

Research Article

Integrating Activity-Based Costing Into Environmental Management Accounting Information Systems: A Conceptual Framework and Research Agenda

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Abstract Environmental Management Accounting Information Systems (EMAIS) have become essential infrastructure for organisations to identify, measure, and manage environmental costs in supporting sustainability objectives. However, their decision-usefulness remains limited because environmental costs are often hidden within general overhead, making the activities generating these costs unclear. Activity-Based Costing (ABC) offers a solution through activity-based cost tracing, yet its integration into EMAIS remains conceptually limited and empirically fragmented. Using previous bibliometric mapping and a theory-synthesis approach, this study develops the Activity-Based EMAIS (AB-EMAIS) framework. The framework incorporates ABC logic into the input, processing, and output layers of EMAIS architecture and expands it through artificial intelligence (AI) augmentation and governance and assurance layers. The framework produces nine testable propositions and a research agenda covering conceptual refinement, empirical validation, technological development, and contextual investigation. AB-EMAIS transforms ABC-EMAIS integration into a coherent design framework, supporting transparent, relevant, and accountable environmental cost information. The framework is particularly relevant for emerging economies advancing Sustainable Development Goal 12.

Keywords: Activity-Based Costing; Environmental Management Accounting; Information Systems; Sustainability; Sustainable Development Goals.

1. Introduction

Climate change and the intensifying degradation of natural systems have reshaped the expectations placed on management accounting. Organisations are no longer evaluated solely on financial returns; they are increasingly held accountable for the environmental consequences of their operations by regulators, investors, and the public (Burritt et al., 2023; Hanif et al., 2023). Within this context, environmental management accounting (EMA) has matured into a strategic instrument for identifying, measuring, and managing environmental costs and performance, and for embedding sustainability considerations within organisational decision-making (Schaltegger & Burritt, 2000; Swalih et al., 2024).

As the volume and complexity of environmental information have grown, EMA has come to depend on dedicated information infrastructure. Environmental Management Accounting Information Systems (EMAIS) have emerged as the technological backbone that collects, processes, and reports environmental cost and performance data in a decision-relevant form (Stanescu et al., 2021; Öncü et al., 2022). EMAIS are best understood not as a single application but as a layered architecture comprising an input layer that captures environmental data, a processing layer that transforms it into cost and performance information, and an output layer that delivers reports and decision support (Stanescu et al., 2021).

Received: February 05, 2026
Revised: June 05, 2026
Accepted: June 26, 2026
Published: July 08, 2026
Curr. Ver.: July 08, 2026



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Despite this progress, the decision-usefulness of EMAIS is constrained by a long-standing measurement problem. Environmental costs such as waste handling, emissions abatement, water treatment, and regulatory compliance are frequently absorbed into general overhead and averaged across products and processes, severing the link between a cost and the activity that generates it (Jasch, 2003; Javed et al., 2022). When environmental costs are invisible at the level of the activities that drive them, managers cannot price, redesign, or prioritise on a sound informational basis, and the strategic promise of EMA goes unrealised.

Activity-Based Costing (ABC) offers a direct response. By assigning costs first to activities and then to cost objects through causal activity drivers, ABC traces costs to their underlying sources rather than spreading them through volume-based allocation (Cooper & Kaplan, 1988, 1991). Applied to the environmental domain, ABC has been shown to sharpen the accuracy and transparency of environmental cost information, including the cost of carbon (Tsai et al., 2010, 2012), and a recent systematic review confirms steady and growing interest in the environmental implications of ABC (García-Díaz et al., 2025). In principle, embedding ABC within EMAIS would resolve the traceability problem at its root.

In practice, the two literatures have developed largely in parallel. The recent systematic review of ABC's environmental applications catalogues a growing but fragmented body of case demonstrations without an integrative system-level logic to connect them (García-Díaz et al., 2025), and the systematic review of EMA for strategic decision-making finds the strategic, system-supported use of environmental cost information comparatively underdeveloped (Swalih et al., 2024). The authors' own bibliometric mapping of two decades of EMAIS scholarship reaches the same conclusion from a complementary vantage, identifying ABC–EMAIS integration as an emerging niche of high growth potential that remains methodologically underdeveloped and conceptually unconsolidated (Sanputra et al., 2026). Across these reviews the pattern is consistent: the field has reached intellectual maturity without producing an integrative design logic for how ABC should be embedded within EMAIS, still less how such a system should evolve under conditions of pervasive artificial intelligence (AI). Constructing that integration framework is the task the present paper takes up.

