

Infrastructuring socio-ecological stewardship: accounting, governance and circular economy transitions in construction

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Abstract

Purpose – This study examines how accounting, adaptive governance and financial infrastructures interact with circular economy (CE) initiatives in the construction industry. It explores how product-as-a-service (PaaS) business models challenge conventional assumptions around ownership, valuation and accountability, foregrounding accounting's infrastructural role in shaping socio-ecological stewardship and long-term material commitments.

Design/methodology/approach – This is a qualitative exploratory study of two PaaS cases (“Road-as-a-Service” and “Façade-as-a-Service”) incorporating eleven focus groups with 45 professionals from financial, legal and technical domains. Data are thematically analysed through a framework integrating corporate biosphere stewardship, adaptive governance and radical traceability, while remaining open to emergent institutional tensions.

Findings – The findings highlight frictions between CE aspirations and linear infrastructures underpinning organisational practices. Participants surfaced challenges around residual value estimation, intertemporal accountability, financing adaptability and governance flexibility. These challenges crystallised into three interconnected themes – transition accountability, adaptive governance and material stewardship – which structure the analysis of how circular economy principles encounter existing institutional arrangements. Accounting emerged not merely as a reporting function but as a dynamic, contested site where ecological, material and financial futures are recursively negotiated and reconfigured. Socio-ecological stewardship emerged as a situated practice requiring continual realignment of valuation, governance and traceability infrastructures across institutional and temporal boundaries.

Originality/value – This study contributes to understanding accounting as constitutive infrastructure for sustainability transitions, moving beyond instrumental approaches to accounting for sustainability. It provides empirical insights into how accounting, legal and financial infrastructures might be reconfigured to support more adaptive and ecologically attuned business practices, offering a situated perspective for enabling socio-ecological stewardship in construction.

Keywords Circular economy, Socio-ecological stewardship, Sustainability accounting, Product-as-a-service, Construction industry, Transition accountability, Adaptive governance, Material stewardship

Paper type Research article



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1. Introduction

The circular economy (CE) has emerged as a prominent agenda across policy, business, and academic domains, aiming to disrupt the dominant “take–make–waste” linear model of industrial production and consumption (Korhonen *et al.*, 2018; Kirchherr *et al.*, 2023). CE has been postulated as a regenerative economic system underpinned by alliances between industry, consumers, policymakers, and academia to enable value maintenance, environmental quality, and social equity across generations (Kirchherr *et al.*, 2023). Rooted in interdisciplinary inquiry, ethical considerations of planetary boundaries, and a growing recognition of systemic interdependencies (Murray *et al.*, 2017), CE principles prioritise reuse, refurbishment, regeneration, and systemic material cycling to realign economic activity with the ecological limits of the planet. This evolving understanding increasingly resonates with contemporary accounting scholarship that calls for integrating ecological and societal dimensions into business, valuation, and governance practices (Arjaliès *et al.*, 2023; Bebbington *et al.*, 2024a; Elliot *et al.*, 2024; Bekier and Parisi, 2025; Larrinaga and Garcia-Torea, 2022).

The broadening of CE thinking reinforces recognition that traditional linear economic models are inadequate to address the pressing contemporary environmental and social challenges. This is particularly evident in material- and carbon-intensive sectors such as construction, which alone accounts for nearly 38% of global CO₂ emissions and 40% of raw material use (Farhadi, 2024; UNEP, 2021). Despite escalating policy attention – from the United Nations Sustainable Development Goals (SDGs) to the European Union’s Circular Economy Action Plans (European Commission, 2015, 2020) – progress remains limited. Recent assessments suggest that just 6.9% of the global economy was circular in 2025, down from 9.1% in 2018 (Circle Economy, 2025). This reversal underscores the stubborn resilience of linear infrastructures and invites deeper interrogation of the institutional, financial, and epistemic systems that mediate circularity in practice.

Scholars increasingly advocate for reframing CE not merely as a matter of waste management but as a site of broader systemic transformation, linking resource cycles with questions of responsibility, valuation, and intergenerational equity (Busco *et al.*, 2024; Arjaliès *et al.*, 2023; Lamont *et al.*, 2023). Recent research highlights that achieving net-zero emissions targets under the Paris Agreement will require CE strategies to account for approximately 45% of emissions reductions by 2050 – beyond what energy efficiency and renewable energy alone can deliver (Ellen MacArthur Foundation, 2015, 2020, 2022). Within this context, construction emerges as a critical site for intervention, demanding innovations in ownership models, material stewardship, and long-term value accounting (Farhadi, 2024; Georg and Justesen, 2017).

Nonetheless, despite the conceptual resonance between CE ambitions and sustainability objectives, accounting and accountability systems remain ill-equipped to support the transition. Traditional financial infrastructures – anchored in short-term asset depreciation, ownership transfer, and linear cash flow models – struggle to represent the circular materiality, shared responsibilities, and extended temporalities central to CE models (Marrone *et al.*, 2020; Moses and Hopper, 2022). As Bebbington and Rubin (2022, p. 584) observe, accounting often fails to “recognise the interconnectedness of organisations with the ecological systems upon which they depend.” These limitations point not only to technical shortcomings but also to deeper institutionalised assumptions embedded within contemporary accounting, governance, and financial infrastructures.

While literature offer promising directions – including frameworks for shaping nature outcomes (Bebbington *et al.*, 2024a), radical traceability infrastructures (Jørgensen *et al.*, 2023), and experimental governance models (Arjaliès *et al.*, 2023) – deeper empirical engagement remains scarce. Contributions by Lamont *et al.* (2023) and Elliot *et al.* (2024) highlight how corporate action might meaningfully link to ecological regeneration. Yet, these insights often operate at the policy or organisational level, leaving the micro-foundations of accounting practice and governance infrastructures underexplored. As Moses and Hopper (2022, p. 1052) note, “Sadly, studies addressing innovations such as shifting to low carbon or

the circular economy [...] lie in non-accounting journals.” Addressing this research gap requires moving beyond high-level conceptualisations toward situated investigations of how accounting, legal, and financial infrastructures are implicated in CE transitions on the ground.

This study addresses the dearth of innovative CE accounting studies identified by [Moses and Hopper \(2022\)](#) by examining how Product-as-a-Service (PaaS) business models challenge and reconfigure accounting frameworks in the construction sector – a domain where capital intensity, asset longevity, and multi-stakeholder coordination amplify the tensions inherent in CE implementation. PaaS models shift the basis of value from asset ownership to service provision over time, retaining provider responsibility for material performance and recovery ([Tukker, 2015](#); [Linder and Williander, 2017](#)). Such models require rethinking asset recognition, residual value estimation, and risk-sharing structures across extended timeframes – dimensions that conventional accounting systems are poorly equipped to accommodate ([Charef and Lu, 2021](#); [Andersson and Buser, 2022](#); [Dávila et al., 2024](#)).

To explore these dynamics, the researchers analyse two pioneering case studies in the Netherlands: “Road-as-a-Service” and “Façade-as-a-Service.” Drawing on eleven focus groups with professionals representing accounting, legal, and financial domains, CE principles are traced, translated, contested, and sometimes constrained through accounting practices. Building on other studies that postulate about the neutrality of accounting ([Solomons, 1991](#); [Fogarty and Radcliffe, 1999](#); [Abrás and Jayasinghe, 2023](#)), this research approaches it as an infrastructural [1] and activated flow site where material futures are rendered (in)visible, actionable, or foreclosed. Analysis is guided by the concept of socio-ecological stewardship ([Folke et al., 2019](#); [Bebbington and Rubin, 2022](#); [Bebbington et al., 2024b](#)), which conceptualises firms as embedded actors within dynamic ecological systems, bearing responsibilities that extend beyond immediate financial returns. Stewardship perspectives foreground the need for accountability mechanisms that are relational, adaptive, and capable of recognising ecological interdependencies across spatial and temporal scales.

Within this framing, the research investigates the spaces between three interdependent dimensions. First, how firms account for their material embeddedness within ecological systems (corporate biosphere stewardship). Second, how contractual, financial, and organisational arrangements evolve to accommodate uncertainty and long-term stewardship (adaptive governance). Third, how infrastructures of material tracking and accountability are reconfigured to enable circular material flows (radical traceability).

To explore the identified interdependencies, this study addresses the following research questions:

- (1) How do Product-as-a-Service (PaaS) business models in construction challenge and reconfigure conventional accounting infrastructures, adaptive governance arrangements, and financial infrastructures?
- (2) What forms of accountability emerge when circular economy principles are operationalised through situated stewardship practices (hereafter, *Transition Accountability*)?
- (3) How might accounting measures, adaptive governance arrangements, and financial infrastructures be relationally reimaged to support dynamic socio-ecological stewardship across circular economy transitions?

For clarity, the researchers have used adaptive governance to denote arrangements that coordinate responsibilities under uncertainty and over extended timescales. Financial infrastructures refer to the interlocking instruments, rules and intermediaries (e.g. loan terms, covenants, securitisation logics) that shape bankability and risk allocation. Stewardship practices are the situated, ongoing activities through which material and socio-ecological care is enacted. Forms of accountability are examined empirically as Transition Accountability,

that is, the calculative devices and routines that render future material value visible and auditable across organisations.

By engaging with these questions, the aim is to contribute to a growing stream of scholarship that moves beyond accounting for sustainability toward accounting with sustainability – treating accounting as an active infrastructure implicated in the constitution of socio-ecological futures (Fernández Chulián *et al.*, 2025; Jabot *et al.*, 2025) – while responding to calls for engaging with “big issues” via diverse methodological approaches (Parker, 2014). Through empirical engagement with situated cases, the research offers a reflexive and problematising account of how accounting practices, financial instruments, and governance arrangements might be reimagined to enable more durable, regenerative, and equitable material economies in construction and beyond.

As Tran *et al.* (2025, p. 1) emphasise, progress toward circular transitions will require overcoming the current dominance of “meso-level institutions” and paying greater attention to “micro transformation to cut waste and enable improvements in green productivity.” This study directly responds to that challenge by foregrounding the micro-level dynamics of accounting, governance, and stewardship within emerging CE business models (see Tables 1 and 2).

2. Accounting, governance, and circular economy transitions

While CE has gained prominence as a strategic response to planetary boundaries (Barker and Mayer, 2025; Williams *et al.*, 2025), its intersection with accounting remains under-theorised and unevenly explored. This section reviews the literatures that inform and motivate this study: accounting and CE, circular transitions in construction, PaaS models, and the emerging lens of socio-ecological stewardship. In doing so, it foregrounds the need to move beyond instrumental extensions of accounting tools toward a more profound interrogation of accounting’s role as an infrastructural condition of socio-ecological transformation.

