Cleaner Manufacturing 1 (2026) 100006

Contents lists available at ScienceDirect

Cleaner Manufacturing

journal homepage: www.sciencedirect.com/journal/cleaner-manufacturing

Industry perspectives on scope 3 emissions reduction in manufacturing: Challenges, opportunities, and the role of AI

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ARTICLE INFO

Keywords:
AI
Alignment
Carbon
Governance
Procurement
Scope 3
Supply chains

ABSTRACT

Scope 3 emissions typically constitute the largest share of manufacturing firms' carbon footprints, yet they remain among the most difficult to manage beyond reporting. Prior research has advanced accounting methods, digital infrastructures, and AI enabled analytics, but offers limited empirical clarity on how practitioners operationalise Scope 3 work in day to day supplier, procurement, and product related decisions. This study addresses that gap through eight semi structured interviews with senior professionals working across manufacturing value chains in multiple regions. Using a Gioia inspired analytic approach, the study develops a transparent data structure linking participant concepts to second order themes and aggregate dimensions. Findings indicate that Scope 3 progress is frequently constrained not only by data limitations, but by organisational and inter-organisational frictions: (i) credibility gaps where estimates are reportable but not "decision grade" due to methodological volatility, baseline drift, and fragmented infrastructures; (ii) supplier engagement routines that remain disclosure heavy unless supported by leverage, segmentation, and capability building mechanisms; (iii) AI valued primarily for workflow acceleration under hybrid human oversight, yet bounded by input quality, governance, and adoption constraints; and (iv) action bottlenecks in procurement where trade-offs require explicit decision rules and accountability loops. Building on these insights, the paper proposes a Scope 3 Alignment Framework showing how credible data, relational supplier models, scalable workflows, and procurement actionability must reinforce one another for reporting to translate into sustained emissions reduction.

1. Introduction

Scope 3 emissions, generated across upstream and downstream value chains, often account for more than 70% of manufacturing firms' total carbon footprints, making them central to credible climate strategies (Hansen et al., 2022), (Fagundes Alves et al., 2024). Yet Scope 3 remains among the most difficult domains of decarbonisation to manage in practice, due to limited visibility across supplier networks, persistent data inaccessibility, and inconsistent carbon accounting methodologies Stenzel and Waichman (2023), (Marlowe and Clarke, 2022), (Downie and Stubbs, 2013). At the same time, regulatory and voluntary regimes are increasing expectations for disclosure and progress, including the EU Corporate Sustainability Reporting Directive (CSRD) and the Science Based Targets initiative (SBTi), intensifying the urgency for firms to move from reporting to implementation.

Existing research offers important advances in technical and procedural approaches to Scope 3 management, including carbon accounting tools (e.g., LCA) (Bassey et al., 2024), AI enabled analytics (Nguyen et al., 2023), and compliance oriented frameworks (Patchell, 2018), (Petrova, 2024), (Martinčević et al., 2024). However, a key limitation in the current discourse is that it often treats Scope 3 progress primarily as a function of improved measurement, better tools, or stronger mandates. This emphasis can understate how implementation depends on organisational and interorganisational conditions such as decision rights, incentives, governance arrangements, procurement authority, and the nature of supplier engagement, that shape whether measurement outputs translate into operational change. What remains underexplored is how practitioners navigate these constraints and what practices they develop to make Scope 3 actionable beyond compliance logics. Rather than departing from a purely technocratic view, this study identifies an emerging practitioner grounded reframing that broadens understanding of Scope 3 management beyond technical and compliance perspectives.

To address this gap, this study asks: (1) How do firms engage suppliers to reduce Scope 3 emissions? (2) How do they measure and monitor progress amid fragmented data and inconsistent methodologies? and (3) How do they manage sustainability complexity and trade-

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https://doi.org/10.1016/j.clman.2026.100006
Received 24 September 2025; Received in revised form 1 April 2026; Accepted 6 July 2026
Available online 9 July 2026
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offs in procurement and product related decisions? We investigate these questions through eight semi structured interviews with professionals involved in Scope 3 programmes in manufacturing value chains (including sustainability, procurement, and AI related roles) across multiple regions. Interviews were designed to elicit participants' problem definitions, routines, constraints, and decision processes without presupposing any single explanatory framing. The resulting data were analysed using inductive thematic analysis to identify recurring barriers, enabling conditions, and emerging practices in real world Scope 3 management.

The findings indicate that organisations face persistent challenges related to Scope 3 data availability, methodological inconsistency, and system fragmentation. At the same time, participants described implementation barriers linked to organisational arrangements and inter-organisational relationships, including how responsibilities are assigned internally, how procurement decisions incorporate carbon information alongside cost and quality constraints, and how supplier engagement is operationalised beyond one way disclosure requests. Drawing these themes together, the paper offers a practice grounded synthesis of the organisational and relational conditions that participants associate with more actionable Scope 3 management. From this synthesis, we develop an empirically grounded integrative framework that links (i) data governance and credibility, (ii) supplier engagement approaches, (iii) procurement decision rules and incentive structures, and (iv) hybrid human-AI workflows. This contribution supports a clearer explanation of how measurement outputs can (or cannot) be converted into decisions and interventions in manufacturing value chains, and it helps clarify implications for both research and practice.

The remainder of the paper is structured as follows. Section 2 reviews the relevant literature and identifies key conceptual gaps in Scope 3 emissions management. Section 3 outlines the methodological approach, including data collection and analysis procedures. Section 4 presents the empirical findings organised around the study's core themes, and Section 5 discusses their implications in relation to the research questions and existing scholarship. Section 6 concludes with contributions, limitations, and directions for future research.

2. Literature review

Scope 3 emissions pose one of the most pressing yet under examined challenges in corporate sustainability. While the academic literature offers a range of tools and strategies for addressing these emissions, including supplier engagement frameworks, AI enabled decision support, and eco design principles, empirical understanding of how these are integrated into day to day operations remains limited. This literature review synthesizes current research on Scope 3 emissions management, with a particular focus on three areas critical to manufacturing firms: supplier collaboration, emissions measurement, and the integration of sustainable product strategies. These themes directly informed the guiding questions used in the empirical component of this study.

2.1. Scope 3 emissions and carbon accounting complexity

Scope 3 emissions typically represent the largest share of emissions in manufacturing value chains (Hansen et al., 2022), yet they are difficult to quantify because they occur outside a firm's operational boundary and depend on heterogeneous upstream and downstream actors (Emborg et al., 2023). The GHG Protocol Scope 3 Standard provides a widely used structure by defining 15 reporting categories and outlining methodological options and minimum reporting expectations (Patchell, 2018), (World Resources Institute WRI, World Business Council for Sustainable Development WBCSD, 2011). However, translating this structure into operational measurement remains challenging. In practice, firms often face inconsistent boundaries, uneven category coverage, and limited supplier specific activity data, which contributes to non-comparability and omissions in corporate Scope 3 disclosures (Zhu and Geng, 2013), (Emborg et al., 2025).

A key methodological choice concerns how firms approximate emissions when primary supplier data are unavailable. Many companies begin with screening or hotspotting approaches (often using spend based environmentally extended input-output (EEIO) factors) to obtain broad coverage across procurement categories, and then progressively refine high impact areas with more specific activity data or supplier information (Patchell, 2018), (World Resources Institute WRI, World Business Council for Sustainable Development WBCSD, 2011), (Huang et al., 2009). Spend based methods offer scalability and completeness, but they are coarse proxies that can misrepresent product level and supplier level variation, particularly when supply chains are complex or when price changes decouple spend from physical activity (Emborg et al., 2025), (Huang et al., 2009). By contrast, process based LCA (pLCA) can improve granularity and decision relevance for targeted products and materials, but it is resource intensive and can suffer from truncation or boundary cut offs when applied at corporate scale (Emborg et al., 2023). This tension helps explain why empirical comparisons report divergent results across sectors (Emborg et al., 2025), (Jha et al., 2023).

To address the trade-off between completeness and specificity, recent work increasingly points toward hybrid approaches that combine process based inventories for key hotspots with IO based coverage for the remainder of the value chain, while explicitly documenting assumptions, boundaries, and uncertainty (Emborg et al., 2023), (Hagenaars et al., 2025). Nevertheless, integrated organisational approaches that link corporate inventories to product level carbon footprints and decision processes remain underdeveloped. Emerging digital infrastructures, such as digital product passports and blockchain enabled data sharing, may improve traceability and verification of lifecycle information, but evidence to date suggests implementation is still nascent and uneven, with significant organisational and data governance requirements for industrial deployment (Alotaibi et al., 2024), (Bager et al., 2022), (Jensen et al., 2023), (Zhang et al., 2020).

