stakeholders to strengthen how companies can innovate, adopt technology, and develop superior systems for mitigating climate change risks, which aligns with the IFRS S1 and S2 standards for sustainability reporting and to several standards like TCFD and GRI.

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7. TRANSPARENCY

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

The data of this research is available and can be accessed at https://doi.org/10.5281/zenodo.17393997

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