2.1 Accounting and the circular economy: reframing value, temporality, and accountability

Despite growing attention to sustainability, accounting scholarship has struggled to keep pace with the systemic and intertemporal challenges posed by CE transitions. Much of the existing literature remains anchored in disclosure practices, sustainability reporting frameworks, and voluntary impact metrics (Bebbington and Larrinaga, 2014; Marrone *et al.*, 2020). While these

Table 1. Focus group participants and their backgrounds

Organisation type*	Road-as-a-service business model		Façade-as-a-service business model	
	Number of organisations	Number of participants	Number of organisations	Number of participants
Accounting firm	2	3	1	2
Case representative organisation	2	5	4	7
Consulting firm	1	3	1	4
Financial institution	3	6	4	9
University	4	4	2	2
Legal firm	–	–	2	2
Social enterprise	1	3	1	3
Total	13	23	16	29

Note(s): * Participants were each given a unique number starting with “PART,” followed by the first letters of the coding referring to the type of organisation: ACC = accounting firm, CASE = case representative organisation, CONS = consulting firm, FIN = financial institution, UNI = University, LEG = legal firm, SOC = social enterprise

Table 2. Overview of the three-step coding structure linking theoretical dimensions to empirical themes

Socio-ecological stewardship dimensions	Topics (coding step 1)	Topics (coding step 2)	Central themes (coding step 3)	
Corporate biosphere stewardship	1. Resource Responsibility	1.1 Material Lifecycle Management	TA	
		1.2 Ecological Embeddedness	TA	
		2.1 Sustainability Challenges	MS	
	2. Sustainability Values	2.2 Waste Awareness	MS	
		3. Ecological Valuation	3.1 Material Value Assessment	TA
	3.2 Long-term Value Recognition		TA	
	3.3 Risk-Value Reframing		TA	
	Adaptive governance	4. Governance Structures	4.1 Dynamic Contract Design	AG
			4.2 Stakeholder Collaboration	AG
4.3 Decision-Making Processes			AG	
5. Financial Mechanisms		5.1 Innovative Financing Models	AG	
		5.2 Risk Management Approaches	AG	
		5.3 Financial Incentives Alignment	AG	
6. Operational Adaptability		6.1 Technology Integration	AG	
		6.2 Performance Monitoring	AG	
		6.3 Service Model Evolution	AG	
Radical traceability		7. Material Tracking	7.1 Digital Monitoring Systems	MS
			7.2 Lifecycle Documentation	MS
		8. Information Transparency	8.1 Accountability Mechanisms	MS
	8.2 Stakeholder Communication		MS	
	9. Value Chain Integration	9.1 Supplier Engagement	MS	
		9.2 Cross-Sector Collaboration	MS	
		9.3 Market Development	MS	

Note(s): TA = Transition Accountability; AG = Adaptive Governance; MS = Material Stewardship

initiatives have advanced corporate transparency, they leave largely unexamined the deeper assumptions embedded in accounting's construction of value, ownership, and temporality (Parker, 2014). Evidence from U.S. corporate sustainability reports suggests that CE terminology is often deployed symbolically, with limited substantive transformation of underlying business practices or accountability structures (Olczak *et al.*, 2023).

Conventional accounting infrastructures – premised on linear flows of production, consumption, and disposal – are poorly equipped to accommodate the regenerative logics and material continuities central to CE strategies (de Aguiar and Bebbington, 2021; Wishart and Antheaume, 2021). Standard asset depreciation models, event-based revenue recognition, and entity-bound reporting conventions reflect assumptions about the ownership and degradation of value over short, discrete periods. These mechanisms struggle to represent the distributed responsibilities, material stewardship commitments, and extended lifecycles demanded by circular business models (Gibassier and Alcouffe, 2018; Aureli *et al.*, 2025). This disconnection between sustainability rhetoric and accounting practice reflects broader organisational tensions, where circular ambitions often outpace the structural changes necessary for their enactment, particularly the reform of incentive systems and accountability mechanisms (Arvidsson, 2023; Waqas, 2025).

Accounting's temporal framing proves especially ill-suited to CE demands. CE initiatives often unfold over decades – requiring adaptive governance arrangements capable of managing evolving asset states, residual value recovery, and intergenerational responsibility. Yet dominant accounting systems remain anchored in annual financial cycles, historical cost conventions, and short-term profitability metrics (Larrinaga and Garcia-Torea, 2022). As Di

Vaio *et al.* (2023) argue, without a profound shift in temporal framing, accounting risks not merely lagging in CE ambitions but actively foreclosing their institutionalisation by privileging immediacy over material continuity. These challenges suggest that forms of accountability must emerge through situated, relational practices rather than fixed mechanisms (Bekier and Parisi, 2025; Moerman *et al.*, 2023).

While approaches such as lifecycle costing, material flow accounting, and biodiversity metrics have been proposed (Scarpellini *et al.*, 2020; Elliot *et al.*, 2024), their integration into mainstream financial infrastructures remains often siloed. Frequently, such innovations are relegated to compliance domains, failing to challenge the underlying architectures of valuation and organisational control. As confirmed by a recent systematic review, traditional accounting and accountability models remain poorly equipped to accommodate CE principles, often privileging linear, short-term economic logics over material stewardship and long-term value preservation (Di Vaio *et al.*, 2023).

Emerging perspectives increasingly view accounting not as a neutral measurement apparatus but as a performative infrastructure – one that co-produces the material, ecological, and financial realities within which organisations operate (Bebbington and Rubin, 2022; Heikkilä, 2023). From this vantage point, accounting systems are not merely reflective of circular ambitions but actively shape the material imaginaries, asset flows, and value commitments that enable or constrain CE transitions.

Empirical investigations into how accounting infrastructures interact with CE business models – particularly in resource-intensive, path-dependent sectors – remain sparse. Among such sectors, the construction industry stands out as noted in the last section. Its material scale, carbon footprint, and embedded institutional routines present both a critical opportunity and a profound challenge for the reconfiguration of accounting practices in support of circularity. The next section examines the construction sector.

2.2 *The built environment: circularity, lock-in, and institutional inertia*

The construction sector occupies a pivotal position in CE transitions. While the construction sector is regarded as a promising domain for CE applications (Zandee *et al.*, 2024; David *et al.*, 2025), its fragmented structure, project-based nature, and entrenched linear practices present formidable barriers to systemic transformation (Çimen, 2021). Challenges around the design of circular construction processes, stakeholder coordination, and long-term material tracking have been identified as critical obstacles to implementing circular strategies at scale (Benachio *et al.*, 2020).

Policy frameworks generally advocate for circular construction through modular design, prefabrication, design-for-disassembly, and digital material passports (Charef and Lu, 2021; Eberhardt *et al.*, 2019), while real-world implementation remains constrained. Global reviews of construction sector practices (Bocken *et al.*, 2019; Antwi-Afari *et al.*, 2021) confirm that despite rising awareness, the uptake of CE principles remains fragmented, with limited systemic integration and persistent reliance on traditional linear models (Guerra *et al.*, 2021). Among the factors contributing to this inertia are linear procurement logics, ownership-centric financing models, and fragmented governance structures, which undermine the viability of long-term material stewardship arrangements (Azcarate-Aguerre *et al.*, 2022; Andersson and Buser, 2022).

While accounting scholarship has increasingly acknowledged the significance of material stewardship and long-term value creation in construction (Bebbington *et al.*, 2024a; Larrinaga and Garcia-Torea, 2022), complementary research from construction management and sustainability fields similarly highlights the sector's pivotal role in achieving CE transitions. For instance, Antwi-Afari *et al.* (2021) identify the construction industry as a key sector where CE initiatives can reduce resource consumption and mitigate environmental impacts. In parallel, Dávila *et al.* (2024, p. 2167) observe that “sustainability and the circular economy were also taking a dominant role in the real estate industry,” particularly in relation to

renovation and new construction practices. Together, these insights reinforce the view that the construction sector is both a high-impact target and a challenging frontier for embedding CE principles.

Accounting infrastructures are deeply implicated in this inertia. Capital budgeting practices privilege short project horizons and front-loaded revenue models, while standard depreciation schedules incentivise rapid asset turnover over maintenance, reuse, or remanufacture (Abdulai *et al.*, 2024; Tran *et al.*, 2025). Moreover, conventional financial reporting fails to accommodate distributed ownership structures or lifecycle-based performance metrics (Deegan, 2013), conditions critical for sustaining circular models in construction.

Beyond technical barriers, the fragmentation of construction value chains – involving contractors, subcontractors, financiers, regulators, and clients – inhibits intertemporal coordination and ecological accountability (Brodhag, 2021). Although the promise of CE for the built environment is well-articulated at the policy level, academic and professional discourse often remains focused on design innovations, overlooking the infrastructural reforms necessary for systemic change. Thus, the construction sector serves as both a testing ground and a critical case for examining how accounting and governance systems might be reimaged to support circular transitions at scale.

2.3 Product-as-a-service models (PaaS): material stewardship and the reconfiguration of value

PaaS business models have gained increasing traction as a means of aligning value creation with durability, reuse, and long-term material stewardship. Rather than selling goods outright, firms offer outcomes or functionalities – such as lighting, heating, or structural performance – while retaining ownership of the physical asset (Tukker, 2015; Linder and Williander, 2017). In doing so, PaaS models reposition firms as custodians of material assets, incentivised to maximise product longevity, minimise waste, and recover residual value. Research has underscored that transitioning to circular service models such as PaaS requires not only technical innovations in design and durability, but also organisational capabilities for managing long-term stakeholder relationships and adaptive financing structures (Saari *et al.*, 2024). These capabilities align with emerging evidence that environmental accounting practices, when embedded as dynamic organisational capabilities, expand firms' circular scope (Scarpellini *et al.*, 2020).

This logic fits closely with CE principles. By decoupling use from ownership, PaaS models encourage design for modularity, maintenance, and reuse across extended life cycles. In construction, emerging applications such as elevators, façades, or road surfaces delivered as services illustrate how providers assume responsibility for upkeep and material performance over multi-decade timeframes (World Economic Forum, 2022; Busco *et al.*, 2024). Revenue recognition shifts from point-in-time capital sales to service-based income streams, often require bespoke contract accounting over long durations. Depreciation schedules must reflect retained ownership, even when assets are physically located off-balance-sheet. Risk provisioning becomes more complex, particularly when asset performance is co-produced by clients, suppliers, and service providers across distributed ownership networks (Koers *et al.*, 2024; Bebbington and Larrinaga, 2014).

PaaS contracts themselves demand new forms of technical, financial, and legal embeddedness. Rather than fixing obligations at inception, contracts must anticipate evolving material states, renegotiation triggers, maintenance interventions, and end-of-life asset transitions. This contractual complexity fundamentally challenges traditional cost accounting systems – which privilege isolated projects, clear ownership transfer, and static asset valuations – rendering them insufficient for managing accountability within circular ecosystems (Aureli *et al.*, 2025; Arjalies *et al.*, 2023).