Despite extensive work on accounting methods and digital solutions, there is still limited empirical clarity on how practitioners actually sequence these approaches in day to day Scope 3 work, how they manage methodological variability and baseline drift over time, and how measurement outputs are translated into supplier engagement, procurement choices, and product related trade-offs. This gap is especially consequential where measurement outputs are expected to inform procurement and product related decisions.

2.2. Sustainable product strategies and scope 3 integration

Sustainable product strategies have emerged as a critical yet often under integrated dimension of Scope 3 emissions management. Recent research emphasizes that design stage decisions substantially determine a product's lifecycle emissions, influencing material sourcing, manufacturing energy intensity, and end of life recovery (Dahmani et al., 2021). In manufacturing industries, circular product design and lean eco-design frameworks, supported by digital tools such as IoT and AI, enable firms to reduce resource use and extend product lifetimes (Rao et al., 2024). Case based studies demonstrate that eco-design principles, such as modularity and design for disassembly, enhance product reuse and remanufacturing potential within circular manufacturing systems, though direct evidence of reduced embedded carbon remains limited (Favi et al., 2021). Circular economy approaches further connect product strategies to Scope 3 reductions by promoting closed loop material recycling, remanufacturing, and shared use models that directly lower upstream and downstream emissions (Tong et al., 2025). System level analyses reveal that these circular strategies can reduce manufacturing emissions by 10-20 % through material recovery and process redesign (Eissa and El-Adaway, 2024). Collectively, these studies indicate that product innovation and circular design should be treated as integral levers, alongside supplier engagement and

procurement policies, for operationalizing Scope 3 decarbonization in manufacturing contexts.

2.3. Supplier engagement and SME constraints

Research increasingly emphasizes the need for supplier engagement in Scope 3 strategies, particularly in sectors reliant on agricultural, energy intensive, or resource heavy supply chains. However, most studies focus on technologies for transparency or compliance audits, overlooking the relational and developmental dimensions critical to building supplier capabilities. Butt et al. (2025) address this gap by identifying six strategic pillars; effective communication, trust building, support and guidance, data utilization, program refinement, and incentive creation; that collectively foster supplier alignment with emissions reduction goals (Butt et al., 2025). Yet, while their framework advances the discussion, it reflects a broader pattern in the literature: a lack of clear differentiation between related but distinct practices such as supplier engagement, development, and selection. Moreover, few studies distinguish between supplier types, such as SMEs vs. multinationals, or address the specific challenges of engaging lower tier suppliers (Tier 2+), where visibility and influence are often weakest. These gaps suggest that supplier strategies need to be not only more relational, but also more context specific and stratified to reflect real world supply chain complexity.

This gap is underscored by Maksymova and Nastase (2024), who find that SMEs across Europe demonstrate significant variability and lag in their ability to implement climate neutral digital models, often due to structural and financial limitations (Maksymova and Nastase, 2024). Complementing these insights, Lintukangas et al. (2023) show that in GHG intensive sectors, supplier engagement in carbon management is frequently driven by instrumental motives, such as risk mitigation or regulatory compliance rather than relational collaboration or strategic integration across supply chain tiers (Lintukangas et al., 2023).

A notable exception is offered by Tidy et al. (2016), who illustrate how structured Supplier Relationship Management (SRM) programs in the UK food retail sector can foster emissions reductions through collaborative, trust based engagement. Their findings suggest that when relational mechanisms are formalized, through long term partnerships, mutual goal setting, and continuous feedback loops, supplier engagement can generate both sustainability and operational benefits (Tidy et al., 2016). However, empirical evidence also cautions against assuming that deeper engagement always yields lower emissions. Dahlmann et al. (2023) demonstrate that firms with extensive supplier measurement systems may paradoxically report higher Scope 3 emissions, due to systemic tensions and improved visibility of upstream impacts (Dahlmann et al., 2023). These findings underscore that while relational strategies hold promise, their effectiveness is contingent on broader governance structures. Fagundes Fagundes Alves et al. (2024) argue for the development of country specific engagement models, and Salminen (2016) advocates contractual approaches involving third party actors, such as NGOs, to enhance legitimacy and accountability in global supply chains (Fagundes Alves et al., 2024), (Salminen, 2016).

Finally, the fragmented and inconsistent nature of supplier level carbon disclosure remains a core barrier (Hansen et al., 2022). Hettler and Graf-Vlachy (2024) identify a general lack of empirical rigor and SME inclusion in Scope 3 reporting frameworks, calling for better integration of supplier voices and practices (Hettler and Graf-Vlachy, 2024). As a result, suppliers are often conceptualized merely as data conduits rather than collaborative partners, limiting the transformative potential of Scope 3 mitigation strategies. This review advocates for a shift toward more holistic, inclusive, and empirically informed approaches to supplier engagement in carbon management.

2.4. Artificial intelligence in emissions management

Artificial intelligence (AI) has been increasingly proposed to address key data challenges in Scope 3 emissions accounting, with applications ranging from automated life cycle assessment (LCA) and anomaly detection in supplier reporting to real time emissions tracking. Machine learning (ML) models, particularly Adaptive Boosting algorithms, have demonstrated improved prediction capabilities for Scope 3 emissions by leveraging financial, industrial, and Scope 1 and 2 data (Wang et al., 2024), (Serafeim and Vélez Caicedo, 2022). These models offer enhanced granularity when estimating individual Scope 3 categories, though their accuracy remains constrained by data fragmentation and inconsistencies across reporting entities.

Beyond emissions estimation, AI is also being deployed for anomaly detection in supplier disclosures and financial records. Grissa and Abaoub (2024) show that ML based anomaly detection improves accuracy and fraud prevention in complex data environments, positioning it as a promising tool for identifying reporting irregularities in carbon accounting (Grissa and Abaoub, 2024).

In parallel, AI powered eco innovation tools such as generative design and predictive analytics have enabled sustainable improvements in product development and process efficiency, especially in LCA applications for renewable energy systems. However, the literature highlights significant trade-offs in adopting AI at scale. Ezzeddine et al. (2024) demonstrate that enforcing privacy protections, like differential privacy, significantly reduces model explainability and performance, raising critical concerns about transparency and trust in AI based emissions systems (Ezzeddine et al., 2024). These concerns are echoed in the broader sustainability literature, where Ahmad (2021) emphasize that AI integration in complex systems like sustainable energy is constrained by high energy intensity, data irregularities, and infrastructure demands, all of which similarly apply to Scope 3 emissions contexts (Ahmad, 2021). Huang (2024) emphasizes that the effectiveness of AI in emissions management is enhanced when guided by human oversight and explainability enhanced AI models, which together optimize decision making processes and improve the robustness of AI applications in climate change mitigation (Huang, 2024).

These insights collectively suggest that while AI holds strong potential for emissions intelligence, scalable and equitable implementation will depend on integrated strategies that address data reliability, environmental cost, ethical trade-offs, and human machine complementarity.

2.5. Procurement and internal carbon pricing

Procurement functions are increasingly viewed as strategic levers in achieving Scope 3 emissions reductions. While multi criteria sourcing models and AI enhanced tools are emerging, the literature emphasizes the foundational role of procurement policies in decarbonization. Procurement activities often account for the majority of upstream emissions, yet are underleveraged due to fragmented data (Blanco et al., 2016), cost pressures, and weak internal incentives. Procurement strategies can drive transformative reductions when embedded with climate aligned objectives and collaborative supplier relationships (Howarth and Winfield, 2023).

Empirical studies reveal that even sustainability committed firms face major implementation barriers. Riedel et al. (2021) show that low carbon procurement is often constrained by methodological uncertainty, limited executive engagement, and lack of cross functional support (Riedel et al., 2021). These barriers limit the translation of green procurement policies into actionable sourcing practices. Moreover, procurement decisions are heavily shaped by short term cost metrics, institutional inertia, and risk aversion, especially in globalized supply chains.

To overcome these limitations, internal carbon pricing (ICP) has gained traction as a voluntary tool that embeds emissions costs into firm level financial decisions. ICP establishes a shadow price on carbon emissions to guide procurement preferences and investment priorities. Ben-Amar et al. (2022) demonstrate that firms tailor their internal

carbon pricing (ICP) practices based on their exposure to external climate policies. Their study shows that ICPs are more likely to be adopted and are more robustly implemented when firms face strong national carbon regulations and perceive high regulatory or opportunity related climate exposure (Ben-Amar et al., 2022). Complementing this, Bento et al. (2021) demonstrate that firms in jurisdictions with explicit carbon regulation tend to set higher ICPs, highlighting the reinforcing role of national climate policies (Bento et al., 2021).

The benefits of ICP implementation are not just theoretical. Zhu et al. (2022) find that companies using internal carbon pricing report significant improvements in emissions intensity metrics, showing reductions of up to 15.7% per revenue unit (Zhu et al., 2022). These gains are linked to stronger dynamic capabilities and alignment with stakeholder expectations.

