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Research article

The digital-sustainability nexus: Business model innovation as the bridge from technology to environmental performance

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ABSTRACT

This study investigates how digital innovation (DII) drives sustainable performance (SUS) through the mediating role of business model innovation (BMI) and the moderating effects of servitization (SER) and relational orientation (REO). Drawing on Service-Dominant Logic, a survey was conducted among 167 medium and large Swedish enterprises in manufacturing, packaging, logistics, and environmental technology. Using partial least squares structural equation modeling, results show that DII significantly enhances BMI, which in turn improves SUS. Servitization strengthens the DII-BMI link, while relational orientation amplifies the BMI-SUS relationship. The findings advance theory by integrating digital innovation, service strategies, and stakeholder collaboration into a sustainability context. Practically, the study provides actionable insights for managers seeking to integrate sustainability into their business models through technology-enabled services and multi-stakeholder ecosystems. This research contributes to the growing body of work on digital-sustainable transformation pathways in advanced economies.

1. Introduction

Achieving environmental sustainability has become a strategic imperative for firms as regulators, investors, and customers increasingly demand measurable progress on emissions, circularity, and social outcomes. Sweden has positioned itself as a leader in climate policy and digital innovation, providing an enabling environment for innovation that simultaneously supports economic and environmental goals (Government Offices of Sweden, 2024). Digital technologies-advanced analytics, IoT, AI, digital platforms-are now central to this transition because they enable new value propositions, data-rich coordination with stakeholders, and service-based revenue models that can decouple growth from resource use (Huang et al., 2025). However, technology alone rarely delivers environmental gains; firms must recompose their business models and embed digital capabilities in service-centric value creation with partners across the broader innovation ecosystem (Huang et al., 2023; Liu et al., 2024).

We ground our study in Service-Dominant Logic (SDL). SDL posits that service, defined as the application of operant resources such as skills and knowledge, is the fundamental basis of exchange, and that value is co-created through networked resource integration among actors (Vargo and Lusch, 2016). Digital innovation (DII) functions as an operant resource in SDL terms: data, algorithms, and platforms reshape how firms propose, deliver, and capture environmental value via business model innovation (BMI). Accordingly, we theorize that DII catalyzes BMI and, through BMI, improves sustainable performance (SUS). This model explicitly ties innovation to eco-systemic sustainability, making it well-suited to explain how digitally enabled BMI translates into environmental performance when coordinated with regulators, communities, and ecological constraints (Carayannis and Campbell, 2010). SDL provides a multi-level account of how digital, service, and relational capabilities convert into measurable sustainability outcomes.

Recent Swedish industry moves illustrate these mechanisms. Steel producer SSAB, mining company LKAB, and Vattenfall in Sweden has

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partnered replace coal with fossil-free hydrogen produced using renewable electricity (Vatenfall (2022). These initiatives align with SDL (service-based value creation) and leverage the Swedish circular economy ecosystem. Volvo Trucks Sweden operates Volvo Connect from Gothenburg, integrating vehicle telematics, eco-driving analytics, and predictive maintenance into a unified digital service. This platform helps fleet operators cut fuel consumption and emissions. Notably, this DII-enabled servitization model is embedded in Sweden's logistics sector, which is under strong national CO_2 reduction targets (InsideEVs, 2024). Similarly, DHL Freight has introduced GoGreen Plus, using real-time routing optimization and local biofuel in setting options to further reduce CO_2 emissions. To enhance transparency, emissions reporting is integrated into customers' digital dashboards (DHL Group, 2025). In the steel sector, SSAB (a steel manufacturer) has adopted a closed loop steel recycling initiative, where they recover scrap and end-of-life steel to reduce the carbon emissions by 70% as compared to conventional steel producing (SSAB, 2026).

Despite such advances, key research gaps remain. First, while prior work links digitalization, servitization, and performance, the mechanism by which DII reconfigures BMI to produce sustainability outcomes remains theoretically under-specified and emperically under-tested in sustainability journals (Abou-Foul et al., 2021; Latifi et al., 2021). SDL implies DII should operate through value-in-use redesign (BMI), however few studies quantify this mediation for environmental, rather than financial, outcomes. This leads us to investigate first research question, "*how does DII drive BMI that enhances SUS?*".

Second, servitization is often considered as a direct antecedent of performance (Vargo and Lusch, 2016), yet SDL suggests a different role, where servitization acts more as a capability amplifier that enhances how DII translates into BMI. Scarce empirical tests have investigated this moderation in sustainability contexts. Third, while relationship-intensive collaboration with customers and partners is central to SDL, rigorous empirical tests of how Relational Orientation moderates the BMI to SUS link remain limited, especially with contemporary, industry-grade environmental performance measures. This lead us the examine second research question, "*To what extent does SER strengthen the relationship between DII and BMI?*

Finally, most existing evidence is context-specific and oriented toward financial performance, underlining the need for sustainability-specific models validated by recent industry practices and robust methodologies. This led us to investigate the third research question, "*Does Relational Orientation amplify the impact of BMI on SUS?*

Addressing these gaps and research questions, we propose and test a model in which DII drives BMI, thereby enhancing SUS; Servitization strengthens the DII to BMI linkage, and Relational Orientation amplifies the BMI to SUS effect. Consistent with SDL, we conceptualize DII as an operant resource that enables service-centric value reconfiguration (BMI).

Our contribution is threefold. Theoretically, we integrate SDL (micro-level value co-creation) to explain the digital-to-sustainability pathway via BMI, clarifying when and how servitization and relational orientation matter (Vargo and Lusch, 2016; Carayannis and Campbell, 2010). Our research advances the understanding of existing digitalization-servitization-performance studies (Paschou et al., 2020), by considering SDL for innovative business models and how it can influence sustainable performance. Empirically we test this moderated-mediation structure using validated constructs adapted from recent literature on digitalization, servitization, and BMI (Abou-Foul et al., 2021; Latifi et al., 2021). Most of the existing studies capture technology enabled performance of digital servitization and oversight the system level value co-creation (Paschou et al., 2020; Vargo et al., 2024, 2026; Vendrell-Herrero et al., 2024). Practically, we align the model with current Swedish industry practice- Volvo Trucks' connected fleet solutions, DHL's decarbonized logistics offerings, and Tetra Pak's circularity approach from design to end of product life with actionable levers that sit squarely within digital innovation for environmental performance. The recent and ongoing calls for papers by Service Science (Agrawal and Gui, 2025) and Journal of Innovation and Knowledge (Deutsch et al., 2026), highlight that technology and innovation are not enough to determine environmental performance. Agrawal and Gui's (2025) special issue highlights what innovation is in circular models and platforms, but do not explain why some technological innovations help in environmental performance and others don't. The other ongoing special issue from Journal of Innovation and Knowledge focuses on integration of technologies but does not explain the business model innovation itself. Our study is positioned to invitigate business model innovation and how they create value and how do Servitization strengthens the relationship between digital innovation and business model innovation. Additionally, we examine how does Relational Orientation amplifies the impact of BMI on SUS?

