ADVANCED BUSINESS JOURNAL
e-ISSN 3110-4053 · advancedbusinessjournal.com
Vol. 2 No. 3 (2026), pp. 20-37
DOI: https://doi.org/10.65875/y2ekws07

RESEARCH PAPER | Sustainability Management & Corporate Environmental Performance

Navigating Carbon Neutrality Transitions: The Role of Data-Driven Decision Making in Corporate Environmental Performance

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ARTICLE INFO

Article history
Received: 15 February 2026
Revised: 8 March 2026
Accepted: 26 August 2026
Published: 30 August 2026

Keywords
Data driven decision making (DDDM)
Carbon neutrality
Corporate environmental performance
Digital transformation
Sustainability governance
Carbon accounting

JEL Classification
M14; O33; Q54; Q56

ABSTRACT

Corporate carbon-neutrality commitments have proliferated, but the credibility of corporate transitions depends on whether climate ambition is translated into measurable operational change. Firms must make connected decisions about energy, production, procurement, logistics, product design, capital allocation, and value-chain relationships while balancing environmental objectives with financial viability. This article examines how data-driven decision-making (DDDM) can strengthen corporate environmental performance during carbon-neutrality transitions. It develops an integrative review of recent research on digital transformation, environmental management, carbon accounting, sustainability disclosure, and net-zero governance, supplemented by authoritative standards and climate assessments published since 2021. The synthesis identifies five mechanisms through which DDDM may create environmental value: impact visibility, analytical diagnosis, operational optimization, cross-functional coordination, and accountability-based learning. It also identifies conditions under which these mechanisms are weakened, including poor data quality, fragmented systems, weak managerial incentives, uncertain Scope 3 estimates, rebound effects, and the substitution of carbon credits for gross emissions reductions. The article proposes a conceptual framework linking data infrastructure and analytical capabilities to decision routines, implemented interventions, and verified environmental outcomes. Governance quality, regulatory pressure, supplier influence, and organizational learning are theorized as important boundary conditions. The article concludes that DDDM should be treated as a strategic organizational capability rather than a reporting tool or technology purchase. Its contribution should be assessed not by the volume of data collected, but by whether the data change decisions and support additional, measurable, and verifiable environmental improvements without undermining long-term economic resilience.

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1. INTRODUCTION

Corporate carbon neutrality has moved from a specialist sustainability aspiration to a visible element of corporate strategy, investor communication, supply-chain governance, and risk management. Companies increasingly announce emissions-reduction targets, publish sustainability reports, and describe plans to reach net zero. This shift reflects the physical risks of climate change, changing regulation, investor scrutiny, buyer expectations, and the possibility that carbon-intensive assets may lose value as markets and technologies evolve. Yet the growth of corporate commitments has also made it harder to distinguish substantive transformation from symbolic pledges. The Intergovernmental Panel on Climate Change (IPCC, 2023) concludes that limiting warming requires rapid, deep, and sustained greenhouse-gas reductions. The International Energy Agency (IEA, 2023) likewise describes net-zero pathways that depend on the deployment of clean technologies, efficiency improvements, infrastructure investment, and changes in production and consumption. For firms, these assessments imply that a credible transition must be operational, measurable, and adaptive rather than confined to the language of ambition.

Corporate emissions arise through interconnected activities. Direct emissions originate from sources owned or controlled by an organization; indirect emissions arise from purchased energy; and other indirect emissions occur across upstream and downstream value chains. Equipment choices, process heat, electricity

procurement, material selection, transport, supplier practices, product use, and end-of-life treatment can all influence a company's carbon footprint. Scope 3 emissions are especially difficult because they often depend on suppliers and customers beyond the reporting firm's direct control. Corporate inventories and targets consequently require clear boundaries, consistent methods, transparent assumptions, and careful treatment of uncertainty. The Greenhouse Gas Protocol remains a widely used foundation for organizational emissions accounting, while newer disclosure and target-setting initiatives have raised expectations for comparability and transition planning (GHG Protocol, 2021; IFRS Foundation, 2023a, 2023b; Science Based Targets initiative [SBTi], 2023).

Data-driven decision-making (DDDM) offers a potential bridge between climate commitments and operational execution. In this article, DDDM refers to the organized use of data, analytical methods, domain expertise, and structured feedback to define environmental problems, compare alternatives, allocate resources, implement interventions, and evaluate outcomes. It includes but goes beyond digital transformation. Sensors, enterprise resource planning systems, emissions databases, machine learning, digital twins, and dashboards can generate or organize information, but their presence does not guarantee better decisions. A company may produce a sophisticated inventory while leaving capital-allocation rules unchanged; a predictive model may reduce energy per unit while total production and absolute emissions increase; and a reporting platform may improve disclosure without affecting physical operations. The strategic question is therefore not whether firms digitize, but whether they build a repeatable capability to convert environmental information into decisions and verified results.

Research increasingly connects digital transformation with corporate environmental performance, but findings remain heterogeneous. Studies report that digital transformation can support environmental performance, carbon-emissions reduction, green innovation, and internal control in particular settings (Gao et al., 2023; Sun, 2024; Song et al., 2023). Reviews also identify potential gains in environmental information capture and management responsiveness while highlighting fragmented constructs and insufficient attention to mediating mechanisms (Xia et al., 2022; Guandalini, 2022). Importantly, digitalization should not be equated with emissions reduction. Broad ESG scores may improve even when direct pollution or energy-efficiency outcomes do not, partly because ESG ratings capture disclosure and governance as well as environmental results. This makes it necessary to distinguish digital capability, information quality, decision quality, implementation, disclosure, and physical environmental performance.

Three gaps motivate this article. First, the literature often treats digital transformation, data analytics, environmental management, ESG performance, and carbon reduction as closely related but insufficiently differentiated concepts. These constructs describe different stages and outcomes. A disclosure score can improve without a reduction in emissions; intensity can decline while absolute emissions rise; and improved environmental management processes may not yet have generated measurable physical change. A more precise framework should separate inputs, mechanisms, decisions, and outcomes.

Second, the mechanisms linking data to environmental performance need clearer specification. Data are frequently described as an enabling resource, but their environmental value depends on how organizations interpret and use them. Firms differ in analytical skills, engineering knowledge, managerial incentives, authority structures, and their ability to coordinate across functions. A company may have advanced monitoring infrastructure but no investment process that prioritizes decarbonization. Another may achieve substantial savings with basic meters, careful maintenance, and accountable managers. The key issue is how data capabilities become embedded in routines and how those routines affect emissions-reduction choices.

Third, carbon-neutrality claims raise problems of measurement and accountability. Boundaries, base years, emission factors, renewable-electricity accounting, removals, and carbon credits can materially influence reported progress. Fragmented or unreliable data can misdirect investment and make comparisons misleading. Climate disclosure requirements can encourage more consistent information, but compliance-oriented collection is not equivalent to operational decarbonization. Firms need a system that links external reporting to internal decisions, verifies the effects of interventions, and prevents favorable metrics from concealing unfavorable physical outcomes.

