Title page

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Tracking the Invisible: A Mobile-Based Approach to Scope 3 Emissions

Abstract

Corporate carbon disclosure, including Scope 3 emissions, has increased significantly in recent years and is becoming increasingly important for regulators, investors, and stakeholders. Scope 3 data remains challenging to quantify due to its reliance on fragmented, secondary sources, resulting in significant information gaps and unreliable disclosures. This study introduces an innovative mobile application framework designed to enhance the collection and management of Scope 3 emissions data. Our app-based, AI-driven estimation addresses these shortcomings through interactive digital tools and gamification, capturing granular and accurate data. By gathering primary data directly from consumers, employees, and suppliers, our app significantly enhances data quality, accuracy, and credibility, thereby fostering richer and more transparent sustainability disclosures. This improved data availability enables firms to fulfill their reporting obligations and provides stakeholders with reliable information, potentially enhancing ESG ratings and market reputation. Beyond improved disclosures, the mobile app facilitates real-time sustainability management through continuous feedback. Management can quickly identify high-emission areas and make informed decisions, fostering operational efficiencies, cost savings, and innovation. The framework also addresses practical challenges in stakeholder engagement, data reliability, verification, and privacy. This paper contributes to sustainable accounting and accounting information systems literature by presenting a scalable, modular solution for enhanced Scope 3 emissions measurement, improved ESG transparency, and effective response to evolving regulatory and market demands. The mobile app facilitates real-time, stakeholder-driven data collection, significantly enhancing corporate decision-making and sustainability management.

Keywords: ESG, Scope 3 Emissions, Mobile Application, Sustainability Accounting, Carbon Disclosure

1. Introduction

In recent years, corporate carbon disclosure has become a central issue in sustainability reporting, as regulators, investors, and other stakeholders require enhanced transparency regarding corporations' climate-related risks and environmental performance (Ding et al., 2023). Scope 3 emissions, which originate indirectly from a company's value chain, are the most substantial and challenging to quantify of the three emission categories established by the Greenhouse Gas (GHG) Protocol (WRI and WBCSD, 2011). They generally exceed the firm's direct influence, encompass several upstream and downstream operations, and are characterized by uneven data availability and insufficient standardization (Talbot and Boiral, 2015). Scope 3 emissions have consistently had a substantial impact and are recognized as a critical component of corporate carbon footprints (EPA, 2025b). Prior studies show that Scope 3 emissions often comprise the majority of a firm's total GHG emissions, far exceeding its direct (Scope 1) and energy-related (Scope 2) emissions (Downie and Stubbs, 2013; CDP, 2021; EPA, 2025a). An average of 84% of large firms' carbon footprints are due to Scope 3 sources, and these indirect emissions account for over 75% of total emissions (Stenzel and Waichman, 2023).

Despite their significance, measuring and managing Scope 3 emissions is complex (Hettler and Graf-Vlachy, 2024). Mahieux et al. (2025) point out that indirect emissions are subject to double counting, allocation errors, and jurisdictional discrepancies, which raise concerns about the comparability and reliability of reported numbers. These constraints highlight the inherent complexity of Scope 3 disclosures and the challenge of providing decision-useful information to stakeholders. The Scope 3 emissions encompass a wide range of upstream and downstream activities, from suppliers' production processes to consumers' use and disposal of products (WRI and WBCSD, 2013). However, data on these activities are often difficult to obtain with high data quality (Hettler and Graf-Vlancy, 2024). Despite the difficulties, revealing Scope 3 emissions can significantly positively affect strategy and reputation, particularly when done proactively in voluntary ESG reporting. Previous studies indicate that voluntary environmental disclosure can reduce information asymmetry, bolster investor trust, and signify robust governance processes (Dhaliwal et al., 2011; Peters and Romi, 2013). However, current corporate reporting on Scope 3 remains mainly voluntary and incomplete. Reporting processes often rely on disparate estimations and generalized emission factors, which limit the accuracy and reliability of Scope 3 data. Prior studies find that the accuracy and dependability of Scope 3 statistics are limited by reporting procedures that frequently rely on varying estimations and generalized emission variables. For example, Hansen et al. (2022) indicate that numerous companies acknowledge certain Scope 3 emissions yet neglect to encompass all pertinent categories; for instance, in the food and beverage sector, disclosed value-chain emissions may account for merely 23-47% of the estimated total emissions. Systematic investigations indicate that self-reported Scope 3 emissions are underestimated by around 50% in comparison to harmonized estimates (Li et al., 2023). The lack of mandatory regulations in numerous jurisdictions has prompted certain organizations to consider Scope 3 reporting as "not worthwhile," prioritizing just the minimal required scopes (Ballentine, 2024). Prior study implies that the absence of credible Scope 3 data presents a significant barrier, as companies and their stakeholders are deprived of a comprehensive understanding of climate-related risks and possibilities. Griffin and Sun (2023) claim that omitting value-chain emissions impairs investors' ability to price climate risk efficiently, and Matsumura et al (2014) claim that companies that fail to disclose significant emissions may face market penalties.

Addressing the Scope 3 data challenge requires innovative approaches beyond traditional top-down reporting. Traditional, top-down reporting approaches, which rely on averages

(Unnewehr et al., 2022), fundamentally struggle to capture the granular, real-time data necessary for accurate Scope 3 inventories. This reliance on secondary, often outdated, sources leads to significant data gaps and unreliable disclosures (Unnewehr et al., 2022), hindering effective climate risk management and impairing investors' ability to price these risks. The limitations of these conventional methods underscore a critical need for a more robust data collection framework. To address this, our study proposes an innovative mobile-app-based, bottom-up approach that enables the direct collection of primary data from the entire value chain. By shifting from a generalized, top-down model to a precise, bottom-up approach, our framework not only enhances data accuracy and credibility but also promotes real-time engagement and transparency, which are crucial for achieving effective emissions reduction and corporate sustainability.

This study introduces an innovative, application-oriented modular architecture for quantifying and reporting Scope 3 emissions through integrating digital tools and stakeholder engagement, directly engaging key stakeholders—consumers, employees, and suppliers—in providing lifecycle information. This framework aims to enhance firms' understanding of their carbon footprint, engage stakeholders, and produce credible disclosure outputs through customer, employee, and supplier interfaces, supported by real-time data collection and AI-driven analysis. By leveraging interactive design, the application can crowdsource primary emissions data such as product usage patterns, commuting habits, and waste disposal from the actors whose activities drive Scope 3 emissions. Brocke et al. (2013) suggest that digital platforms can play a transformative role in sustainability efforts. Mobile applications provide a scalable method for collecting real-time data. This potential is substantiated by systematic assessments indicating that IoT-enabled sensors and real-time monitoring methods substantially augment dynamic life cycle inventories and facilitate decision-making across many industrial contexts (da Costa et al., 2024).

In the realms of environment and mobility, sensor-based real-time monitoring provides immediate feedback and continuous data streams, enabling prompt interventions (Sivasubrmanivam et al., 2025). Unlike purely automated technologies, such as sensors and IoT, an app-based solution emphasizes user input and engagement. It brings distinct benefits: it may acquire detailed, context-specific data that general industry estimates miss and influence user behavior through feedback and incentives. Hoffmann et al. (2024) demonstrate that continuous feedback provided by carbon footprint tracking applications (CFTAs) can reduce consumer emissions by up to 23%. Building on this insight, our study extends the application of feedback mechanisms beyond consumers to encompass employees and suppliers along corporate value chains. This integrated approach is important for two reasons. First, carbon emissions are distributed across multiple points in the value chain, such that focusing on consumers alone overlooks substantial sources of emissions from employee practices and supplier operations. Extending feedback mechanisms across these groups allows firms to address emissions more holistically, thereby capturing reduction opportunities that would otherwise remain invisible. Second, by creating consistent, real-time feedback loops across consumers, employees, and suppliers, organizations can align incentives and behaviors throughout the value chain. This reduces information asymmetries, strengthens accountability, and fosters a shared culture of sustainability, ultimately amplifying the effectiveness of carbon reduction initiatives beyond the consumer domain.

App-based technology may promote voluntary disclosure, thereby adding new information to the market that is not currently included in formal reports, which can potentially diminish information asymmetry and enhance corporate transparency. Firms that proactively disclose more complete emissions data tend to experience higher valuations than non-disclosers (Matsumura et al., 2014), and making previously hidden Scope 3 information visible can enhance sustainability management and reputation.

Accurate measurement of Scope 3 emissions is essential for enhancing ESG evaluations, fostering investor trust, and supporting credible sustainability performance metrics. Regulatory advancements, including the European Union's Corporate Sustainability Reporting Directive (CSRD) and the California Air Resources Board (CARB), increasingly emphasize the necessity of incorporating Scope 3 emissions in mandatory reporting (Climate Corporate Data Accountability Act [SB 253], 2023). As companies increasingly demand to disclose their carbon impacts across their value chains, innovative solutions are needed to bridge the ongoing disparity between carbon reporting standards and data accessibility.

Therefore, this study contributes to the literature on sustainable accounting and accounting information systems by proposing a mobile application framework for measuring Scope 3 emissions throughout the business value chain. Prior studies have emphasized the complexity and data gaps associated with measuring indirect emissions beyond organizational boundaries (Weinhofer and Busch, 2012; Schoenmaker and Schramade, 2019). This paper addresses the measurement challenges related to Scope 3 emissions, which include firms' reliance on proxy data such as industry-average emission factors and spend-based estimates, systematic under-reporting of material categories (Nguyen et al., 2023), and structural issues such as double-counting (Ma and Duan, 2024), heterogeneous data quality, and fragmented regulation (Mahieux et al., 2025), as delineated in the GHG Protocol (WRI and WBCSD, 2011), by conceptualizing a stakeholder-driven digital platform that engages consumers, employees, and suppliers. The proposed artifact enhances theoretical discussions on ESG data collecting and illustrates how mobile technology might facilitate more inclusive and dynamic sustainability accounting practices.