The purpose of this paper is to move beyond mapping the field by developing the integrative framework that the field currently lacks. This paper aims to synthesise the conceptual foundations of Environmental Management Accounting (EMA), Environmental Management Accounting Information Systems (EMAIS), and Activity-Based Costing (ABC), while explaining why their integration is both necessary and challenging. Furthermore, this study seeks to develop the Activity-Based EMAIS (AB-EMAIS) framework, which embeds ABC logic within the layered architecture of EMAIS and enhances it through artificial intelligence (AI) augmentation and governance dimensions. Finally, this paper aims to formulate testable propositions and establish a structured research agenda to support cumulative research development at the intersection of ABC and EMAIS.

The contribution is best stated against what already exists. The integration of ABC with environmental cost accounting has been demonstrated empirically (Tsai et al., 2010, 2012), and the layered conception of EMAIS has been modelled conceptually (Stanescu et al., 2021). This paper does not restate either. Its contribution is the system-level design logic that joins them, together with two elements absent from prior work: an AI-augmentation layer that specifies how the historically prohibitive cost of activity-based environmental costing can be lowered, and a governance and assurance layer that specifies the conditions under which AI-derived cost information can be trusted. The pairing of these two layers, rather than ABC or EMAIS individually, is the paper's distinctive theoretical move. The remainder of the paper proceeds as follows. Section 2 states the conceptual approach and synthesises the foundations. Section 3 develops the framework. Section 4 sets out the propositions and research agenda. Section 5 discusses implications, and Section 6 concludes.

2. Conceptual Approach and Foundations

This is a conceptual paper, and conceptual work has a method that must be made explicit (Jaakkola, 2020). The paper follows a theory-synthesis logic combined with a model-building aim: it draws together three established bodies of theory, EMA, accounting information systems, and ABC, and integrates them into a single framework that solves a defined problem, the loss of environmental cost traceability within EMAIS. The bodies of work synthesised were identified through the authors' prior bibliometric mapping of two decades of EMAIS scholarship (Sanputra et al., 2026) and supplemented with the seminal ABC, MFCA, and design-science sources on which those literatures rest; the synthesis is accordingly integrative rather than systematic in the sense of a protocol-driven review (Jaakkola, 2020), and the choice of theories and their role in the analysis are justified in the synthesis that follows. The resulting framework is treated as a design artifact in the sense of design-science research, oriented toward utility in building systems rather than toward explaining existing behaviour (Hevner et al., 2004). As a design-science contribution at the theory-building stage, it is offered as a designed artifact whose evaluation, which design-science research ultimately requires (Hevner et al., 2004), is specified as part of the research agenda in Section 4 rather than undertaken here. The two subsections below establish the foundations on which the framework is constructed; Section 2.3 explains why their integration has remained elusive.

Environmental Management Accounting and Its Information Systems

Environmental management accounting developed from the recognition that conventional management accounting systematically understates the costs and consequences of environmental activity. Early frameworks positioned EMA as a bridge between environmental management and accounting, distinguishing physical environmental accounting (flows of energy, water, and materials) from monetary environmental accounting (the costs and benefits attached to those flows) (Burritt et al., 2002; Schaltegger & Burritt, 2000). Subsequent guidance consolidated these ideas into practical methods for identifying environmental costs that conventional systems leave hidden (Jasch, 2003; International Federation of Accountants, 2005), and a twenty-year retrospective confirms that EMA has accumulated a substantial repertoire of tools spanning water, carbon, waste, material-flow, and biodiversity applications (Burritt et al., 2023).

Two strands of evidence establish why EMA matters for organisational outcomes. First, a growing body of work links EMA to environmental and economic performance, often through eco-control mechanisms that connect environmental information to managerial action (Henri & Journeault, 2010; Gunaratne & Lee, 2015), with a meta-analysis confirming a positive association between EMA and performance that is contingent on national EMA maturity (Barani et al., 2025). Second, EMA has been increasingly framed as an input to strategic, not merely operational, decision-making, although a systematic review finds that the strategic decision-making dimension remains comparatively underdeveloped (Swalih et al., 2024). Across both strands, the value of EMA is realised only when environmental information is accurate, granular, and delivered in a form that supports decisions.