Therefore, the article addresses three research questions:

RQ1. Through which organizational mechanisms can DDDM improve corporate environmental performance during carbon-neutrality transitions?

RQ2. Which technological, managerial, and governance conditions strengthen or weaken these relationships?

RQ3. How can firms design data-to-decision processes that align reporting, operational improvement, and credible climate targets?

The article develops a theory-informed conceptual framework rather than reporting a new causal estimate. It contributes by linking the data lifecycle to environmental action, distinguishing environmental performance from disclosure, identifying failure modes, and formulating propositions for empirical testing. The contribution is fourfold. First, DDDM is conceptualized as a strategic capability combining data infrastructure, analytical competence, decision routines, and accountability. Second, five mechanisms are identified: visibility, diagnosis, optimization, coordination, and verification. Third, boundary conditions are specified, including data quality, governance, organizational capacity, supply-chain influence, regulatory pressure, and rebound effects. Fourth, the article proposes an implementation roadmap and research agenda for firms at different stages of digital and environmental maturity. The argument is particularly relevant to sectors in which emissions are distributed across operations and value chains and in which firms must balance near-term financial constraints with long-term transition requirements.

The remainder of the article is organized as follows. Section 2 reviews the theoretical foundations and recent evidence. Section 3 explains the integrative review method. Section 4 presents the synthesized framework and its mechanisms. Section 5 discusses managerial, governance, and policy implications. Section 6 concludes and outlines limitations and a future research agenda.

2. LITERATURE REVIEW AND THEORETICAL FOUNDATIONS

2.1 Carbon neutrality as a strategic transition

Carbon neutrality generally describes a balance between anthropogenic greenhouse-gas emissions and removals within a defined boundary and period. Net-zero terminology is used across climate science and corporate practice, but its meaning depends on the gases covered, the organizational boundary, the target year, and the treatment of residual emissions. A claim may refer to a product, facility, event, or entire value chain; these scopes are not interchangeable. The IPCC (2023) distinguishes global net-zero carbon dioxide pathways from net-zero greenhouse-gas pathways, while corporate standards translate climate objectives into inventory and target-setting rules. Companies should therefore specify the boundary, base year, gases, scopes, assumptions, and role of removals or credits associated with a neutrality claim.

A transition perspective is essential because neutrality is not a one-time certification exercise. It requires changes to capital stock, procurement, technologies, operating procedures, product portfolios, and supplier relationships. The IEA (2023) describes pathways involving both mature and emerging technologies, each with different costs, readiness, and deployment constraints. The United Nations Environment Programme (UNEP, 2023) highlights the continuing gap between current emissions trajectories and the reductions needed to meet global temperature goals. For firms, these conditions create a sequencing problem: which sources should be addressed first, which investments should be made now, and how should plans adapt as energy prices, regulation, technology costs, and supply availability change? DDDM can make these choices more transparent, but cannot eliminate uncertainty or replace strategic judgment.

2.2 Data-driven decision-making in corporate sustainability

DDDM can be understood as a recurring process: defining a decision problem, identifying relevant evidence, collecting and validating data, analyzing patterns and alternatives, selecting an action, implementing it, and evaluating the consequences. The process is iterative. New measurements may change a baseline, reveal an overlooked hotspot, or show that an intervention underperforms. In environmental management, the unit of analysis can be a machine, production process, facility, product line, supplier network, or corporate portfolio. These levels must be connected so that local optimization does not undermine enterprise-wide goals.

DDDM is not synonymous with artificial intelligence, big data, or automation. Basic meter readings, verified invoices, process logs, and a transparent emission-factor table can support more defensible decisions than an elaborate model built on incomplete information. Advanced analytics are useful when the problem is sufficiently complex, the data are adequate, and model outputs can change a decision. Otherwise, complexity can raise costs, reduce explainability, and create false precision. Reviews of digital transformation and environmental management identify multiple routes through which digital tools may affect sustainability, but also emphasize the need to specify mediating mechanisms and boundary conditions (Xia et al., 2022; Guandalini, 2022). A capability-based view therefore evaluates technology in relation to decision tasks rather than treating adoption as an end in itself.

2.3 Resource-based view and dynamic capabilities

The resource-based view explains performance differences through resources and capabilities that are valuable, difficult to imitate, and effectively organized. Relevant resources for carbon transitions include emissions data, process knowledge, energy-management systems, supplier relationships, analytical talent, and routines for evaluating environmental investments. Data alone are rarely a durable advantage because competitors can acquire similar software and access similar emission factors. More defensible capability arises from integrating data with tacit operational knowledge, decision rights, and execution across functions. Evidence linking digitalization with internal control and green innovation illustrates the importance of organizational mechanisms rather than technology in isolation (Sun, 2024).

Dynamic capabilities emphasize the ability to sense changes, seize opportunities, and reconfigure resources. A carbon-intensive firm may use operational data to identify an inefficient process, compare electrification or fuel-switching options, redirect capital, retrain workers, renegotiate energy contracts, and revise supplier requirements. DDDM can support sensing through visibility, seizing through comparative analysis, and reconfiguration through monitoring and learning. Yet analytical capacity is not inherently sustainable. The same tools may be used to expand output or reduce costs in ways that increase total environmental pressure. The environmental direction of a capability depends on strategy, incentives, and governance.

2.4 Institutional theory and stakeholder accountability

Institutional theory helps explain why firms adopt environmental measurement and reporting. Regulation, professional standards, investor expectations, buyer requirements, and peer behavior can create pressure to demonstrate responsibility. Such pressures may encourage credible measurement, but they can also lead to symbolic conformity when reporting offers reputational benefits while operational change remains costly. Disclosure rules are therefore necessary but insufficient, enforcement and scrutiny influence whether data systems support substantive decarbonization or mainly manage appearances.

Stakeholder theory emphasizes that environmental decisions affect investors, employees, customers, local communities, suppliers, regulators, and future generations. DDDM can improve transparency around trade-offs, but it cannot determine normative priorities by itself. A facility-level carbon reduction might shift pollution to a supplier, increase water use, or impose transition costs on workers. A narrow carbon metric can make such a choice appear successful despite broader harm. Stakeholder engagement and multi-dimensional assessment are necessary complements to analytics. Digital tools may improve ESG tracking and disclosure, but the information must be connected to decision consequences and external accountability (Quaser, 2026).