Real world applications also validate the utility of ICP in procurement decision making. Palander (2023) illustrates how a wood energy firm used a data driven internal carbon pricing mechanism to balance cost efficiency and environmental goals, optimizing supply chain emissions while preserving profitability (Palander, 2023). Wang et al. (2024) reinforce this by demonstrating that grouped internal carbon pricing, tailored across divisions, can enhance operational efficiency and carbon performance in large scale industrial settings (Wang et al., 2024). Complementing these operational insights, Fahimnia et al. (2015) provide policy level guidance by modelling green supply chain optimization, offering a framework to align carbon regulation costs with long term profitability and environmental responsibility (Fahimnia et al., 2015). Additionally, Wang and Peng (2023) show that emissions linked financing models influence ordering, pricing, and carbon reduction strategies within supply chains, providing an operational link between carbon economics and supplier management (Wang and Peng, 2023).

Together, these findings underscore that while procurement and internal carbon pricing are promising tools, their effectiveness depends on consistent integration, institutional support, and alignment with external policy frameworks.

2.6. Regulation, accountability, and organizational governance

Recent policy developments, particularly the European Union's Corporate Sustainability Reporting Directive (CSRD), have significantly elevated expectations for corporate disclosure of Scope 3 emissions. The CSRD mandates detailed reporting on environmental and social impacts for all large companies and listed entities, marking a pivotal step toward harmonized sustainability governance across the EU (Martinčević et al., 2024). The directive expands the Non-Financial Reporting Directive (NFRD), aligning corporate transparency mandates with the goals of the European Green Deal and sustainable finance frameworks (Tascione et al., 2024).

Despite its regulatory momentum, the CSRD's phased implementation from 2024 to 2029 and varying national interpretations have led to significant fragmentation and compliance asymmetries (Poulle et al., 2024). These inconsistencies are further exacerbated by recent amendments under Delegated Regulation (EU) 2023/2772, which reduced reporting requirements by up to 50%, raising concerns about the CSRD's long term ability to ensure comparability and accountability (Martínez-Torres, 2024).

While regulatory frameworks like the CSRD represent an important shift, the literature often underestimates the internal readiness of firms to operationalize such complex mandates. Petrova (2024) finds that in jurisdictions preparing for CSRD, firms face challenges such as unclear midlevel roles, lack of ESG expertise, and inconsistent internal methodologies (Petrova, 2024). Similarly, Spataru (2024) highlights how global ESG regulation remains fragmented, with firms facing major compliance challenges navigating divergent disclosure expectations across the EU, US, and Asia Pacific regions (Spataru, 2024).

Moreover, while ESG frameworks are widely adopted, they often emphasize investor relations and board level declarations, with little emphasis on intra organizational accountability. Müller et al. (2024) propose a taxonomy of 11 ESG governance dimensions, ranging from reporting lines and role clarity to cross functional oversight, that must be structurally embedded for effective implementation (Müller et al., 2024). Without this structural coherence, ESG reporting risks becoming symbolic rather than substantive.

The sustainability balanced scorecard has emerged as one tool to bridge the gap between governance and implementation. Yang (2024) argues for embedding ESG metrics into traditional scorecard logic, enabling better alignment between strategic objectives and operational activities (Yang, 2024). However, the literature warns that such tools are only effective when supported by transparent communication structures, appropriate incentives, and managerial ownership. Transparency remains a central tenet of ESG accountability. Raghavan (2022) emphasizes the role of financial professionals in ensuring both the reliability and interpretability of ESG data, particularly as stakeholders demand verifiable information beyond marketing narratives (Raghavan, 2022). Dathe et al. (2024) further assert that effective ESG reporting must overcome the principal agent dilemma by fostering clarity in cross functional expectations and stakeholder engagement strategies (Dathe et al., 2024). In sum, while regulatory shifts like the CSRD are vital, they must be matched by internal governance reforms that extend beyond the boardroom. Ensuring that Scope 3 disclosure and ESG accountability cascade through operational tiers requires clarity in roles, coherence in reporting systems, and a cultural shift toward integrated, data driven sustainability management.

2.7. Synthesis of literature gaps and research questions

Across the measurement, supplier engagement, product strategy, and digitalisation literatures, several gaps remain that limit understanding of how Scope 3 emissions management is operationalised in manufacturing value chains.

First, although a rich body of work proposes accounting methods, fewer studies describe the end to end organisational workflows through which firms build baselines, prioritise hotspots, refine data quality over time, and monitor progress while methods and boundaries evolve. Empirical insight is also limited on how organisations navigate multi-jurisdictional reporting requirements and how these interact with methodological choices and data availability.

Second, supplier engagement research often emphasises disclosure and compliance mechanisms, but provides less detail on how firms shift from transactional requests to engagement models that reflect supplier heterogeneity, leverage conditions, and capability building needs, particularly beyond Tier 1.

Third, sustainable product strategies are frequently discussed in the eco-design and circular economy literatures, yet are less often integrated into Scope 3 governance research as an operational decision context. In practice, product and sourcing decisions involve multidimensional trade-offs that shape whether carbon information influences design and procurement choices.

Finally, AI enabled approaches are commonly positioned as solutions to data and complexity challenges, but organisational conditions for effective use remain underexplored in empirical Scope 3 settings.

These gaps motivate the study's three research questions, which examine (RQ1) supplier engagement practices for Scope 3 reduction, (RQ2) how firms measure and monitor progress amid fragmented data and methodological variability, and (RQ3) how sustainability complexity and trade-offs are managed in procurement and product related decision making.

3. Methodology

This study employs a qualitative exploratory design using semi structured interviews, which is a recognized approach for investigating

complex, emergent issues in sustainability and procurement practice. Semi structured interviews are widely used in exploratory supply chain and sustainability research to investigate complex organisational processes and emergent practices that are not easily captured through quantitative approaches (Voss et al., 2002), (Barratt et al., 2011). This is particularly relevant in sustainable supply chain contexts, where practices are shaped by interorganisational dynamics, regulatory variation, and evolving capabilities (Seuring and Müller, 2008), (Carter and Rogers, 2008). Such approaches are therefore appropriate for under theorised phenomena such as the organisational implementation of Scope 3 emissions strategies, where practices remain context dependent and continuously evolving. The interview guide was developed by synthesizing themes from recent literature and initial consultations with industry practitioners, ensuring relevance to both academic and real world challenges.

To reduce the risk of a predetermined outcome, the research design was structured so that participants could define the problem in their own terms. The interview guide used descriptive prompts and avoided introducing interpretive labels or hypothesised framings. The analysis combined inductive coding with iterative comparison across interviews to identify recurring patterns and boundary conditions. The Gioia inspired data structure presented in the Results section provides an audit trail from participant centred concepts to researcher themes and aggregate dimensions. While participants were encouraged to articulate challenges in their own terms, comparability was maintained through the use of a consistent interview guide and systematic coding procedures. The Gioia methodology further ensured that variations in framing were analytically reconciled into shared second-order themes, supporting consistency and interpretive rigor across cases. This qualitative design enables an in depth examination of how organisations operationalise Scope 3 strategies in practice, directly addressing the study's research questions on supplier engagement, measurement, and decision making processes.

3.1. Data collection

Primary data were collected through semi structured interviews with eight senior professionals who were purposively selected for direct, sustained involvement in Scope 3 initiatives within manufacturing value chains, including roles within manufacturing firms and roles responsible for designing or implementing Scope 3 measurement, supplier engagement, procurement sustainability, and emissions data systems used by manufacturers and their suppliers.

Interviews were conducted online between February and May 2025 and lasted around 45 minutes. Participants were selected through purposive sampling based on their experience and role relevance, with snowballing used to identify additional informants. The number of interviews conducted was guided by qualitative research principles around saturation. Saunders et al. (2018) emphasize that data saturation is not a fixed numerical threshold but rather a function of the study's objectives, participant homogeneity, and the richness of the data (Saunders et al., 2018). In focused, expert driven studies such as this, saturation is often achieved with a relatively small number of interviews when recurring themes begin to emerge and no substantial new insights are generated. In this research, after six interviews, the major themes such as limited AI integration in supplier strategy, data trust barriers, and procurement sustainability misalignment began to repeat, indicating that thematic saturation had been reached by the eighth interview.

Each interview followed a semi structured guide covering themes such as Scope 3 data challenges, supplier engagement practices, emissions reporting methodologies, the use of digital and AI tools, procurement decision making, and organizational governance. The semi structured interview guide is provided in Appendix A. Questions were designed to be open ended and neutral, without introducing any hypothesised explanation or preferred framing. Interviews were audio recorded with consent and transcribed verbatim for analysis. All participants were anonymized using identifiers. Direct engagement was defined as responsibility for Scope 3 related decisions or systems embedded in manufacturing operations, procurement, supplier programmes, product lifecycle processes, or manufacturing critical logistics. Table 1 summarises participants' profiles and their value chain touchpoints. Although some interviewees operate in consulting or technology roles, all directly serve manufacturing value chains, either by providing tools, data systems, or advisory services embedded in manufacturing procurement and production contexts.