The remainder of the paper proceeds as follows: Section 2 develops hypotheses from SDL; Section 3 details the methodology; Section 4 reports results; Section 5 discusses theoretical and managerial implications as well as limitations and future scope of research; and Section 6 concludes.

2. Research framework and research model

2.1. Theoretical foundation

This research framework integrates SDL (Vargo and Lusch, 2016) to explain the pathways from Digital Innovation (DII) to Sustainable Performance (SUS) via Business Model Innovation (BMI), with the moderating roles of Servitization (SER) and Relational Orientation (REO).

From an SDL perspective, value is co-created in networks through the application of operant resources such as skills, knowledge, and technologies (Vargo and Lusch, 2016; Vargo et al., 2024). DII functions as an operant resource, enabling firms to reconfigure value propositions and delivery systems toward sustainability outcomes. BMI represents this reconfiguration (Foss and Saebi, 2017), while SER and REO act as contextual enablers or amplifiers of the value co-creation process (Brax et al., 2021; Baines et al., 2020). These constructs of SDL focus on "service-for-service" exchange highlighting the co-creation of processes, and collaboration among resources of the ecosystem.

The lens of SDL helps in generating micro-level value, where system addresses the "forgotten effects" of innovation in terms of ecological consequences by engaging all stakeholders.

Recent developments in SDL significantly enhance the theoretical explanation of how digital innovations contribute to sustainable performance. Most of the existing studies on digital innovation are either technology centered or company specific and consider digital technology as a means of efficiency and competitive advantage. However, existing and growing literature of SDL argues that digital innovation needs to be understood as ecosystemic and relational among diverse actors, resources, and institutional arrangements (Vargo et al., 2024). The digital technologies ranging from artificial intelligence to internet of things, blockchain, and digital platforms alone do not create value rather they help enable collaboration and integration among resources and stakeholders to co-create the value (Mačiulienė and Skaržauskienė, 2021). SDL as a systemic capability enhances organizational resilience, stakeholder engagement and sustainable value creation in long term view (Vargo et al., 2024, 2026). Sustainable performance is no longer dependent solely on technology, but an ecosystem capability, hence, the integration of SDL offers a holistic understanding of digital innovation and sustainable performance.

2.2. Digital innovation (DII) to business model innovation (BMI)

Under SDL, DII is an operant resource that enables new forms of service exchange and value co-creation. By integrating IoT, AI, blockchain, and analytics, firms can reconfigure their value creation, delivery, and capture mechanisms, laying the groundwork for BMI (Mačiulienė and Skaržauskienė, 2021). Earlier studies indicate the product and process innovation, including digital servitization are critical for technological innovation (Opazo-Basáez et al., 2022, 2024; Vargo et al., 2024).

Sandvik Sweden's SAM platform connects mining equipment with real-time monitoring, predictive maintenance, and process optimization tools. This DII allows Sandvik to shift from one-off equipment sales to integrated service offerings, thereby driving BMI that incorporates efficiency, reduced downtime, and lower energy use (Sandvik, 2025). Such a shift aligns with SDL's emphasis on service-centric value in Sweden's industrial ecosystem. Therefore, we propose.

H1. Digital Innovation (DII) positively influences Business Model Innovation (BMI).

2.3. Business model innovation (BMI) to sustainable performance (SUS)

SDL posits that BMI, through redesigned value propositions and delivery systems, creates “value-in-use” that can include environmental benefits. SSAB, a steel manufacturer, adopted a closed loop steel manufacturing model, where production scarp is digitally traced, recovered and reintroduced into the process powered by fossil-free electricity and biogas. This business model innovation meets the rising demand for low carbon steel and delivers tangible environmental benefits and performance.

It reflects SDL's emphasis on ongoing value co-creation with stakeholders (customers such as Volvo Group, recyclers) (Opazo-Basáez et al., 2024). When firms reconfigure their business models around such digitally enabled, circularity and service-oriented mechanisms, it helps in environmental value creation. Therefore, we propose.

H2. Business Model Innovation (BMI) positively influences Sustainable Performance (SUS).

2.4. Servitization as a moderator (DII to BMI)

SDL highlights that service integration deepens value co-creation by embedding continuous customer interaction and customization into offerings (Vargo and Lusch, 2016). Servitization aligns with societal and environmental needs when services promote efficiency, lifecycle extension, or resource reduction. Servitization amplifies the DII to BMI link by providing a recurring channel for applying digital capabilities to refine and expand business models.

Volvo Trucks Sweden's Volvo Connect platform bundles real-time telematics, eco-driving guidance, and predictive maintenance into a subscription-based service. This servitized model increases the impact of DII by ensuring continuous data flows and iterative service improvements, leading to BMI that prioritizes fuel efficiency and emissions reduction (InsideEVs, 2024). The recurring engagement also fosters alignment with Sweden's strict transport-sector decarbonization targets. Therefore, we propose.

H3. Servitization positively moderates the relationship between Digital Innovation (DII) and Business Model Innovation (BMI).

2.5. Relational orientation as a moderator (BMI to SUS)

In SDL, relational orientation ensures that value is co-created through trust, shared goals, and long-term collaboration with stakeholders (Brax et al., 2021; Vargo and Lusch, 2016). These relationships extend beyond the firm to encompass universities, government agencies, NGOs, and communities, all of which are critical to achieving sustainability outcomes (Carayannis and Campbell, 2010). A high relational orientation strengthens the BMI to SUS relationship by facilitating adoption, joint problem-solving, and alignment with societal sustainability objectives.

Sandvik's carbon transparency initiative openly shares CO_2 emissions data for its equipment with customers and regulators. This trust-building measure supports the adoption of new, sustainability-oriented business models by reducing uncertainty and fostering cooperative environmental action (Sandvik, 2025). The initiative aligns with SDL's co-creation principle. Therefore, we propose.