Vernacular innovations have begun to emerge as actors experiment with new practices. Heikkilä (2023) documents how circular construction networks develop “value-based

business” models that blend maintenance regimes, environmental monitoring, and adaptive accounting routines. Similarly, [Parisi and Bekier \(2022\)](#) highlight how municipalities engaged in circular projects co-create performance indicators tailored to local material flows, regulatory frameworks, and citizen engagement. These studies illustrate that new accounting forms are not purely technical adaptations, but situated, negotiated responses to the normative and institutional tensions of circular transition.

Yet despite such promising developments, the broader field remains conceptually fragmented and empirically thin. As [Moses and Hopper \(2022\)](#) note, critical investigations into accounting’s role in enabling or constraining CE adoption often remain located outside traditional accounting journals, suggesting an urgent need for deeper interdisciplinary engagement and theoretical innovation within the accounting field itself. Against this backdrop, PaaS models represent a critical empirical site – and a conceptual frontier – for rethinking how accounting can support material stewardship, distributed accountability, and regenerative business models across extended temporal horizons.

2.4 Reframing accounting through socio-ecological stewardship

Collectively, the strands of literature highlight the need for a more profound reframing of accounting’s role within CE transitions. Circularity is not simply a technical adjustment to existing practices; it demands systemic reconfigurations of how value, responsibility, and accountability are defined, operationalised, and institutionalised.

This paper presents a socio-ecological stewardship framing that treats accounting not as a passive, representational tool but as a dynamic infrastructural practice – one that actively co-produces material, economic, and ecological realities ([Folke et al., 2019](#); [Bebbington and Rubin, 2022](#); [Bebbington et al., 2024b](#)). From this perspective, stewardship entails recognising firms as embedded actors within broader socio-ecological systems, bearing intertemporal responsibilities that extend beyond contractual closure or fiscal cycles. Stewardship-oriented accounting practices would centre on maintaining material continuity, fostering adaptive governance arrangements, and sustaining intergenerational ecological viability – in stark contrast to the transaction-focused, entity-bound logics of conventional financial reporting.

Rather than simply expanding disclosure regimes or layering environmental metrics onto existing structures, a socio-ecological stewardship approach invites more radical reflection ([Bebbington and Rubin, 2022](#)). It asks how accounting systems could be reconfigured to trace ecological entanglements, valorise regenerative material flows, and support collaborative, flexible governance across multiple temporal and organisational scales ([Bebbington et al., 2024b](#); [Jørgensen et al., 2023](#)). Critically, this perspective does not assume that new accounting tools alone will suffice. It foregrounds accounting as a contested terrain, where ecological futures are rendered more or less visible, actionable, or foreclosed through situated infrastructural practices. By treating accounting as a constitutive site of socio-ecological negotiation, this paper opens pathways for research that moves beyond accounting *for* sustainability toward accounting *with* sustainability – embracing accounting’s potential to materially enable, rather than merely monitor, circular and regenerative economic transitions.

3. Theoretical framing: stewarding material flows, accountability, and valuation in circular economy transitions

CE invites organisations to fundamentally rethink their engagements with material flows, ecological systems, and intergenerational responsibilities. As [Bebbington and Rubin \(2022\)](#) and [Folke et al. \(2019\)](#) emphasise, realising such systemic transformations demands more than technological innovation or managerial reform – it requires new modes of accounting and governance capable of navigating socio-ecological complexity. Accounting’s role in socio-ecological transitions has been increasingly framed as infrastructural and performative rather

than purely representational (Moses and Hopper, 2022; Baker *et al.*, 2023). From this perspective, stewardship initiatives are not merely technical extensions of existing practices but contested efforts to reconfigure material, temporal, and organisational imaginaries under conditions of uncertainty and competing interests.

This study draws on the evolving concept of socio-ecological stewardship to interrogate how accounting systems are implicated in – and potentially reshaped by – efforts to implement CE models in resource-intensive industries. Stewardship, in this framing, is not a static principle to be operationalised, but an emergent, negotiated, and contested practice that challenges foundational assumptions about value, responsibility, and organisational boundaries (Bebbington *et al.*, 2024b; Jørgensen *et al.*, 2023; Perkiss *et al.*, 2025). Through a socio-ecological stewardship lens, accounting is a relational infrastructure – one that both reflects and shapes how organisations engage with ecological interdependencies and future material flows. This framing foregrounds three mutually constitutive dimensions: *corporate biosphere stewardship*, *adaptive governance*, and *radical traceability*.

3.1 Corporate biosphere stewardship: accounting beyond organisational boundaries

The concept of *corporate biosphere stewardship* originates in sustainability science and has been extended to corporate contexts to reflect the idea that firms are not external to the biosphere but materially and ethically embedded within it (Folke *et al.*, 2019; Bebbington and Rubin, 2022). Stewardship implies an obligation not merely to reduce harm, but to actively support the regenerative capacity of ecological systems upon which economies depend.

From an accounting perspective, this dimension destabilises the treatment of natural resources as inputs or externalities and reframes them as co-produced sources of value. In sectors such as construction, this has direct implications for how materials are acquired, designed, tracked, and valued. Rather than viewing concrete, steel, or façade elements as depreciable commodities, stewardship invites firms to see these materials as ecological assets – with durability, reuse potential, and embedded ecosystem value.

Prevailing accounting systems, however, remain poorly equipped to recognise these relationships. Historical cost conventions and entity-bound reporting frameworks tend to obscure the systemic material dependencies that underlie asset valuations (Larrinaga and Garcia-Torea, 2022). Although integrated reporting initiatives and ESG frameworks have attempted to address environmental impacts, they often remain decoupled from core financial logic and decision-making structures (Bebbington *et al.*, 2024a).

Corporate biosphere stewardship thus challenges accounting to move beyond surface-level disclosures and to reorient its representational practices toward material durability, ecological interdependence, and intertemporal risk – particularly where firms retain ownership of materials over extended life cycles, as in PaaS arrangements. However, as Heikkilä (2023) and Costa *et al.* (2023) highlight, efforts to embed ecological stewardship into corporate accounting often encounter tensions between sustainability ambitions and entrenched economic rationalities, suggesting that stewardship practices must negotiate, rather than assume, new material value logics.

3.2 Adaptive governance: accounting for complexity, uncertainty, and shared responsibility

While biosphere stewardship emphasises material interconnectedness, *adaptive governance* addresses the institutional capacity needed to manage socio-ecological complexity over long time horizons. In contrast to control-based models premised on standardisation and predictability, adaptive governance entails flexibility, ongoing learning, and the negotiation of shared responsibility among diverse actors (Chaffin *et al.*, 2014; Folke *et al.*, 2019; Lamont *et al.*, 2023).

This dimension is especially salient in construction, where the delivery of built assets typically involves a constellation of contractors, suppliers, regulators, and clients, each with

distinct interests and risk profiles. The implementation of circular business models – such as PaaS – compounds this complexity by extending material responsibility across organisational boundaries and over decades.

For accounting, adaptive governance calls into question the adequacy of periodic, backward-looking financial reporting to support forward oriented, negotiated accountability (Rinaldi, 2019; Arjalies *et al.*, 2023). Conventional accounts privilege fixed performance metrics and pre-defined risk allocations. Yet CE arrangements demand accounting infrastructures that enable dynamic valuation, stakeholder-inclusive planning, and scenario-based performance monitoring (Sobkowiak *et al.*, 2025; Arjalies *et al.*, 2023).

The ability to account for shifting contractual relationships, evolving ecological risks, and emergent material states becomes central. Governance, in this view, is not an *ex post* control exercise but an anticipatory practice in which accounting participates – mediating evolving claims to value, risk, and responsibility across time and across actors. Recent studies (e.g. Busco *et al.*, 2024) underline that adaptive governance in sustainability contexts often involves not only technical innovations but also complex negotiations over organisational accountability, stakeholder legitimacy, and evolving material imaginaries.

3.3 *Radical traceability: accounting for material flows across time and space*

The third dimension, *radical traceability*, addresses the informational infrastructure necessary to enact stewardship in practice. Traceability has long been a feature of accounting systems, but traditionally it has focused on tracking financial transactions within fixed organisational and temporal boundaries.

Radical traceability, by contrast, demands the ability to follow material, ecological, and financial flows across time, space, and institutions (Bebbington and Rubin, 2022; Jørgensen *et al.*, 2023). It extends accountability beyond the firm to encompass value chain partners, regulatory systems, and future users – making visible the distributed and intertemporal risks associated with material engagements. Empirical studies in sectors such as fashion and manufacturing further demonstrate that robust traceability and transparency infrastructures are critical for enabling sustainable material flows and circular business models across distributed supply chains (Rinaldi *et al.*, 2022). Evidence from industrial product-service systems similarly shows how digital data enable circular control and resource-loop decisions across partners (Johnstone, 2024).

In construction, where materials often pass through fragmented supply chains and multiple ownership changes (Zandee *et al.*, 2024), traceability is critical for operationalizing CE principles such as reuse, remanufacturing, and recovery. For PaaS models, accurate tracking of material condition, location, and embedded value underpins the economic and ecological rationale for retaining ownership. Yet existing accounting systems are poorly adapted to these demands. They tend to treat materials as either inventory or expended costs, offering little capacity to account for material states, residual value, or ecological functions over extended periods (Marrone *et al.*, 2020; Tran *et al.*, 2025). Radical traceability thus calls for the integration of real-time data systems, material passports, and distributed ledger technologies into accounting infrastructures – not simply to enhance transparency, but to restructure accountability relationships. However, as Bebbington and Rubin (2022) caution, transparency initiatives alone are insufficient without corresponding shifts in valuation and governance practices. Traceability infrastructures must be embedded within broader ecological accounting commitments if they are to materially support circular transitions. Traceability, in this framing, is not merely informational; it is constitutive of new forms of ecological and interorganisational governance.

3.4 *Stewardship as emergent, situated practice*

Individually, each of the three dimensions elaborates a tension between conventional accounting practices and the requirements of CE transitions. Yet, these dimensions should not

be treated as stable categories or guaranteed pathways. As accounting scholars suggest, attempts to instantiate stewardship are always partial, situated, and contested – shaped by institutional path dependencies, power asymmetries, and material uncertainties (Moses and Hopper, 2022; Baker et al., 2023). Collectively, these dimensions suggest that accounting is not simply a neutral technology to be adapted to new sustainability goals. It is a site where possibilities for stewardship are constituted – where assumptions about time, value, responsibility, and materiality are negotiated, stabilised, or contested (Bebbington et al., 2024b; Moses and Hopper, 2022).

In line with emerging streams in socio-ecological accounting (Scarpellini et al., 2020; Jørgensen et al., 2023), this research treats stewardship not as a managerial aspiration but as an emergent property of socio-material systems in transition. Accounting, in this view, is implicated in structuring how futures become thinkable, accountable, and actionable.