From a practical perspective, this research provides a blueprint for firms seeking to comply with emerging regulatory expectations and stakeholder pressures on carbon disclosure. While Scope 3 emissions often account for the majority of a firm's total carbon footprint, they are often omitted or reported inconsistently due to insufficient and unreliable data infrastructure (EPA, 2025a). This study presents a scalable, modular structure that facilitates decentralized yet uniform emission tracking, improving data accessibility and utility. The artifact promotes proactive stakeholder engagement and enhances the efficacy of ESG reporting and climate risk management.

The remainder of the paper is organized as follows. Section 2 provides background information and reviews the prior literature on Scope 3 emissions measurement and sustainability reporting with supporting theory. Section 3 introduces the conceptual framework of the proposed mobile application, detailing its core structure and functionality across the three key stakeholder modules: consumers, employees, suppliers, and the corporate-level perspective for integrated monitoring and data governance. Section 4 discusses the incentive mechanisms and motivational structures embedded in the app. Section 5 outlines the potential benefits to companies, and an accounting-oriented discussion is followed in section 6. Finally, Section 7 concludes the paper with a summary of key insights and implications.

2. Background and related research

2.1. GHG Protocol – Scope 3 Emissions

The most widely used framework for measuring and reporting greenhouse gas emissions is the Greenhouse Gas (GHG) Protocol. Emissions are categorized into three classifications: Scope 1 (direct emissions from owned or controlled sources), Scope 2 (indirect emissions from acquired electricity, steam, or heating), and Scope 3 (all other indirect emissions occurring within the value chain). Scope 3 emissions encompass all indirect emissions occurring across a company's upstream and downstream value chain (Stenzel and Waichman, 2023). Scope 3 emissions are generally the most substantial yet challenging to measure due to their indirect characteristics and reliance on data from other parties (Tabot and Boiral, 2015). Stenzel and Waichman (2023) report that, on average, indirect value-chain emissions account for 84% of a company's total emissions, with nearly two-thirds of industries experiencing more than 75% of their emissions falling under Scope 3. Industry and sector surveys, such as the EuroCommerce report (EuroCommerce, 2024), estimate that roughly 98% of greenhouse gas emissions in the European retail and wholesale industry are classified as Scope 3 emissions. Recent studies indicate that downstream activities, particularly the utilization of sold products, often constitute a significant portion of Scope 3 emissions in retail sectors (Buchenau et al., 2025). Furthermore, numerous firms encounter challenges in obtaining visibility into downstream phases and rely on assumptions due to the lack of data regarding the use phase or end-of-life (Hettler and Graf-Vlachy, 2024). These findings underscore that corporate climate action requires extending focus beyond the firm's facilities and into its supply network and customer base.

However, capturing a complete picture of Scope 3 emissions is inherently complex. There are 15 categories of Scope 3 activities under the GHG Protocol (WRI and WBCSD, 2004), ranging from Category 1: Purchased Goods and Services to Category 15: Investments, and relevant categories differ by industry (Stenzel and Waichman, 2023). The data needed is distributed across external parties, including suppliers at multiple tiers, consumers, logistics providers, recyclers, and others. Aggregating these data into a reliable emissions inventory is an enormous information integration task. Furthermore, operational boundaries and overlaps can be ambiguous: multiple firms in a chain might claim or omit the same emissions in their reports if guidance is unclear. Consequently, companies encounter methodological and practical obstacles in monitoring and regulating their Scope 3 emissions.

2.2. Measuring and Voluntary Disclosure

Recent research highlights the inherent complexity of measuring and managing Scope 3 emissions. Mahieux et al. (2025) state that various levels of uncertainty influence indirect emissions outside a firm's direct control. Initially, distributing emissions among multiple suppliers and downstream activities is fundamentally inaccurate, frequently leading to double-counting (Ma and Duan, 2024) when identical upstream emissions are assigned to different downstream entities. Secondly, the variability in data quality throughout organizations results in considerable discrepancies in reporting (Macknick, 2009). Third, regulatory frameworks are significantly fragmented, exhibiting disparate requirements across the United States, the European Union, and other countries (Gardinis, 2024), thereby facilitating carbon leakage as companies relocate operations to areas with less rigorous regulations. Fourth, the process of calculating and attributing indirect emissions is often imprecise (Vieira et al., 2024), due to the absence of standardized procedures and the challenges of tracking emissions across complex global supply chains. When taken as a whole, these restrictions cast doubt on the validity, comparability, and use of Scope 3 disclosures for investors and regulators.

The majority of businesses utilize proxies and estimates to measure their Scope 3 emissions (Stenzel and Wahichman, 2023), instead of gathering primary data for every emission source because of these restrictions. Common approaches include using industry-average emissions factors, spend-based estimates, or other secondary data sources to approximate emissions in each category (WRI and WBCSD, 2013). While such methods are expedient, they suffer from significant accuracy issues. Industry averages may be reasonable for coarse estimates, but they often diverge significantly from any specific firm's emissions (WRI and WBCSD, 2013). Downie and Stubbs (2012) highlight significant variations in reported Scope 3 emissions among firms engaged in comparable operations, primarily due to inconsistencies in the estimation methods and emission conversion factors. Nguyen et al. (2023) note that third-party emissions databases exhibit discrepancies in figures for identical Scope 3 categories among various suppliers, highlighting the inherent uncertainties. Significantly, the majority of corporations typically report on less material categories, such as business travel (<1%), while neglecting considerable categories like the consumption of sold items (up to 66%), which frequently represent dominating downstream sources (Nguyen et al., 2023). Current Scope 3 disclosures so often understate actual emissions (Li et al., 2024). These findings are supported by extensive benchmarking analyses indicating that, across numerous firms, downstream categories—especially the utilization of sold products—consistently prevail in Scope 3 emissions profiles, whereas upstream categories are comparatively insignificant (Buchenau et al., 2025). Nevertheless, previous research consistently highlights problems regarding the reliability and validity of ESG data (Christensen et al., 2021; Nguyen et al., 2023), particularly in relation to Scope 3 estimations that frequently depend on self-reported or modeled inputs. Table 1 presents the comprehensive category-level data that underpins this discussion.

Table 1. Illustrative Distribution of Scope 3 Emissions and Under-Reporting

Category / Measure	Share of Total Scope 3 Emissions (%)	Source/Note
Business Travel	< 1%	Nguyen et al. (2023, *PLOS Climate*)
Use of Sold Products	Up to 66%	Nguyen et al. (2023, *PLOS Climate*);consistent dominance also reported by Buchenau et al. (2025)
Under-reporting Potential (if all categories reported)	≈ 44% increase	Nguyen et al. (2023, *PLOS Climate*)

In other words, nearly half of Scope 3 emissions are not accounted for in public data due to incomplete reporting.

Multiple organizational and technical factors contribute to this shortfall. Companies face knowledge and resource constraints. Measuring Scope 3 requires supply chain carbon accounting expertise and significant data management capacity, which many firms lack (Klaveret al., 2024). Gathering primary data from suppliers or customers can be costly and time-consuming, and firms may not prioritize it without clear regulatory drivers or return on investment (ROI). Externally, supplier cooperation is a significant bottleneck: small suppliers may not have the advanced carbon measurement capabilities to provide customer data (Millot et al., 2025).

Additionally, the lack of mandatory legislation for Scope 3 emissions in many jurisdictions means that disclosure often remains optional. Voluntary environmental disclosures are strategic instruments companies employ to improve transparency, establish legitimacy, and fulfill stakeholder expectations (Clarkson et al., 2007; Hahn and Kühnen, 2013). Previous studies indicate that companies exhibiting exceptional environmental performance are more inclined to voluntarily share carbon-related information to distinguish themselves and mitigate information asymmetry (Dhaliwal et al., 2011; Peters and Romi, 2013).

Voluntary Scope 3 disclosures may be perceived as indicators of sophisticated carbon governance and supply chain management proficiency. These disclosures may facilitate stakeholder assessments of a firm's long-term risk exposure, especially concerning climate policy, resource dependence, or consumer behavior patterns (Eccles et al., 2012). Nonetheless, the lack of standardization frequently hampers investors' ability to evaluate the trustworthiness and comparability of Scope 3 data, particularly when such disclosures are self-reported and unaudited (Tang and Demeritt, 2018). This voluntary nature has led many firms to conclude that Scope 3 reporting offers little immediate benefit. Hettler and Graf Vlachy (2024) claim that managers "consider scope 3 reporting not worthwhile". Current methods and incentives are misaligned: companies lean on averaging (WRI and WBCSD, 2013) to produce partial Scope 3 figures, which are insufficient for robust decision-making. As a result, the net result is an information gap wherein neither firms nor investors have a clear line of sight into the largest share of emissions in the supply chain. This deficiency is not confined to corporate disclosures but also encompasses the technologies designed to facilitate them. Current sustainability dashboards and prevalent carbon footprint calculators predominantly depend on average emission factors (Unnewehr et al., 2022) and secondary databases for their inputs (Stenzel et al., 2023). Although these methodologies facilitate swift evaluations, they often reproduce the measurement deficiencies evident in corporate disclosures (Li et al., 2024): insufficient granularity, discrepancies among providers, and significant divergences from firm-specific emissions.