H4. Relational Orientation positively moderates the relationship between Business Model Innovation (BMI) and Sustainable Performance (SUS).

Table 1 summarizes the key constructs in the proposed research model, their definitions, associated hypotheses, theoretical underpinnings, and supporting literature. The table integrates conceptual clarity with empirical relevance, ensuring that each construct is situated within the broader theoretical frameworks of Service-Dominant Logic. By linking each construct to its hypothesized role in the model and providing real-world justifications, the table offers a clear roadmap for how Digital Innovation (DII) is expected to drive Business Model Innovation (BMI), ultimately enhancing Sustainable Performance (SUS), with Servitization and Relational Orientation acting as moderators. This synthesis facilitates both theoretical grounding and practical interpretation of the proposed research relationships.

2.6. Research model

Fig. 1 illustrates the proposed research model. DII is positioned as the driver of BMI, which in turn enhances SUS. Servitization moderates the relationship between DII and BMI, and Relational Orientation moderates the BMI to SUS pathway, consistent with SDL's micro-level mechanisms. We conceptualize the servitization as moderator between digital innovation and BMI based on Vendrell-Herrero et al. (2024), where they prefer standardized pathway on how effectively servitization influence DII.

3. Research methods

3.1. Research design

We employed a quantitative, cross-sectional survey to test the hypothesized relationships among DII, BMI, SUS, and moderators SER and REO. Cross-sectional surveys are appropriate for theory testing in organizational settings where constructs are perceptual and measured at the firm level, and for estimating structural models with multiple mediation and moderation paths (Hair et al., 2021). Sweden provides a relevant empirical setting given its advanced digital infrastructure and strong environmental policy ambitions, enabling meaningful variance in both digital and sustainability practices across firms.

3.2. Ethical considerations

Participation was voluntary and based on informed consent. Respondents were assured anonymity and confidentiality. We stored data securely and used it only for research. Institutional ethical clearance was obtained prior to data collection, consistent with good practice for organizational surveys (Hair et al., 2021).

3.3. Population and sampling

The population comprised medium and large Swedish firms in manufacturing, packaging, logistics, and environmental technology-sectors where digitalization, servitization, and sustainability is strategically salient. We used purposive sampling to reach decision-makers (e.g., operations, sustainability, and innovation managers; senior executives) who possess knowledge of digital and business model transformation. We approached 856 Individuals working in different capacities in different sectors. After fortnightly follow-ups in first three months, we approached 357 respondents, where 74 executives

Table 1
Variables, explanations, hypotheses, theoretical basis, and justifications.

Variable	Explanation	Hypothesis	Theoretical Basis	Key References	Justification
Digital Innovation (DII)	Creation or enhancement of products, processes, or services through digital technologies such as IoT, AI, blockchain, and data analytics.	H1: DII positively influences BMI.	SDL - DII as an operant resource enabling new forms of value co-creation	Nambisan et al. (2017); Vargo and Lusch (2016); Carayannis and Campbell (2010); Mačiulienė and Skaržauskienė (2021)	DII provides capabilities and insights to reconfigure business models for environmental and economic gains. *Example:* Sandvik's SAM™ platform connects mining equipment to real-time monitoring, enabling service-oriented BMI that supports Sweden's industrial sustainability policies.
Business Model Innovation (BMI)	Reconfiguration of value creation, delivery, and capture mechanisms to align with strategic and sustainability goals.	H2: BMI positively influences SUS.	SDL - BMI as the service system reconfiguration to deliver greater "value-in-use" with environmental benefits	Foss and Saebi (2017); Vargo and Lusch (2016); Carayannis and Campbell (2010)	BMI translates DII into tangible sustainability outcomes. *Example:* SSAB is a producer of steel, and illustrates, how business model innovation can help in producing steel, relying on documented production processes and material traceability rather than carbon offsets.
Sustainable Performance (SUS)	Achievement of environmental, social, and economic objectives, with emphasis on environmental outcomes such as carbon reduction, waste minimization, and circularity.	Dependent variable.	SDL - Value co-created includes ecological and societal outcomes	Elkington (1998); Carayannis and Campbell (2010)	SUS ensures innovation-driven transformation produces real environmental impact. *Example:* Tetra Pak: illustrates how multi-actor systems can support BMI and positively influence sustainable performance.
Servitization	Strategic move from selling products to delivering integrated product-service solutions.	H3: Servitization positively moderates the DII-BMI relationship.	SDL - Service integration increases opportunities for continuous co-creation and BMI	Baines et al. (2020); Vargo and Lusch (2016); Carayannis and Campbell (2010)	Servitization embeds DII into ongoing solutions. *Example:* Volvo Trucks Sweden's Volvo Connect platform offers continuous eco-driving guidance and predictive maintenance, amplifying the DII to BMI pathway.
Relational Orientation	Commitment to building and sustaining trust-based, long-term collaborations with stakeholders.	H4: Relational Orientation positively moderates the BMI-SUS relationship.	SDL - Strong relationships enhance co-creation of sustainable value	Vargo and Lusch (2016); Carayannis and Campbell (2010)	High relational orientation increases adoption and impact of sustainable BMIs. *Example:* Sandvik's open carbon emissions data fosters trust and collaboration with customers and regulators, enhancing environmental outcomes.

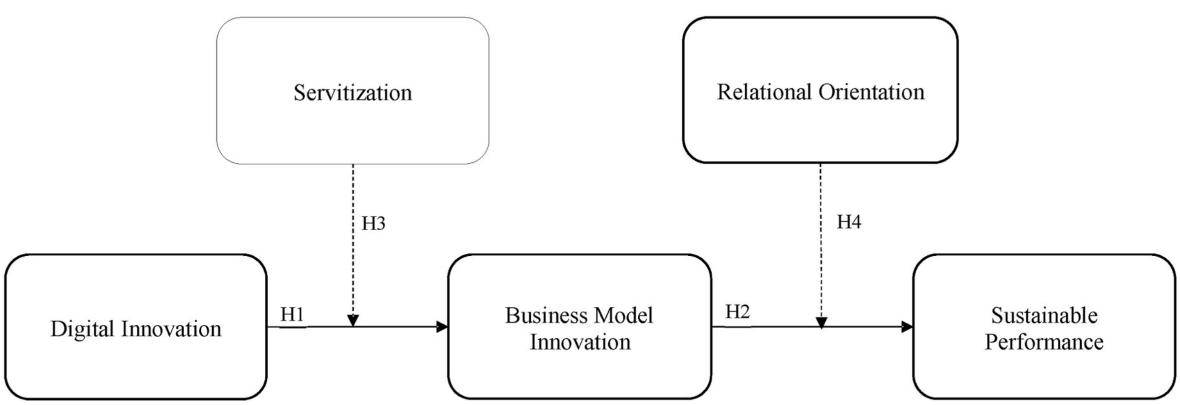

Fig. 1. Research model.