Building on this theoretical framing, the study empirically investigates how accounting practices are mobilised, challenged, and reconfigured in the context of CE transitions within the construction sector. Focusing on pioneering PaaS initiatives, the research examines how actors engage with the tensions and possibilities of socio-ecological stewardship as they seek to embed material durability, adaptive governance, and radical traceability into organisational routines and infrastructures.

4. Research design and methodology

To explore how accounting infrastructures interact with emerging stewardship practices in CE initiatives, a qualitative, exploratory, case-based research design was adopted. This constructivist inquiry employed a multidisciplinary qualitative design combining case study analysis with focus group discussions to explore how accounting, financial, and governance practices interact with CE initiatives in the construction sector. Two pioneering PaaS business models – “Road-as-a-Service” and “Façade-as-a-Service” – served as the empirical foundation for the research.

The study was partially sponsored by a professional accounting association and a governmental entity supporting CE innovation. Sponsorship supported engagement with external expertise but did not cover the preparation or dissemination of the present academic analysis. Recruitment of participants leveraged academic, professional, and industry networks, culminating in the formation of the Coalition Circular Accounting (CCA, 2023) by the Netherlands Institute of Chartered Accountants and the Circle Economy Foundation. By integrating case study and focus group methodologies (Stone and Redmer, 2006; Ecem Yildiz et al., 2020; Rahman et al., 2024), the study captured multiple disciplinary perspectives and illuminated the complex tensions encountered when translating CE ambitions into accounting and governance practice.

4.1 Case studies

The two case studies were selected for their innovative application of CE principles in a sector historically dominated by linear ownership and resource consumption models. Each case was developed through consultations with project representatives, documentary review, and engagement with implementation processes. The documentary review encompassed: (1) draft contractual frameworks detailing service scope, ownership structures, and risk allocation mechanisms; (2) financial projections including NPV scenarios, payment schedules, and residual value assumptions; (3) technical specifications outlining material requirements, performance standards, and monitoring protocols; (4) procurement and tender documentation; (5) internal project presentations and briefing notes; and (6) relevant regulatory and professional guidance on CE implementation in construction. These materials were synthesised into structured case narrative briefs (summarised in Appendix Table A2) that provided participants with consistent baseline information about each PaaS model’s

operational, financial, and governance dimensions. These briefs were pre-circulated to participants and presented during kick-off sessions to establish a shared understanding before thematic discussions.

4.1.1 Road-as-a-service business model. The “Road-as-a-Service” project, launched in a Dutch province, reimagines infrastructure provision by separating legal and economic ownership. The provincial government retains legal ownership of the road, while the contractor retains economic ownership of materials and provides continuous road services under long-term contract terms.

Conventional models involve lump-sum payments to contractors for completed projects, with limited incentives for lifecycle material stewardship. Under the Road-as-a-Service model, contractors receive staggered payments based on road performance, maintenance standards, and availability metrics. They are incentivised to use durable, recyclable materials to maximise residual value at the contract’s end. Contractual mechanisms explicitly stipulate material monitoring, maintenance responsibilities, and end-of-contract material recovery procedures, embedding CE principles into infrastructure governance.

In practice, this model distributed responsibilities across multiple actors, including the contractor consortium, material suppliers, and third-party service providers. While the contractor held economic ownership of materials, operational tasks (such as performance monitoring and maintenance) were often shared or subcontracted.

4.1.2 Façade-as-a-service business model. The “Façade-as-a-Service” pilot project, implemented in a residential development in a major Dutch city, involved collaboration between façade construction firms and a real estate developer. Here, the façade service company retains economic ownership of the building façades, which are provided as a long-term service to apartment owners.

Rather than transferring ownership at project completion, the façade company remains responsible for maintenance, upgrades, and eventual material recovery across a 30-year contract. Apartment owners purchase rights to the façade services (including protection, ventilation, and energy management) while the provider remains incentivised to prioritise material durability and technological adaptability.

The contractual framework details obligations around performance standards, maintenance interventions, and end-of-life material recovery. Payment structures – combining upfront investment with service fees – align financial incentives with material stewardship and lifecycle optimisation.

While the Façade Service Company (FSC) formally retains ownership of the asset, much of the day-to-day performance responsibility is delegated to partner organisations involved in design, construction, and maintenance. These collaborators operate under long-term contractual obligations yet may not carry the asset on their balance sheets.

4.2 Focus group sessions

The case studies served as the foundation for a series of eleven focus group sessions designed to explore accounting, adaptive governance, and financial infrastructure challenges in CE transitions. The sessions facilitated multi-perspective dialogue among accountants, lawyers, consultants, financial professionals, and academic researchers, enabling an interdisciplinary examination of how CE business models interact with established institutional infrastructures.

In total, forty-five participants contributed to the evaluation of the two cases (Table 1; further details provided in Appendix Table A1). Participants were selected based on their specialised expertise and invited to attend one or more sessions depending on their relevance to the thematic focus. Each focus group, typically comprising ten to fifteen participants, was guided by an independent moderator unaffiliated with the research team, who ensured structured yet open-ended engagement. Some of the participants attended more than one focus group sessions (see Appendix Table A1) contributing to the total count of participants reported in Table 1. This study received ethical clearance from the Institutional Review Board of

Nyenrode Business University, and all participants provided written informed consent prior to participation.

Each focus group series commenced with a kick-off session, during which participants received comprehensive information packages, including case descriptions, draft contractual structures, financial projections, and background materials on CE principles. The Road-as-a-Service kick-off session lasted approximately 145 minutes, while the Façade-as-a-Service kick-off session lasted approximately 180 minutes. Expert facilitators delivered presentations outlining the business models, stakeholder configurations, and material flow considerations specific to each case. The kick-off sessions established a shared knowledge base, setting the foundation for subsequent thematic exploration.

Following the initial meetings, participants engaged in thematically structured “deep dive” sessions that interrogated key accounting and adaptive governance challenges associated with each business model. For the Road-as-a-Service initiative, discussions centred on Residual Value Determination – focusing on methodologies for assessing material value over extended periods – and Balance Sheet Recognition and Financial Reporting – examining accounting treatments for service-based, long-lived infrastructure assets. For the Façade-as-a-Service initiative, thematic sessions addressed Business Case Profitability (scenario-based financial viability assessments), Legal Framework and Contractual Structures (governance and risk-sharing challenges in long-term service contracting), and Innovative Financing Models (alternative funding approaches aligned with CE principles).

These thematic deep dives enabled a structured yet flexible examination of core issues, while also accommodating emergent concerns and participant-driven elaborations. Each case study within the focus groups concluded with a dedicated synthesis session, where participants reflected on the most significant insights generated and identified practical implications for adapting accounting, legal, and financial frameworks to enable CE transitions and socio-ecological stewardship.

Focus group discussions employed a semi-structured approach that began with open exploration of each case, allowing participants to identify key challenges before moving to more targeted discussion of specific domains. While the theoretical framework (accounting practices, governance arrangements, and financing/traceability systems) provided broad thematic areas for exploration, participants were explicitly encouraged to raise issues outside these categories. This approach ensured that data collection remained open to emergent themes whilst maintaining sufficient structure for cross-case comparison. The thematic areas explored are summarised in [Appendix Table A3](#), which represents the post-hoc organisation of discussion topics rather than a predetermined interview script.

4.3 Data analysis

Focus group sessions were conducted in Dutch, recorded, and subsequently translated into English by certified translators. The final corpus comprised 64,313 words (Road-as-a-Service) and 105,101 words (Façade-as-a-Service). Using template analysis (King, 2012), both deductive and inductive approaches were employed: while the initial coding template drew on our socio-ecological stewardship framework (corporate biosphere stewardship, adaptive governance, and radical traceability), the researchers remained open to emergent themes, creating new categories where participant insights diverged from or extended the initial conceptualisation. This iterative approach was crucial for maintaining analytical openness; while the theoretical framework provided initial sensitising concepts, the researchers consciously avoided imposing these categories during data collection, instead allowing them to guide the subsequent analysis of naturally occurring discussion themes. This method is well suited to developing *a priori* theoretical frameworks while remaining open to inductively emerging themes. Transcripts were chronologically organised (FG1-FG11) and imported into NVivo 12 for systematic coding. Participants were anonymised using alphanumeric identifiers.

The initial coding template was informed by the socio-ecological stewardship dimensions outlined in [Section 3](#): *corporate biosphere stewardship*, *adaptive governance*, and *radical traceability*. These sensitizing concepts were enriched with additional perspectives from environmental accounting and CE literatures ([Arjaliès et al., 2023](#); [Bekier and Parisi, 2025](#); [Costa et al., 2023](#); [Parisi and Bekier, 2022](#); [Tran et al., 2025](#); [Aranda-Usón et al., 2024](#); [Werning and Spinler, 2020](#); [Susur and Engwall, 2023](#)).

Following [Chun Tie et al. \(2019\)](#), coding proceeded through multiple iterative rounds, with two researchers independently coding all transcripts and holding collaborative refinement meetings ([Choi and Pak, 2006](#)). This investigator triangulation approach enhanced analytical rigour whilst strengthening the validity of emergent themes.

In the final stage of analysis, following methods outlined by [Berg et al. \(2021\)](#), [Werning and Spinler \(2020\)](#), and [Susur and Engwall \(2023\)](#), the coding structure was refined to better capture tensions and enabling conditions for CE transitions. New sub-topics were created where empirical divergence emerged, and categories were iteratively adjusted to reflect participant insights, particularly around investor and financial institution concerns.

This iterative refinement produced three central empirical themes: *Transition Accountability* (TA), *Adaptive Governance* (AG), and *Material Stewardship* (MS). Each theme corresponded closely but not fully symmetrically to the dimensions of the socio-ecological stewardship framework ([Table 2](#)).

The empirical themes developed through the analysis – *Transition Accountability*, *Adaptive Governance*, and *Material Stewardship* – were informed by the socio-ecological stewardship framework guiding this study. However, the relationship between theoretical framing and empirical findings was not one of simple correspondence. *Transition Accountability*, for example, articulated concerns around valuation practices and temporal horizons that extended the focus of corporate biosphere stewardship. Likewise, *Material Stewardship*, while drawing on radical traceability, also encompassed issues of lifecycle management, value retention, and cross-sector collaboration. This pattern reflects the situated and evolving character of stewardship commitments within CE contexts. As accounting practices interact with material flows, governance structures, and financial logics, new forms of accountability and valuation emerge that may not align neatly with initial conceptual categories. Recognizing these dynamics draws attention to the ways in which stewardship is not only theorised but enacted and reshaped through organisational practices, suggesting that analytical frameworks for CE transitions must remain attentive to emergent configurations of responsibility and value over time. This multi-stakeholder, practice-engaged research design aligns with longstanding calls in social and environmental accounting to bridge critique and engagement, widen stakeholder participation, and develop new theories and practices through field and action-research experimentation ([Parker, 2011](#)).