3.2. Data analysis

Interview transcripts were analysed using an inductive abductive approach consistent with the Gioia methodology (Gioia et al., 2013) for building grounded process models from qualitative data. Analysis proceeded in three stages. First, transcripts were read iteratively and coded using first order concepts that stayed close to participants' language and descriptions of practice (staged measurement workflows, supplier engagement routines, procurement decision constraints, and AI enabled data handling). Second, related first order concepts were compared across interviews and consolidated into second order themes expressed in researcher terms (e.g., "measurement is staged but rarely decision

Table 1
Overview of interview participants.

ID	Sector	Role	Region	Years of experience
P1	Manufacturing supply chain decarbonisation technology	Product leader for supplier decarbonisation platforms used by manufacturers	Europe (UK)	18
P2	Scope 3 measurement & mitigation for corporate supply chains (incl. manufacturing value chains)	Senior lead on Scope 3 carbon programmes used by manufacturing facing supply chains	North America (USA)	19
P3	Industrial / manufacturing decarbonisation consulting	Sustainability consultant supporting manufacturing clients' inventories, targets, and supplier programmes	Europe (UK/ France)	12
P4	Industrial sustainability & supply chain carbon (manufacturing adjacent operations)	Consultant / cofounder delivering carbon footprinting and ESG projects in industrial contexts	Asia (Malaysia)	15
P5	Manufacturing supply chain disclosure & supplier decarbonisation ecosystems	Advisor/ambassador shaping supplier carbon data systems used by manufacturing procurement teams	Europe (France/ UK)	18
P6	Carbon accounting methods + manufacturing process exposure	Sustainability R&D (carbon methods) with prior additive manufacturing experience	Europe (Germany)	14
P7	Procurement + Scope 3 tech for large manufacturing supply chains	CEO of a platform used by procurement to manage suppliers and Scope 3 reduction	Europe (UK)	25
P8	Product sustainability & manufacturing operations (apparel/ consumer goods manufacturing)	Sustainability leader with direct product LCA, factory auditing, and design/ manufacturing integration	Global (NZ based)	22

grade," "supplier engagement depends on leverage and capability," "procurement requires permission and decision rules," and "AI enables workflow acceleration but remains bounded by judgement and adoption risk"). Third, second order themes were synthesised into aggregate dimensions that structure the study's core contribution and inform the resulting framework. This approach has been widely adopted in sustainability oriented qualitative studies to provide a transparent first order/second order data structure and audit trail (Hasnaoui and Lebbar, 2025).

Throughout analysis, constant comparison was used to refine code definitions, merge overlapping categories, and identify areas of convergence and divergence across roles and regions. Analytic memos were maintained to document coding decisions, evolving interpretations, and emerging relationships between themes. To strengthen credibility, the analysis actively searched for negative or disconfirming cases (contrasting views on SME materiality and supplier engagement depth) and incorporated them into the thematic narrative rather than treating findings as uniform.

Saturation was assessed at the level of new first order concepts and second order themes. After the sixth interview, no materially new second order themes emerged; interviews seven and eight primarily added nuance, boundary conditions, and disconfirming cases, supporting thematic saturation for the study's focused research questions. Table 2 represents Theme coverage across participants and provides illustrative quotes supporting each second-order theme to enhance transparency between empirical evidence and thematic interpretation. This distribution indicates that each second order theme is supported by multiple interviews, with repeated emphasis across roles and regions.

Table 2
Theme coverage across participants.

Second-order theme	Description	Illustrative quote (verbatim)	Participants
A1. Staged measurement approaches lacking decision-grade reliability	Firms rely on screening methods that provide coverage but are insufficient for actionable decision-making	"You can't decarbonize if you're using a spend based analysis… the only way you can reduce carbon is to spend less, and no business wants to spend less" (P1)	P1, P2, P3, P5
A2. Baseline instability and fragmented data infrastructures	Scope 3 reporting is undermined by inconsistent datasets, methodological variability, and system fragmentation	"We have like 15 files… there's going to be double counting" (P6)	P3, P4, P6
B1. Shift from transactional disclosure to relational engagement	Supplier engagement evolves from one-way data requests toward deeper collaboration and capability building	"Just asking suppliers 'give me your scope one and two'… it's very superficial… that's the most basic level of engagement" (P8)	P2, P5, P8 (also P3)
B2. Supplier engagement shaped by leverage and segmentation	Engagement strategies depend on buyer influence, supplier type, and prioritisation across the supply base	"SMEs don't matter… they're not a really big carbon footprint" (P7)	P3, P4, P7 (also P5)
C1. AI as a workflow accelerator	AI is primarily valued for efficiency gains, automation, and handling complexity rather than generating "accurate" emissions data	"We save people like 40% of their time" (P7)	P4, P5, P7
C2. AI constrained by data quality and need for human oversight	AI outputs are limited by uncertain inputs and require human validation and governance	"When people tell me… we're 99% accurate, I have alarm bells… what are you accurate as compared to? We don't know what the right answer is" (P2)	P2, P3, P4, P5
D1. Procurement requires explicit decision rules and mandate	Procurement action depends on formal mechanisms that legitimise carbon trade-offs	"One way… is by setting an internal cost of carbon… that makes it really easy and objective" (P7)	P1, P5, P7
D2. Weak accountability and enforcement mechanisms	Lack of ownership, monitoring, and enforcement limits implementation of Scope 3 strategies	"Nobody actually checks that they are on track for their target" (P3)	P3, P4, P6

4. Results

Following a Gioia informed thematic structure, findings are presented using a transparent data structure linking (i) participants' first order concepts (close to informant language), to (ii) second order themes (researcher terms), and (iii) aggregate dimensions that organise the study's contribution. This section presents empirical patterns derived from participant accounts, focusing on observed practices and recurring themes without theoretical interpretation. The implications of these findings are developed in the subsequent discussion section. Fig. 1 presents the data structure.

These four dimensions collectively address the study's research questions by illustrating how firms engage suppliers (RQ1), how they measure and monitor Scope 3 emissions under data constraints (RQ2), and how they manage sustainability trade-offs in procurement and product related decisions (RQ3).

4.1. Data credibility: methods and infrastructure challenges

Participants consistently described challenges related to the credibility of Scope 3 data, particularly its limited usefulness for procurement or design interventions. A recurring concern was the reliance on spend based accounting as the default baseline. One participant argued that spend based approaches can distort decarbonisation logic: "You can't decarbonize if you're using a spend based analysis… the only way you can reduce carbon is to spend less, and no business wants to spend less" (P1). This critique was less about rejecting screening methods entirely, and more about their limitations as a basis for action.

A second issue concerned methodological variability. Even when tools claim alignment with similar standards, outputs can diverge substantially. As P2 noted, estimates can vary by "two to five times" in greenhouse gas intensity (P2). Participants described this variability as making it difficult to use results consistently in internal decision processes, particularly when different tools or emission factors produce conflicting outcomes.

Beyond methodology, participants highlighted challenges related to the operational organisation of Scope 3 reporting infrastructures. Reporting was described as dependent on fragmented datasets and reconciliation work. P6 captured this in practical terms: "We have like 15 files… there's going to be double counting" (P6). Others pointed to uneven digital maturity and missing historical datasets: "Historical datasets are massively missing… there is still a lot of manual logging in Asia" (P4). These descriptions indicate that assembling and maintaining Scope 3 datasets involves significant manual effort, inconsistencies across systems, and gaps in data availability.