responded. In next 4 months, we approached 499 respondents and managed to get 97 responses. However, after careful analysis, we found 167 useable responses. Respondent data is presented in.Appendix DFor models of this complexity, PLS-SEM is suitable for small-to-medium samples and non-normal data, prioritizing prediction and theory development (Hair et al., 2021). Given our effect sizes and model structure, n = 167 exceeds the common minimum sample size guidance for PLS-SEM and affords adequate statistical power (Hair et al., 2021).

3.4. Measurement of constructs

We operationalized the constructs with multi-items using seven-point Likert scale adapted from validated sources and carefully contextualized to Swedish industry (see Appendix B). Items for DII and SER were adapted from Abou-Foul et al. (2021); BMI from Latifi et al. (2021); REO from Brax et al. (2021); and SUS from Pesch et al. (2021). This approach preserves validity while tailoring to the focal context (Hair et al., 2021).

3.5. Data analysis techniques

Before modeling, we executed data integrity checks. We did not find any missing values, zero-variance items, duplicate column names, or rank deficiencies. All indicators were standardized to ensure comparability and to avoid scaling biases-a recommended step when constructs combine items with potentially different dispersions (Hair et al., 2021).

We estimated the hypothesized model via Partial Least Squares Structural Equation Modeling (PLS-SEM) because it handles complex models with multiple moderators/mediators, is robust to non-normality, and emphasizes prediction (Hair et al., 2021). We assessed reliability and validity following established PLS-SEM procedures (Hair et al., 2021; Fornell and Larcker, 1981). Collinearity diagnostics used full collinearity VIFs, with the conservative ≤ 3.3 heuristic (Kock and Lynn, 2012). In addition to conventional assessments, we report WarpPLS-family fit/causality indices-APC, ARS, AVIF, SPR, RSCR, SSR-with interpretation anchored in Kock (2015).

3.6. Model fit and quality assessment

Table 2 summarizes global model diagnostics. The Average Path Coefficient (APC) = 0.312, $p < 0.001$, indicates that, on average, there are statistically significant structural paths. The Average R-squared (ARS) = 0.342, $p < 0.001$ reflects substantive explanatory power for endogenous constructs, consistent with typical effect magnitudes in organizational and behavioral research (Hair et al., 2021). The Average Block VIF (AVIF) = 1.503 is well below the 5.0 upper bound and the 3.3 ideal threshold, signaling that multicollinearity is not a concern (Kock and Lynn, 2012; Kock, 2015).

3.7. Causality assessment

Causality diagnostics (Table 3) further support model adequacy. The Simpson's Paradox Ratio (SPR) = 1.000 exceeds the ≥ 0.70 benchmark (ideal = 1), indicating no paradoxical reversals between bivariate and multivariate effects. The R-squared Contribution Ratio (RSCR) = 1.000 exceeds the ≥ 0.90 threshold, indicating that all predictors contribute positively to the explained variance. The Statistical Suppression Ratio (SSR) = 1.000 exceeds ≥ 0.70, implying the absence of suppressor effects (Kock, 2015). Collectively, these indices indicate stable, directionally consistent structural relations.

3.8. Latent variable coefficients

Table 4 reports construct-level statistics. R^2 (BMI) = 0.425 indicates that DII (and its moderator SER, on the relevant path) explains 42.5% of the variance in BMI. R^2 (SUS) = 0.260 shows that BMI (under varying REO) accounts for 26.0% of the variance in sustainable performance. Adjusted R^2 values (0.418; 0.251) are close to R^2, suggesting no overfitting.

Reliability is strong: Composite Reliability (CR) = 0.846-0.923 and Cronbach's α = 0.853-0.924, comfortably exceeding the 0.70 guideline for established scales (Nunnally and Bernstein, 1994; Hair et al., 2021). VIFs (1.572-3.637) are below conservative thresholds, supporting the absence of problematic collinearity (Kock and Lynn, 2012).

3.9. Discriminant validity assessment

Table 5 lists inter-construct correlations with the square roots of the AVEs on the diagonal. For each construct, the diagonal element exceeds its correlations with other constructs, satisfying the Fornell-Larcker criteria (Fornell and Larcker, 1981). For example, $\sqrt{\text{AVE(DII)}} = 0.681$ exceeds DII's highest correlation (0.680 with SER). Patterns align with theorized relations-e.g., DII↔BMI = 0.638, providing preliminary support for H1 and, indirectly, for BMI's role preceding SUS (BMI↔SUS = 0.490).

Table 2
Model fit and quality indices.

Average path coefficient (APC)	0.312, $p < 0.001$
Average R-squared (ARS)	0.342, $p < 0.001$
Average block VIF (AVIF)	1.503, acceptable if ≤ 5, ideally ≤ 3.3

Table 3
Causality assessment indices.

Simpson's paradox ratio (SPR)	1.000, acceptable if ≥ 0.7, ideally = 1
R-squared contribution ratio (RSCR)	1.000, acceptable if ≥ 0.9, ideally = 1
Statistical suppression ratio (SSR)	1.000, acceptable if ≥ 0.7

Table 4
Latent variable coefficients.

	DII	BMI	SUS	SER	REO
R-squared coefficients	-	0.425	0.26	-	-
Adjusted R-squared coefficients	-	0.418	0.251	-	-
Composite reliability coefficients	0.885	0.923	0.889	0.899	0.846
Cronbach's alpha coefficients	0.888	0.924	0.892	0.896	0.853
Variance inflation factors (VIF)	2.301	3.091	1.572	3.637	2.541

Table 5
Correlations among latent variables with square root of AVEs.