2.5 Information-processing theory and decision quality

Information-processing theory suggests that organizational performance depends partly on the fit between information-processing requirements and organizational capacity. Environmental decisions involve uncertainty and interdependence. Choosing among electrification, process redesign, renewable electricity, and supplier substitution requires reconciliation of engineering data, financial forecasts, emission factors, regulatory constraints, and operational risks. When data are siloed across finance, sustainability, procurement, and production, decision-makers face high coordination costs. Interoperable data structures and cross-functional routines can reduce these costs and expose inconsistent assumptions.

More information does not necessarily mean better information. Data overload, incompatible definitions, uncertain estimates, and poorly designed dashboards can increase cognitive burden. Decision quality depends on selecting material information, understanding its limitations, and making uncertainty explicit. Systems should distinguish measured values from estimates, primary data from secondary factors, and observed outcomes from modeled projections. They should also record provenance and version changes so that a revised estimate is not mistaken for a physical change. These distinctions matter as climate disclosure expectations become more standardized (IFRS Foundation, 2023a, 2023b).

2.6 Corporate environmental performance and its measurement

Corporate environmental performance is multidimensional. It can include absolute greenhouse-gas emissions, emissions intensity, energy consumption, renewable-energy share, water use, waste, pollution, compliance, and process improvements. For carbon transitions, emissions are central, but carbon reduction does not automatically improve every environmental dimension. Electrification may reduce direct combustion emissions while increasing electricity demand; material substitution may reduce carbon intensity while increasing water use or toxicity; and recycling may add transport and processing burdens. Indicators should reflect material impacts and be interpreted as a portfolio rather than a single universal score.

Absolute emissions and emissions intensity answer different questions. Absolute emissions indicate the total contribution to atmospheric loading within the inventory boundary. Intensity relates emissions to output, revenue, or product units. Intensity can improve while absolute emissions rise if production expands faster than efficiency improves. Absolute emissions can fall because output contracts even when the technology is not cleaner. A robust system tracks both measures and decomposes changes into activity, energy mix, efficiency, product mix, and accounting-boundary effects. This prevents a favorable denominator from being presented as decarbonization.

Environmental performance should also be distinguished from ESG ratings and disclosure quality. ESG scores aggregate diverse topics and use different weights; they may reward policies or reports rather than verified physical outcomes. Digitization can improve overall ESG scores without a corresponding improvement in pollution or energy efficiency in some contexts (Yang et al., 2023). DDDM should therefore be evaluated against physical and operational indicators, while disclosure quality is treated as an enabling and accountability outcome rather than a substitute for environmental performance.

2.7 Digital technologies and environmental decision-making

Relevant technologies include smart meters, industrial internet of things sensors, enterprise systems, digital twins, geospatial tools, cloud platforms, machine learning, blockchain-based traceability, and automated control. Their usefulness varies by task. Sensors provide high-frequency observations; enterprise systems connect production and purchasing records; digital twins simulate alternatives; machine learning detects anomalies or forecasts demand; and traceability tools may improve supplier-data provenance. Each technology also carries costs, data requirements, cybersecurity risks, and potential environmental footprints.

Digital tools can improve energy management and reduce waste where they change process design or control. However, digital infrastructure consumes electricity and materials, and rebound effects may offset efficiency gains. The environmental case for a technology must therefore be evaluated across its lifecycle and against a plausible counterfactual. A data center, AI model, or sensor network should not be assumed beneficial simply because it supports a sustainability initiative. The key test is whether the system enables a net improvement that would not otherwise have occurred.

2.8 Carbon accounting, disclosure, and transition plans

Carbon accounting provides the measurement foundation for corporate decarbonization. The GHG Protocol standards offer widely used guidance for organizational inventories and value-chain emissions (GHG Protocol, 2021). Their usefulness depends on consistent boundaries, reliable activity data, appropriate emission factors, transparent assumptions, and suitable treatment of uncertainty. Scope 3 estimates often rely on spend-based or industry-average factors when supplier-specific data are unavailable. Such methods

can support initial screening but may be too imprecise to evaluate a particular supplier intervention. Firms should improve data quality progressively in categories that are both material and decision sensitive.

Climate disclosure standards have increased the strategic relevance of governance, risk, metrics, targets, and transition planning. IFRS S1 and IFRS S2, issued in 2023, establish a global baseline for sustainability-related and climate-related financial disclosures (IFRS Foundation, 2023a, 2023b). The European Union's Corporate Sustainability Reporting Directive and European Sustainability Reporting Standards establish more extensive reporting obligations for entities within their scope (European Commission, 2023). The Task Force on Climate-related Financial Disclosures also helped shape practice through recommendations on governance, strategy, risk management, and metrics (TCFD, 2021). Such frameworks can improve comparability, but companies must still distinguish compliance, financial materiality, impact materiality, and internal operational needs.

Science-based target-setting and net-zero guidance emphasize that targets should be grounded in climate science and prioritize actual value-chain reductions. The SBTi Corporate Net-Zero Standard sets criteria for near-term and long-term targets and addresses residual-emissions neutralization (SBTi, 2023). The Voluntary Carbon Markets Integrity Initiative (VCMI, 2023) provides guidance for claims associated with carbon credits, while the Integrity Council for the Voluntary Carbon Market (ICVCM, 2023) developed a framework for credit quality. These initiatives reflect concern that credits and neutrality labels can overstate progress. DDDM should separate gross reductions, removals, and credits in internal records and public reporting.

2.9 Green innovation, eco-efficiency, and profitability

Green innovation can mediate the relationship between DDDM and environmental performance. Data may reveal an energy-intensive production stage, material losses, or a product-use phase with a large lifecycle footprint. These insights can stimulate redesign, cleaner production, alternative materials, circularity, electrification, or service-based business models. Yet innovation requires engineering expertise, experimentation budgets, management support, and time to change production systems. Digitalization may support green innovation, but patents, pilots, or software installations are intermediate outputs rather than proof of sustained emissions reductions (Sun, 2024).

Eco-efficiency offers an early route to both environmental and financial gains. Monitoring can identify idle energy use, leaks, inefficient equipment, avoidable transport, or process variability. Predictive maintenance may reduce failures and material waste; demand forecasting can reduce overproduction; and route optimization can lower fuel use. Such measures can improve margins while reducing emissions, making them attractive early actions. Nevertheless, firms should not allow low-cost efficiency projects to crowd out structural changes needed for deep decarbonization. Incremental optimization may be insufficient when core assets are carbon intensive or output growth overwhelms efficiency gains.

Profitability should be treated as a dynamic rather than purely short-term criterion. Some decarbonization measures generate rapid savings; others require long payback periods, infrastructure coordination, or protection against future regulation and asset stranding. A narrow payback rule may reject a project that is strategically necessary for long-term competitiveness. DDDM can improve appraisal by making energy-price scenarios, carbon costs, technology learning curves, transition risks, and co-benefits explicit. It cannot eliminate trade-offs, but can make them more transparent and comparable.