5. Findings

The Road-as-a-Service discussions comprised four sessions (FG1-FG4) progressing from case exploration to examining residual value determination and balance sheet recognition. The Façade-as-a-Service discussions spanned seven sessions (FG5-FG11) addressing business case profitability, legal frameworks, and financing models (see [Table A1](#) in [appendix](#) for further focus group details).

The study explored how actors engaged in CE initiatives within the construction sector articulate, contest, and attempt to embed new practices of material stewardship, valuation, and governance. The empirical material was organised around three interconnected themes – *Transition Accountability*, *Adaptive Governance*, and *Material Stewardship* – which reflected the multiple domains through which CE initiatives intersect with accounting, legal, and financial practices. Participant accounts were treated as situated articulations that opened windows into the practical work involved in experimenting with new stewardship models within established institutional contexts.

5.1 Transition Accountability

Conversations around *Transition Accountability* revealed that prevailing accounting logics – particularly those embedded in asset valuation and depreciation practices – sit uneasily with the temporal and material dynamics of CE models. Rather than offering neutral representations of material value, conventional accounting frameworks emerged as active sites of tension, where the assumptions of linearity, obsolescence, and monetary erosion clashed with aspirations for material persistence and regenerative use.

The Road-as-a-Service case exemplified these tensions through its ownership structure. The conventional model involved lump-sum government payments for completed infrastructure. The circular model retained legal ownership with the government client while transferring economic ownership of materials to the contractor, who received performance-based payments over a 10-year period. This incentivised recyclable materials and explicit contractual provisions for material recovery yet exposed fundamental inadequacies in accounting treatments.

As one case organisation participant (CASE-13, FG3, RaaS [2]) explained:

When we think of standard accounting, we are taught that assets depreciate over time toward zero. But in circular systems, materials often retain significant value if designed properly. Our accounting systems simply don't capture this potential.

The participant's observation points to a deeper epistemic tension underlying circular business models: while contractors' viability depended on recovering substantial residual value, conventional accounting would systematically erase this value through depreciation schedules.

The Façade-as-a-Service case illustrated similar challenges through ownership separation. The service company retained ownership of 30-year modular building envelopes while apartment owners purchased functionality rights. This enabled investment in high-quality, adaptable materials with future reuse potential, yet accounting for distributed ownership arrangements proved problematic.

The fundamental challenge was ontological: representing materials as simultaneously depleted through use yet enhanced through stewardship. In the Road-as-a-Service model, intensive maintenance and monitoring could actually increase material value over time by optimizing performance and extending usable life. Yet no existing accounting framework could capture this value enhancement. As a social enterprise representative (SOC-1, FG1, RaaS) noted, "*Mapping out cash flows and doing further research to determine residual value at several points in time*" required entirely new methodological approaches accommodating dynamic, context-dependent valuations.

These valuation challenges cascaded into financing constraints. Financial arrangements themselves – such as loan terms and amortisation schedules – were shown to encode temporalities misaligned with circular objectives. In the Façade-as-a-Service discussions, this temporal misalignment became particularly acute:

The term that is now proposed is 10 years so if you look at 30 years, the service provider, the service around the façade, then you would have to extend it 3 times. On the other hand, as a lender, are there any reasons why you would want to have that financing also as long as a service? (SOC-1, FG1, RaaS).

This temporal mismatch exposed how financing infrastructures constrain the enactment of stewardship practices, forcing artificial segmentation of what should be integrated material lifecycles. The data also revealed sophisticated attempts by participants to bridge these institutional gaps through analogical reasoning and creative interpretations. Beyond analogy, participants also turned to contractual architecture to make circular arrangements legible and enforceable to lenders.

While some participants explored analogies to existing financial instruments, others proposed more fundamental legal innovations. A legal expert (LEG-45, FG10, FaaS) involved

in structuring the façade contracts explained their approach to creating enforceable security without traditional asset mortgages:

We do not rely on a mortgage over the façade. We use a simple tenancy over the attachment points and include an explicit right of removal. If there is an insolvency, the trustee either honours the service contract or we take the façade off. Together with step-in rights for the bank, that gives enforceable security on the cash flows.

In this focus groups data, however, such contractual architecture functioned as a bridge rather than an endpoint. It solved enforceability for financiers, but it did not bring the evolving value of materials into the ledger. Participants described the need for calculative devices that accompany the façade over time: component registers, condition based revaluation triggers, and residual value appraisals linked to verified maintenance and recovery pathways. Delivering these devices requires new information flows, including sensor data, inspection logs and performance reports, and also new cross organisational routines that make future oriented value auditable. Put differently, *Transition Accountability* rests on practices that protect option value and material reusability across contract renewals, not only on the punctual settlement of fees. Until such devices become institutionalised, contractual architecture improves bankability but leaves the central valuation problem of circular assets outside the accounting system.

Taken together, the cases indicate that *Transition Accountability* is not a minor policy tweak but an infrastructural project. Financial recognition must be reattached to the changing condition of materials through integrated devices and routines. In practice this means coupling contractual rights with calculative artefacts that travel with the asset, for example component registers linked to material passports, condition-based revaluation triggers, verified recovery pathways, and periodic attestations by independent engineers, and then wiring these artefacts into lenders' covenants and auditors' evidence thresholds. Such arrangements begin to translate stewardship into bookable and auditable claims, yet they also redistribute responsibility across the service provider, the owners' association, financiers and assurance actors, and they require new cross organisational routines and information flows. In short, accountability for transition depends on stitching legal contracting, technical monitoring and accounting measurement so that option value and reusability become visible in the ledger rather than remaining outside the accounting system.

Yet, several participants pushed beyond contractual fixes, articulating alternative value logics that challenged the foundations of linear accounting. As synthesised in the RaaS valuation deep-dive, participants described an "ideal-world" logic in which only labour is written off while material value is preserved through stewardship:

In an ideal world, you only write off labour hours. The residual value is just the purchase price excluding materials. Then you would say that building a new road, i.e. new materials and labour, has the same value as the materials in it (CASE-37, FG8, FaaS [3]).

This radical reframing proposed separating labour and material components in accounting treatments – depreciating labour inputs while maintaining material values as stewardship assets. Under this logic, road construction would involve permanent material assets (retained at historical cost) combined with service inputs (depreciated annually). Such an approach would fundamentally restructure how infrastructure value is conceived, moving from asset consumption models toward material stewardship frameworks. As one valuation expert from a Big4 consulting firm (CONS-10, FG9, FaaS) elaborated:

It's not the material that determines the value, but rather what can be done with it. Destination and other factors matter. Is the material important? Yes, but the residual value is determined in various ways, and frequently by the land value, which is usually much higher than the material itself. I would like to see it differently, but currently, material doesn't matter that much. It's going to matter a lot more, though.

This expert's reflection revealed the paradox facing circular initiatives: while materials theoretically retain value through stewardship, current valuation practices systematically undervalue material potential relative to land and location factors. The prediction that materials will "matter a lot more" suggests an anticipated shift in value hierarchies that current accounting frameworks are poorly equipped to anticipate or capture. The focus group discussions revealed how these valuation challenges translated into concrete operational difficulties in both case studies.

In the Road-as-a-Service pilot, performance measurement systems struggled to incorporate circularity indicators alongside traditional infrastructure metrics. As noted by a case organisation participant (CASE-13, FG3, RaaS): "*The contract was set up around the usual indicators – surface condition, safety checks, and alike. But we weren't able to include circularity in that.*" This limitation was not merely technical but reflected deeper institutional inertia: existing performance frameworks were designed around immediate functional delivery rather than long-term material stewardship. The contractor could excel at surface maintenance while failing to optimize material reuse potential, or conversely, could invest heavily in circular design while struggling to meet conventional performance benchmarks.

In the same focus group, a participant from an accounting firm (ACC-26, FG3, RaaS) also noted that this led to a misalignment between what the project was trying to deliver and how it was measured: "*There was an ambition to work differently, but the KPIs remained unchanged. It was difficult to reflect circular goals in the performance agreements*".

This misalignment revealed how accounting infrastructures actively shape organisational priorities through performance measurement. Without circular indicators embedded in formal accountability systems, stewardship remained an aspirational add-on rather than a core operational requirement. The inability to measure and reward circular performance created perverse incentives that undermined the business model's theoretical benefits. While standardised frameworks such as GRI 300 offer disclosure pathways for circular strategies (Massari and Giannoccaro, 2023), the findings suggest that such frameworks require substantial adaptation to capture the distributed accountability relationships and extended temporalities in PaaS models.

These dynamics reveal *Transition Accountability* as an ongoing negotiation between circular material aspirations and linear institutional logics. Rather than neutral measurement systems, accounting frameworks actively constitute the temporal and material possibilities within which stewardship can be enacted, suggesting that circular transitions require infrastructural rather than merely technical accounting innovations.

5.2 Adaptive governance

While concerns about valuation animated much of the discussion, participants also underscored the necessity of governance arrangements capable of navigating uncertainty, relational complexity, and ecological dynamism. Participants acknowledged the difficulty of risk assessment in the absence of longitudinal material data. As the valuation expert from the Big4 consulting firm (CONS-10, FG9, FaaS) noted, "*There is not much experience with that yet, so how is the residual value determined? Very frankly, it's a very big black box in valuation land.*"

This "black box" metaphor captured a fundamental challenge for *Adaptive Governance*: how to structure accountability relationships when the material foundations of value remain opaque and contested. In a Road-as-a-Service focus group, a consulting-firm participant (CONS-39, FG2, RaaS) articulated this dilemma:

You can agree on 15% of the purchase price, say 100,000 euros, and include materials in that amount. After 30 years, is the quality of the material still the same? You can only value it at 100,000 euros now because you cannot yet estimate the market percentages.

This conservative approach reflected how uncertainty translates into restrictive financial practices that systematically undervalue circular potential. The inability to assess future

material states forces adaptive governance arrangements into defensive postures that constrain rather than enable stewardship innovations.

Participants expressed dissatisfaction with inherited templates, calling for more dynamic governance models. As a case-organisation participant (CASE-28, FG5, RaaS) shared in Road-as-a-Service discussions, “*When you’ve got service models that run for 30 years, you can’t really predict everything . . . Contracts need to be able to shift as the tech changes, or when the value of materials isn’t what we expected*”. An accounting professional (ACC-14, FG3, RaaS) reinforced this concern: “*Traditional contracts – they try to cover every single scenario upfront. But that kind of thinking makes it hard to adjust, or to learn as you go*”. These reflections revealed how conventional contracting approaches actively constrain the adaptive capacity required for long-term material stewardship.