This dependence on information quality motivates the systematisation of EMA into information systems. Stanescu et al. (2021) propose a conceptual model in which environmental impact is integrated into managerial accounting information systems through three functional layers: an input layer that captures environmental data from operational and external sources; a processing layer that transforms that data into cost and performance information through classification, allocation, and analysis; and an output layer that delivers reports, indicators, and decision support. Complementary bibliometric evidence confirms that the systematisation of accounting information has become a research field in its own right (Öncü et al., 2022). This layered conception provides the structural scaffolding on which the present framework is built.

Activity-Based Costing, Material Flow Cost Accounting, and Environmental Cost Allocation

Activity-Based Costing emerged as a response to the distortions introduced by volume-based overhead allocation. Its central insight is that resources are consumed by activities, and activities by cost objects; costs should therefore be assigned in two stages, from resources to activities via resource drivers, and from activities to cost objects via activity drivers, so that the resulting figures reflect causation rather than convenient averages (Cooper & Kaplan, 1988, 1991). Because environmental costs are

disproportionately concentrated in support and overhead functions, they are among the costs most severely distorted by volume-based allocation, and therefore among those for which ABC offers the greatest corrective potential. The application of ABC to environmental costing has been demonstrated in concrete settings: Tsai et al. (2010) show that integrating ABC with environmental cost accounting yields more accurate information for decision-making, and Tsai et al. (2012) extend the logic to the cost of carbon. A systematic review of fifty-eight studies documents a stable increase in interest in the environmental implications of ABC (García-Díaz et al., 2025), and related work reinforces the value of activity- and process-level tracing in environmentally intensive operations (Wang et al., 2018).

ABC is not, however, the only environmental costing technique, and the framework developed here must be positioned against the most prominent alternative. Material Flow Cost Accounting (MFCA), formalised in the ISO 14051 standard, traces the physical flows of materials and energy through a production system and assigns costs to both products and material losses, thereby exposing the cost of waste (International Organization for Standardization, 2011; Christ & Burritt, 2015). MFCA and ABC are complementary rather than substitutive: MFCA excels at quantifying the cost of physical material and energy losses, whereas ABC excels at tracing the cost of environmental support activities and overhead to the products and processes that drive them. As Section 3 argues, the physical material-flow data generated by MFCA can serve as an input to the activity-based processing engine, so that the two techniques reinforce one another within a single system. A further consideration concerns implementation cost. Conventional ABC is data- and effort-intensive, a limitation that prompted the development of Time-Driven ABC (TDABC), which reduces the maintenance burden by estimating the practical capacity and unit time of resources directly (Kaplan & Anderson, 2004). The persistence of this cost barrier, and the partial responses to it, motivate the AI-augmentation layer introduced below.

The Integration Gap and Its Causes

If EMAIS supply the architecture and ABC supplies the costing logic, their integration would appear straightforward. Several factors explain why it is not. The first is adoption cost and complexity: ABC implementation is data- and effort-intensive, and the identification, measurement, and maintenance of environmental activity drivers compounds this burden (Javed et al., 2022; Kaplan & Anderson, 2004). The second is contingency: the benefits of both EMA and ABC are conditional on organisational and environmental characteristics, so integration that is valuable in one setting may be uneconomic in another (Christ & Burritt, 2013; Mokhtar et al., 2016). The third is the parallel development of the literatures themselves, which has left the integration zone without an integrative framework (Swalih et al., 2024).

These barriers are not merely theoretical, and they invite a sharper objection than an integration gap. Survey evidence indicates that ABC adoption among large firms has remained modest and, in some settings, declined: a comparison of UK surveys conducted five years apart recorded a fall in the adoption rate and documented firms that had implemented ABC and subsequently abandoned it, alongside others that investigated and rejected it (Innes et al., 2000), with implementation cost and complexity among the principal reasons (Gosselin, 1997). If ABC has repeatedly proven too costly to sustain, an EMAIS that embeds it may inherit the same fragility, and proposing to rescue it through automation could compound a known problem rather than solve it. The framework developed here takes this objection seriously rather than setting it aside. Its claim is not that ABC is costless, but that the specific tasks responsible for ABC's cost and abandonment, namely activity identification, driver specification, and model maintenance, are the tasks now most amenable to automation, so that lowering their cost is the precondition for sustainable integration rather than an incidental enhancement. Whether automation in fact lowers this cost without introducing offsetting burdens is an empirical question the framework is designed to expose rather than assume, and one to which the propositions and limitations below return.