Despite these limitations, participants frequently referred to supplier specific data, particularly product carbon footprints (PCFs), as a more credible form of measurement. As P3 stated, PCFs are "the Holy Grail,"

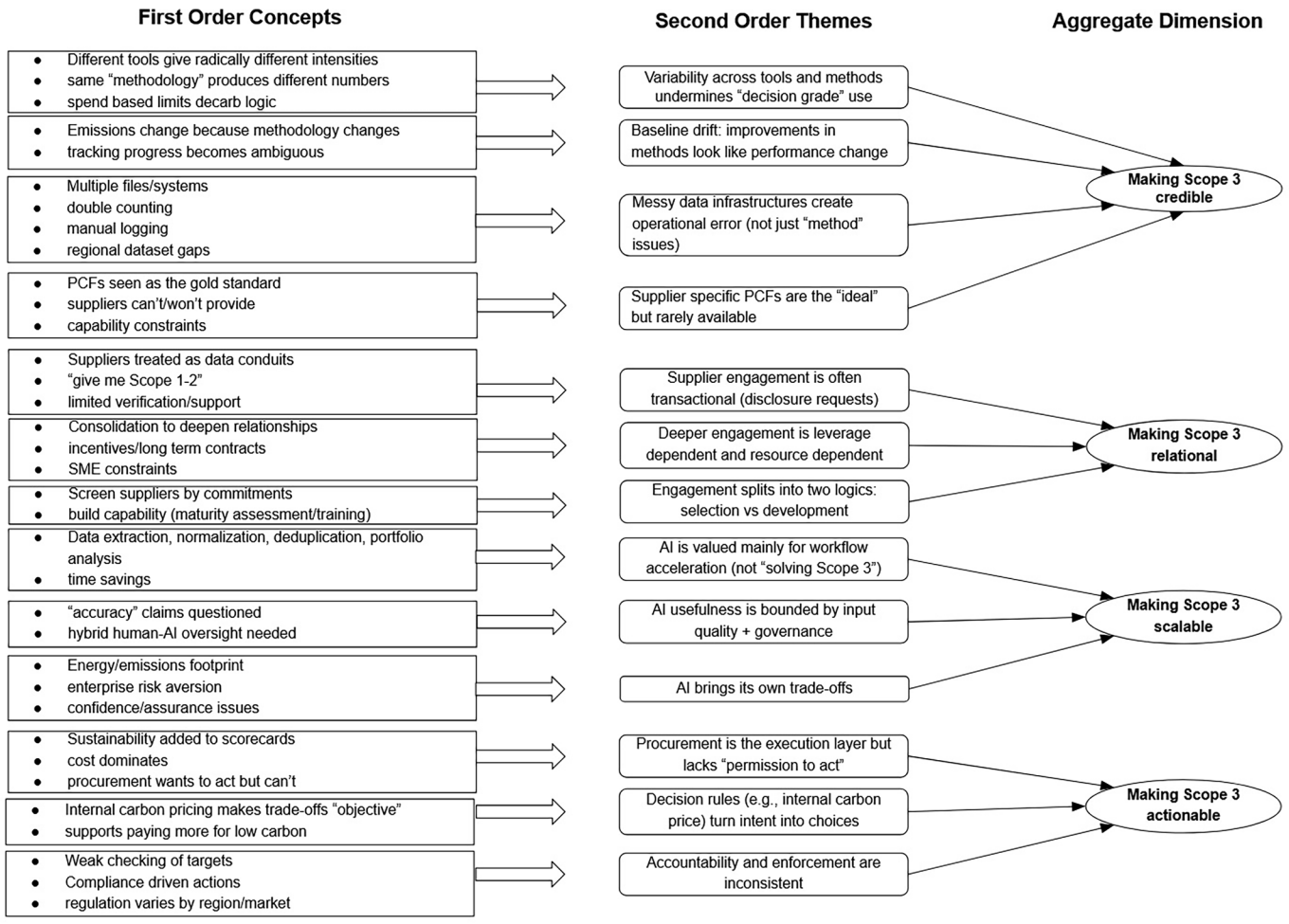


Fig. 1. Data structure

Data structure showing how interview evidence was translated into the study's four aggregate dimensions. The left column summarises representative first-order concepts (informant centric terms), which were clustered into second order themes (researcher centric interpretations) and then synthesised into four aggregate dimensions: Making Scope 3 credible, relational, scalable, and actionable. This structure provides an audit trail from interview data to the conceptual framework developed in the paper.

yet they remain uncommon in practice (P3). Participants consistently referred to three recurring issues: the limitations of screening methods for decision making, variability across tools and methodologies, and fragmented data infrastructures.

4.2. From transactional disclosure to relational supplier engagement

Participants distinguished between supplier engagement that is primarily transactional disclosure and engagement that becomes relational and capability based. Many criticised the dominant approach as superficial: suppliers are asked for data (often Scope 1 and 2) without support, verification, or joint problem solving. As P8 put it: "Just asking suppliers 'give me your scope one and two'… it's very superficial… that's the most basic level of engagement" (P8). P2 also suggested that disclosure heavy approaches are "falling out of favour" because they do not reliably translate into measurable reduction outcomes (P2).

More advanced engagement models were described as those that are tied to leverage and incentives, rather than one off data requests. One route is procurement embedded incentives: P5 described engagement models that "score suppliers on their ability to adhere to requirements, rewarding them financially or with longer term contracts" (P5). Another route is deepening relationships through supply base strategies and clearer expectations for key suppliers (P2; P5). In these models, engagement becomes less about "collecting supplier numbers" and more about shaping supplier behaviour through longer term commercial logic.

Participants also described variation in engagement approaches across supplier types and contexts. SMEs were discussed differently by participants: P7 downplayed their materiality, stating "SMEs don't matter… they're not a really big carbon footprint" (P7), while P4 emphasised constraints in emerging markets where "affordability of the products" dominates and decarbonisation expectations are harder to enforce (P4). These accounts illustrate that supplier engagement practices vary depending on buyer leverage, supplier capability, regional context, and supply chain structure.

Across interviews, participants referred to the shift from disclosure based approaches toward more relational engagement models, while also noting practical constraints related to procurement integration, incentives, and leverage across the supply chain.

4.3. AI enabled workflows: capabilities and constraints

Participants viewed AI as potentially valuable, but mostly as a tool for workflow acceleration rather than as a substitute for credible data, methodological judgement, or governance. A core concern was the lack of reliable ground truth. As P2 explained: "When people tell me… we're 99% accurate, I have alarm bells… what are you accurate as compared to? We don't know what the right answer is" (P2). Similarly, P3 noted

that "AI can't really do that for you" when baseline inputs are weak or missing (P3). These accounts link the perceived limitations of AI to challenges related to data credibility.

At the same time, participants identified practical areas where AI can add value, particularly in reducing manual effort and enabling scale. P7 described efficiency benefits: "We save people like 40% of their time" (P7). P4 emphasised that a hybrid model is most applicable, where AI supports processing and monitoring while humans retain methodological control: "a combination of AI and human intelligence would give you the best practice" (P4). P5 also noted that AI can contribute to improved LCA workflows when paired with better primary data availability (P5).

Participants also referred to constraints related to governance, cost, and environmental impact. Several noted that AI outputs require human oversight to avoid amplifying uncertainty. In addition, concerns were raised about AI's resource intensity. P5 described AI as "outrageously emissions and energy intensive" (P5), and P2 emphasised that it is "not costless" (P2). Across interviews, AI was described as useful for handling complexity and improving efficiency, while remaining dependent on data quality, governance structures, and resource considerations.

4.4. Organisational conditions for decision making

Participants described challenges related to procurement and governance in translating Scope 3 goals into action. Procurement was presented as the operational layer where Scope 3 considerations may influence supplier decisions or remain symbolic. Some participants described progress toward integrating sustainability into supplier evaluation: "We've seen many businesses start to integrate… sustainability onto a balanced scorecard" (P1). This indicates increasing inclusion of emissions performance within supplier selection and contract management processes.

Participants also described constraints related to trade-offs and decision rules. Cost tensions were frequently mentioned: "If you move from soy oil or palm oil to sunflower oil, you may get a fantastic carbon benefit… but it may be awful on a cost marker" (P1). In this context, P7 described internal carbon pricing as a governance mechanism: "One way… is by setting an internal cost of carbon… that makes it really easy and objective" (P7). This example shows how governance mechanisms can influence procurement decisions.

Participants also referred to challenges related to accountability and enforcement. P3 observed: "Nobody actually checks that they are on track for their target" (P3), while P6 highlighted uncertainty regarding resourcing: "We want to do something too, but we have no clue what… what should be our budget?" (P6). In some contexts, compliance rather than strategy was described as the primary driver: "They will rather be able to tell you that because we are forced to do so" (P4). Participants also expressed differing views on the role of market forces and regulation, with some emphasising market signals and others pointing to weak enforcement across regions (P4; P7). Financial incentives were also mentioned as influencing investment decisions and access to capital (P6).

Across interviews, participants referred to organisational conditions related to procurement authority, decision rules, accountability structures, and budget ownership in relation to Scope 3 implementation.

Across the four thematic areas, the results reveal recurring organisational patterns related to data credibility, supplier engagement, technological integration, and procurement governance. These findings provide the empirical basis for the following discussion, which interprets these patterns in relation to existing literature and the study's research questions.

5. Discussion

Building on these findings, this section interprets the patterns identified across interviews and links them to the three research questions and prior literature. Rather than treating Scope 3 as primarily a reporting exercise, participants described a set of organisational mechanisms that determine whether measurement becomes actionable: the credibility of emissions information for decisions, the mode of supplier engagement (transactional versus relational), the role of AI as a workflow enabler under human oversight, and the governance and procurement decision rules that translate ambition into practice.