A university researcher (UNI-12, FG10, FaaS) observed, “*In circular models, the financial set-up isn’t something resolved independently. It needs to adapt as material values change, technologies advance, and performance expectations evolve*”. This observation pointed to governance as an ecology of interdependent practices rather than discrete contractual arrangements.

Participants attempted to navigate these entanglements through analogical reasoning, translating unfamiliar CE arrangements into more institutionally recognisable forms. A case-organisation participant (CASE-42, FG6, FaaS) illustrated this adaptive approach:

Of course, you can provide the façade as collateral and the contracts to the owners’ association. Yes, it’s still a matter of discussion with those banks, but structurally, it would be similar to a thermal installation where a household owns a heat pump financed by Bank A, separate from the homeowner’s mortgage.

Such analogies revealed the performative work involved in making novel stewardship arrangements intelligible within established financing norms, yet also highlighted the constraints of translating circular innovations into linear institutional categories.

This interdependency was particularly evident when participants grappled with the limitations of traditional accounting representations in contexts where long-term service commitments were distributed across multiple organisations. Another case-organisation participant (CASE-28, FG10, FaaS) explained how conventional financing logic broke down when responsibilities and asset ownership were structurally decoupled:

We were responsible for the façade’s performance over these years, but it wasn’t on our balance sheet because the [Façade Service Company] owns it. That raised real questions with the bank – they said, ‘how do we assess your creditworthiness when you have these long-term obligations but no corresponding assets?’.

This disjuncture between operational responsibility and asset recognition revealed how distributed stewardship challenges fundamental assumptions about organisational boundaries and financial accountability embedded in conventional governance frameworks.

The empirical material suggests that *Adaptive Governance* emerges not as a predetermined model but as an ongoing accomplishment requiring continuous recalibration of legal, financial, and accounting infrastructures to accommodate the distributed and temporal complexities of material stewardship.

5.3 Material stewardship

Discussions around *Material Stewardship* illuminated that informational infrastructures are not auxiliary supports but foundational mechanisms for stabilising accountability in CE models. Participants emphasised that without robust mechanisms to track material performance, location, and residual value, the financial and contractual innovations supporting CE initiatives would unravel. As noted by a social-enterprise participant in Road-as-a-Service focus group (SOC-1, FG4, RaaS):

A very important one [aspect] is how are you going to finance it. Because in lease structures you might be able to finance 100% where you truly assume the value of the asset. However, with project finance or corporate finance there always has to be equity.

This observation revealed how financing viability becomes contingent upon the credibility of asset valuations, which in turn depends on the visibility and trackability of material conditions over time. These dynamics were complicated in the Façade-as-a-Service case, where the formal separation of asset ownership and day-to-day operational responsibility raised new challenges.

Traceability was framed not merely as a technical affordance but as a trust-building infrastructure. As a social enterprise representative noted, “*Circular economy is new and involves risks . . . From the financiers’ point of view, the requirements are stricter*” (SOC-1, FG5, FaaS). This comment highlighted how material uncertainty translates into institutional scepticism, positioning traceability as essential for legitimising circular business models within risk-averse financial frameworks.

Participants pointed to systemic mismatches between the temporal demands of CE contracts and conventional lending horizons. As a case-organisation participant (CASE-42, FG6, FaaS) explained:

We actually looked mainly at the first 15 years. What the banks indicate is: Well, it’s nice that you have a project with a term of 30 years, but the maximum term that we can provide a loan for is 15 years. Given the current business case, a principal amount of 70 percent of your financing requirement seems feasible to us for those first 15 years.

This temporal constraint forced artificial segmentation of integrated material lifecycles, undermining the economic rationale for long-term *Material Stewardship* that depends on capturing value across full asset lifecycles.

Building on this, several participants pointed to digital monitoring and material passports as practical infrastructures for enacting *Material Stewardship* over time. As one participant from a consulting firm (CONS-10, FG9, FaaS) observed, “*With real-time monitoring, it becomes easier to track how materials are holding up over time, which makes it a lot easier to justify long-term value in a business case*”. This comment linked material visibility directly to financial justification, suggesting that traceability infrastructures function as mediating devices between material realities and financial representations.

Alongside these digital tools, as a social enterprise participant noted in Façade-as-a-Service discussions (SOC-1, FG5, FaaS), “*One of the important conclusions there is that the contract is actually leading; the financial reality comes from it, so the accounting also comes from it and you base your financing on that*”. This observation revealed the hierarchical relationship between contractual arrangements, accounting representations, and financing possibilities, with contracts serving as foundational infrastructures that shape subsequent financial and accounting practices.

These dynamics illustrate that *Material Stewardship* operates as a socio-technical assemblage where digital monitoring, contractual frameworks, and financial arrangements must be continuously calibrated to sustain circular value propositions across extended temporal horizons.

5.4 Interdependencies and emergent tensions

Analysis of participant accounts revealed that the challenges identified in *Transition Accountability*, *Adaptive Governance*, and *Material Stewardship* do not operate in isolation but constitute interconnected institutional tensions that amplify across domains. Rather than discrete implementation problems, these themes represent systemic frictions where conventional accounting, legal, and financial infrastructures encounter circular material logics. The empirical material illuminated three critical interdependencies that expose the relational character of circular transitions.

First, valuation innovations proved inseparable from adaptive governance. The Road-as-a-Service contractor's ability to capture residual material value required not only alternative depreciation models but also contractual mechanisms capable of accommodating technological change and performance evolution over decades. As one case-organisation participant (CASE-37, FG8, FaaS) observed, attempts to "write off only labour hours" whilst maintaining material values demanded governance structures that could distinguish between depleting service inputs and stewardship-enhanced assets – a distinction that existing frameworks could not accommodate.

Second, traceability emerged as both enabling and constraining stewardship practices. Digital monitoring systems promised to resolve valuation uncertainties by providing real-time material condition data. However, the Façade-as-a-Service discussions revealed how enhanced visibility also amplified governance complexities. More granular data on façade performance created new demands for responsive maintenance protocols, renegotiation triggers, and risk-sharing mechanisms that existing contractual templates could not accommodate. The consulting-firm participant's (CONS-10, FG9, FaaS) observation that monitoring "makes it easier to justify long-term value" was coupled with recognition that such systems also made traditional governance arrangements obsolete.

Third, financing constraints systematically reshaped both valuation logics and adaptive governance possibilities. The temporal mismatch between 30-year material lifecycles and 15-year lending horizons did not merely create funding gaps; it forced artificial segmentation of stewardship responsibilities that undermined the integrated material management central to circular business models. The social-enterprise participant's (SOC-1, FG4, RaaS) distinction between lease structures that "assume the value of the asset" and project finance requiring equity revealed how financing modalities actively constitute what counts as an asset and who can claim stewardship authority.

These interdependencies generated three emergent tensions that pervaded both case studies. The first concerned temporal misalignment: whilst circular business models required extended time horizons for value capture, institutional infrastructures remained anchored in annual cycles and short-term performance metrics. This created what participants termed "value erosion" – where stewardship investments could not be recognised or rewarded within existing accountability systems.

The second tension involved distributed responsibility: circular models diffused *Material Stewardship* across multiple organisations, yet accountability systems remained entity-bound. The Façade-as-a-Service case exemplified this challenge, where service delivery partners bore performance obligations without corresponding asset recognition, creating "accountability gaps" that complicated credit assessment and risk management.

The third tension centred on material valorisation: whilst participants advocated for recognising materials as appreciating stewardship assets, market conditions systematically undervalued material recovery relative to land and location premiums. This "valorisation paradox" meant that even successful circular stewardship might not translate into economic viability without broader shifts in material market structures.

Rather than representing implementation failures, these tensions illuminate the systemic character of circular transitions. They suggest that meaningful CE adoption requires not merely new business models but coordinated transformations across valuation practices, adaptive governance arrangements, and accountability infrastructures – transformations that challenge fundamental assumptions about ownership, temporality, and organisational boundaries embedded in contemporary accounting and financial systems.

5.5 Towards situated socio-ecological stewardship: integrating Transition Accountability, adaptive governance, and material stewardship

The findings invite a reconsideration of socio-ecological stewardship as a situated and emergent practice rather than a stable model within CE transitions, specifically through the

integration of *Transition Accountability*, *Adaptive Governance*, and *Material Stewardship* as identified in [Figure 1](#). The interdependencies and tensions identified in the empirical analysis converge around a fundamental insight: socio-ecological stewardship in circular transitions emerges through the dynamic integration of legal, accounting, and financial expertise rather than through isolated technical interventions. As [Figure 1](#) illustrates, this integration occurs across three interconnected domains that must be continuously calibrated to sustain circular value propositions.

The framework reflects how the three empirical themes operate as interdependent dimensions of stewardship practice. *Transition Accountability* emerged as participants grappled with temporal misalignments between circular aspirations and linear accounting infrastructures, revealing the need for valuation and reporting innovations that can recognise material lifecycle assessment and residual value across extended timeframes. *Adaptive Governance* surfaced through participants’ attempts to navigate uncertainty and distributed responsibility, highlighting requirements for service-based contracts and performance metrics that can accommodate evolving material conditions. *Material Stewardship* materialised as participants sought to establish credible foundations for long-term commitments, emphasising digital monitoring infrastructures and performance-based financing mechanisms.

The framework demonstrates that implementing CE models in construction demands the careful coordination of three domains of expertise. Legal frameworks must evolve to accommodate service-based contracts that separate ownership from use, whilst establishing clear material responsibility allocations across extended timeframes. Accounting practices must move beyond historical cost conventions to develop valuation approaches that can recognise residual value, material lifecycle performance, and distributed stewardship responsibilities. Financial mechanisms must accommodate long-term investment horizons

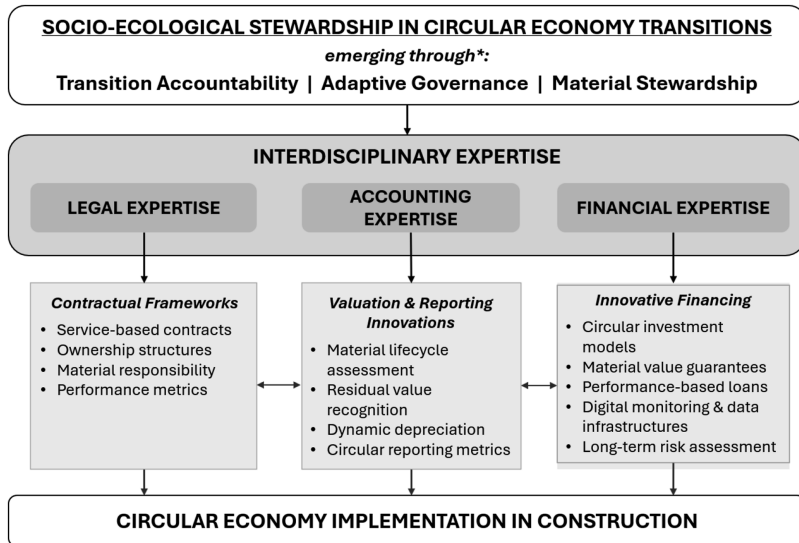


Figure 1. Enabling situated socio-ecological stewardship: integrating accounting, legal, and financial infrastructures for circular economy implementation through *Transition Accountability*, *Adaptive Governance*, and *Material Stewardship*. *Note: The three central stewardship themes – *Transition Accountability*, *Adaptive Governance*, and *Material Stewardship* – emerged through empirical analysis of focus group discussions. These themes build upon, but do not map one-to-one onto, the initial theoretical framing of corporate biosphere stewardship, adaptive governance, and radical traceability. The framework reflects this evolution, positioning socio-ecological stewardship as a situated and relational accomplishment within circular economy transitions

through innovative structures such as circular investment models and material value guarantees that align with dynamic material conditions rather than static asset valuations.