A fourth and increasingly salient factor is the arrival of artificial intelligence. The data-capture, driver-identification, and allocation tasks that make ABC costly are precisely the tasks most amenable to automation, suggesting that AI may dissolve some of the historical barriers to integration. At the same time, AI introduces new questions of

trust, auditability, and accountability for algorithmically derived cost information that the EMAIS literature has scarcely begun to address. A framework that ignores AI would already be incomplete; one that embraces AI without addressing governance would be irresponsible. The framework developed next is constructed to meet both requirements.

The Activity-Based EMAIS (AB-EMAIS) Framework

Framed as a design artifact (Hevner et al. 2004), the AB-EMAIS framework integrates ABC logic into the three functional layers of EMAIS identified by Stanescu et al. (2021), input, processing, and output, and extends that architecture through two cross-cutting layers that operate across all three: an AI-augmentation layer and a governance and assurance layer. The framework is organised by a single design principle: every environmental cost reported by the system should be traceable to the activity that causes it, and every activity-cost assignment should be auditable. Figure 1 presents the framework, and Table 1 summarises its layers; the discussion below elaborates each.

Three constructs recur through the framework and the propositions that follow, and are defined here at the point they are introduced rather than left implicit. Environmental cost transparency denotes the extent to which an organisation's environmental costs are traced to the specific activities that cause them rather than absorbed into undifferentiated overhead. Decision-usefulness denotes the degree to which the resulting cost information is actually used in, and improves the quality of, environmental decisions such as pricing, product-mix, and process redesign. Data quality denotes the completeness, accuracy, and timeliness of the operational data from which activities, drivers, and costs are derived. These working definitions fix the meaning of the constructs that the propositions relate, and Section 4.1 returns to them as measurement targets for empirical work.

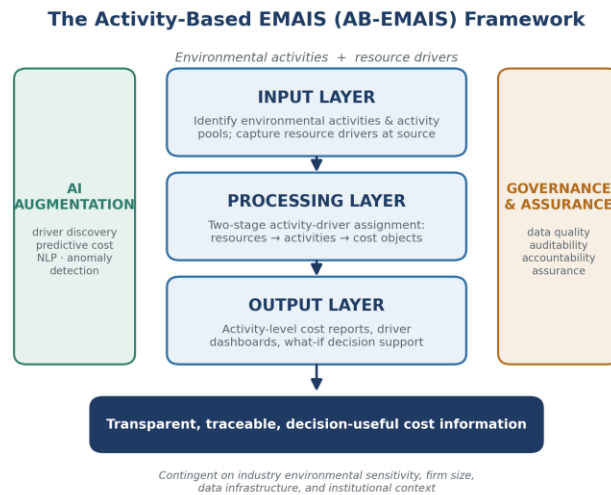


Figure 1. *The Activity-Based EMAIS (AB-EMAIS) framework.*

Table 1. *Layers of the AB-EMAIS framework*

Layer	Core function (EMAIS)	ABC contribution / design logic
Input	Capture of environmental data from operational and external sources (sensors/IoT, ERP, sustainability disclosures, MFCA material-flow data).	Define environmental activities and activity pools; capture resource drivers so environmental resource consumption is tagged to activities at source.
Processing	Transformation of data into environmental cost and performance information through classification, allocation, and analysis.	Two-stage activity-driver assignment: resources to environmental activity pools to cost objects. Replaces volume-based averaging with causal tracing.
Output	Delivery of reports, indicators, and decision support to managers.	Activity-level environmental cost reports, cost-driver dashboards, and what-if analysis supporting pricing, product-mix, and process-redesign decisions.

Layer	Core function (EMAIS)	ABC contribution / design logic
AI augmentation (cross-cutting)	Operates across input, processing, and output to automate and enhance system functions.	Automated activity and driver discovery; predictive environmental cost modelling; NLP extraction of cost signals from unstructured disclosures; anomaly detection. Lowers the implementation burden that constrains ABC adoption.
Governance & assurance (cross-cutting)	Ensures the integrity and accountability of system outputs.	Data-quality controls, auditability of AI-derived drivers, accountability for algorithmic allocations, and alignment with assurance practice. The condition under which AI-derived information becomes trustworthy.