5.1. Decision legitimacy in scope 3 measurement

Prior research has extensively discussed the methodological complexity of Scope 3 accounting and the variability that can arise across spend based/EEIO screening, process based LCA, and hybrid approaches, particularly when boundaries, databases, and assumptions differ (Stenzel and Waichman, 2023), (Marlowe and Clarke, 2022), (Bassey et al., 2024), (Tidy et al., 2016). The present study aligns with this literature but suggests that, for practitioners, the most salient issue is not only methodological selection in principle, but whether emissions numbers achieve decision legitimacy, that is, whether they are trusted and stable enough to justify interventions in procurement, supplier programmes, or product related trade-offs.

A central interpretive insight concerns the challenge of maintaining a stable baseline over time. Participants described how improvements in category coverage, emission factors, and data sources can cause reported Scope 3 totals to shift even in the absence of operational change. This dynamic resonates with academic debates on uncertainty and boundary setting in Scope 3 measurement (Stenzel and Waichman, 2023), (Bassey et al., 2024), but it extends them by foregrounding the organisational consequences of "baseline drift": progress tracking becomes contested internally, targets become harder to evaluate, and the credibility of sustainability functions can be undermined when year on year changes are difficult to explain. In this sense, methodological refinement alone does not guarantee better management outcomes; it must be accompanied by explicit baseline governance to preserve interpretability and comparability across reporting cycles.

The study also indicates that credibility problems are not reducible to modelling assumptions alone. Participants highlighted the operational realities of assembling Scope 3 datasets across fragmented systems, inconsistent categorisations, and uneven regional data maturity. This supports scholarship arguing that digital infrastructures and traceability initiatives may improve lifecycle data availability, but only when supported by robust data governance, interoperability, and organisational readiness (Huang et al., 2009), (Jha et al., 2023), (Dahmani et al., 2021), (Rao et al., 2024). Put differently, even technically defensible methods may fail to produce usable decision inputs when the underlying data infrastructure is not designed for auditability, deduplication, and repeatable reporting.

These observations speak directly to the gap identified in the literature review: despite extensive work on accounting methods and digital tools, empirical understanding remains limited regarding how firms sequence measurement work in day to day practice and how they translate inventories into actionable decisions. The findings suggest that a staged approach is often unavoidable, but it becomes organisationally effective only when paired with clear rules about what constitutes "good enough" data for different decision contexts and when baseline management practices prevent methodological change from being misread as performance change.

5.2. Disclosure: differentiated and relational governance of suppliers

The supplier engagement literature commonly frames Scope 3 progress as a transparency problem: improve supplier disclosure, deploy traceability platforms, and strengthen compliance mechanisms so that upstream emissions become visible and measurable (Hagenaars et al., 2025), (Bager et al., 2022). The present study does not reject the importance of disclosure, but it indicates that disclosure driven

engagement is frequently interpreted by practitioners as insufficient for decarbonisation because it rarely changes supplier behaviour on its own. This provides empirical support for critiques that treating suppliers primarily as data providers can produce reporting activity without corresponding operational transformation, and it reinforces calls for engagement models that move from information extraction to relationship based influence (Fagundes Alves et al., 2024), (Dahmani et al., 2021).

Across interviews, a clear distinction emerged between transactional engagement and relational engagement. This distinction resonates with relational views of supplier relationship management and collaborative sustainability programmes, where trust, repeated interaction, and mutual adaptation are conditions for sustained improvement (Jensen et al., 2023). The contribution here is to show how practitioners connect these relational mechanisms to procurement leverage: deeper engagement is concentrated where buyers have commercial influence and where resources exist to sustain ongoing interaction. This helps specify a boundary condition sometimes underdeveloped in normative supplier engagement frameworks: relational approaches are not simply "better practice" but are constrained by time, organisational capacity, and bargaining position.

A second interpretive insight concerns supplier heterogeneity particularly the contested role of SMEs. Prior literature documents that SMEs often face structural limitations that reduce their capacity to participate in decarbonisation programmes, even when expectations exist (Alotaibi et al., 2024), (Rao et al., 2024). The interview evidence aligns with this but adds an important tension: some practitioners justify deprioritising SMEs on materiality grounds, while others emphasise that affordability pressures and institutional context can make conventional engagement models unrealistic even when SMEs are embedded in critical supply networks. This tension reframes the "SME problem" from a simple inclusion gap to a governance dilemma about where to allocate scarce engagement capacity without reproducing inequities or creating blind spots in lower tiers.

Taken together, the findings suggest that supplier engagement operates through at least two partially competing logics: development and selection/screening. This distinction speaks directly to the literature gap noted in Section 2.3: existing research often bundles engagement, development, and selection without clearly differentiating the mechanisms. Empirically, the interviews indicate that decarbonisation strategies become more actionable when firms explicitly choose and combine these logics based on supplier segmentation, leverage conditions, and local constraints rather than applying a uniform disclosure model across the supply base.

5.3. AI as a capacity multiplier under hybrid governance

The literature increasingly positions AI as a way to overcome Scope 3 complexity, automating LCA tasks, improving estimation, detecting anomalies, and enabling near real time reporting (Favi et al., 2021; Tong et al., 2025; Eissa and El-Adaway, 2024). The interview evidence supports the idea that AI can improve speed and handling of complexity, but it reframes where that value sits. Practitioners consistently located AI's contribution in workflow acceleration rather than in producing "correct" emissions numbers in the absence of credible inputs. This is an important corrective to technology forward narratives: in operational contexts where data quality, boundaries, and factor choice remain contested, AI is treated less as an epistemic authority and more as a capacity multiplier.

This interpretation aligns with research emphasising that ML performance is bounded by data availability, representativeness, and domain mismatch, especially in complex sustainability settings (Butt et al., 2025). Several participants' scepticism toward claims of high accuracy is consistent with the methodological point that, without a reliable ground truth, "accuracy" becomes difficult to define and can create false certainty. In that sense, the key issue is not whether AI can generate outputs, but whether organisations can trust and defend those outputs in decision contexts. This links AI directly back to the "credibility" challenge identified in the accounting literature and digital traceability debates (Huang et al., 2009; Jha et al., 2023; Dahmani et al., 2021; Rao et al., 2024).

A second implication concerns governance. The interviews repeatedly implied that AI becomes useful when embedded in hybrid decision processes: automation handles classification and scale, while humans retain responsibility for methodological judgement. This is consistent with arguments that explainability, oversight, and accountability are necessary conditions for responsible AI in sustainability applications (Lintukangas et al., 2023), and it also reflects the trade-offs identified in privacy and security research, where stronger protections can reduce performance and interpretability (Butt et al., 2025). Practically, AI does not remove the need for judgement; it shifts judgement toward designing controls around the AI enabled workflow.

Third, participants highlighted two constraints that the academic AI for sustainability debate sometimes treats as secondary but practitioners experience as central. One is the environmental cost of AI itself, an instance of the "efficiency paradox" where computational approaches deployed for climate goals carry their own energy and emissions burdens (Maksymova and Nastase, 2024). The other is organisational adoption risk: enterprise concerns around security, IP, and reputational exposure can limit deployment even when technical value exists. These constraints reinforce that "AI potential" cannot be evaluated purely on analytic capability; it must be assessed as part of a sociotechnical system that includes governance, risk tolerance, and legitimacy.

Overall, the interviews suggest that AI's most defensible contribution to Scope 3 management is to make organisations able to do the work, reduce manual friction, stabilise categories, highlight gaps, and free time for supplier and procurement engagement while remaining bounded by input quality, oversight requirements, and adoption constraints. This reframing helps connect AI scholarship to the operational realities that are often missing from conceptual discussions of digital solutions in Scope 3 settings.

5.4. Institutionalising scope 3 accountability

Prior research consistently identifies procurement as one of the strongest levers for reducing upstream Scope 3 emissions because it sits at the interface between sustainability ambition and supplier selection, contracting, and specification choices (Tidy et al., 2016; Dahlmann et al., 2023; Salminen, 2016). The interviews reinforce this positioning, but they also clarify why procurement often fails to operationalise Scope 3 goals: it is not only a question of tools or awareness, but of decision authority and rules that determine what procurement is permitted to optimise when cost, quality, risk, and delivery constraints conflict.

This finding extends work on implementation barriers in green procurement, where methodological uncertainty, weak executive engagement, and lack of cross functional support are shown to constrain procurement's ability to act (Salminen, 2016). In the interviews, the constraint appeared most clearly when participants described cost sensitive substitutions and trade-offs that sustainability teams can identify but procurement cannot consistently justify. Here, the contribution is the emphasis on "permission to act" as an organisational mechanism: unless governance converts carbon considerations into legitimate procurement criteria, carbon remains an "aspirational" metric rather than a decision variable.