	DII	BMI	SUS	SER	REO
DII	**0.681**				
BMI	0.638	**0.755**			
SUS	0.439	0.49	**0.671**		
SER	0.68	0.793	0.513	**0.71**	
REO	0.447	0.647	0.553	0.661	**0.761**

Note: Square roots of average variances extracted (AVEs) shown on diagonal.

4. Data analysis and results

4.1. Measurement model results

The assessment of the measurement model confirmed strong reliability and validity across all constructs. As shown in Table 4, composite reliability (CR) values ranged from 0.846 to 0.923, and Cronbach's alpha values ranged from 0.853 to 0.924, surpassing the recommended threshold of 0.70 (Hair et al., 2021). Discriminant validity was supported via the Fornell-Larcker criterion (Fornell and Larcker, 1981), with the square roots of AVEs (diagonal values in Table 5) exceeding corresponding inter-construct correlations. Additionally, the heterotrait-monotrait ratio of correlations (HTMT) values for all construct pairs were below the conservative threshold of 0.85, further confirming discriminant validity (Henseler et al., 2015). Multicollinearity was not an issue, with all VIF values well below the conservative threshold of 3.3.

For transparency and reproducibility, Appendix C provides the combined loadings and cross-loadings for all indicators, along with their standard errors and p-values. These results demonstrate that all reflective indicators are statistically significant ($p < 0.001$) and exhibit strong loadings on their intended constructs, thereby supporting the robustness of the measurement model.

4.2. Model fit and causality assessment

The structural model exhibited robust fit and explanatory capacity. The Average Path Coefficient (APC) was 0.312 ($p < 0.001$), confirming statistically significant positive relationships across the hypothesized paths. The Average R-squared (ARS) of 0.342 ($p < 0.001$) indicates that, on average, the model explains 34.2% of the variance in its endogenous constructs, which is considered substantial for management and organizational research (Chin, 1998; Hair et al., 2021). The Average Block VIF (AVIF) of 1.503 is well below both the maximum permissible limit of 5 and the ideal limit of 3.3, showing low collinearity among predictor constructs.

Causality assessment indices (Table 3) all met ideal benchmarks: the Simpson's Paradox Ratio (SPR), R-squared Contribution Ratio (RSCR), and Statistical Suppression Ratio (SSR) each achieved a value of 1.000, exceeding the recommended minimum thresholds (Kock, 2015). This provides assurance that the observed relationships are free from suppression effects, paradoxical results, and inconsistent causal patterns.

4.3. Structural model results

The model explained 42.5% of the variance in Business Model Innovation (BMI) and 26% of the variance in Sustainable Performance (SUS). These R^2 values indicate moderate-to-substantial explanatory power, consistent PLS-SEM standards in strategic management research (Hair et al., 2021). Adjusted R^2 values (0.418 for BMI and 0.251 for SUS) were only marginally lower, indicating that the model maintains predictive accuracy and is not overfitted to the current dataset.

The positive and significant path from DII to BMI supports the argument that adoption of digital technologies fosters fundamental reconfigurations in how firms create, deliver, and capture value, especially when sustainability is a strategic priority (Broccardo et al., 2023). Similarly, the significant BMI to SUS path reinforces prior findings that innovative business models enable firms to achieve improved environmental and social outcomes (Latifi et al., 2021).

4.4. Hypothesis testing

The results of hypothesis testing are summarized in Table 6. All proposed relationships were significant and in the expected positive direction. The strongest effect was observed for H1 (DII to BMI), confirming that digital innovation is a central driver of business model transformation.

Moderation results further validate the conceptual model: Servitization significantly strengthens the DII to BMI relationship (H3), suggesting that service-based delivery models enhance the transformative potential of digital technologies. Likewise, Relational Orientation amplifies the BMI to SUS link (H4), indicating that collaborative, trust-based stakeholder relationships increase the effectiveness of innovative business models in achieving sustainability objectives. These findings are consistent with the Service-Dominant Logic perspective, which emphasizes that value co-creation is enhanced by strong relational ties for sustainability. Fig. 2 indicates the output of structural model, highlighting beta, p and R^2 values.

Although this study theorized BMI as the central mechanism linking DII to SUS, the distinction between indirect-only (full) mediation and complementary (partial) mediation warrants consideration. In mediation analysis, full mediation is supported when the direct DII to SUS relationship becomes non-significant after inclusion of BMI, whereas partial mediation exists when both direct and indirect effects remain significant (Hair et al., 2021; Zhao et al., 2010). Consistent with recent moderated mediation research (Bustinza et al., 2026), the strength and

Table 6
Hypothesis testing results.

Hypothesis	Path	β (Path Coefficient)	*p*-value	Supported?
H1	DII to BMI	0.57	<0.01	Yes
H2	BMI to SUS	0.43	<0.01	Yes
H3	DII × (SER to BMI)	0.13	0.04	Yes
H4	BMI × (REO to SUS)	0.12	0.05	Yes

proportion of mediation may vary under different levels of Servitization and Relational Orientation. While our model focused on the indirect transmission pathway, future studies could extend the analysis by estimating conditional indirect effects and variance-accounted-for (VAF) statistics across moderator levels to further distinguish between partial and full mediation mechanisms.

5. Discussion

This section interprets the empirical findings considering the study's theoretical lenses - Service-Dominant Logic, situates it within the current industrial context of Sweden. The results confirm that DII is a strong driver of BMI, which, in turn, enhances SUS with SER and REO significantly moderating these relationships.

These findings have implications both for advancing theory and guiding managerial practice, particularly in contexts where environmental sustainability and digital innovation are national priorities (Vendrell-Herrero et al., 2024), as is the case in Sweden (Tillväxtverket, 2023; Government Offices of Sweden, 2024).

5.1. Theoretical contributions

This study enriches S-D Logic by empirically demonstrating how digital technologies act as operant resources that enable value co-creation across extended service ecosystems (Vargo and Lusch, 2016). The significant DII to BMI path indicates that firms that leverage IoT, AI, and analytics do not merely digitize existing processes but fundamentally redesign their value creation and delivery mechanisms to support sustainability. This extends prior conceptual work (Nambisan et al., 2017) by confirming the mediating role of BMI in translating digital capabilities into measurable sustainability outcomes.