Critically, these domains are not independent but constitute an ecology of interdependent practices. The findings revealed that *Material Stewardship* commitments require legal frameworks to clarify evolving rights and obligations, accounting infrastructures to render circular value visible across organisational boundaries, and financial mechanisms capable of sustaining long-term commitments despite material and market uncertainties. Their interaction is dynamic and continuously negotiated, generating both the possibilities and constraints for socio-ecological stewardship within specific institutional and material contexts.

Rather than prescribing definitive solutions, the framework serves as a heuristic for identifying where systemic tensions are likely to emerge and where institutional innovations may be required. The three emergent tensions identified in the analysis – temporal misalignment, distributed responsibility, and material valorisation – reflect points where current institutional arrangements prove inadequate for sustaining circular stewardship practices. Addressing these tensions requires coordinated innovations across all three domains rather than isolated adjustments within any single area.

The framework thus positions socio-ecological stewardship not as a stable endpoint but as an ongoing accomplishment requiring continuous recalibration of institutional arrangements to accommodate the temporal and relational complexities of circular material flows. This perspective suggests that meaningful circular transitions depend less on perfecting individual tools or techniques and more on developing capacities for sustained institutional experimentation and adaptive coordination across legal, accounting, and financial domains.

6. Discussion and conclusion

This study demonstrated that implementing CE models in construction unsettles not only technical routines but also the foundational infrastructures of accounting, governance, and finance. Rather than unfolding as discrete technical interventions, the findings revealed socio-ecological stewardship as an emergent, situated practice continually negotiated across material flows, institutional routines, and epistemic commitments – a phenomenon inviting the terminology of infrastructuring (Kornberger *et al.*, 2017; Martinez *et al.*, 2022; Fong Chua *et al.*, 2024) referring to the situated activities, practices, and devices enabling new organisational and market structures to emerge and function. This section discusses responses to the three research questions within the spaces between the interdependent dimensions of *Transition Accountability*, *Adaptive Governance*, and *Material Stewardship*.

6.1 Addressing the research questions

The first research question examined how CE business models, particularly PaaS arrangements, challenge conventional accounting frameworks. The Road-as-a-Service and Façade-as-a-Service cases revealed that traditional accounting practices – grounded in linear assumptions of asset depreciation, ownership transfer, and obsolescence – prove fundamentally inadequate for representing the durability, reusability, and ecological embeddedness of materials in circular systems. The case-organisation participant's (CASE-13, FG3, RaaS) observation that accounting systems “simply don't capture” the potential of materials that “retain significant value if designed properly” illuminated how prevailing financial infrastructures actively constrain stewardship ambitions. These findings extend critiques within sustainability accounting (Hopwood, 2009; Bebbington and Larrinaga, 2014; Larrinaga and Garcia-Torea, 2022), demonstrating that technical adaptations alone are insufficient. Instead, they point toward infrastructural reconfigurations of how accounting systems trace and constitute value, risk, and responsibility across temporal and organisational boundaries.

The second research question explored what new forms of accountability emerge when CE principles are integrated with socio-ecological stewardship perspectives. The findings demonstrate that accountability within CE contexts operates through adaptive, relational governance arrangements capable of accommodating distributed material responsibilities and unfolding uncertainties over extended temporal horizons. The temporal mismatch between 30-year façade lifecycles and 15-year lending horizons, as articulated by participants, exemplified how conventional institutional arrangements systematically undermine circular stewardship through artificial segmentation. These insights extend calls for adaptive governance frameworks (Folke *et al.*, 2019; Bebbington *et al.*, 2024b), revealing that governance innovation requires not merely contractual redesign but dynamic calibration of financing instruments, valuation practices, and traceability systems.

The third research question asked how accounting practices might evolve to support CE transitions in resource-intensive sectors. Here, *Material Stewardship* proved particularly salient, with traceability emerging not as an auxiliary technical function but as a foundational infrastructural condition for sustaining long-term material commitments. The social enterprise representative's observation that circular economy "involves risks" requiring "stricter" requirements from financiers highlighted how material uncertainty translates into institutional scepticism. This insight extends emerging scholarship on radical traceability (Bebbington *et al.*, 2024a; Jørgensen *et al.*, 2023) by demonstrating that traceability must be integrated within accounting, legal, and financial infrastructures as a constitutive element of stewardship enactment rather than merely a transparency mechanism.

6.2 Theoretical contributions

This study reframes accounting as an infrastructural and performative practice implicated in the constitution of socio-ecological futures. Rather than serving as a neutral representational system, accounting practices actively shape how material futures become visible, negotiable, and actionable. These interdependencies reveal a fundamental reconceptualisation of accounting: from a system that measures independent variables to one that actively constitutes the relationships between valuation, governance, and material flows. This positions accounting as an active participant in creating the conditions for circular futures rather than a retrospective measurement apparatus.

The study contributes to environmental and sustainability accounting literature by providing empirical evidence that existing frameworks require fundamental rather than marginal reconfigurations to accommodate regenerative material logics and extended temporalities (Bebbington and Rubin, 2022; Larrinaga and Garcia-Torea, 2022). It enriches management control debates (Svensson and Funck, 2019) by demonstrating how control systems must be reoriented around relational, ecological, and intertemporal accountabilities. The research operationalises socio-ecological stewardship concepts from sustainability science (Folke *et al.*, 2019) into empirically grounded accounts of organisational experimentation, bridging theoretical ambitions with situated practices. Finally, it foregrounds that interdisciplinary collaboration – across accounting, legal, and financial domains – is not an auxiliary support, but a constitutive necessity for enabling CE transitions, reinforcing infrastructural perspectives advanced by Arjaliès *et al.* (2023) and Lamont *et al.* (2023).

The findings also raise fundamental questions about corporate form and purpose in circular transitions. The tensions between stewardship responsibilities and conventional profit maximisation suggest that CE implementation may require not merely new accounting tools but potentially new organisational forms. While benefit corporations and social enterprises offer alternative models that explicitly balance profit with purpose, the case study findings reveal how even traditional firms can partially reconfigure their responsibilities through contractual innovation and service-based business models. However, whether financial incentives alone can sustain such reconfigurations remains an open question. The PaaS

arrangements we studied create temporary alignments between profit and stewardship, yet these remain vulnerable to market pressures and institutional inertia. This suggests that meaningful circular transitions may ultimately require complementary innovations in corporate law, fiduciary duties, and organisational purpose—extending beyond the accounting, governance, and financial infrastructures examined here.

6.3 Methodological insights and transparency

The multidisciplinary focus group design proved effective for capturing the systemic character of circular transitions. The sequential structure – progressing from case exploration through thematic deep-dives to synthesis sessions – enabled participants to build shared understanding whilst revealing emerging tensions across professional domains. The convergence of concerns from financial institutions (risk assessment challenges), case organisations (performance measurement difficulties), accounting professionals (depreciation inadequacies), and legal experts (contractual complexities) reinforced the systemic rather than technical nature of identified challenges.

However, the study’s reliance on focus groups, whilst enabling rich cross-sectoral dialogue, limited direct observation of stewardship practices in action. Future research would benefit from longitudinal ethnographic engagement with circular initiatives to trace how stewardship arrangements evolve through material and institutional encounters over time. Additionally, whilst the Dutch context provided advanced institutional support for CE innovation, generalising to jurisdictions with different regulatory frameworks requires caution.

6.4 Practical contributions

The findings underscore practical requirements for new valuation methodologies capable of recognising the enduring and regenerative potentials embedded within circular materials. The case-organisation participant’s (CASE-37, FG8, FaaS) proposal to “write off only labour hours” whilst maintaining material values as stewardship assets suggests innovative depreciation frameworks that distinguish between depleting service inputs and appreciating material assets. Adaptive governance arrangements must evolve toward procedural flexibility, permitting iterative renegotiation in response to changing material conditions and technological developments, as emphasised by participants who advocated for contracts that “shift as the tech changes” (e.g. CASE-28, FG5, RaaS).

Traceability infrastructures must be designed not merely to satisfy compliance imperatives but to sustain relational accountability across distributed organisational networks. The consulting-firm participant’s (CONS-10, FG9, FaaS) observation that real-time monitoring “makes it easier to justify long-term value” highlights how digital infrastructures serve as crucial intermediaries that translate material conditions into credible financial narratives. Financial institutions require innovative instruments – including circular investment models, material value guarantees, and performance-based loans – capable of accommodating extended temporal horizons and dynamic asset valuations.

The framework presented in [Figure 1](#) offers practical guidance for practitioners seeking to implement circular business models by highlighting the necessity of coordinated legal, accounting, and financial innovations. Rather than isolated technical solutions, meaningful circular transitions require institutional experimentation and adaptive coordination across professional domains.

6.5 Limitations and future directions

The study’s empirical material derives from pioneering cases within the Netherlands, potentially limiting transferability to contexts with different institutional arrangements. The focus on accounting, legal, and financial infrastructures, whilst revealing critical

interdependencies, could be enriched through investigation of how political, cultural, and technological dynamics interact with stewardship practices.

Future research should explore longitudinal studies tracing how stewardship infrastructures evolve through successes, failures, and adaptations over time. Cross-jurisdictional comparative studies would illuminate how different regulatory and economic contexts shape circular transition possibilities. Additionally, research examining how digital technologies and material passports are actually implemented and contested within specific organisational settings would provide valuable insights into the practical work of infrastructuring circular accountability.

6.6 Conclusion

This study positions socio-ecological stewardship not as a stabilised achievement but as an ongoing, situated negotiation – a recursive process of infrastructuring possibilities for more sustainable material futures amid ecological, financial, and institutional complexity. The three emergent tensions identified – temporal misalignment, distributed responsibility, and material valorisation – illuminate points where current institutional arrangements prove inadequate for sustaining circular practices, requiring coordinated rather than isolated innovations.