2.10 Research gap and conceptual positioning

The literature calls for an integrated explanation of how DDDM contributes to environmental performance during carbon-neutrality transitions. Existing work establishes plausible links between digital transformation and environmental management, but constructs often remain broad. A technology-adoption measure does not reveal whether data are valid, whether managers use them, or whether decisions change. An ESG score does not reveal whether absolute emissions decline. Disclosure standards clarify what firms should report but do not explain how information becomes operational change. This article positions DDDM as a multi-stage capability and environmental performance as a set of differentiated outcomes.

The distinction matters for both theory and practice. Data infrastructure creates potential visibility; analytical capability supports diagnosis; decision routines connect diagnosis to resource allocation; implementation capability converts decisions into operational change; and verification determines whether the expected effect occurred. Governance influences each stage, while external pressures shape incentives to act. This process view makes it possible to identify where a pathway fails: data may be accurate but unused, decisions may be made but not implemented, or efficiency gains may be offset by higher output.

3. METHOD

3.1 Research design

This article adopts an integrative literature review and theory-building approach. The topic crosses information systems, strategic management, environmental management, climate accounting, and sustainability governance. An integrative review is appropriate because the aim is to synthesize mechanisms and contradictions across different evidence types rather than calculate a pooled effect size. The studies considered use different constructs, samples, outcomes, and methods, making a single meta-analytic estimate inappropriate without a more narrowly defined research question. The article is not presented as a preregistered systematic review or a meta-analysis, and it does not report original firm-level observations.

The evidence base prioritizes peer-reviewed research and authoritative standards or reports published from 2021 onward. Search concepts include data-driven decision-making, digital transformation, corporate environmental performance, carbon emissions, carbon neutrality, net zero, green innovation, carbon accounting, climate disclosure, and sustainability analytics. Relevant source categories include research on digital transformation and corporate environmental outcomes; reviews of digital technology and environmental management; standards for greenhouse-gas inventories and targets; climate-science assessments; and guidance on disclosure and carbon-credit integrity. Sources were retained when they directly informed at least one research question and had traceable publication details.

3.2 Inclusion logic and analytical boundaries

Academic sources were included when they addressed corporate digitalization, environmental management, emissions performance, ESG measurement, green innovation, or climate governance. Official sources were used to establish standards, policy requirements, and climate pathways. Research focused only on consumer behavior or country-level emissions was used sparingly unless it informed a transferable mechanism. Studies measuring broad ESG performance were retained but interpreted cautiously when environmental outcomes were not separately reported. This reduces the risk of treating better disclosure or governance as direct evidence of lower emissions.

The synthesis distinguishes conceptual guidance from empirical findings. Standards define expectations; they do not establish causal effects. Empirical studies estimate relationships within particular samples and contexts; their results do not automatically generalize to every sector or country. Climate reports describe pathways and scenarios rather than guaranteed forecasts. These distinctions are maintained throughout the discussion. The analysis also differentiates gross emissions reductions, removals, and offsets because they represent different contributions to a carbon-neutrality claim.

3.3 Analytical procedure

The synthesis proceeded in four stages. First, sources were grouped by topic: data and digital capabilities, decision processes, environmental outcomes, accounting and disclosure, organizational conditions, and external governance. Second, the evidence was organized according to the stages of a data-to-action process: visibility, diagnosis, decision, implementation, and verification. Third, studies reporting positive relationships were compared with evidence of mixed or limited environmental effects, with attention to outcome definitions and mediating mechanisms. Fourth, the framework was refined to incorporate boundary conditions and unintended consequences such as rebound effects, greenwashing, data bias, and dependence on credits.

The resulting framework was evaluated for explanatory coherence, empirical testability, managerial relevance, and governance sensitivity. Explanatory coherence asks whether it specifies a plausible sequence

from data to performance. Testability asks whether constructs can be operationalized. Managerial relevance asks whether firms can influence the mechanisms. Governance sensitivity asks whether incentives and accountability are recognized. The framework is intended to guide future empirical tests and practical system design, not to assert a universal causal law.

4. RESULTS AND ANALYTICAL SYNTHESIS

4.1 The data to action framework

The synthesis identifies five connected mechanisms through which DDDM may contribute to corporate environmental performance: environmental visibility, analytical diagnosis, operational optimization, cross-functional coordination, and accountability-based learning. The mechanisms are sequential but recursive. Visibility makes impacts observable; diagnosis identifies causes and opportunities; optimization compares and implements interventions; coordination aligns functions and value-chain partners; and accountability verifies whether outcomes match commitments. Research on digital transformation is broadly consistent with the proposition that digital capabilities can support environmental management, while also showing that outcomes depend on organizational mechanisms and measurement choices (Xia et al., 2022; Song et al., 2023; Sun, 2024).

The framework begins with data infrastructure, standards, analytical skills, domain expertise, governance arrangements, and leadership commitment. These inputs support routines such as emissions-inventory management, energy review, investment appraisal, supplier engagement, and performance evaluation. Routines shape decisions about process redesign, energy sourcing, product development, logistics, and capital expenditure. Decisions affect environmental outcomes only when implemented and sustained. Verification then compares actual results with the baseline and expected pathway, allowing the organization to revise assumptions or interventions. A breakdown at any stage weakens the final effect.

Data quality and decision integration should be treated as distinct constructs. Data quality concerns reliability, completeness, timeliness, consistency, and traceability. Decision integration concerns whether information is used in planning, budgeting, procurement, production, and performance review. A company can perform well on one and poorly on the other. An accurate inventory may be used only for disclosure, while a modest energy dashboard may directly inform daily adjustments. Research should not assume that better data automatically produce better outcomes.

4.2 Environmental visibility

Environmental visibility is the ability to locate, quantify, and attribute environmental impacts across relevant organizational boundaries. At the operational level, this can require linking meter readings, fuel consumption, production volumes, equipment schedules, material flows, and maintenance records. At the corporate level, it requires reconciling facility data with energy purchases, fleet activity, procurement records, product-use assumptions, and value-chain estimates. Visibility is not merely accumulation; it requires consistent definitions and the ability to trace an aggregate result to the activities that generated it.

Visibility can change managerial attention. When energy and emissions are measured at a sufficiently granular level, managers may identify losses previously hidden in overheads. Annual electricity totals may not reveal which shifts or machines drive peak demand. Supplier inventories based only on spend may obscure whether emissions are driven by material volume, production technology, or transport. Granularity should nevertheless be proportionate to the decision: excessive detail can raise costs without improving actionability.

Boundary discipline is equally important. Acquisitions, divestments, outsourcing, revised emission factors, and methodological changes can affect reported emissions without representing a physical reduction. DDDM should preserve the distinction between operational change and accounting change. Restated baselines and changes in estimation methods should be documented explicitly. This supports internal learning and credible external reporting under evolving climate disclosure expectations (IFRS Foundation, 2023b; GHG Protocol, 2021).