Likewise, examinations of corporate dashboards indicate that corporations utilize proxy-based supplier data and broad conversion factors instead of specific supplier-level emissions, hence sustaining discrepancies among enterprises within the same industry (Downie and Stubbs, 2012). The Greenhouse Gas Protocol's Scope 3 standard, although extensively utilized, specifically allows for the use of secondary data and industry averages when primary data is unavailable, hence formalizing the dependence on proxies (WRI and WBCSD, 2013).

This data indicates that the current ecosystem of disclosure practices and accompanying tools has failed to resolve the Scope 3 measurement issue, instead perpetuating it in alternative formats. The continued reliance on proxy-driven methods highlights the systemic nature of the information gap and emphasizes the challenges in producing decision-useful Scope 3 data under existing circumstances.

2.3. App-Based Solution: A Collaborative Data Collection Framework

Given the shortcomings above, there is a pressing need for new approaches to collect Scope 3 data at scale. Recent developments in cloud computing, the Internet of Things (IoT), and big data analytics have created new opportunities for organizing and estimating emissions data, particularly Scope 3. Application-based technologies and digital platforms enable companies to gather real-time activity data across global supply chains and customer usage contexts, facilitating more dynamic and detailed monitoring of indirect emissions (Wamba et al., 2015). Hybrid estimating techniques that integrate process-based life cycle assessments (LCA) with input-output modeling and machine learning are increasingly being adopted for Scope 3 estimation (Wiedmann and Minx, 2008).

We propose a mobile application-centered framework that engages the distributed network of stakeholders, such as consumers, employees, and suppliers, in reporting and sharing emissions-related information. App-based solutions offer several advantages. An application can obtain primary, detailed data directly from the sources of Scope 3 emissions, enhancing precision compared to generic estimates (Wamba et al., 2015). Mobile applications utilize personal devices and cloud infrastructure to facilitate scalability at a comparatively low marginal cost (Paixão et al., 2024) for each additional user. Previous studies confirm this scalability which demonstrates that service allocation algorithms can effectively manage a substantial number of concurrent users while sustaining performance (Rahimi et al., 2013), as well as by evaluations of cloud data center resource elasticity in response to fluctuating demand loads (Ghandour et al., 2023). Enlund (2023) indicates that users of carbon footprint applications decreased their emissions by approximately 10% following installation, demonstrating the behavioral influence of ongoing digital feedback. Furthermore, applications can integrate interactive and gamified elements to gather data and encourage sustainable behaviors, as assessments of carbon footprint calculators indicate that usability, incentives, and social comparison can markedly improve user involvement (Mulrow, 2019). By providing feedback, rewards, and a sense of participation, the application adds value for users, thereby encouraging ongoing involvement in the data collection process. This contrasts with one-time surveys or top-down audits; instead, the app fosters a continuous, two-way information flow between the company and its stakeholders.

While sensors and automated monitors have their place, they often require significant capital investment. They may not capture the human behavioral aspects of emissions, such as how consumers use a product. Previous study finds that a mobile application can collect contextually rich user information regarding their actions and decisions that affect emissions by utilizing integrated smartphone sensors like GPS and accelerometers. Gillis (2023) indicates that smartphone monitoring yields more comprehensive and reliable travel behavior data compared to traditional survey methods, while simultaneously alleviating participant burden. Innovative information systems can significantly reduce emissions by bridging information gaps and altering user behavior. In our context, the app connects the firm's accounting information system to the external world of its value chain, effectively transforming Scope 3 accounting into a more collaborative, data-driven process.

At the same time, we acknowledge that reliance on self-reported user input raises important concerns regarding data reliability, potential manipulation, and auditability, issues that are central to both sustainability accounting and regulatory compliance (Christensen et al., 2021; Mahieux et al., 2025). These challenges highlight the need for robust data validation mechanisms, triangulation with external datasets, and governance structures to ensure the trustworthiness of collected information. We return to these issues in Section 3, where we elaborate on how consumer-, supplier-, and employee-level models can be integrated with data control mechanisms to mitigate these risks.

Furthermore, an app-based approach is a practical solution. It enables the collection of primary data at the source. Rather than relying on industry averages, the company can obtain actual usage data of its products from consumers, commuting distances from employees, and supplier process data. In our framework, if a supplier adopts a cleaner technology or a consumer changes their usage habits, these improvements can be recorded through the app, giving proper credit and creating incentives that exceed industry averages. An app leverages network effects and the scale of crowdsourcing. Smartphones are ubiquitous, essential tools today, and even offer personalized services. The approach is globally scalable—new users can be onboarded with a simple download. The richer the dataset becomes as more participants use the system, enabling benchmarks and insights that benefit all participants. Another advantage of mobile technology is its capacity for efficient functional enhancement (Rahimi et al., 2013); the app can be continuously updated and refined. It is a flexible platform where data validation checks, user interface improvements, and new features can be rolled out via software updates. This adaptability is essential in the face of evolving standards and user feedback.

A notable advantage of this approach is that it produces information beyond what is currently mandated, thus contributing to greater transparency in the market. The app-facilitated data enables a voluntary disclosure of Scope 3 details that most firms lack. A previous study finds that markets reward firms for greater carbon transparency; firms that voluntarily disclose their emissions tend to have higher valuations than those that do not (Aulia et al., 2024). Matsumura et al. (2014) found that companies that did not disclose their emissions information suffered a further value discount compared to similar companies that did disclose, suggesting that investors penalize opacity.

By populating the firm's sustainability reports with more comprehensive Scope 3 data collected via the app, the company can signal better oversight of climate risks and responsiveness to stakeholder concerns. This could translate into concrete benefits such as improved investor confidence, lower cost of capital (Cheng et al., 2014), or enhanced brand value. Additionally, such rich data support better internal decision-making: managers can identify the emission flash point in the value chain and pursue mitigation strategies based on actual usage and supply chain patterns revealed by app data. In turn, this proactive management can further strengthen the business case by reducing waste and improving efficiency. Regulators and standard-setters are increasingly moving toward requiring Scope 3. Our proposed application framework establishes a structured approach to assessing, tracking, and managing emissions reporting obligations, while anticipating future disclosure requirements. By bridging the information gap, the app adds value to the firm and the broader market, as it converts previously hidden data into actionable disclosures, thereby fostering stakeholder trust.

2.4 Theoretical Foundations

We ground the proposed framework in Stakeholder Theory (Freeman, 1984), which explains how firms engage heterogeneous stakeholder groups whose interests, capacities, and salience (power, legitimacy, urgency) differ. This perspective provides a theoretical rationale for addressing the measurement limitations. The reason for Scope 3 data gaps is that different stakeholders have varying incentives to disclose information, differ in their capacity to pay for reporting, and have diverse expectations regarding the benefits of involvement. By connecting the application's design attributes with these characteristics, the framework translates Stakeholder Theory into an effective mechanism for collecting information.

In this paper, consumers, employees, and suppliers vary in motivation to share Scope 3 data, ability to bear reporting costs, and expectations about value from participation. The app operationalizes Stakeholder Theory by matching stakeholder attributes to design levers—incentive type (intrinsic vs. extrinsic), reporting burden (simple vs. advanced), and verification depth (light vs. stringent)—to increase engagement and data provision quality. This general mapping is illustrated through the following design choices across different stakeholder groups. For consumers, who typically have limited individual power in governance but exert collective influence through purchasing behavior, the app provides low-burden reporting combined with dual-track incentives: gamified features (leaderboards, badges) for sustainability-oriented consumers, and loyalty points or discounts for less engaged ones. Employees, who hold moderate power within the organization and whose alignment is strongly shaped by corporate culture, are provided with customizable incentives that firms can embed into HR practices, including performance evaluations, recognition systems, and vacation policies. Suppliers, who frequently manage significant amounts of upstream emissions, are assisted by a tiered reporting path: advanced suppliers can integrate their own carbon accounting systems into the app, while resource-constrained suppliers can utilize simplified forms and guided calculators. Stakeholder Theory also helps clarify the boundary conditions of the framework. The efficacy of an app in businesses where suppliers predominate is dependent on supplier-oriented design levers (e.g., integration possibilities, reporting load). In more consumer-focused industries, modules that capture use-phase emissions are expected to be more prominent. Stakeholder salience is dynamic; changes in the market or in regulations (such as the requirement for Scope 3 disclosure) may reshape which groups have more sway. The app's incentive structures and reporting systems must be flexible over time. This theoretical alignment generates testable hypotheses for future verification. Aligning design levers with stakeholder qualities is expected to enhance participation rates and data retention. Minimizing reporting obligations while preserving feedback and fundamental validation might enhance completeness without sacrificing accuracy. Aligning rewards with motivational profiles (intrinsic versus extrinsic) is anticipated to enhance data quality while also encouraging low-carbon actions observable via the application. As the quality of primary data enhances in completeness, granularity, and verifiability, the credibility of Scope 3 disclosures will rise, hence augmenting their utility for managers, investors, and regulators. The approach not only employs Stakeholder Theory but also enhances it by illustrating how diverse stakeholder traits can be methodically associated with artifact design in sustainability accounting.