The Input Layer: Environmental Activity Identification and Data Capture

In a conventional EMAIS, the input layer captures environmental data largely as aggregate flows. The AB-EMAIS framework reconceives the input layer around activities. Drawing on the principle that resources are consumed by activities (Cooper & Kaplan, 1991), the layer first identifies the environmental activities an organisation performs, such as emissions handling, waste treatment, water management, and regulatory compliance, and defines them as activity pools. It then captures the resource drivers that feed those pools: the energy, materials, and labour devoted to each environmental activity. Where MFCA is in use, its material-flow and loss data enter here as a structured input, enriching the activity picture with physical-flow detail (International Organization for Standardization, 2011). The decisive design move is to tag environmental resource consumption to activities at the point of capture, rather than allowing it to accumulate undifferentiated in overhead. This addresses the traceability problem (Jasch, 2003) at its source.

The Processing Layer: The Activity-Driver Assignment Engine

The processing layer is where the corrective power of ABC is realised. Conventional environmental cost processing allocates costs using volume-based measures, reproducing the distortion that obscures environmental cost causation. The AB-EMAIS processing layer instead implements two-stage activity-driver assignment: resources are assigned to environmental activity pools via resource drivers, and the cost of each activity pool is assigned to cost objects via activity drivers that reflect each object's actual demand for the activity. The result is environmental cost information that reflects causation. The feasibility of this design is not speculative; it is the architecture demonstrated by Tsai et al. (2010) for environmental cost accounting and extended by Tsai et al. (2012) to carbon. The framework generalises these standalone demonstrations into a permanent processing layer within EMAIS, and, where implementation cost is a concern, the time-driven variant of ABC can be adopted within this layer to reduce the maintenance burden (Kaplan & Anderson, 2004).

The Output Layer: Environmental Cost Reporting and Decision Support

Because the processing layer preserves the link between cost and activity, the output layer can deliver information that conventional EMAIS cannot. Rather than reporting an undifferentiated environmental overhead figure, it produces activity-level environmental cost reports, cost-driver dashboards that reveal which activities drive environmental cost, and what-if analyses that quantify the cost consequences of process or product changes. This is the level of information required to support the strategic environmental decisions that the EMA literature identifies as underserved (Swalih et al., 2024). The output layer thus converts the accuracy generated in processing into decision relevance, closing the loop between measurement and management that eco-control theory regards as essential (Henri & Journeault, 2010).

The AI-Augmentation Layer

The historical barriers to ABC, namely the cost and effort of identifying activities, specifying drivers, and maintaining the model (Javed et al., 2022; Kaplan & Anderson, 2004), are concentrated in tasks that are increasingly automatable through the digitalisation of management accounting (Möller et al., 2020). The AI-augmentation layer

performs four functions across the three core layers. First, automated activity and driver discovery applies process mining and machine learning to ERP and sensor event logs to infer environmental activities and candidate drivers; process mining has been shown in audit settings to extract process structures and reveal control deviations that conventional analysis misses (Jans et al., 2014), and the same techniques can surface the activity structure that ABC requires. Second, predictive environmental cost modelling extends the output layer from historical reporting to forward-looking estimation, consistent with evidence that analytics-based digitalisation can raise the decision quality of management accounting information (Möller et al., 2020). Third, natural-language processing extracts environmental cost signals from unstructured sustainability disclosures, applying the textual-analysis methods now established in accounting research (Loughran & McDonald, 2016). Fourth, anomaly detection flags environmental cost overruns and data-quality failures in real time (Jans et al., 2014). This layer therefore specifies, as operational components, the AI-augmented analytics that prior work identified only as a promising direction. Its feasibility rests on demonstrated techniques rather than speculation, although, as the propositions below make clear, its benefits are conditional on data quality and governance.