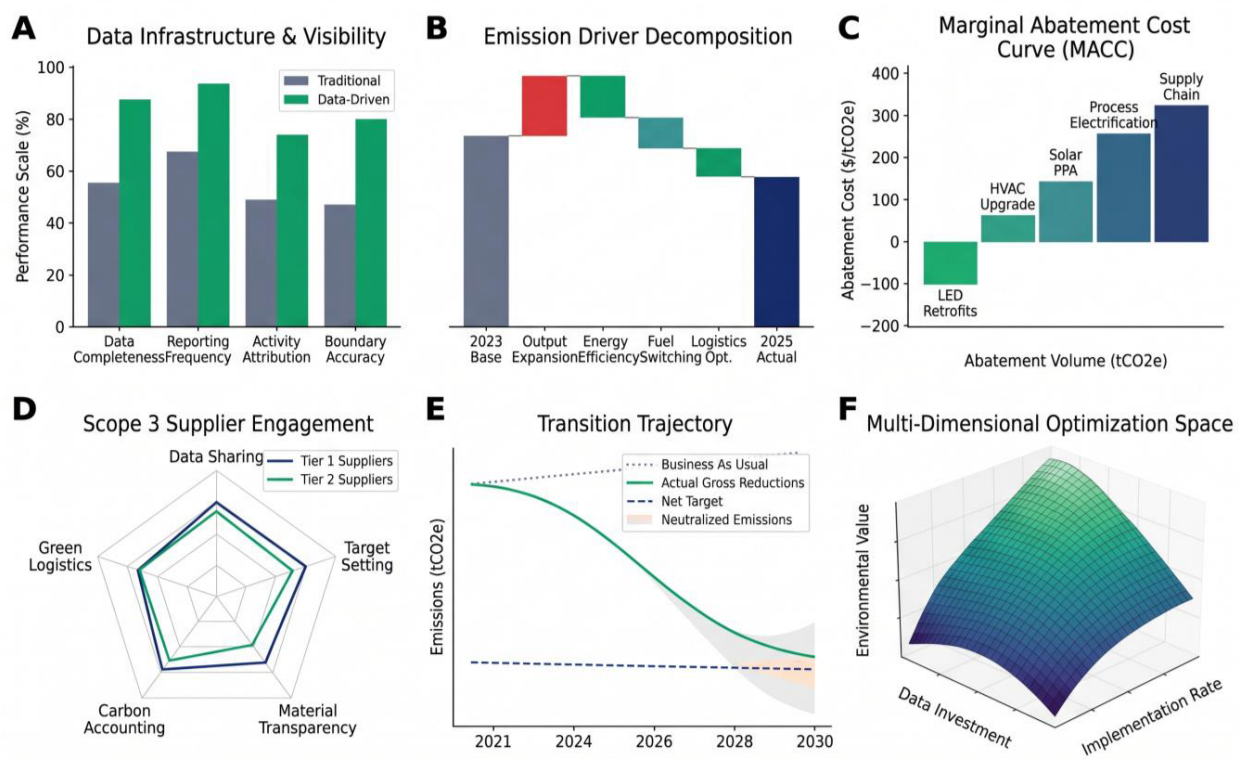

Figure 1. Conceptual framework and analytical mechanisms of data-driven decision-making

Source: Authors' elaboration.

4.3 Analytical diagnosis

Analytical diagnosis converts visibility into an explanation of environmental drivers and the interventions most likely to matter. Descriptive analytics identify trends and anomalies; diagnostic analytics compare sites or processes; predictive analytics forecast demand, emissions, or equipment failure; and prescriptive analytics evaluate actions subject to technical and operational constraints. Decomposition analysis can explain the contribution of output growth and energy intensity to emissions change, while process simulation can compare operating parameters.

Diagnosis must distinguish correlation from causation. If emissions fall after a digital platform is introduced, the change may instead reflect lower production, weather, product mix, or a new energy contract. Facilities that adopt advanced systems may already have stronger management, more capital, or greater regulatory exposure. Empirical studies should address selection effects and confounding factors rather than interpreting a positive coefficient as definitive causal proof. Mixed findings in the literature reinforce this caution: digital transformation can be associated with better environmental performance in some settings, while other work reports weaker links between digitization and direct environmental outcomes (Song et al., 2023; Yang et al., 2023).

Models should represent uncertainty. Scope 3 estimates may depend on incomplete supplier data, industry-average factors, product-lifetime assumptions, or customer behavior. A point estimate can conceal substantial uncertainty. Firms should use ranges, sensitivity analysis, and explicit data-quality scores where appropriate. The goal is not to create an appearance of precision but to help decision-makers distinguish robust conclusions from those dependent on weak assumptions. For material decisions, the preferred option should be tested against plausible alternative assumptions.

4.4 Operational optimization and innovation

Operational optimization uses evidence to improve existing processes and identify structural change. Near-term actions may include reducing idle energy consumption, improving process control, preventing leaks, optimizing refrigeration, reducing scrap, improving maintenance, or coordinating logistics. Structural options include electrification, renewable-energy procurement, redesign of production systems, substitution of high-emissions materials, circular business models, and changes to product portfolios. DDDM can compare

options using expected reductions, cost, technical feasibility, implementation time, reliability, and co-benefits.

Optimization should not maximize a single metric blindly. A model designed to minimize energy cost may increase emissions if consumption shifts toward a more carbon-intensive period. Production algorithms can reduce emissions per unit while increasing total output enough to raise absolute emissions. Logistics models can reduce distance but increase packaging or spoilage. Environmental optimization should therefore use explicit constraints and multiple metrics, including absolute emissions, intensity, energy use, waste, and other material impacts. The objective should reflect the transition pathway rather than the easiest metric to measure.

Digital transformation can support green innovation by lowering the cost of experimentation and improving feedback on new technologies. Digital twins can compare process settings before physical changes; sensor data can reveal whether a retrofit performs as expected; and lifecycle data can identify high-impact product stages. Research linking digitalization with green innovation provides a basis for this mechanism, although innovation outcomes must be distinguished from realized environmental benefits (Sun, 2024). A pilot or patent is an intermediate output, not proof of sustained emissions reduction.

4.5 Cross-functional and value-chain coordination

Environmental performance is distributed across organizational boundaries. Sustainability teams may own reporting, but operations control equipment, procurement selects suppliers, finance approves investment, product teams determine material requirements, and sales influence demand and customer use. Without shared data and routines, each function can optimize its own objectives while undermining corporate targets. DDDM can support coordination through common emission factors, shared baselines, aligned investment criteria, and decision records that make trade-offs explicit.