3. Framework of the Proposed Scope 3 Data Collection App

Scope 3 emissions are complex, and accounting techniques are inefficient, leading to a need for precise (Wamba et al., 2015), scalable, and real-time measuring solutions. Application-based solutions gather and evaluate data along the entire value chain, facilitating external disclosure and improving managerial decision-making. This is corroborated by recent studies that demonstrate the limitations of static models and the advantages of dynamic, value-added emission tracing (Meng et al., 2018), as well as by digital supply chain innovations and big data analytics which enable real-time tracking across upstream and downstream processes (EPA, 2024). These platforms can overcome incomplete data and inconsistent reporting by integrating emissions estimation into digital workflows (Wiedmann and Minx, 2008). We outline a modular framework for the Scope 3 Data Collection Application to realize the above sight. The app is conceived as a unified platform with different interfaces tailored to three primary stakeholder groups: (1) Consumers, (2) Employees, and (3) Suppliers. Each module is designed to collect specific data relevant to that group's contribution to Scope 3 emissions, while also providing value back to the users through personalized feedback, rewards, or useful analytics. All modules feed into a central corporate database that integrates the incoming data, performs carbon footprint calculations, and interfaces with the company's accounting and reporting systems. Figure 1 below provides a conceptual overview of the system architecture, illustrating the data flows between the user modules and the central platform and the feedback loops for user incentives. Consumers, employees, and suppliers input lifecycle data through dedicated modules in a mobile application. These data are transmitted to a centralized corporate platform, where Scope 3 emissions are computed and analyzed. Feedback, such as sustainability scores, rewards, and benchmarking information, is returned to users via the app to encourage continued engagement. By facilitating an ongoing information flow between the company and its stakeholders, the system enhances the comprehensiveness of Scope 3 emissions reporting.

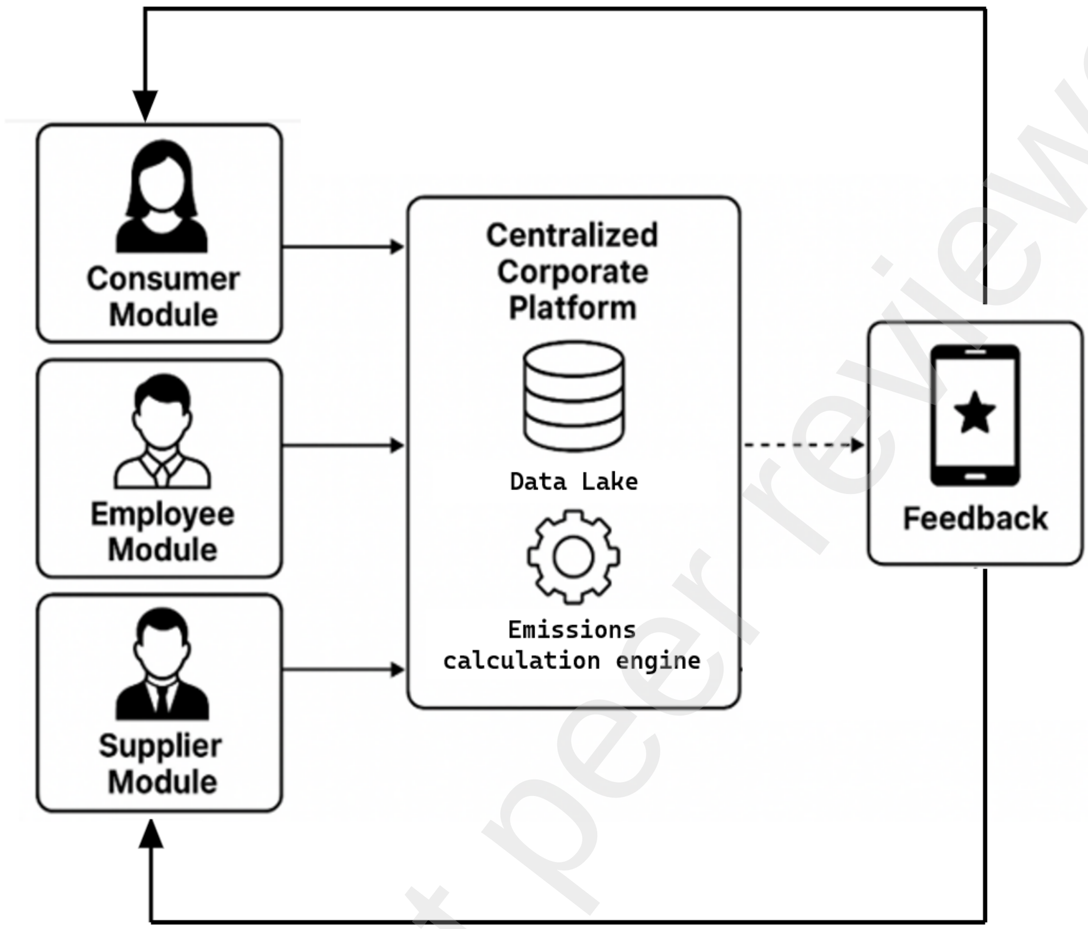

Figure 1. Conceptual architecture of the Scope 3 Data Collection App

3.1. Consumer Module

The consumer module of the app targets end-users of the company's products and services. Its primary goal is to gather data on the downstream phase of the product lifecycle, such as product usage and end-of-life disposal, which fall under Scope 3 categories like "Use of Sold Products" and "End-of-Life Treatment of Sold Products." Businesses frequently rely on general hypotheses about customer behavior and have limited insight into the use-phase and product disposal phases of the value chain. Empirical research indicates that constraints in data collection capacity and visibility significantly hinder the assessment and management of indirect Scope 3 emissions (Vieira, Longo and Mura, 2024). Furthermore, analyses of Scope 3 reporting indicate that companies often neglect high materiality categories—such as the utilization of sold products—favoring instead more conspicuous yet less significant categories like travel, highlighting reliance on proxies and assumptions (Nguyen et al., 2023).The consumer module closes this gap by enabling customers to easily log and share information about how they use and dispose of the products. Moreover, pressure from external stakeholders, particularly consumers demanding transparency, has been shown to increase the likelihood of corporate greenhouse gas disclosure; yet, such reporting often remains incomplete and selective (Liesen et al, 2015).

Upon installing the app, consumers can scan or register the products they purchase from the company. When installing the app or scanning product codes, the purchase QR code can be used easily. The app then provides an interface for users to input usage data at appropriate intervals. This could include the frequency and duration of product use and any maintenance or repairs that might extend the product's life. In the case of consumable goods, the app tracks the quantity or manner of use. For the end-of-life stage, the app assists users in reporting how they disposed of the product—whether they recycled it, refurbished it, resold it, or sent it to a landfill. Each disposal method has a distinct emissions profile, making this information crucial for accurate calculations of Scope 3 Categories 11 (Use of Sold Products) and 12 (End-of-Life Treatment of Sold Products) (WRI and WBCSD, 2011). The app makes reporting simple by offering one-click options or by integrating with smartphone features, such as using the camera to recognize if an item has been placed in a recycling bin.

The module employs gamification and rewards aligned with sustainable behavior to encourage consumers to participate. Users earn points or credits for each valid data submission or for completing certain activities. These points could be redeemed for discounts on future purchases, vouchers, or donated to environmental causes on the user's behalf. To reflect heterogeneous consumer motivations, the app introduces a dual incentive design. For sustainability-oriented users, the system emphasizes gamified elements such as leaderboards, badges, and community challenges that foster intrinsic motivation. For less sustainability-focused consumers, the app incorporates monetary loyalty rewards including discount coupons, loyalty points convertible to gift cards, or donations to NGOs on behalf of the user. By offering both symbolic and tangible incentives, the module ensures broader participation across diverse consumer profiles and avoids restricting engagement to only environmentally conscious segments. From a stakeholder-theoretic standpoint, the dual-incentive design matches heterogeneous consumer motivations and lowers reporting burden, increasing participation persistence and data completeness.

The module also provides personalized feedback, that of other users, or an optimal benchmark. Shahzad et al. (2023) indicate that when people are informed and engaged through technology, they can make better, more informed, environmentally sustainable decisions. Thus, the consumer module collects data and nudges consumers toward lower-carbon usage patterns. Gamification through social features enables users to share achievements or compete on leaderboards, achieving a minimal footprint while leveraging competitive and community dynamics to sustain engagement. Shahzad et al. (2023) claim that gamification effectively engages people in sustainable practices by increasing environmental awareness, fostering social connection and competition, and making eco-friendly behavior more enjoyable and lasting.

On the back end, consumer data is transmitted to the corporate platform. The company's algorithms convert the usage and disposal info into emissions estimates. For instance, if a consumer logs that they use a washing machine product 3 times a week with cold water, the app back-end can calculate the energy consumed and derive emissions based on local electricity grid factors. If a product is disposed of in a landfill, the system can estimate methane emissions from its decomposition over time. By aggregating data from potential consumers, the company obtains a much more tangible picture of Category 11 (Use of Sold Products) and Category 12 (End-of-Life Treatment of Sold Products) emissions than it would by guessing usage patterns. It also allows for segmentation: the firm can identify whether certain consumer groups or regions have higher use-phase emissions, inform product design or customer outreach, and design more effective recycling programs if the data indicates low recycling rates in specific areas.