Internal carbon pricing (ICP) provides a concrete example of such a rule. The literature positions ICP as a way to embed emissions externalities into firm level decisions and align investment and sourcing choices with climate objectives (Hettler and Graf-Vlachy, 2024; Wang et al., 2024; Serafeim and Vélez Caicedo, 2022; Grissa and Abaoub, 2024). The interviews are consistent with this logic, but they also imply a more specific managerial role: ICP is valuable because it makes

trade-offs auditable and defensible within procurement, turning a normative preference ("choose greener") into an operationalised decision calculus. This interpretation also resonates with evidence that ICP adoption and robustness tend to vary with regulatory exposure and institutional context (Hettler and Graf-Vlachy, 2024; Wang et al., 2024), suggesting that decision rule design is not purely internal but shaped by external policy signals.

However, procurement mechanisms alone were not described as sufficient. Participants repeatedly linked actionability to accountability loops, clear ownership, monitoring frequency, and follow up routines, echoing governance research arguing that ESG structures must be embedded across roles and reporting lines to avoid symbolic compliance (Ben-Amar et al., 2022; Palander, 2023). The discussion of balanced scorecards is relevant here: while scorecards can help translate strategy into operational metrics (Bento et al., 2021), their effectiveness depends on role clarity, incentives, and managerial ownership, conditions that the interviews suggest are frequently weak or fragmented. This helps explain why firms may accumulate reporting activity without credible evidence of progress: the organisational infrastructure for "closing the loop" from targets to budgets, responsibilities, and enforcement is missing or underpowered.

Moreover, external pressure was described as uneven: market and customer requirements can impose strong expectations in some value chains, while regulatory enforcement and reporting methodologies differ across regions. This fits with regulatory scholarship noting fragmentation across regimes and the challenges firms face in navigating divergent disclosure expectations (Blanco et al., 2016; Howarth and Winfield, 2023; Riedel et al., 2021). In practical terms, "actionability" becomes contingent: decision rules and accountability mechanisms have to operate across jurisdictions that vary in their reporting mandates, data availability, and enforcement intensity.

Taken together, the procurement findings support a clearer interpretation of Scope 3 execution as a governance problem of institutionalising carbon in routine decisions. The data suggest that progress is most likely when (i) sustainability metrics are embedded in procurement evaluation systems, (ii) explicit decision rules translate emissions information into comparable trade-offs, and (iii) accountability mechanisms ensure follow up beyond disclosure cycles. This aligns procurement scholarship with governance theory by showing that the effectiveness of procurement levers depends on the organisational systems that legitimise and sustain them, and on the external environments that shape incentives and feasibility.

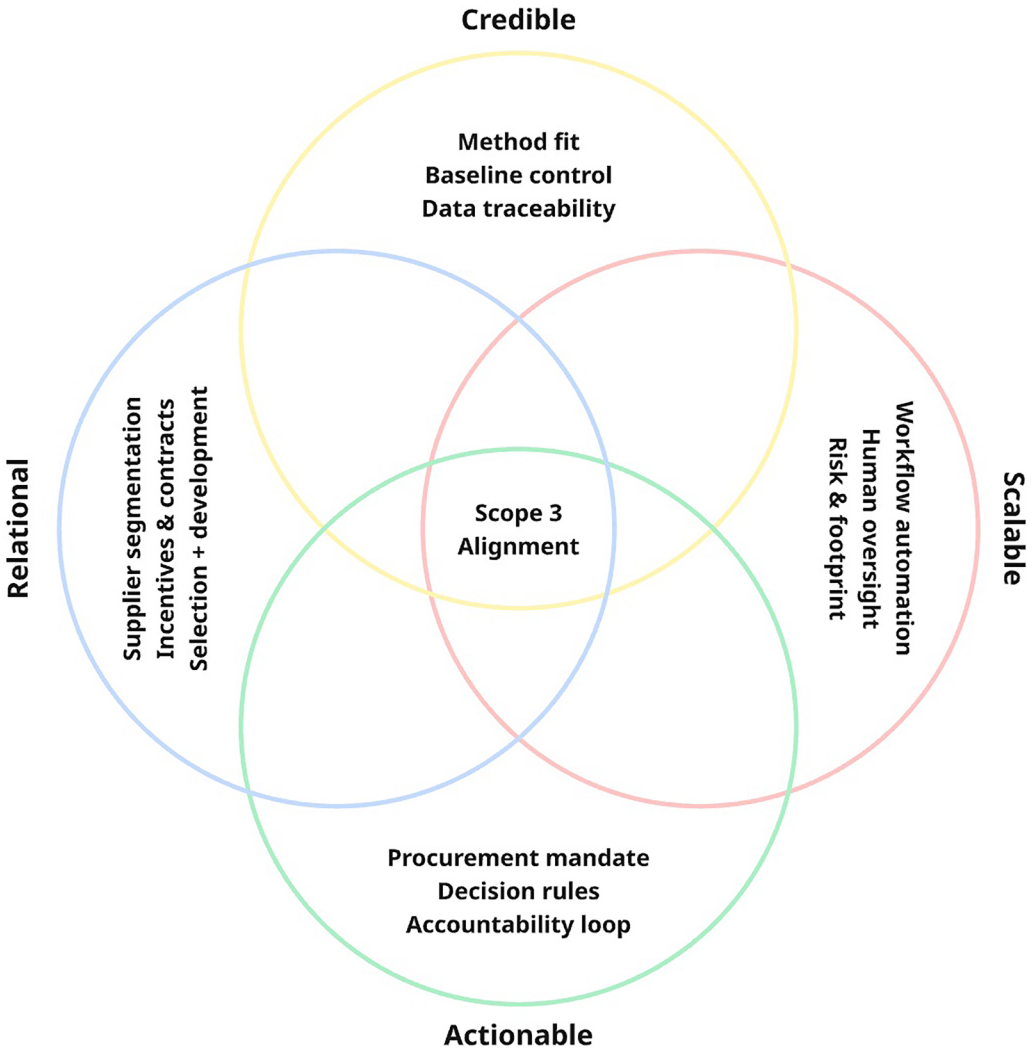


Fig. 2. Scope 3 alignment framework
Conceptual framework derived from the thematic analysis illustrating four interdependent organisational capabilities required to translate Scope 3 reporting into sustained decarbonisation action: Credible (method fit, baseline control, data traceability), Relational (supplier segmentation, incentives/contracts, selection and development logics), Scalable (workflow automation, human oversight, risk and footprint considerations), and Actionable (procurement mandate, decision rules, accountability loop). The overlaps represent reinforcing interdependencies between capabilities; the central overlap (Scope 3 Alignment) denotes the systemic alignment required for Scope 3 information to become decision relevant and operationally actionable.

5.5. The scope 3 alignment framework

Building on the second order themes developed in the Gioia analysis, this study proposes the Scope 3 Alignment Framework (Fig. 2) as a practice grounded synthesis of the organisational capabilities that enable Scope 3 reporting to translate into emissions reduction. Fig. 2 synthesises the empirical themes into a practice grounded framework that explains how organisations translate Scope 3 reporting into reduction. The framework is derived from the study's coding structure and is intended as an interdependence model, not a linear maturity sequence. Each domain captures a distinct organisational capability identified across participants, while the overlaps represent reinforcing mechanisms observed in practice. The proposed framework should be understood as an initial conceptual structure derived from exploratory qualitative evidence, intended to organise observed patterns rather than provide a definitive or validated model. Further research is needed to refine, operationalise, and empirically test its components across contexts.

Making Scope 3 credible refers to the conditions under which emissions information becomes reliable enough to support decisions (method fit, traceability, baseline control, and the operational management of fragmented systems). Making Scope 3 relational captures the shift from disclosure only supplier routines toward segmentation, capability building, and incentive/contracting mechanisms that create ongoing cooperation. Making Scope 3 scalable reflects the role of AI and digital tools as workflow accelerators (extraction, normalisation, deduplication, portfolio analysis) under human oversight, constrained by input quality and adoption risks. Making Scope 3 actionable centres on procurement mandate, decision rules (internal carbon price or carbon cost proxies), and follow up mechanisms that make lower carbon choices legitimate alongside cost and quality constraints.

The overlaps highlight why single point interventions often fail. For example, relational engagement can improve credibility by enabling supplier specific inputs and stronger traceability over time. Scalability supports credibility and action only when governance defines what counts as "good enough" data and when procurement rules specify how carbon information changes choices. Actionability reinforces relational engagement when decision rules and incentives create consistent market signals to priority suppliers. The central overlap, Scope 3 Alignment, captures the study's core implication: measurement improvements, disclosure mandates, or AI tools are unlikely to deliver sustained reductions unless credibility, relationships, scalability, and actionability reinforce one another in routine decision making.

In this sense, the framework is offered as an integrative lens, derived from the empirical material and interpreted in light of prior literature, rather than as a universal maturity model.