The Governance and Assurance Layer

Automation that determines how environmental costs are assigned cannot be left unaccountable. The governance and assurance layer establishes the conditions under which AI-derived environmental cost information can be trusted: controls over the quality of the data feeding the system; auditability of the activities and drivers that AI infers; clear accountability for algorithmic cost allocations; and alignment with assurance practice for sustainability information. These requirements are specific rather than generic: the use of artificial intelligence in accounting and assurance raises identifiable ethical and accountability risks, including the opacity of automated inference, the displacement of professional judgement, and unclear responsibility for machine-generated outputs, which recent work in the auditing context documents directly (Munoko et al. 2020) and which the governance layer is designed to contain. The credibility benefits of independent assurance are well documented in the sustainability-reporting context, where assurance is associated with enhanced report credibility and is shaped by country-level and industry factors (Simnett et al., 2009). Within AB-EMAIS, the same logic applies internally: without governance, AI-augmented allocation risks substituting opaque algorithmic averaging for the transparent causal tracing that motivates the framework, whereas with governance the decision-usefulness of the system's outputs is underwritten by their verifiability. This layer responds directly to the accountability concerns increasingly raised in the EMA literature (Gunarathne et al., 2023).

Contingency, Boundary Conditions, and Context

The framework is a reference architecture, not a universal prescription. Consistent with contingency evidence on EMA and ABC adoption (Christ & Burritt, 2013; Mokhtar et al., 2016), the value an organisation derives from AB-EMAIS integration is conditioned by its environmental sensitivity, size, and resource endowment, and its components should be adopted selectively. The boundary conditions are explicit. For organisations with low environmental cost intensity, limited data infrastructure, or scarce accounting capacity, including many small and medium-sized enterprises, full activity-based integration may be uneconomic, and a lighter configuration, or MFCA alone, may be preferable. The framework is most valuable where environmental costs are material, where activity structures are complex, and where the data infrastructure to support automated capture already exists. A tension internal to the framework follows directly and must be acknowledged. The AI-augmentation layer is presented as the means by which the historically prohibitive cost of activity-based environmental costing is lowered, yet that layer is itself data- and infrastructure-intensive: it presupposes the event logs, sensor streams, and analytical capacity that resource-constrained organisations are least likely to possess. The capability intended to make integration affordable may therefore be least available precisely where the underlying cost barrier bites hardest, so that AI augmentation, applied without regard to context, could widen rather than narrow the gap between data-rich and data-poor organisations. The framework's response is that its layers are separable and incremental: the activity-based input, processing, and output layers deliver traceability without AI, and AI augmentation is a later, optional intensification appropriate only once the requisite data

infrastructure exists. This separability is what makes selective adoption a genuine design choice rather than a concession, and it bears directly on contexts of uneven infrastructure. This contingency is especially consequential in emerging economies, where institutional pressures, data infrastructure, and accounting capacity differ from the settings in which most EMA and ABC evidence has been generated, and where integrated environmental accounting systems remain at an early stage.

An Illustrative Application

A simplified example shows the framework in operation. Consider a textile manufacturer for which wastewater treatment is a significant but opaque cost, currently pooled within plant overhead. In the input layer, wastewater treatment is defined as an environmental activity, and its resource drivers, the chemicals, energy, and labour it consumes, are captured and, where available, combined with MFCA data on effluent volumes. In the processing layer, the cost of the wastewater-treatment activity pool is assigned to individual fabric lines through an activity driver such as litres of effluent generated per line. In the output layer, management sees, for the first time, the wastewater-treatment cost attributable to each fabric line, and a what-if analysis quantifies the saving from switching a high-effluent line to a less polluting dye. The AI-augmentation layer can infer the effluent-by-line driver automatically from sensor logs and flag anomalous discharge, while the governance layer ensures the inferred driver is auditable before it informs a pricing or process decision. What was an undifferentiated overhead becomes a traceable, decision-relevant, and verifiable cost.

3. Propositions and Research Agenda

The framework is intended as a generative structure rather than a terminal claim. This section derives nine propositions that render it testable and organises the inquiry they imply into a four-stream research agenda. The propositions are summarised in Table 2. They are stated so as to be falsifiable, and several are deliberately built around the framework's distinctive elements, the interaction between AI augmentation and governance and the complementarity with MFCA, rather than restating established results.