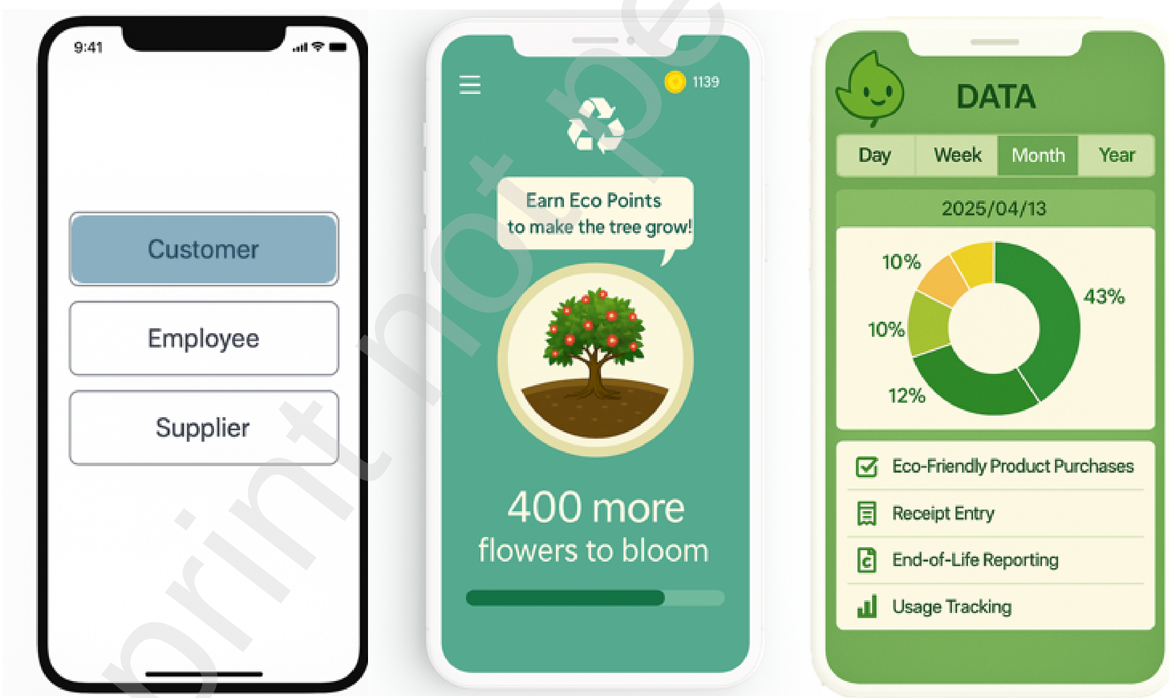

Figure 2. Customer Module UI: Interactive Sustainability Tracking and Rewards

3.2. Employee Module

The employee module captures Scope 3 data related to a company's workforce activities, primarily employee commuting (Category 7) and business travel (Category 6) (WRI and WBCSD, 2011). Empirical research indicates that, despite and because of their low magnitude, categories like business travel (Category 6) and employee commuting (Category 7) continue to be strategically relevant for many organizations, even though they typically produce a relatively tiny fraction of overall Scope 3 emissions. Nguyen et al. (2023) indicate that business travel constitutes less than 1% of overall value-chain emissions, although remains one of the most commonly reported categories. In corporate clusters analyzed by Buchenau et al. (2025), downstream categories such as 'usage of sold items' predominate across numerous industries, although categories like travel and commuting, though lesser, remain significant. In other words, while often smaller in magnitude than upstream or product use emissions, these categories are still significant for many firms. Moreover, these categories are where improved data can directly inform internal policies. Many companies estimate employee commuting emissions using national averages or survey data (WRI and WBCSD, 201), which can be inaccurate. The employee module aims to collect and keep this information up-to-date directly. Additionally, to safeguard privacy, the employee module is designed to minimize the collection of personally identifiable information (PII). Data are aggregated at the departmental or organizational level where feasible, and individual entries are encrypted. Users provide explicit consent before data submission, ensuring compliance with major privacy regulations such as the General Data Protection Regulation (GDPR) in European Union (EU) and the California Consumer Privacy Act (CCPA) (Bonta 2022) Furthermore, the module incorporates governance features such as role-based access controls and audit trails, allowing firms to monitor how data are used and ensuring accountability in line with corporate sustainability and IT governance standards (Voigt and Von dem Bussche, 2017).

Employees use the app to log their commute details and business travel. The application facilitates low-carbon commuting in urban environments by allowing employees to accumulate Eco-Money points for walking or cycling to their workplace. The distance between home and the office can be quantified using GPS monitoring, while public transportation usage, such as subway or bus rides, can be detected via NFC integration. The application continuously monitors commuting behaviors and encourages users to periodically report any changes, facilitating precise, real-time tracking of commuting-related emissions. The app rewards employees who commute by car and choose environmentally conscious alternatives for work-related purposes, such as fuel-efficient or electric vehicles, carpooling initiatives, or sustainable commuting accessories. These options reduce resource consumption relative to traditional commuting practices and advance the company's environmental objectives.

Since companies often have records of flights and trips, the app might integrate with travel booking systems for business travel. Whenever an employee takes a flight or train for work, a notification could appear in the app to confirm details or add context. Alternatively, employees can manually enter trips if needed. The key is to gather accurate mileage and mode information for all significant travel. Since business travel emissions are typically reported anyway, the app primarily streamlines data capture to ensure nothing is missed.

Encouraging employees to use the app may require a different approach than that for consumers, as employees can be motivated by factors such as altruism and organizational loyalty. The app can help employees understand how their participation contributes to the company's sustainability goals and climate leadership. Gamified elements could include competitions or challenges such as a “Green Commuter Challenge” where departments compete to log the most low-carbon commutes. The app can award badges or recognition, for instance, an employee who consistently bikes to work might earn a "Carbon Cutter" badge visible on their profile. Recognizing organizational and industry differences, the employee module is designed with customizable incentive schemes that can be tailored by firms to fit their internal culture and policies. For example, technology firms may emphasize recognition awards and digital badges linked to sustainability dashboards, while manufacturing companies may offer tangible benefits such as additional vacation days, gift cards, or direct monetary bonuses for consistent low-carbon commuting. By enabling such flexibility, the app aligns with human resource management practices across industries and increases the likelihood of sustained engagement among employees with diverse motivations. The module also provides personalized analytics for employees. Such feedback can reinforce positive behavior. In addition, Customizable HR-aligned incentives operationalize stakeholder fit for employees, strengthening engagement consistent with Stakeholder Theory.

The central system aggregates the information collected to calculate total emissions from commuting and travel. This can enhance the accuracy of Scope 3 Category 6 (Business Travel) and 7 (Employee Commuting) estimates (WRI and WBCSD, 2011). The company will have actual distances and modes rather than assuming an average commute distance. Furthermore, measuring tends to encourage improvement: as employees see their data, they may be more inclined to try alternatives supported by company incentives. This aligns with the notion that what gets measured gets managed; by turning abstract commuting habits into tracked data, the app helps manage those emissions.

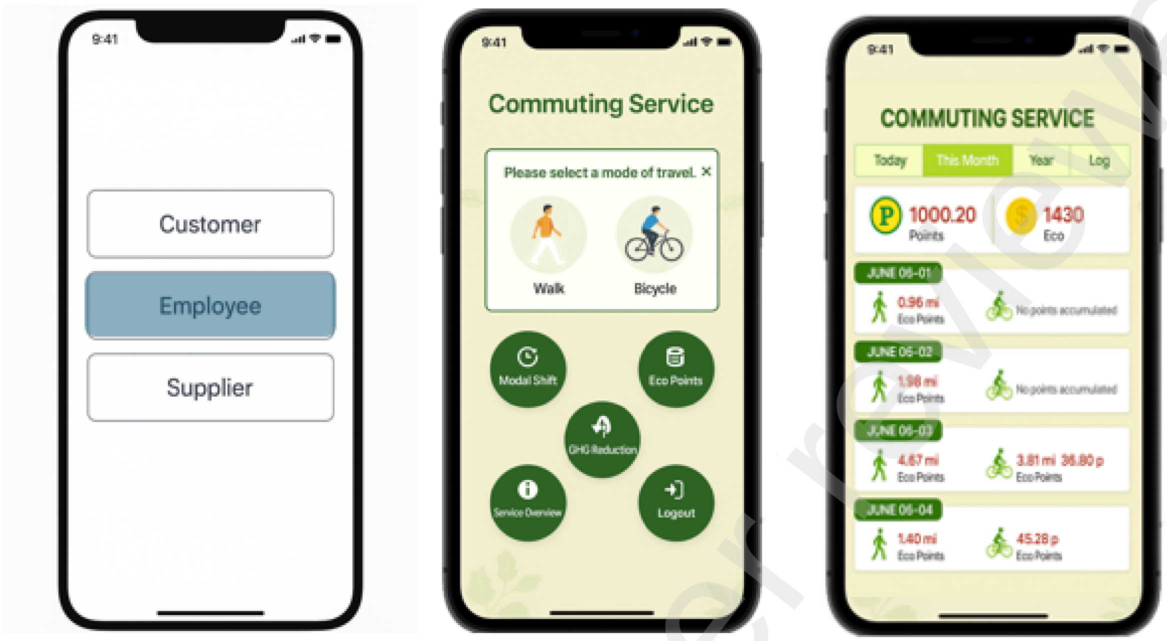

Figure 3. Employee Module UI: Sustainability Engagement and Incentives

3.3. Supplier Module

The supplier module is designed for upstream supply chain partners. These correspond to multiple Scope 3 categories, including Category 1 (Purchased Goods and Services), Category 2 (Capital Goods), Category 4 and 9 (Upstream and Downstream Transportation), and others, such as Category 10 (Processing of Sold Products) (WRI and WBCSD, 2011). Purchased goods and services are often the single most significant component of Scope 3 for certain firms (Downie and Stubbs, 2012; Burchart et al., 2025), yet obtaining emissions data from suppliers is one of the most challenging tasks (Greenhouse Gas Protocol, 2022). Typically, a firm might send surveys to suppliers or use industry-average emission factors per dollar of spend in each procurement category (WRI and WBCSD, 2013). These methods yield very rough estimates and do not allow comparison of supplier-specific performance (Nguyen et al., 2023). The supplier module addresses this by creating a structured channel for suppliers to input their emissions data directly in a consistent format. Suppliers may also disclose carbon emissions in response to institutional pressures, although previous research indicates that this type of reporting often serves symbolic reasons that are more concerned with legitimacy than accuracy (Kolk et al., 2008).