Scope 3 management requires firms to treat suppliers as partners in measurement and change, not merely as data sources. Supplier-specific information can improve estimates and identify opportunities for material efficiency, lower-carbon inputs, renewable electricity, or logistics redesign. However, suppliers may lack measurement capacity or be reluctant to share commercially sensitive information. Large buyers can support improvement through standardized requests, technical assistance, long-term purchasing commitments, and collaborative projects. Data demands should be proportionate; otherwise, smaller firms may be excluded without meaningful reductions.

Coordination requires alignment with capital allocation. If project approval depends exclusively on short payback periods, deeper decarbonization investments may be rejected even when necessary for long-term targets. DDDM can make carbon prices, regulatory exposure, energy-price scenarios, technology learning curves, and asset-lock-in risks explicit. It cannot resolve every conflict between short-term financial metrics and long-term environmental goals, but it can expose assumptions and support consistent comparisons.

4.6 Accountability and organizational learning

Accountability closes the loop by comparing actual results with targets, checking data reliability, and assigning responsibility for corrective action. Internal mechanisms may include plant-level reviews, management incentives, investment gates, and escalation procedures. External mechanisms include assurance, regulatory reporting, investor scrutiny, customer requirements, and public disclosure. These should reinforce one another. A credible public inventory that is not used internally misses an opportunity for improvement; operational optimization without transparent accounting may struggle to demonstrate progress.

An effective system distinguishes a performance deviation from misconduct. Environmental results may worsen because of weather, supply disruptions, production changes, or technical failures. If managers are punished for every unfavorable result, they may conceal problems or manipulate baselines. A learning-oriented system requires accurate reporting, investigation, corrective action, and clear consequences for deliberate misrepresentation or negligent non-compliance. Decision logs can record assumptions, expected outcomes, responsible owners, and review dates, helping firms learn which interventions work under which conditions.

Assurance can increase confidence in reported data, but it does not prove that a transition pathway is scientifically aligned. An inventory can be calculated consistently while a target remains inadequate. A company may also report credits correctly while gross emissions remain high. Credible reporting should separate gross emissions, reductions, removals, and credits; disclose boundaries and methods; and explain how targets connect to operational changes. SBTi (2023), VCMI (2023), and ICVCM (2023) provide complementary guidance on target setting and claims integrity, but they have different purposes and should not be treated as interchangeable.

4.7 Boundary conditions

Data quality is a primary moderator. Incomplete records and inconsistent boundaries can direct investment toward the wrong hotspot. Firms should prioritize improvement in categories that are both environmentally material and decision-sensitive rather than attempting to perfect every data field at once. Governance is a second moderator: board oversight, executive accountability, internal controls, and cross-functional authority determine whether environmental evidence influences decisions. Climate-governance guidance similarly emphasizes the importance of board oversight, strategic integration, and accountability in managing climate-related risks (OECD, 2022).

Regulatory and stakeholder pressure form a third boundary condition. Credible disclosure requirements, carbon pricing, buyer standards, and enforcement can increase the value of reliable data, although firms differ markedly in their capacity to adapt to such pressures (Supranta & Permatasari, 2025). Yet pressure can also encourage compliance-oriented behavior that prioritizes auditable indicators over difficult operational changes. Organizational capacity is a fourth condition. Firms need people who understand environmental science, process engineering, analytics, accounting, and change management. Smaller firms may begin with utility records, material-flow mapping, standard factors, and prioritized action logs, improving the system as capability grows.

4.8 Failure modes and unintended consequences

The first failure mode is reporting without operational integration. A firm may purchase carbon-accounting software while leaving procurement rules, maintenance practices, and capital budgets unchanged. The second is poor data quality: incomplete supplier records, inconsistent boundaries, and outdated factors can produce false rankings. The third is analytical overconfidence, where model outputs are treated as objective despite uncertain assumptions. The fourth is fragmented accountability, in which sustainability teams identify opportunities but lack authority to implement them.

A fifth failure mode is rebound. Efficiency improvements reduce the cost of production or service delivery, potentially encouraging greater use and offsetting some initial gains. Emissions per unit may fall while total output and absolute emissions rise. Rebound does not eliminate the value of efficiency, but it means that absolute emissions must be tracked alongside intensity. A sixth failure mode is greenwashing or selective disclosure: firms may emphasize favorable metrics, change baselines without explanation, narrow boundaries, or rely on offsets to support broad neutrality claims. Data systems can make these claims more sophisticated rather than more credible if governance is weak.

A seventh issue is the environmental footprint of digital infrastructure, including electricity, hardware, cooling, storage, and electronic waste. The net value of a digital intervention should be assessed where material. There are also social implications: monitoring can improve safety but may undermine worker trust if it becomes excessive surveillance; automated systems may make decisions difficult to challenge. Environmental DDDM is therefore a sociotechnical governance problem, not simply a technical optimization task.

4.9 Practical measurement architecture

A practical architecture contains five linked layers. The activity-data layer records energy, fuel, materials, production, transport, waste, and other physical flows. The emissions-accounting layer applies documented factors and methods. The decision layer links emissions sources to operational owners, investment options, deadlines, and expected outcomes. The performance layer tracks absolute emissions, intensity, energy

efficiency, renewable-energy share, waste, and other material indicators. The assurance-and-learning layer documents verification, methodological revisions, and corrective actions.

Each indicator should have a defined owner, unit, boundary, frequency, source, validation rule, and intended decision use. A plant-level energy-intensity measure may be reviewed weekly by operations, while Scope 3 supplier data may be reviewed quarterly by procurement and sustainability teams. Corporate targets and capital allocation should be reviewed by executive leadership at a cadence consistent with investment cycles. An indicator without a decision use risks becoming reporting overhead; a decision without a relevant indicator risks becoming an untested assumption.

Data lineage should be preserved. Users need to know where a number originated, whether it is measured or estimated, which factor version was applied, and whether it was restated. Version control matters when emission factors or standards change. An honest inventory may initially show higher emissions after better Scope 3 measurement; that increase can represent improved visibility rather than environmental deterioration. Transparent treatment of such changes protects the credibility of the learning process.

4.10 Implementation roadmap

The first stage is materiality and boundary definition. Firms should identify major sources, determine organizational and value-chain boundaries, document the base year, and map data owners. This should be connected to strategy and transition targets rather than treated as a separate reporting exercise. Materiality should consider both emissions contribution and whether a decision could materially change the outcome. A small source may merit attention if it is easy to eliminate or signals a wider process failure, while a large source may require a long-term technology pathway. The second stage is minimum viable data quality. Organizations should standardize definitions, reconcile energy and production data, select appropriate emission factors, identify missing supplier information, and introduce validation checks. Firms should not postpone all action until every estimate is perfect. They can act on robust, high-impact opportunities while documenting uncertainty and improving the inventory in parallel.