Our study also demonstrates that DII-enabled BMI is not an isolated process but emerges from interactions among multiple stakeholders. For example, HYBRIT a fossil-free steel project, where SSAB- the manufacturer, LKAB- the mining company and energy utility Vattenfall collaborated with universities to eliminate emissions across the value chain (Vatenfall, 2022). Further, Tetra Pak's carbon circularity program, collaborating with municipalities, recyclers, and other stakeholders to enhance the network of recycling infrastructure (Tetra Pak, 2024), illustrates how multi-actor systems can support BMI and positively influence sustainable performance.

The moderation effect of Servitization supports the argument that transitioning from product-based to service-based value propositions enhances the transformation potential of digital innovation (Baines et al., 2020). The positive DII × (SER to BMI) relationship aligns with S-D Logic's premise that services are the fundamental basis of exchange, and that digital tools augment service delivery through personalization, monitoring, and adaptive maintenance. This result adds empirical depth to prior studies (Coreynen et al., 2017) by confirming that digital innovation and Servitization are mutually reinforcing drivers of business model change in sustainability contexts.

The moderating effect of Relational Orientation on the BMI to SUS path confirms that strong stakeholder relationships magnify the sustainability outcomes of innovative business models. This finding extends S-D Logic by showing that value co-creation in sustainability contexts depends on deep, trust-based engagement with customers, suppliers, communities, and regulators. For example, Volvo Cars' Care by Volvo subscription service, which previously collaborated closely with municipalities on charging infrastructure, exemplified how relational orientation can ensure that innovative mobility models deliver real environmental benefits. However, as of August 2024, Volvo Cars has suspended the Care by Volvo subscription program in the United States and Europe for the foreseeable future. Customers who were enrolled in the program can complete their current term and may be eligible for credit toward a new Volvo purchase or lease (InsideEVs, 2024).

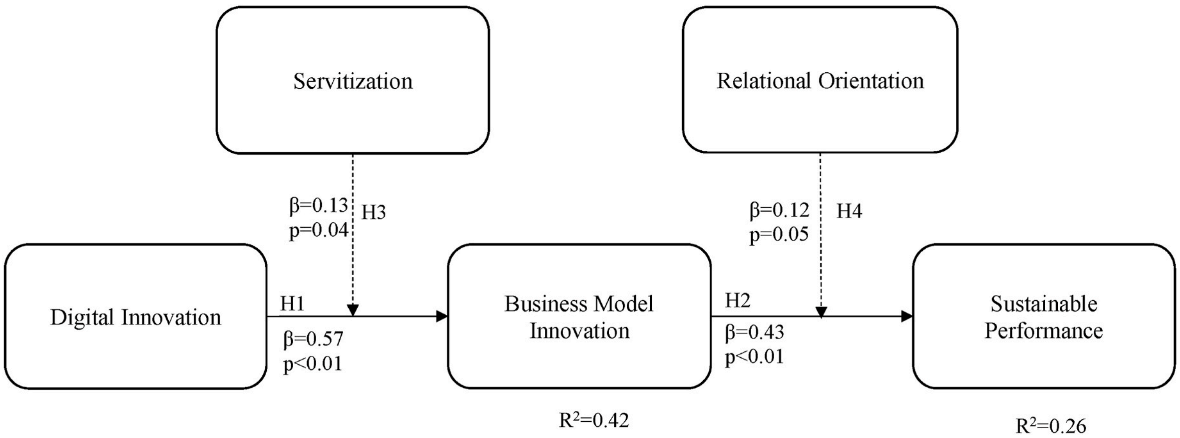

Fig. 2. Structural results.

5.2. Managerial implications

For managers, the results emphasize that DII should not be pursued as a standalone technology adoption strategy. Instead, organizations should integrate digital capabilities into broader service-oriented business models that support circular economy principles, lifecycle management, and resource efficiency. Swedish manufacturers like Sandvik have demonstrated this approach by embedding predictive maintenance and energy optimization into long-term service contracts, thereby reducing operational waste and energy costs for clients (Sandvik, 2019).

Managers should proactively seek partnerships with universities, municipalities, NGOs, and policymakers to align business model changes with societal and environmental goals. For instance, Electrolux's appliance-as-a-service model collaborates with local authorities to manage reverse logistics for returned appliances, thereby ensuring higher recycling rates (Electrolux, 2022).

Relational orientation emerged as a significant amplifier of sustainability performance. Managers should invest in building relational capital - through joint sustainability projects, transparent communication, and shared measurement systems - to ensure that BMI achieves its intended environmental impact. This could involve creating joint performance dashboards with clients or engaging suppliers in co-innovation programs for sustainable materials, as seen in H&M Group's partnerships with textile recycling innovators in Sweden (H&M Group, 2024).

While DII and BMI can deliver near-term operational efficiencies, their greatest potential lies in long-term systemic transformation, this requires managers to align incentives, KPIs, and investment decisions with long-term sustainability outcomes rather than short-term financial returns. Swedish energy company Vattenfall has adopted such an approach by tying executive bonuses to progress toward carbon-neutrality targets, which are partly enabled by digital monitoring and demand-response services (Vattenfall, 2025).

5.3. Limitations and future scope of research

Despite its contributions, this study has several limitations that should be acknowledged to guide future research.

First, the research design is cross-sectional, especially for DII↔BMI and BMI↔SUS. Future research can be conducted with longitudinal data to see the influence of moderators and mediation as prescribed in this study. Although PLS-SEM provides robust evidence of directional associations, longitudinal or panel data could better capture the dynamic nature of digital innovation, servitization, and sustainability performance over time (Ringle et al., 2011). Future studies could employ time-lagged designs to examine whether the effects of Business Model Innovation (BMI) on Sustainable Performance (SUS) strengthen or weaken over extended periods.

Second, the study's dataset is restricted to Swedish medium and large-size enterprises operating in the manufacturing, packaging, logistics, and environmental technology sectors. While Sweden offers a valuable context due to its advanced digital infrastructure and sustainability policies, the findings may not fully generalize to countries with different institutional frameworks, digital maturity levels, or regulatory environments. Comparative cross-country studies, particularly between Nordic economies and emerging markets, could uncover contextual variations in the DII-BMI-SUS pathway.

Third, the study focuses primarily on the environmental dimension of sustainability performance, given its strong alignment with the journal's scope. However, the social and economic dimensions of the triple bottom line (Elkington, 1998) are also important for comprehensive sustainability outcomes. Future research could incorporate multi-dimensional sustainability metrics, resilient entrepreneurship, including employee well-being, social equity which can contribute long-term economic resilience (Lafuente et al., 2019).