Through the app, suppliers would report data needed to calculate the carbon footprint of the products or materials they supply. There are two approaches: have suppliers report their own carbon footprint metrics or report underlying activity data, such as energy consumption and process yields, which the system can use to compute emissions. Large suppliers may already measure their GHG emissions and can share those figures directly. The app could integrate uploads of standard formats. For smaller suppliers, the app may offer a guided form, a simplified carbon calculator that allows them to input key data such as the quantity of raw materials used, the type and amount of energy consumed during production, and the volume of waste generated. The app calculates the emissions for that supplier's operations related to the product supplied.

In order to accommodate variations in industries, sizes, and geographical settings, the module uses a tiered reporting structure. Major suppliers possessing well-established sustainability divisions—such as automobile and electronics manufacturers—are currently exploring sophisticated Scope 3 management strategies, which include cloud-based platforms, life-cycle assessment integration, and supplier engagement initiatives (Wang et al., 2024; PwC, 2024). These companies can directly incorporate their current carbon accounting systems via standardized data interfaces. Conversely, smaller suppliers, such as local food processors or component manufacturers in emerging markets, may lack advanced measurement capabilities. The application offers guided calculators and streamlined forms to collect critical data points (e.g., energy use, material inputs, transportation methods) for these enterprises, eliminating the need for specialized knowledge. This difference guarantees that both well-resourced and resource-limited suppliers can engage effectively, hence enhancing feasibility across various industry sectors and improving the comparability of emissions data.

The module integrates confidentiality and governance controls due to the potential inclusion of commercially sensitive information in supplier data, such as energy use, production methodologies, or transportation documentation. All supplier inputs are encrypted, access is role-specific, and audit trails document data utilization for accountability. Information is consolidated prior to external dissemination, and only non-sensitive outputs are disseminated unless specific authorization is obtained. These methods guarantee adherence to data protection and trade secrecy regulations (Voigt and Von dem Bussche, 2017; Bonta, 2022).

To facilitate adoption, the supplier module is integrated into existing supplier processes. It could be linked with procurement systems so that the supplier is prompted to provide or update the associated carbon data whenever a purchase order is made. The app aligns with qualification and sustainability reporting processes. Suppliers may be required to fill out the emissions information annually as part of their qualification to be a preferred vendor. A progressive approach can be used. Even if suppliers only provide partial data, it raises awareness. Over time, the app encourages the collection of more complete data. It is also necessary to establish confidence with suppliers in order to ensure adoption. The framework prioritizes confidentiality and governance, ensuring that critical business data is safeguarded and only aggregated, non-identifiable information is disclosed unless express consent is obtained.

Suppliers are typically businesses themselves, so their motivation to participate will hinge on the business value and relational incentives. One major incentive is continued or expanded business with the company. The firm can clarify that reporting through this app is part of its supplier sustainability program, and that good performance will be considered in supplier evaluations. The app forms the backbone of a Supplier Sustainability Scorecard. Each supplier using the app receives a sustainability rating or score derived from their emissions data, which is shared with them. This score is benchmarked against peer suppliers to show where they stand. Demonstrating lower carbon products could give suppliers a competitive edge in procurement decisions. The company could publicly recognize top-performing suppliers for positive reinforcement, providing reputational benefits. The app includes a feature where suppliers can see resources to reduce their emissions, adding value beyond data entry.

From a gamification standpoint, while traditional game elements might be less directly applicable to businesses, a form of gamification could involve ranking and competition. Suppliers could see a leaderboard of emissions intensity among all suppliers in a category, which can drive friendly competition to climb the ranks by improving efficiency. Also, a collaborative aspect is introduced. The app allows suppliers to form groups or forums to discuss improvement measures, thereby creating a community of practice in sustainability. This sense of partnership and shared goal can strengthen supplier engagement.

The supplier data flows into the central platform, where the company can aggregate upstream emissions. By collecting data at the product and supplier levels, the company can transition from generic emissions factors to supplier-specific emissions accounting. Over time, as more suppliers participate, the company can identify which suppliers or commodities contribute most to its Scope 3 and target those for improvement or support. Also, by having primary data, the company can avoid the problem of double-counting or inconsistencies in Scope 3 since it is getting direct numbers from suppliers. This sharing of primary data aligns with recent research advocating data collaboration along supply chains to tackle emissions more effectively. When companies share emissions data, the dynamic shifts to a more cooperative approach to alleviate GHG emissions (Stenzel and Waichman, 2023).

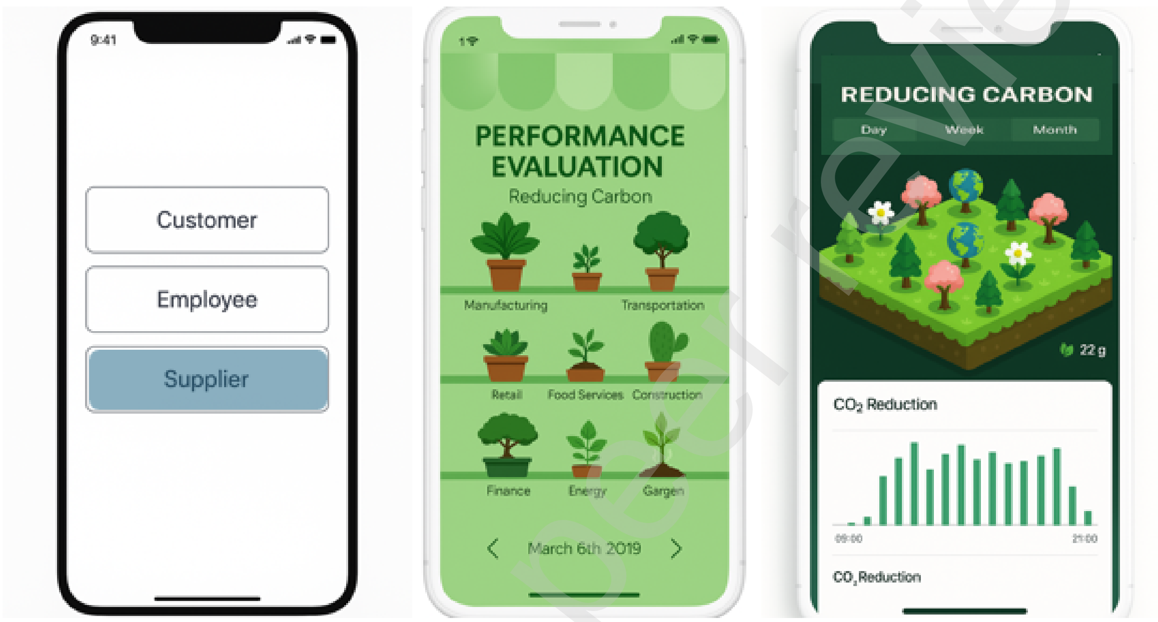

Figure 4. Supplier Module UI: Carbon Footprint Performance Evaluation and Visualization

3.4. Data Integration and Quality Control

An efficient sustainability information system necessitates collecting ESG-related data from stakeholders, including consumers, employees, and suppliers, and integrating these data streams to produce consistent, accurate, and actionable insights. Integrating data from various app modules enables a more comprehensive understanding of carbon emissions throughout the value chain, empowering companies to prioritize reduction initiatives and comply with reporting standards such as the GHG Protocol and CSRD (WRI and WBCSD, 2011; European Commission, 2023). All modules contribute to a unified data infrastructure on the corporate side, as depicted in

Figure 1. The system comprises a cloud-based data lake or warehouse that stores the raw inputs from users, a calculation engine that applies emission factors and calculates emissions per category, and analytical dashboards for sustainability managers to monitor the incoming data. Ensuring data quality is vital; thus, the app should have built-in validation rules.

To improve data reliability, the app incorporates validation mechanisms such as anomaly detection using machine learning algorithms, periodic random audits, and optional third-party assurance modules. Furthermore, Application Programming Interfaces (APIs) facilitate interoperability with Enterprise Resource Planning (ERP), Supply Chain Management (SCM), and AIS systems, enabling seamless integration of carbon-related data streams. To ensure compliance with privacy regulations such as the General Data Protection Regulation (GDPR) and the California Consumer Privacy Act (CCPA) (Bonta 2022), the app employs encryption, data minimization, and anonymization features.

Moreover, leveraging machine learning (ML) methodologies can significantly improve data quality by identifying abnormalities, forecasting absent values, and refining pattern identification in user behavior and emission trends (Qolomany et al., 2019). In cases of suspicious data, the system can prompt for confirmation or provide a guide to correct errors. Machine learning-driven data validation enhances confidence in reporting and supports real-time decision-making, enabling organizations to adjust their sustainability strategies dynamically.

Notwithstanding these advantages, data integration and machine learning applications must be developed with data security and privacy issues. The platform must protect the personal data of consumers and employees, as well as safeguard sensitive supplier information. The integration of consumer commuting data, product utilization, and supplier records presents ethical and regulatory challenges, especially when this information may be linked to personally identifiable or sensitive data. To alleviate these concerns, organizations must establish robust data governance policies that encompass data minimization, anonymization, and encryption protocols. Only non-sensitive, aggregated data should be used for assessment and reporting, unless an express user agreement is obtained. Personal and sensitive information must be securely maintained and safeguarded in accordance with regulations such as GDPR and other regional data privacy frameworks (Voigt and Von dem Bussche, 2017). By establishing a robust, privacy-aware data infrastructure that integrates multiple sources and applies ML-based quality control, companies can gain a strategic advantage in ESG performance monitoring, regulatory compliance, and stakeholder trust.