Accounting, rather than retreating into neutrality, emerges as a vital and contested terrain where the futures of circular and regenerative economies are continually negotiated, constrained, and reimaged. The study invites scholars and practitioners to reframe CE implementation not as a technical optimisation problem but as a deeply ecological, political, and infrastructural project requiring sustained interdisciplinary collaboration and institutional experimentation. Stewardship, in this view, remains an open-ended, provisional, and collective endeavour – demanding accounting *with* rather than merely *for* sustainability.

Acknowledgments

We thank all forty-five participants who generously contributed their time and expertise to the focus group discussions. We are particularly grateful for the thoughtful comments provided by Jan Bebbington, Kalle Kraus, and Richard Pucci during the development of this research.

Appendix

Table A1. Focus group details and stakeholder representation

Focus group ID	Date	RaaS-FaaS*	Group	Participant ID*	Participant
FG1	20-9-2019	RaaS	Social	SOC-1	1
			Client	CASE-5	5
			Consultant	CONS-6	6
			Client	CASE-7	7
			University	UNI-12	12
			Client	CASE-13	13
			Accountant	ACC-14	14
			Social	SOC-15	15
			Consultant	CONS-17	17
			Financial	FIN-19	19
			University	UNI-21	21
			University	UNI-23	23

(continued)

Table A1. Continued

Focus group ID	Date	RaaS-FaaS*	Group	Participant ID*	Participant
FG2	21-10-2019	RaaS	Accountant	ACC-26	26
			University	UNI-27	27
			Accountant	ACC-33	33
			Financial	FIN-34	34
			Client	CASE-37	37
			Social	SOC-1	1
			Financial	FIN-11	11
			Consultant	CONS-17	17
			Social	SOC-22	22
			Accountant	ACC-26	26
			Financial	FIN-31	31
			Client	CASE-37	37
FG3	24-10-2019	RaaS	Consultant	CONS-39	39
			Financial	FIN-43	43
			Social	SOC-1	1
			Client	CASE-5	5
			Client	CASE-9	9
			University	UNI-12	12
			Client	CASE-13	13
			Accountant	ACC-14	14
			Social	SOC-22	22
			Accountant	ACC-26	26
			University	UNI-27	27
			Accountant	ACC-33	33
FG4	11-08-2019	RaaS	Consultant	CONS-39	39
			Social	SOC-1	1
			Client	CASE-9	9
			Financial	FIN-11	11
			Client	CASE-13	13
			Accountant	ACC-14	14
			Accountant	ACC-26	26
			Financial	FIN-31	31
			Accountant	ACC-33	33
			Financial	FIN-37	37
			Financial	FIN-38	38
			Financial	FIN-43	43
FG5	24-04-2020	FaaS	Social	SOC-1	1
			Social	SOC-2	2
			Financial	FIN-4	4
			Consultant	CONS-6	6
			University	UNI-12	12
			Social	SOC-15	15
			Consultant	CONS-17	17
			Client	CASE-18	18
			Accountant	ACC-26	26
			University	UNI-27	27
			Client	CASE-28	28
			Financial	FIN-29	29
Financial	FIN-32	32			
Accountant	ACC-33	33			

(continued)

Table A1. Continued

Focus group ID	Date	RaaS-FaaS*	Group	Participant ID*	Participant
			Client	CASE-36	36
			Financial	FIN-38	38
			Financial	FIN-41	41
			Client	CASE-44	44
			Legal	LEG-45	45
FG6	15-05-2020	FaaS	Social	SOC-1	1
			Social	SOC-2	2
			Financial	FIN-4	4
			University	UNI-12	12
			Consultant	CONS-17	17
			Consultant	CONS-20	20
			Accountant	ACC-26	26
			Client	CASE-28	28
			Accountant	ACC-33	33
			Client	CASE-40	40
			Client	CASE-42	42
FG7	19-05-2020	FaaS	Social	SOC-1	1
			University	UNI-12	12
			Client	CASE-28	28
			Client	CASE-42	42
FG8	26-05-2020	FaaS	Social	SOC-1	1
			Social	SOC-2	2
			Financial	FIN-8	8
			University	UNI-12	12
			Financial	FIN-24	24
			Legal	LEG-25	25
			Accountant	ACC-26	26
			Client	CASE-28	28
			Financial	FIN-30	30
			Accountant	ACC-33	33
			Legal	LEG-45	45
FG9	29-05-2020	FaaS	Social	SOC-1	1
			Social	SOC-2	2
			Consultant	CONS-10	10
			Client	CASE-28	28
			Financial	FIN-29	29
			Accountant	ACC-33	33
			Financial	FIN-35	35
			Financial	FIN-38	38
			Financial	FIN-41	41
FG10	03-06-2020	FaaS	Social	SOC-1	1
			Social	SOC-2	2
			Client	CASE-3	3
			University	UNI-12	12
			Client	CASE-18	18
			Financial	FIN-24	24
			University	UNI-27	27
			Client	CASE-28	28
			Financial	FIN-29	29
			Accountant	ACC-33	33

(continued)

Table A1. Continued

Focus group ID	Date	RaaS-FaaS*	Group	Participant ID*	Participant
FG11	12-06-2020	FaaS	Client	CASE-40	40
			Financial	FIN-41	41
			Client	CASE-42	42
			Legal	LEG-45	45
			Social	SOC-1	1
			Social	SOC-2	2
			Consulting	CONS-6	6
			University	UNI-12	12
			Social	SOC-15	15
			Consultant	CONS-17	17
			Consultant	CONS-20	20
			Accountant	ACC-26	26
			University	UNI-27	27
			Client	CASE-28	28
			Financial	FIN-29	29
			Accountant	ACC-33	33
			Client	CASE-36	36
			Financial	FIN-38	38
			Client	CASE-40	40
			Financial	FIN-41	41
Client	CASE-42	42			
Legal	LEG-45	45			

Note(s): *Coding: RaaS = Road-as-a-Service, FaaS = Façade-as-a-Service; ACC = accounting firm, CASE = case representative organisation, CONS = consulting firm, FIN = financial institution, UNI = University, LEG = legal firm, SOC = social enterprise

Table A2. Case study descriptions: road-as-a-service and façade-as-a-service business models

Topic	Road-as-a-service	Façade-as-a-service
Case summary	The Road-as-a-Service pilot explores a circular business model for road construction and maintenance in the Netherlands. Instead of traditional procurement, infrastructure is delivered as a service, shifting focus from ownership of materials to long-term performance and reuse	The Façade-as-a-Service pilot explores a circular construction model where a building's façade is no longer sold as a product but delivered as a service. This shifts incentives from short-term delivery to long-term performance, maintenance, and material reuse
Key contracts	The model uses performance-based contracts, where the contractor is responsible not only for construction but also for maintenance, material recovery, and end-of-life reuse. Payment is tied to road functionality and durability over time, encouraging circular practices	The model is based on service and performance contracts. These agreements ensure that the façade provider remains responsible for the façade's functionality, energy performance, maintenance, and end-of-life recovery. Ownership of materials often stays with the supplier, enabling reuse and high residual value retention

(continued)

Table A2. Continued

Topic	Road-as-a-service	Façade-as-a-service
Stakeholders	<ul style="list-style-type: none"> Provincial Government: Client and asset owner Contractor: responsible for road performance, maintenance, and material recovery Bank: Financial partner exploring circular financing 	<ul style="list-style-type: none"> Façade Supplier(s): Responsible for delivery, monitoring, and maintenance Building Owner or Developer: Purchases façade service instead of asset Architect and Engineer Teams: Design for circularity and adaptability
Material flow assumptions	<p>The model assumes high-value retention through</p> <ul style="list-style-type: none"> Design for disassembly Use of recycled asphalt and modular elements Reverse logistics for end-of-life materials Monitoring road usage and wear for predictive maintenance <p>This RaaS approach aims to reduce raw material consumption, extend asset life, and shift incentives toward sustainable infrastructure management</p>	<p>The façades are described as modular, demountable building envelopes that are retained by the service provider. Users lease the façades' functionality (e.g. insulation, aesthetics) over time, while the provider remains responsible for maintenance, upgrades, and material recovery at the end of the contract. These façades are designed for reuse or repurposing in future projects, aligning with circular economy principles. This FaaS model reduces material waste, promotes modular and adaptable design, and aligns financial incentives with long-term circular value</p>

Table A3. Summary of focus group discussion framework

Domain	Theoretical link	Key topics explored	Case-specific applications
Accounting practices	<i>Transition Accountability</i> (Section 5.1)	<ul style="list-style-type: none"> Asset lifecycle valuation and recognition Depreciation under service models Residual value estimation Residual value estimation Residual value estimation Residual value estimation Performance measurement and KPIs Audit evidence requirements 	<p>RaaS</p> <ul style="list-style-type: none"> Pavement condition indices Resurfacing intervals Reclaimed asphalt valuation Maintenance cost patterns <p>FaaS</p> <ul style="list-style-type: none"> Component degradation rates Thermal performance metrics Panel replacement cycles Weatherproofing integrity

(continued)

Table A3. Continued

Domain	Theoretical link	Key topics explored	Case-specific applications
Governance arrangements	<i>Adaptive Governance</i> (Section 5.2)	<ul style="list-style-type: none"> • Rights and obligations allocation • Risk-sharing mechanisms • Renegotiation triggers • Organizational accountability mapping • Data governance protocols 	RaaS <ul style="list-style-type: none"> • Road authority oversight • Traffic load variations • Winter maintenance duties • Defect liability periods FaaS <ul style="list-style-type: none"> • Building access protocols • Interface coordination with other trades • Warranty enforcement • Occupant disruption management
Financial and traceability systems	<i>Material Stewardship</i> (Section 5.3)	<ul style="list-style-type: none"> • Lending horizon alignment • Collateral and covenant structures • Digital monitoring requirements • Material passport systems • Residual value realization 	RaaS <ul style="list-style-type: none"> • Availability-based payment mechanisms • Pavement sensor data • Maintenance logs • Secondary asphalt markets FaaS <ul style="list-style-type: none"> • Performance bonds • Component tracking systems • Inspection certificates • Panel refurbishment pathways

Note(s): *This table summarises the key thematic areas that emerged across focus group discussions. While these domains provided broad structure for the sessions, discussions remained open-ended, with participants free to introduce topics and perspectives beyond this framework. The organisation shown here reflects our analytical categorisation of discussion content rather than a predetermined interview script

Notes

1. The term “infrastructuring” refers to the situated activities, practices, and devices (such as accounting models, legal contracts, and traceability systems) that enable new organisational and market structures to emerge and function. This usage aligns with recent critical accounting and management research emphasising the dynamic, temporal, and material qualities of infrastructural work (Kornberger *et al.*, 2017; Martinez *et al.*, 2022; Fong Chua *et al.*, 2024).
2. “Road-as-a-Service” business model.
3. “Façade-as-a-Service” business model.

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