Fourth, although the constructs were measured using perceptual survey data from managers, self-reported measures may be subject to common-method bias (Podsakoff et al., 2012). Future research could triangulate these findings with objective performance indicators, such as energy usage data, carbon emission reductions, or verified circularity metrics.

Finally, the model considers SER and REO as single moderators. However, in practice, these capabilities may interact with other organizational factors - such as leadership vision, cultural readiness, and supply chain integration - that influence the translation of DII into sustainability outcomes. Future studies could extend the model by incorporating multi-level moderators and by exploring sector-specific mechanisms, such as predictive maintenance in heavy manufacturing or digital traceability in food logistics.

Future research avenues lie in exploring dual-purpose firms, those who pursue shareholders such as financial value and stakeholder interests such as environmental and social value. Earlier studies have highlighted that firms face paradoxes and tensions due to conflicting goals of shareholders and stakeholders (Battilana et al., 2015, 2022). At present our study has indicated a positive association among sustainability initiatives and firm outcomes, which may diverse when association among both becomes complex.

Future researchers can consider investigation whether the BMI differs when sustainable performance is decomposed into environmental, financial, and social dimensions separately. Research can be conducted on how hybrid and dual-purpose organizations manage tensions for short-term profitability and long-term sustainability commitments. How governance structures, ownership models, leadership orientation and institutional pressures can shape the ability of a firm to balance stakeholder expectations. Also, the future research can check if the servitation and relational orientation vary across firms, where strategic priorities are different. This can advance the understanding of how firms manage through paradoxical tensions while pursuing and achieving sustainable transformation.

6. Conclusion

This study provides empirical evidence on how DII contributes to Sustainable Performance (SUS) through the mediating role of BMI and the moderating effects of SER and REO. Grounded in Service-Dominant Logic (Vargo and Lusch, 2016), the research offers a nuanced understanding of how digital technologies, service strategies, and stakeholder relationships combine to enable sustainability-driven business transformation.

The results of a survey of 167 Swedish medium and large size enterprises reveal several key insights. First, DII strongly and positively influences BMI, highlighting that digital technologies are most effective when leveraged to reconfigure value propositions, value creation processes, and value capture mechanisms. Second, BMI significantly enhances SUS, confirming its pivotal role in translating technological capabilities into measurable environmental benefits. Third, servitization strengthens the DII-BMI relationship, suggesting that service-based delivery models provide a more fertile ground for embedding sustainability into business models. Fourth, relational orientation amplifies the BMI-SUS relationship, demonstrating the importance of trust-based stakeholder collaboration for achieving sustainability goals.

The study contributes theoretically by extending S-D Logic to a sustainability context, showing that digital technologies function as operant resources whose transformative potential is realized through co-created service ecosystems.

From a managerial standpoint, the findings encourage decision-makers to integrate digital innovation into service strategies, build cross-sector collaborations, and invest in relational capital to ensure that sustainability-oriented business models deliver tangible outcomes. Real-world cases from Swedish industry - such as Tetra Pak's circular leasing program, Volvo's subscription-based mobility services, SSAB's strong steel recycling mechanism, and Sandvik's predictive maintenance solutions - underscore the practical relevance of these strategies. Appendix A highlights the value creation through cases as a snapshot to highlight the initiatives taken in this direction.

In conclusion, this study underscores the imperative for firms to view digital innovation not as a technology adoption exercise but as a catalyst for systemic business model transformation, driven by service logic and embedded within collaborative, sustainability-oriented ecosystems. By addressing both the technological and relational dimensions of sustainable transformation, organizations can more effectively meet the twin challenges of digital competitiveness and environmental stewardship in the coming decades.

CRediT authorship contribution statement

Shivam Gupta: Writing – review & editing, Writing – original draft, Supervision, Software, Resources, Project administration, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Sachin Modgil:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation. **Vinit Parida:** Writing – review & editing, Resources. **Luna Leoni:** Writing – review & editing, Writing – original draft. **Marco Ardolino:** Writing – review & editing, Writing – original draft.

Declaration of competing interests

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

Appendix A. Value Creation Through Cases

Company/ Dimention	Primary Construct	Key Initiative	Value creation logic	Sustainability aspect	Policy alignment
Sandvik (SAM^{TM}) (Mining Equipment)	Digital Innovation	IoT-based real time equipment monitoring	Shift selling equipment to sell uptime and operational performance as a service.	Condition-based maintenance minimizes energy waste and unplanned downtime.	Sweden's Industrial Sustainability Strategy, EU Green Deal digitalization targets
SSAB (Fossil-free steel)	Business Model Innovation	HYBRIT hydrogen-reduced, fossil-free steelmaking	Reconfigures the value proposition from commodity carbon steel to a premium low-carob “fossil-free steel”	Replace coal with fossil free hydrogen, near eliminating process CO_2 across the mine-to-steel value chain	Fossil-Free Sweden initiative, Sweden's net zero by 2045 climate law, EU CBAM industrial decarbonization
Tetra Pak (Packaging)	Sustainable Performance	Renewable, FSC- certified paper-based and plant-based cartons designed for recycling.	Differentiate on “World's most sustainable food packaging” integrating with customer brand value to low carbon packaging.	Renewable and recycled materials lower carbon footprint and pressure on finite resources.	EU-Green Deal: Sweden's circular-economy strategy; Ellen Macarthur Global Commitment
Volvo Trucks (Commercial vehicles)	Servitization	Volvo connect platform for retrieving continuous feedback and offer predictive maintenance	Outcome-based fleet management, value creation through fuel savings and minimized total cost of ownership	Real-time eco-driving guidance to reduce the fleet level carbon and fuel	EU CO_2 standards for heavy duty vehicles, Sweden's 2030 transport climate targets
Sandvik (Emissions data)	Relational Orientation	Open disclosure of Scope 1,2, and 3 carbon emissions data	Transparency as relational asset for long term trust with customers and regulatory agencies.	Verified emission data enables evidence based decarbonization across value chain	EU Corporate Sustainability Reporting Directive requirements.

Appendix B. Operationalization of Constructs

Digital Innovation (DII)
Adapted from Abou-foul, M., Ruiz-Alba, J. L., & Soares, A. (2021). The impact *of digitalization and servitization on the financial performance of a firm: an empirical analysis. Production Planning & Control, 32(12), 975-989.*
1. We are using digital technologies (such as analytics, social media, mobile, and embedded devices) to understand our customers better.
2. We market and sell our products and services through digital channels.