3.5. Data Governance and Assurance

A strong framework for governance and assurance is necessary to guarantee the reliability and accountability of Scope 3 data. Although app-based solutions enable extensive, grassroots data collecting, their dependence on self-reported data poses significant concerns of bias, manipulation, and unverifiable information. In the absence of well-defined safeguards, these deficiencies may compromise the veracity of reported emissions data and restrict its use for sustainability accounting and regulatory adherence (Christensen et al., 2021; Mahieux et al., 2025).

The suggested platform has a multi-layered governance framework to mitigate these risks. Initially, internal validation methods guarantee consistency and identify irregularities by cross-referencing submitted data among consumer, employee, and supplier modules. Suspicious entries can be identified and either verified by the user or cross-checked with external datasets like product lifecycle databases, energy bills, or commuter records. Secondly, external assurance techniques enable independent auditors or third-party verifiers to do random assessments or specific validations, thus enhancing auditability and discouraging deliberate manipulation (Liesen et al. , 2015). Third, immutable audit trails enabled by blockchain or distributed ledger technology can prevent data manipulation, maintain historical records, and promote transparent supervision (Casino et al., 2019).

Moreover, robust data governance procedures must be instituted to reconcile assurance with data privacy. These policies must delineate acceptable data utilizations, enforce data minimization, and require the anonymization of personally identifiable or sensitive supplier information. Aggregated, non-sensitive data may be utilized for corporate reporting and benchmarking, however access to disaggregated information must be limited and contingent upon specific user agreement in accordance with privacy legislation such as the GDPR and CCPA (Voigt and Von dem Bussche, 2017; Bonta, 2022).

The technology optimizes the accuracy and reliability of Scope 3 disclosures and builds stakeholder confidence by integrating internal validation, third-party assurance, immutable audit trails, and privacy-conscious governance standards. Implementing a governance and assurance framework is crucial for validating mobile, stakeholder-driven data gathering as a reliable addition to current sustainability reporting systems.

4. Incentive Mechanisms and Motivation for Participation

4.1. Incentive Mechanisms in Application

A major challenge for any crowdsourced data initiative is sustaining user participation. The app's success hinges on users continuing to input accurate data over time. Our framework incorporates motivational mechanisms tailored to each stakeholder module to achieve this. Gamification has increased engagement and enjoyment (Shahzad et al., 2023). In the context of environmental data collection and sustainable behavior, gamification encourages individuals to adopt environmentally friendly actions by leveraging motivational elements to help them achieve desired outcomes (Shahzad et al., 2023).

Our app's consumer module implements a points and rewards system to incentivize regular data logging. The application utilizes a structured incentive system based on collecting "Eco Points" to encourage long-term user engagement and environmentally conscious behavior. Users accumulate points by engaging in consistent sustainability practices, including scanning product QR codes, recording their weekly usage, and reporting the disposal of products. Additional points are granted for confirmed low-carbon activities, such as walking or cycling for transportation, or engaging in educational quizzes on environmental subjects. Eco Points can be exchanged for various meaningful rewards. Users can redeem their points for Eco Money gift cards, which are redeemable at participating retailers, including local cafés, restaurants, and shops. Users may alternatively contribute points in $1 increments to accredited environmental non-governmental organizations (NGOs). At year-end, customers receive a digital donation certificate summarizing their impact, which can be used for tax or personal reporting purposes. Additionally, highly engaged users may access unique advantages, such as reduced entry fees to national parks, municipal fitness centers, or cultural events. This reward mechanism promotes ongoing engagement and enables users to visualize their cumulative environmental impact through indicators, such as the metaphorical number of trees "planted" corresponding to their CO_2 reductions. The software also enables users to share their CO2 contributions with friends or competitors, encouraging greater engagement. Leaderboards tap into competitive spirit; seeing oneself climb the ranks can be highly motivating. Lu and Ho (2020) suggest that these game mechanics can increase user engagement.

This reward system integrates gamification and tangible rewards to harness inner and extrinsic drive, thereby enhancing individual contributions to overarching climate objectives. It establishes a feedback loop that enhances data completeness and reliability, thereby improving the app's overall effectiveness as a tool for environmental accounting.

Figure 5. Incentive system UI

4.2. Incentives and Engagement

A powerful motivator for users is the sense of purpose of environmental impact. The app makes the consumer's contribution transparent, showing cumulative stats. Recognizing that one's small actions contribute to a larger climate effort can fulfill individuals' desire for meaning and align with their values, particularly for environmentally conscious consumers. Prior studies indicate that consumers are willing to participate in green initiatives. The app's treatment of users as collaborators in climate action can help increase brand loyalty. Empirical research indicates that customers are progressively inclined to pay premium pricing for brands that prioritize sustainability and societal benefit (Gomes et al., 2023; Goedertier et al.,2024).. Our app capitalizes on this goodwill by directly involving them in the brand's sustainability performance. The app can also enhance brand loyalty by treating consumers as partners in climate action. Research shows that consumer satisfaction with mobile applications significantly influences loyalty to both the apps themselves and the associated brands (Kim and Kim, 2022). Users may feel a closer connection to the company because they are actively engaged in its sustainability journey.

For employees, participation might initially be seen as an extra chore beyond their job duties. To overcome this, the app's employee module ties into corporate culture and personal benefits. Yang and Jiang (2023) find that employees who witness their leaders recognizing colleagues will likely enhance their work engagement. The app incorporates internal recognition and reward programs: departments or teams that achieve high participation or significant reductions in emissions may be publicly praised by leadership. Recognizing employees markedly enhances task performance and organizational citizenship behaviors by cultivating a sense of pride (Yang et al., 2022).

Employees can also benefit from competitive elements in gamification. For example, the app features a dashboard that allows employees to compare their commuting emissions to the company's average or target. The app's social feed might highlight stories of employees who took innovative steps, recognizing them and spreading ideas to others.

The app can also incentivize employees by offering a commute planner that suggests lower-carbon routes or options. For example, employees can discover through the app that a colleague is nearby with whom they can carpool. Likewise, the app could track how much money an employee saves. Monetary savings can be a direct personal incentive. Coupled with any company-provided support, employees see tangible benefits. Additionally, as sustainability becomes a core value for many organizations, employees may feel a greater intrinsic motivation to participate in these efforts, thereby enhancing their job satisfaction. The app sends encouraging messages or tips to keep engagement.

Motivating suppliers can be different, as this is a B2B relationship. The primary incentive for suppliers is business-driven. If providing emissions data and improving their performance increases their likelihood of securing or maintaining contracts, they are strongly motivated to do so. Therefore, the app essentially acts as a portal for suppliers to demonstrate their sustainability credentials. We propose integrating a supplier sustainability score that is visible to the supplier and the company's procurement team. Zhan et al. (2021) suggest that managers emphasize sustainability in supplier assessments and are more significantly dissuaded by inadequate sustainability performance. Previous studies argue that information visibility is a fundamental communication construct, and scholars generally assume that increased visibility of information leads to greater organizational transparency (Hoeven et al., 2019). Therefore, making supplier sustainability scores visible can serve as a driver of sustainability-related decisions. Suppliers actively using the app to report data and achieve lower product emissions would earn higher scores.

The company can then preferentially reward those suppliers with continued business or public recognition. For example, the firm might issue an annual sustainability report highlighting "Top 10 Green Suppliers"; inclusion in that list can be prestigious and commercially valuable for the suppliers, as it signals their leadership to other clients. This creates a reputational incentive. Suppliers motivated by climate change incentives tend to be more responsive to normative pressures, leading them to demonstrate higher levels of carbon transparency (Villena and Dhaorkar, 2020). Being proactive through this app could further differentiate them from their peers.

Scales Jr et al. (2016) find that team-based competition enhances engagement and boosts participation. To encourage participation, the app can provide benchmarking information to suppliers. After inputting their data, a supplier might receive feedback like "Your carbon intensity for Product X is 10% above the average of our suppliers in this category" or "You are in the top quartile of low-emission suppliers in your field." This confidential feedback lets suppliers know where they stand and can spur those lagging to improve and stay competitive. This could create a race to the top, where suppliers compete to offer lower-carbon products to the company, driving innovation in the supply chain.

While traditional game elements might be less overt for suppliers, the app incorporates elements of status and achievement. Suppliers could earn digital badges within the app, like "Certified Low-Carbon Supplier". These badges or certifications can be used in their marketing. As sustainability becomes a selling point in B2B relations (Lichtenau and Cleghorn, 2024), having a badge from a major client acknowledging their efforts can be a selling point to other customers.

Environmental behaviors often suffer from a lack of tangible feedback, making it difficult for individuals to perceive the effects of their actions (Darby, 2006). To address this gap, the proposed app integrates a feedback mechanism that immediately reflects users' contributions.

When users submit environmental data, they receive a real-time update reinforcing their behavior. This approach mirrors the effectiveness of fitness and habit-tracking apps, which sustain engagement by providing continuous progress updates (Rahimi et al., 2013; Ghandour et al., 2023). The app encourages consistent participation and builds a sense of accomplishment by offering instant feedback and gratification. The app simulates the otherwise intangible outcomes of sustainable actions, creating a proxy feedback loop that enhances motivation and behavior change.

The app's multi-faceted incentive scheme is expected to improve user uptake and retention. The app tackles one of the most significant barriers in Scope 3 accounting by making data reporting rewarding, informative, and fun.

5. Practical Implications

Adopting a mobile application to collect Scope 3 emissions data fundamentally transforms corporate sustainability management into a proactive, data-driven process. By capturing real-time, source-level inputs across all stages of the value chain, the app enhances the accuracy, completeness, and timeliness of emissions data, core principles emphasized by the EPA (2025b).