The third stage embeds data in routines. Environmental indicators should inform operational reviews, procurement, product development, capital appraisal, and executive discussions. Each material hotspot should have an accountable owner and decision pathway. For each major intervention, the firm should record expected reductions, costs, risks, implementation milestones, and verification methods. This makes it possible to compare planned and realized reductions and identify systematic overestimation.

The fourth stage is verification and adaptive learning. Companies should compare actual performance with baselines and targets, investigate deviations, and update forecasts. Independent assurance should be prioritized for material disclosures and high-risk categories. Internal audits can test whether changes occurred as described, while external assurance can improve confidence in reporting. The final stage is strategic reconfiguration: use evidence to redirect capital, revise product portfolios, engage suppliers, and update transition plans. The roadmap remains iterative because technologies, regulation, and supply chains change.

The integrative analysis yields four central findings. First, DDDM creates environmental value through a chain of mechanisms rather than through technology adoption alone. Second, data quality and decision integration are separate and jointly necessary: information can be accurate yet unused, or actionable yet unreliable. Third, governance determines whether analytical insight changes budgets and operating practices. Fourth, credible performance assessment requires both absolute and intensity metrics and a transparent distinction between gross reductions, removals, and credits. These findings help explain why digital transformation studies can report positive, mixed, or indirect relationships with environmental outcomes.

The framework also suggests that the time horizon matters. Visibility and disclosure quality can improve relatively quickly after a data system is implemented. Operational efficiency may improve over months, while structural decarbonization can require multi-year investment cycles and supplier coordination. Evaluations that observe only short windows may therefore overstate or understate the eventual effect. Researchers should distinguish leading indicators—such as data coverage, intervention approval, and project completion—from lagging indicators such as verified emissions reductions. DDDM should not be treated as

a substitute for strategic ambition or institutional change. Data can reveal that a target is infeasible under current technology or that a company's capital plan is inconsistent with its stated pathway. Whether leadership responds by revising the plan, accelerating investment, or changing the claim is a governance decision. The value of the system lies partly in making such contradictions difficult to ignore.

5. DISCUSSION

5.1 DDDM as a strategic capability

The principal implication is that DDDM should be viewed as a strategic capability rather than a technology stack. Environmental data infrastructure is valuable when it supports sensing, decision-making, execution, and learning. The capability is distributed across people, routines, governance, and systems, and depends on connecting measurement with engineering expertise, financial decisions, procurement choices, and operational accountability. This interpretation is consistent with research that treats digital transformation as an organizational process with environmental implications rather than an isolated technical input (Pontjoharyo, 2026; Xia et al., 2022).

This distinction helps explain variation in empirical findings. Studies may use broad proxies for digital transformation, while environmental performance may refer to emissions, pollution, ESG ratings, or disclosure. A positive association with an aggregate score does not necessarily imply that emissions have fallen. Future research should measure the data-to-action process explicitly and avoid collapsing digital capability, environmental management, and environmental performance into a single index.

5.2 Carbon neutrality requires decision architecture

Carbon accounting is necessary because managers cannot systematically reduce what they cannot locate or quantify. However, accounting is a means rather than an outcome. Inventory findings must connect to decisions about equipment, energy, materials, suppliers, products, and investment. Climate disclosure standards can encourage consistent information and clarify accountability, but internal decision routines determine whether that information changes behavior. This distinction is important when firms face pressure to publish targets quickly even though operational transitions require long investment cycles.

A credible transition plan should make the relationship between near-term actions and long-term targets visible. It should identify material sources, expected reductions, capital requirements, dependencies, milestones, and residual emissions. DDDM can track whether the plan remains plausible as actual data emerge. It can also reveal when a target depends on future technologies, supplier improvements, or removals that are not yet secure. The IPCC (2023), IEA (2023), and SBTi (2023) offer complementary perspectives on urgency, technology pathways, and target-setting principles.

5.3 Separating physical performance from disclosure

A central risk is conflating transparency with environmental success. Better data may initially increase reported emissions because firms discover previously uncounted sources. Conversely, disclosure scores can improve without any change in physical operations. Research showing that digitization may improve overall ESG performance without improving direct pollution or energy efficiency underscores this concern (Yang et al., 2023). Firms should use separate scorecards for data maturity, disclosure quality, management action, and physical outcomes.

External communication should report gross emissions, intensity, target progress, methodological changes, and the role of offsets or removals separately. If a reduction results from lower output, asset sale, or boundary change, the report should say so. If data quality improves and the baseline is restated, the revision should be explained. Transparent treatment of unfavorable findings is not a reputational failure; it is a condition of credible learning and accountability.

5.4 Capital allocation and profitability

For senior managers, one of DDDM's most important functions is prioritizing capital and attention. Firms generally face more possible decarbonization actions than they can implement at once. A structured appraisal should compare emissions-reduction potential, cost, operational risk, technical readiness, time to

impact, co-benefits, and alignment with the transition pathway. Marginal abatement cost curves can be useful but are incomplete if they omit strategic dependencies, uncertainty, asset lock-in, and learning effects. A low-cost project may be attractive early, while a higher-cost infrastructure investment may be essential to avoid long-term carbon lock-in.

Environmental metrics should be incorporated into project appraisal before financial decisions are finalized. This may involve shadow carbon prices, scenario analysis, sensitivity testing, and explicit consideration of regulatory exposure. The aim is not to replace financial discipline with a single carbon number, but to ensure that emissions and transition risk are considered alongside cost, quality, and reliability. Board oversight should challenge assumptions about offsets, future technology availability, and the credibility of claimed reductions.

The phrase "without sacrificing profitability" should not be interpreted as a guarantee that every decarbonization action increases short-term profit. Some interventions generate quick savings; others require upfront costs or temporarily lower returns. A more defensible strategic objective is to protect long-term economic viability while avoiding preventable emissions and transition risk. Profitability should be assessed across relevant horizons and include exposure to regulation, energy-price volatility, customer requirements, asset stranding, and operational resilience. DDDM can clarify these trade-offs, but cannot make every environmental investment immediately profitable.

5.5 Procurement and supply-chain governance

Scope 3 management requires treating suppliers as partners in measurement and change rather than simply sources of data. Procurement teams can segment suppliers by emissions materiality, spend, strategic importance, and readiness. For high-impact suppliers, the company may require primary data, support measurement capability, coordinate technical improvements, or develop long-term purchasing arrangements that make lower-carbon investments viable. For low-impact suppliers, standardized estimates may be proportionate. Uniform demands for detailed data can impose high costs without materially improving the inventory.

Supply-chain data also raise questions of trust and commercial sensitivity. Suppliers may resist sharing process data if they fear that it will be used to renegotiate prices or replace them. Firms should clarify purpose, access, retention, and acceptable use. Shared data standards can reduce repeated reporting burdens, while independent verification can provide confidence without unrestricted access to proprietary information. This is especially important for smaller suppliers and emerging-market value chains, where measurement capacity may be uneven.