6. Conclusion

This study set out to understand how practitioners involved in manufacturing value chains approach Scope 3 emissions reduction in practice, focusing on supplier engagement, measurement and monitoring, and the management of trade-offs in procurement and product related decisions. Drawing on eight semi structured interviews conducted between February and May 2025, the findings show that persistent technical challenges are only part of the difficulty. Participants repeatedly emphasised that the binding constraint is often organisational: weak governance for Scope 3 ownership, limited decision authority to act on carbon information, and supplier engagement models that remain disclosure heavy rather than capability building. Taken together, these patterns support a reframing of Scope 3 management as not only a measurement challenge, but an alignment challenge, where data, incentives, decision rules, and relationships must be configured to make decarbonisation operational.

Building on this evidence, the paper proposes the Scope 3 Alignment Framework. The framework organises actionable Scope 3 capability into four interdependent domains: making Scope 3 credible, making Scope 3 relational, making Scope 3 scalable, and making Scope 3 actionable. The central overlap, Scope 3 Alignment, captures the core implication of the findings: advances in tools or disclosure standards are unlikely to deliver reductions unless these domains reinforce one another in day to day decision making.

The findings contribute to Scope 3 scholarship in three ways. First, they complement method focused research by foregrounding the organisational conditions under which Scope 3 information becomes usable for decisions. Second, they extend supplier engagement discussions by distinguishing between transactional disclosure routines and more relational or incentive based approaches, while highlighting how leverage, supplier segmentation, and contextual constraints shape what is feasible. Third, they clarify the role of AI as enabling workflow acceleration while remaining bounded by input quality, human judgement, and practical constraints including adoption risk and energy intensity considerations raised by participants.

For corporate sustainability leaders, Scope 3 programme owners, and ESG reporting teams, the results suggest prioritising not only accounting tools but also the mechanisms that convert insights into action: clear ownership and accountability for Scope 3 categories, baseline governance, and auditable data traceability. For procurement directors, category managers, and supplier relationship managers, the findings highlight the value of decision rules that legitimise carbon aware trade-offs and engagement models that move beyond one way data requests toward capability building with priority suppliers. For Tier 1 suppliers and supplier sustainability teams, the framework clarifies what buyers' "serious" engagement looks like in practice. For policymakers, standard setters, and industry initiatives, the findings imply that disclosure mandates and technical guidance are necessary but insufficient: implementation is strengthened when requirements are paired with incentives, comparability infrastructure, and governance expectations that cascade into procurement and supplier facing processes. Indirectly, investors, lenders, and assurance providers benefit from more decision grade Scope 3 data and clearer accountability, which improves the credibility and comparability of reported progress.

This study has several limitations that shape how the conclusions should be interpreted. The evidence is based on eight interviews and therefore provides analytic rather than statistical generalisation; it offers depth into recurring patterns but cannot claim representativeness across manufacturing sectors or geographies. Participants worked across manufacturing value chains, including roles in consulting and enabling organisations, which strengthens breadth of perspective but also means the sample is not restricted to internal roles within manufacturing firms. In addition, the study relies on self-reported practices rather than direct observation of organisational processes, which may influence how challenges and practices are represented.

The geographical distribution of the sample is skewed toward developed economies (Europe, North America, and Oceania), with more limited representation from developing contexts. This reflects the current maturity and institutionalisation of Scope 3 practices, which are more established in regions with stronger regulatory frameworks and reporting requirements. However, this imbalance may limit the transferability of findings to contexts where sustainability governance, data infrastructures, and supplier capabilities are less developed. Finally, supplier engagement dynamics may differ significantly beyond Tier 1 suppliers, where visibility and influence are more limited, and this is only partially captured in the current sample. Future research could therefore examine how Scope 3 implementation differs across regulatory and economic environments, particularly in emerging markets, and across different supply chain tiers.

Overall, the study reinforces a practical implication: progress on Scope 3 is unlikely to come from better data or regulation alone. Progress will likely depend on whether organisations build the internal and interorganisational alignment that allows existing tools, supplier information, and procurement choices to translate into consistent,

accountable decarbonisation action.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

CRediT authorship contribution statement

Soufiane El Khiam: Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Lampros Litos:** Writing – review & editing, Visualization, Validation, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Semi structured interview guide

A0. Opening, ethics, and context

1. **Study purpose:** "This interview explores how organisations approach Scope 3 emissions reduction in practice, focusing on (i) supplier engagement, (ii) measurement and tracking, and (iii) procurement/governance and trade-offs."
2. **Consent & confidentiality**

A1. Participant role and organisational context

3. **Role overview:** "Could you describe your role and how it relates to Scope 3 emissions reduction or reporting?"
4. **Scope of involvement:** "Which parts of Scope 3 work are you most involved in?"
5. **Organisational setting:** "What sector(s) and geographies does your work primarily cover, and how does that shape the Scope 3 topics you encounter?"

RQ2 - Measurement and tracking of Scope 3 emissions

A2. Scoping and prioritisation

6. **Scoping process:** "How do you typically scope Scope 3 for an organisation?"
7. Materiality approach: "How do you identify which Scope 3 categories are most material or most important to focus on?"
8. Prioritising suppliers/products: "What criteria, if any, are used to prioritise suppliers or product areas for deeper measurement or engagement?"

A3. Measurement approaches in practice

9. **Current methods used:** "What approaches do you see organisations using to quantify Scope 3 emissions?"
10. **Phasing over time:** "How do organisations combine or transition between these approaches over time?"
11. **Data infrastructure barriers:** "What practical factors affect the ability to start or improve Scope 3 measurement?"
12. **Data hierarchy:** "How do organisations handle differences in data quality?"
13. **Comparability:** "When comparing footprints across suppliers/products, what makes comparability easier or harder?"
14. **Tool consistency:** "If multiple tools/calculators are used, how do organisations assess consistency or differences between outputs?"

A4. Monitoring and progress tracking

15. **Repeatable monitoring:** "How do organisations set up repeatable monitoring?"
16. **Baseline changes:** "How do organisations interpret changes in Scope 3 results over time when methods or data quality are improving (when the baseline may shift)?"
17. **Verification/assurance:** "What forms of assurance or verification are involved, if any, and how does that influence measurement choices or reporting behaviour?"

RQ1 - Supplier engagement for Scope 3 reduction

A7. Forms of supplier engagement

18. **Engagement modes:** "What forms of supplier engagement do you observe?"
19. **Development vs selection:** "When is supplier development used versus supplier selection/deselection, and what factors influence that choice?"
20. **Leverage and relationships:** "How do relationship structures or buyer leverage affect what engagement is feasible?"
21. **Supplier requirements:** "What types of requirements are used in practice, and how are they applied?"
22. **SMEs vs large suppliers:** "How do approaches differ for SMEs versus large or strategic suppliers?"

RQ3 - Procurement, governance, and trade-offs

A8. Procurement as an execution mechanism

23. **Decision criteria:** "How is carbon information integrated into procurement decisions alongside cost, quality, risk, and availability?"
24. **Operationalisation:** "What mechanisms are used to operationalise sustainability within procurement?"
25. **Decision rules:** "Are there governance mechanisms that make lower carbon choices easier to justify?"

A9. Internal governance and accountability

26. **Ownership:** "Who typically owns Scope 3 data, monitoring, and reporting inside organisations (functions/roles), and how is responsibility coordinated?"
27. **External signals:** "What external signals most influence Scope 3 action, and how do they interact with internal governance?"

A10. Managing complexity in sustainable product decisions

28. **Complexity management:** "How do organisations manage increasing complexity in sustainable product and supply decisions?"
29. **Link to product/process levers:** "How is supplier engagement connected to product/process changes identified through LCA or hotspot analysis?"

Cross cutting - AI and digital tools

A11. Where AI/tools help and where limits exist

30. **Use cases:** "Where do digital tools or AI support Scope 3 work in practice (e.g., data extraction, categorisation/normalisation, validation, prioritisation, monitoring)?"
31. **Human oversight:** "Which parts typically require human judgement, and which parts can be automated?"

Data availability statement

The data that support the findings of this study are based on expert interviews conducted with sustainability professionals across manufacturing sectors. Due to confidentiality agreements and ethical considerations, the full transcripts of these interviews are not publicly available.

However, anonymized thematic data and summaries have been presented within the article to support transparency and reproducibility. Further details may be available from the corresponding author upon reasonable request, subject to the interviewees' consent and institutional approval.

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2026-12
Elsevier
https://doi.org/10.1016/j.clman.2026.100006
El Khiam S, Litos L. (2026) Industry Perspectives on Scope 3 Emissions Reduction in Manufacturing: Challenges, Opportunities, and the Role of AI. Cleaner Manufacturing, Volume 1, Issue 2, December 2026, Article number 100006

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