One of the most immediate benefits lies in the app's ability to identify emissions-intensive activities across the value chain. This visibility allows companies to pinpoint where operational changes, supplier engagement, or process redesigns can lead to meaningful emissions reductions. For example, emission insights might reveal opportunities to streamline logistics or reconfigure supplier networks, reducing carbon output and operational costs.

The modular architecture of the proposed app allows for industry-specific adaptation. For example, in retail, consumer use-phase emissions (Category 11) constitute the largest share of Scope 3, whereas in heavy manufacturing, upstream purchased goods and transportation

(Categories 1 and 4) dominate. Firms can therefore prioritize the consumer, supplier, or employee modules according to their sectoral context, ensuring that implementation is both feasible and effective across diverse industries.

Beyond emissions tracking, the app fosters supply chain transparency. Emissions data collected and shared through the platform enhances trust among stakeholders by demonstrating a credible commitment to sustainability. Mobile technology, including mobile devices and IoT sensors, has been acknowledged in peer-reviewed literature as crucial for offering clients insights into supply chain sustainability. Sharma et al. (2023) illustrate how IoT-based traceability and mobile device data enhance transparency and accountability throughout the upstream and downstream phases of the supply chain. In the RMG industry, Ahad (2022) demonstrates that mobile-enabled supply chain management frameworks enhance communication, information dissemination, and visibility among supply chain participants. Thus, sharing Scope 3 data via an app promotes collaborative emissions reduction plans with corporate customers and suppliers, strengthening inter-organizational relationships. Suppliers can regularly report emissions or activity data through a user-friendly interface, and increased engagement improves data quality and drives shared accountability across the supply chain.

From a governance perspective, integrating mobile Scope 3 data collection elevates climate risk management into the corporate strategy. Real-time data enables management to establish evidence-based emission targets, monitor progress, and embed climate consideration into core business functions such as procurement, product development, and financial planning. In practice, app-generated data can be integrated directly into departmental workflows. Procurement teams can access supplier-level data through APIs linked to supply chain management systems, incorporating emissions information into vendor scorecards and qualifications. Product development teams can use consumer use-phase data to inform lifecycle assessments and prioritize low-carbon design. Finance departments can feed aggregated Scope 3 figures into ESG dashboards and budgeting processes, linking emissions performance to capital allocation and risk controls. By embedding Scope 3 information into these core functions, the app fosters cross-functional engagement and aligns climate considerations with daily business decisions.

The app helps distribute accountability across departments, embedding emissions awareness into daily decision-making and accelerating the company's transition to a low-carbon economy. However, there can be practical challenges to implementation. Internal resistance can occur when new reporting interrupts current workflows or is regarded as subordinate to immediate performance goals. Smaller enterprises and suppliers may be deficient in the requisite IT infrastructure for seamless integration. Effective adoption necessitates agreement among procurement, finance, and product development teams over data standards and governance mechanisms. Ultimately, training and capacity development for employees and suppliers contribute to the initial adoption burden. Understanding these difficulties emphasizes the value of leadership support, gradual rollouts, and ongoing engagement strategies.

Even with these challenges, a mobile app replaces manual, error-prone processes with automation and standardization. Emissions calculations, informed by embedded emission factors, are executed consistently and efficiently. Data collected through the app arrives in uniform formats, eliminating the need for manual reconciliation. Integrated validation technologies can identify discrepancies in real time, improving integrity and lowering administrative expenses. These improvements expedite reporting timelines and can also uncover value-chain inefficiencies—such as energy waste or excessive packaging—that result in both cost savings and diminished emissions. The strategic value of the app extends to innovation. The app can even support internal competitions or incentive programs tied to emissions reductions, encouraging product teams to innovate in ways that align with corporate sustainability goals. From a firm-level perspective, successful adoption requires embedding the app into existing business practices. Companies can integrate app participation into supplier qualification and sustainability scorecards, connect consumer participation to loyalty and reward programs, and align employee engagement with performance evaluations and internal recognition systems. These strategies provide concrete mechanisms for scaling stakeholder participation and ensuring long-term engagement.

Ultimately, a mobile Scope 3 emissions app helps embed a dynamic and continuous cycle into the organization. It shifts sustainability reporting from a retrospective compliance task to a constant improvement process, fostering a culture of innovation and agility. As companies pursue long-term net-zero goals, such tools will be critical for maintaining competitive advantage and adapting to evolving regulatory and market expectations. Mobile Scope 3 data applications elevate sustainability performance by delivering real-time insights, operational efficiency, and strategic alignment.

6. Accounting and Reporting Implications

Introducing a mobile app for Scope 3 emissions data enhances the quality of sustainability disclosures, promoting closer integration between financial and non-financial reporting. Scope 3 data extends the traditional accounting framework beyond a firm's internal operations to incorporate the entire value chain, including upstream and downstream activities such as supplier production and customer product utilization (Burritt and Schaltegger, 2010). This transition indicates an overall shift towards sustainability accounting, when externalities are no longer considered "non-accounting" matters but are incorporated into the assessment of business performance. The app directly links environmental impacts to business outcomes by providing granular, quantitative data, enabling companies to implement effective internal carbon pricing or budgets. Incorporating Scope 3 emissions into reporting frameworks supports the increasing alignment between financial accounting and sustainability disclosure. With the expansion of international standards like IFRS S2 (IFRS Foundation, 2023), the EU's Corporate Sustainability Reporting Directive (CSRD), and the California's Senate Bill 253 to encompass Scope 3 emissions, companies are anticipated to gather, organize, and present ESG-related data with the same diligence as conventional financial information. This obscures the distinction between sustainability teams and accounting activities, necessitating increased collaboration and improved data systems (Burritt and Schaltegger, 2010).

Moreover, detailed emissions data enable precise modeling of climate-related financial risks, such as potential regulatory penalties or future carbon pricing scenarios, supporting informed procurement and product development decisions. Scope 3 data augments the strategic function of accounting within the organization. Sustainability accounting reports on historical performance and guides operational and investment decisions, including selecting low-emission suppliers, designing more sustainable products, and assessing carbon pricing scenarios. Thus, accounting transforms from a retrospective reporting mechanism to a prospective decision-support system that assists corporations in internalizing environmental costs and aligning with long-term climate objectives (Burritt and Schaltegger, 2010).

Overall, adopting a Scope 3 emissions app strengthens regulatory compliance and transparency and embeds climate considerations into strategic and operational decision-making, positioning companies as proactive leaders in sustainability.

7. Discussion and Conclusion

This study presents a comprehensive framework for utilizing a mobile application to enhance the collection and management of Scope 3 greenhouse gas emissions data. Our app-based solution addresses critical shortcomings in current Scope 3 reporting, data quality, availability, and completeness. Current approaches rely on secondary (Greenhouse Gas Protocol, 2022) which implies that results will be incomplete or unreliable. By contrast, our mobile app gathers primary emissions data directly from consumers, employees, and suppliers, resulting in richer, more accurate, and credible disclosures.

Improved data availability and quality enable firms to fulfill their reporting obligations better. Consequently, stakeholders gain access to detailed and trustworthy emissions data that was previously difficult to obtain. This enhanced transparency mitigates uncertainty and may positively influence investor evaluations, ESG ratings, and market reputation.

Beyond improved disclosures, the mobile app substantially enhances sustainability management through real-time data collection and continuous feedback mechanisms. Management can quickly identify areas with high emissions, monitor progress toward reduction targets, and make informed decisions, such as refining product designs or collaborating with suppliers to reduce emissions. This proactive management approach facilitates operational efficiencies, cost savings, and innovation, embedding sustainability considerations into daily business processes.

Achieving widespread adoption of the app requires addressing practical challenges associated with stakeholder engagement. We suggest methods to increase adoption across organizations, such as gamification and clear value propositions for customers, compliance with internal regulations and HR-related incentives for staff, and less reporting requirements and sustainability scorecards for suppliers. A method of implementation that is staggered or gradual acknowledges the diversity of stakeholder capacities while promoting long-term engagement. Data reliability, verification, and privacy are necessary components for successful implementation. To guarantee accuracy and reliability, the app uses automated validation techniques, cross-checking procedures, random audits, and optional third-party assurance. Ethical data management procedures, including encryption, anonymization, and adherence to GDPR/CCPA, are implemented to ensure user confidence and legal compliance. While the app significantly advances Scope 3 data collection, several limitations remain. Inherently complex emission categories cannot be fully captured, and disparities in digital access may restrict participation for certain stakeholders. Sustaining motivation and long-term engagement is also challenging, particularly among consumers and small suppliers. Data validation and assurance require hybrid solutions that integrate algorithmic checks with third-party verification. Furthermore, external validity across industries may be limited, as Scope 3 profiles differ significantly per sector. Although these difficulties are significant, they do not call into question the conceptual framework; rather, they draw attention to areas that could use empirical testing and improvement. Future studies should examine behavioral dynamics of stakeholder participation, sector-specific modifications, and comparisons of digital and traditional reporting methods. At the same time, the app's scalability and flexibility allow adaptation across industries, supporting its practical applicability. Widespread adoption of mobile-based Scope 3 data collection can foster standardization across industries and influence future regulatory frameworks. Companies that proactively implement such technologies may benefit from early compliance advantages and a differentiated market positioning, thereby reinforcing brand trust and competitive advantage.

This research contributes to the intersection of sustainability accounting and accounting information systems by proposing a novel, practical solution to address longstanding data challenges in Scope 3 emissions reporting. The mobile application framework transforms Scope 3 accounting from a static, estimation-heavy process into a dynamic, participatory, data-rich system integrated with strategic decision-making. Ultimately, this approach facilitates more accurate, transparent, and actionable sustainability reporting, aligning corporate strategy with societal goals for environmental stewardship and climate action.

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