5.6 Governance, greenwashing, and integrity of neutrality claims

The integrity of carbon-neutrality claims depends on a hierarchy of evidence. Firms first need a transparent and appropriately bounded inventory, then credible near- and long-term reduction targets, documented operational measures, and progress verified against those targets. Residual emissions and any use of removals or credits should be disclosed separately and according to the relevant framework. The SBTi (2023), VCMI (2023), and ICVCM (2023) address different aspects of target-setting and credit claims, but none substitutes for actual reductions and transparent accounting.

DDDM can reduce greenwashing by making claims traceable to activity data and verified decisions. It can also facilitate greenwashing if firms selectively present favorable metrics or use analytics to produce persuasive but opaque narratives. Governance therefore requires independent assurance, board scrutiny, methodological transparency, and a willingness to publish mixed results. Credibility depends not only on the technology used to calculate a figure, but on the rules governing what is counted, omitted, and acted upon.

5.7 Digital infrastructure and social trade-offs

Digital systems have environmental footprints. Sensors and industrial devices require materials and replacement; cloud infrastructure consumes electricity and cooling; AI training and inference can be energy intensive; and rapid hardware turnover creates electronic waste. The net value of a digital intervention should be assessed against the environmental burden of the system and the physical reduction it enables.

This does not imply that digital tools should be avoided; rather, their use should be proportionate to decision value, and resource-intensive analytics should not be deployed where simpler methods suffice.

There are also social and organizational consequences. Monitoring can improve safety and environmental performance, but excessive surveillance may undermine worker trust. Automated systems can shift responsibility away from operators or make decisions difficult to challenge. Data governance should clarify purpose, restrict access, protect sensitive information, and preserve human review for consequential decisions. Environmental DDDM must therefore be governed as a sociotechnical system rather than a purely technical optimization exercise.

5.8 Relevance for emerging economies

The framework is relevant to emerging economies where industrial transformation, energy-system constraints, export-market requirements, and uneven digital capacity interact. Firms may face pressure from multinational buyers to disclose Scope 3 data while lacking affordable measurement tools or technical expertise. Electricity carbon intensity and grid reliability can change the emissions value of electrification; local suppliers may have limited capacity to provide product-level data; and environmental enforcement may vary across sectors. In these contexts, a phased approach that prioritizes material sources and shared standards may be more effective than immediate adoption of expensive enterprise platforms.

For Indonesian firms, data-driven environmental management can inform energy efficiency, renewable electricity, industrial process upgrades, logistics, land-use-related supply chains, and export-market compliance. The design will differ by sector: manufacturers may prioritize process energy and material flows; mining and energy firms may need strong operational monitoring and transition-risk analysis; agriculture and food supply chains may focus on land use, fertilizer, methane, traceability, and supplier practices; and service firms may focus on purchased electricity, buildings, travel, and procurement. Public policy can facilitate adoption through interoperable guidance, skills development, credible verification, and support for smaller suppliers. DDDM cannot overcome structural barriers such as carbon-intensive infrastructure, capital constraints, or weak enforcement by itself. It can make barriers more visible and help compare responses, but some reductions require public infrastructure, regulation, coordinated investment, or technology beyond the control of an individual firm. Corporate environmental performance is produced through interaction between internal capabilities and the external institutional environment.

6. CONCLUSION

This article examined how data-driven decision-making can support corporate environmental performance during carbon-neutrality transitions. The central conclusion is that DDDM creates value through an organizational process, not through technology adoption alone. Environmental visibility, analytical diagnosis, operational optimization, cross-functional coordination, and accountability-based learning connect data infrastructure to implemented changes and verified outcomes. The relationship depends on data quality, managerial capabilities, governance, stakeholder pressure, supplier participation, and the ability to recognize unintended consequences.

The framework clarifies why data-rich firms do not necessarily decarbonize. Accurate inventories may remain disconnected from capital allocation; sophisticated models may optimize cost rather than emissions; and disclosure improvements may be mistaken for physical progress. Rebound effects, output growth, boundary changes, and reliance on credits can also weaken the relationship between digitalization and genuine reductions. For this reason, firms should track absolute emissions alongside intensity, separate gross reductions from removals and credits, document assumptions, and verify whether interventions produce the expected effect.

For managers, the practical recommendation is to begin with materiality and decision use rather than software procurement. Firms should identify the emissions sources most relevant to their transition pathway, establish credible baselines, improve data quality in high-impact categories, assign accountable owners, and embed environmental indicators in budgeting, procurement, operations, and product development. They should assess investments using both financial and environmental criteria over relevant time horizons. Digital tools should be selected only where they improve a real decision, and their own

environmental and social costs should be considered. For boards and senior leadership, environmental data should be treated as strategic information. Oversight should test the consistency of targets, capital plans, supplier strategies, and public claims. Incentives should reward verified improvement rather than favorable reporting alone, while allowing managers to surface unfavorable findings without concealment. For policymakers and standard setters, priorities include interoperable reporting rules, proportionate expectations for smaller firms, credible assurance, workforce capability development, and support for supplier data-sharing arrangements. These measures can reduce fragmented reporting and help move firms from compliance toward operational change.

The article has limitations. It presents an integrative conceptual synthesis rather than a systematic review or a new empirical test. The reviewed evidence is heterogeneous and often based on particular national or sectoral contexts. The propositions therefore require testing through longitudinal, comparative, and mixed-method studies. Future research should operationalize DDDM capability, decision integration, implementation quality, and environmental performance as distinct constructs, using survey responses alongside objective indicators such as emissions records, energy bills, sustainability reports, and capital-expenditure data. Ten testable propositions suggest that DDDM can improve environmental performance through better environmental visibility, analytical diagnosis, green innovation, and operational eco-efficiency, with outcomes shaped by governance quality, stakeholder pressure, data quality, digital maturity, implementation effectiveness, rebound effects, and supplier collaboration. Longitudinal panel studies, difference-in-differences designs, event studies, and mixed-method case studies can help establish causal mechanisms and explain variations across sectors. Researchers should clearly report emissions scopes, organizational boundaries, absolute and intensity-based measures, emission factors, external assurance, and changes caused by production shifts or acquisitions. Future studies should also examine how digital reporting costs and environmental burdens are distributed across firms and supply chains, particularly between large corporations and smaller suppliers.

DECLARATIONS

Author contributions (CRediT). Shirin Saiyed: Conceptualization, Methodology, Writing – original draft. Made Ratih Nurmalasari: Investigation, Validation, Writing – review & editing.

Funding. This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Conflict of interest. The authors declare no conflict of interest.

Data availability. No new data were created or analysed in this study. Data sharing is not applicable to this article.

Declaration of generative AI use. During the preparation of this work, the authors used Gramarly solely for the purpose of checking grammar, proofreading, and improving the linguistic clarity and readability of the manuscript.

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