Table 2. *Propositions derived from the AB-EMAIS framework.*

No.	Proposition	Theoretical anchor
P1	Environmental cost information produced through two-stage activity-driver assignment diverges from, and more accurately reflects causal resource consumption than, information produced through volume-based allocation; the divergence increases with the share of environmental costs residing in overhead.	Cooper & Kaplan (1991); Tsai et al. (2010)
P2	Embedding activity-based environmental cost information in EMAIS outputs improves the quality of environmental decisions only to the extent that the information is actually used; availability alone is insufficient.	Swalih et al. (2024); Henri & Journeault (2010)
P3	AI-augmented activity and driver discovery weakens the negative relationship between ABC implementation cost and EMAIS adoption, lowering the threshold at which activity-based environmental costing becomes economically viable.	Javed et al. (2022); Kaplan & Anderson (2004); Möller et al. (2020)
P4	Relative to manual driver specification, automated driver discovery improves environmental cost accuracy when data completeness exceeds a specifiable threshold and reduces it below that threshold; because the crossover point is measurable, the proposition is falsified if automated discovery matches or exceeds manual specification irrespective of data completeness, or fails to do so at any level of completeness.	Jans et al. (2014)
P5	The decision-usefulness and external credibility of AI-derived environmental cost information increase monotonically with the strength of the governance and assurance layer, measured through data-quality controls, driver auditability, and assurance coverage; the proposition is falsified if AI-augmented systems	Simnett et al. (2009); Munoko et al. (2020); Gunarathne et al. (2023)

No.	Proposition	Theoretical anchor
	lacking governance attain trust or credibility ratings equal to or above otherwise-comparable governed systems.	
P6	The association between AB-EMAIS adoption and environmental performance is mediated by environmental cost transparency rather than being direct.	Barani et al. (2025)
P7	The environmental cost transparency gains from AB-EMAIS adoption increase with industry environmental sensitivity and firm size, and are attenuated for resource-constrained organisations.	Christ & Burritt (2013); Mokhtar et al. (2016)
P8	AB-EMAIS and material flow cost accounting are complementary, not substitutive: integrating physical material-flow data into the input layer increases the completeness of activity-based environmental cost information relative to either approach alone.	Christ & Burritt (2015); ISO (2011)
P9	In emerging economies, the relationship between AB-EMAIS adoption and realised environmental cost transparency is moderated by institutional pressure, such as mandatory sustainability-reporting regimes, and by data-infrastructure maturity.	Otoritas Jasa Keuangan (2017); Burritt et al. (2023)

Stream 1: Conceptual Refinement and Measurement

The first stream concerns the framework and its constructs. Testing P1, P2, and P8 presupposes that the framework's central constructs can be measured. Environmental cost transparency might be operationalised as the proportion of environmental cost traced to specific activities rather than residing in overhead; decision-usefulness through established decision-quality and technology-use instruments (Möller et al., 2020); data quality through completeness and accuracy metrics; and adoption through a maturity scale spanning the framework's layers. Developing and validating such measures, together with taxonomies of environmental activities and drivers that distinguish the generalisable from the context-specific, is a foundational task and a precondition for the empirical stream.

Stream 2: Empirical Validation

The second stream subjects the framework's behavioural and performance claims to evidence. Propositions P2, P6, and P7 invite field studies, case-based, survey, and design-science, that examine whether embedding ABC within EMAIS improves decision use, whether transparency mediates the link to performance, and how these relationships vary with industry and firm size. Because P2 makes explicit that information availability does not guarantee information use, designs should measure actual use rather than mere provision. Longitudinal and comparative designs are especially valuable, moving the ABC–EMAIS frontier from demonstration to systematic test.

Stream 3: Technological Development

The third stream develops and evaluates the AI-augmentation layer. Propositions P3 and P4 raise design-science questions (Hevner et al. 2004): can process mining and machine learning reliably infer environmental activities and drivers from operational data, and at what accuracy relative to manual specification; how does predictive cost modelling perform against realised costs; and, critically, how does data quality condition these results? Establishing the data infrastructure required for automated capture, and the failure modes of automated driver discovery, connects EMAIS research to the broader transformation of accounting information systems (Jans et al., 2014; Möller et al., 2020).

Stream 4: Contextual and Policy Inquiry

The fourth stream situates the framework in context. Propositions P5 and P9 raise questions of governance and setting: which assurance practices and accountability arrangements render AI-derived environmental cost information trustworthy (Simnett et al. 2009), and how do institutional pressure and data-infrastructure maturity shape adoption and outcomes in emerging economies? In Indonesia, the mandatory sustainability-reporting regime introduced through OJK Regulation 51/POJK.03/2017 and the long-running PROPER environmental rating programme provide concrete

institutional levers whose interaction with AB-EMAIS adoption is an open empirical question (Otoritas Jasa Keuangan, 2017). This stream keeps the framework's development responsive to the environments in which transparent environmental cost information is most needed.

4. Discussion and Implications

The AB-EMAIS framework carries implications for theory, practice, and policy. Theoretically, it integrates three bodies of work that have developed in parallel, EMA, information systems, and ABC, supplying the integrative design logic whose absence has left the ABC-EMAIS frontier unconsolidated. It extends the layered EMAIS conception of Stanescu et al. (2021) by specifying how ABC logic populates each layer and by adding AI-augmentation and governance layers that the original model did not contemplate, and it positions MFCA as a complementary input rather than a rival (Christ & Burritt, 2015). It also converts a descriptive observation, that ABC-EMAIS integration is an emerging niche, into a propositional structure that supports cumulative, testable inquiry.

For practice, the framework offers design guidance to organisations building or upgrading environmental accounting systems. It indicates where in the system architecture environmental costs lose their traceability and how activity-driver logic restores it, as the wastewater example illustrates; it identifies the AI capabilities that can lower the historically prohibitive cost of activity-based environmental costing; and it warns that those capabilities deliver decision-useful information only when matched by governance. Its boundary conditions are equally practical: organisations with low environmental cost intensity or weak data infrastructure should adopt selectively rather than wholesale.

For policy, the contextual stream connects system design to national sustainability objectives. In emerging economies such as Indonesia, where integrated environmental accounting remains nascent, mandatory sustainability reporting under OJK Regulation 51/POJK.03/2017 and the PROPER programme create institutional demand for exactly the kind of transparent environmental cost information the framework is designed to produce (Otoritas Jasa Keuangan, 2017). The framework offers policymakers and standard-setters a reference for the capabilities environmental accounting systems should possess to support responsible consumption and production under Sustainable Development Goal 12, and, by foregrounding governance and assurance, it anticipates the regulatory questions that the diffusion of AI-derived sustainability information will raise.

5. Conclusion and Limitations

Environmental management accounting information systems will deliver on their promise only if the environmental costs they report can be traced to the activities that cause them. This paper has argued that Activity-Based Costing supplies the costing logic required, and that its integration into EMAIS, long identified as desirable but never consolidated into a framework, can now be specified as a coherent design architecture. The Activity-Based EMAIS framework embeds ABC logic within the input, processing, and output layers of EMAIS and extends that architecture through AI-augmentation and governance layers, yielding a system in which environmental cost information is at once transparent, decision-useful, and accountable. From the framework the paper has derived nine testable propositions and a four-stream research agenda.

As a conceptual contribution, the paper has clear limitations. The framework is a theoretical construction that awaits empirical validation; its propositions are offered as hypotheses rather than findings, and the feasibility and value of its components will vary with context. The AI-augmentation layer in particular rests on capabilities whose performance in environmental cost settings remains to be established, and whose benefits the propositions hold to be conditional on data quality and governance. These limitations define the research agenda the paper sets out and the next stage of a programme that moves from the conceptual framework presented here toward empirical and design-science validation in organisational settings. We invite scholars to test, refine, and extend the framework, and practitioners to treat it as a reference for building

environmental accounting systems equal to the demands of a carbon-constrained economy.

Funding

This research was supported by the Internal Research Grant of Universitas Negeri Malang for the 2026 fiscal year.

Author Contributions

Conceptualisation, A.H.D.S. and E.A.S.; methodology, A.H.D.S.; investigation and literature synthesis, A.H.D.S. and T.R.N.; writing—original draft, A.H.D.S.; writing—review and editing, T.R.N. and E.A.S.; supervision, E.A.S. All authors have read and agreed to the submitted version of the manuscript.

Conflict of Interest

The authors declare no conflict of interest.

Data Availability Statement

Data sharing is not applicable to this article, as no new empirical data were created or analysed. The conceptual framework is fully described within the article.

Use of Artificial Intelligence

The authors used an AI-assisted tool to support literature organisation and language editing during preparation of this manuscript. All sources were independently verified, and the authors take full responsibility for the framework, arguments, and final content.

Acknowledgement

An earlier bibliometric mapping of the EMAIS field by the authors was presented at the 12th International Management and Accounting Conference (IMAC 2026); the present paper builds on that mapping to develop the conceptual integration framework the analysis identified as a priority direction. The authors thank colleagues in the Department of Accounting for their constructive feedback.

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