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Digital Innovation (DII)	
3. We use digital channels to provide customers service.	
4. Technology is allowing us to link customer-facing and operational process in new ways.	
5. Our core processes are automated.	
6. We have an integrated view of key operational and customer information.	
7. We use analytics to make better operational decisions.	
8. We use digital technologies to increase the performance or added value of our existing products and services.	
9. We have launched a new business model based on digital technologies.	
Business Model Innovation (BMI)	
Adapted from Latifi, M. A., Nikou, S., & Bouwman, H. (2021). *Business model innovation and firm performance: Exploring causal mechanisms in SMEs. Technovation, 107, 102,274.*	
1. We introduced new products as a new value proposition	Creation
2. We introduced new services as a new value proposition	
3. We introduced new combinations of products, services, and software	
4. We continuously introduced novel operation processes, routines and norms to deliver value	Delivery
5. We started to collaborate with new business partners	
6. We shared new responsibilities with business partners	
7. We created new revenue streams	Capture
8. We introduced a new pricing mechanism	
9. We created new ways to profit	
Servitization (SER)	
Adapted from Abou-foul, M., Ruiz-Alba, J. L., & Soares, A. (2021). *The impact of digitalization and servitization on the financial performance of a firm: an empirical analysis. Production Planning & Control, 32(12), 975-989.*	
1. Our senior leaders are aligned around the strategic importance of servitization transformation.	Top management service orientation
2. Our senior leaders are actively promoting a vision of the future that involves servitized offerings.	
3. We regularly review with the top team our progress on servitization transformation.	
4. Our employees understand the benefits of servitization change.	Mobilization of resources
5. We are investing in the necessary skills and capabilities to provide servitized offerings.	
6. Our business cases and key performance indicators are linked to our roadmap.	
7. We have taken over some of our customers' business processes.	Market offering
8. We have taken over the operational functions of our products in customer businesses.	
9. Our service contracts related to our products is designed to share risk and reward with our customers, so our customers pay for the product capabilities outcomes and results.	
Relational Orientation (REO)	
Adapted from Brax, S. A., Calabrese, A., Levialdi Ghiron, N., Tiburzi, L., & Grönroos, C. (2021). *Explaining the servitization paradox: a configurational theory and a performance measurement framework. International Journal of Operations and Production Management, 41(5), 517-546.*	
1. Our services are designed to solve the targeted problem of our customer	Customer orientation
2. The starting point for value creation is meeting customer needs with the services we provide	
3. Customers are strongly involved in our value creating service activities	Service co-creation
4. We collaborate closely with our customers to reach better service outcomes	
Sustainable Performance (SUS)	
Adapted from Pesch, R., Endres, H., & Bouncken, R. B. (2021). *Digital product innovation management: Balancing stability and fluidity through formalization. Journal of Product Innovation Management, 38(6), 726-744.*	
1. We have helped our customers in reducing their energy consumption	Environmental Performance
2. We have helped our customers in reducing their waste generation	
3. We have helped our customers in reducing their atmospheric pollution	
4. We have helped our customers in increasing the profitability of their operations	Financial Performance
5. We have helped our customers in reducing their waste and inefficient processes	
6. We have helped our customers in decreasing their manufacturing/operational costs	
7. We have helped our customers in increasing their productivity	
8. We have helped our customers in increasing the safety of their workers	Social Performance
9. We have helped our customers in removing their dangerous work tasks	
10. We have helped our customers in improving the working conditions of their staff	

Appendix C. Combined Loadings and Cross-loadings

	DII	BMI	SUS	SER	REO	SE	p-value
DII1	**0.672**	−0.074	−0.068	−0.067	0.133	0.067	<0.001
DII2	**0.572**	0.169	0.008	−0.153	−0.098	0.069	<0.001
DII3	**0.721**	−0.059	0.108	−0.066	−0.124	0.066	<0.001
DII4	**0.794**	0.129	0.121	−0.413	0.034	0.065	<0.001
DII5	**0.625**	−0.433	0.142	0.336	−0.311	0.068	<0.001
DII6	**0.689**	−0.459	−0.007	0.15	0.071	0.067	<0.001
DII7	**0.638**	0.166	−0.142	−0.295	−0.142	0.068	<0.001
DII8	**0.728**	−0.057	0.054	0.317	−0.068	0.066	<0.001
DII9	**0.665**	0.309	−0.057	0.345	−0.212	0.067	<0.001
BMI1	−0.087	**0.672**	−0.133	−0.217	−0.217	0.067	<0.001
BMI2	−0.076	**0.797**	−0.026	0.305	−0.107	0.065	<0.001
BMI3	−0.048	**0.823**	0.141	−0.155	−0.073	0.065	<0.001
BMI4	−0.025	**0.788**	0.114	0.284	−0.387	0.066	<0.001

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	DII	BMI	SUS	SER	REO	SE	p-value
BMI5	−0.133	**0.726**	−0.028	−0.516	0.487	0.066	<0.001
BMI6	−0.056	**0.744**	−0.019	−0.035	0.162	0.066	<0.001
BMI7	−0.203	**0.742**	−0.027	0.01	−0.036	0.066	<0.001
BMI8	0.114	**0.761**	−0.251	−0.13	0.096	0.066	<0.001
BMI9	0.038	**0.734**	−0.226	−0.267	0.152	0.066	<0.001
SUS1	0.153	−0.041	**0.74**	0.035	−0.093	0.066	<0.001
SUS2	0.017	−0.069	**0.516**	0.152	−0.286	0.069	<0.001
SUS3	0.359	−0.363	**0.567**	0.067	−0.066	0.069	<0.001
SUS4	−0.232	0.341	**0.729**	−0.188	0.075	0.066	<0.001
SUS5	0.078	−0.218	**0.681**	0.118	−0.052	0.067	<0.001
SUS6	−0.156	−0.053	**0.833**	0.175	−0.085	0.065	<0.001
SUS7	−0.176	0.249	**0.718**	−0.271	0.26	0.067	<0.001
SUS8	−0.239	0.173	**0.65**	−0.233	0.092	0.067	<0.001
SUS9	−0.12	0.273	**0.617**	−0.283	0.06	0.068	<0.001
SUS10	−0.11	0.447	**0.597**	−0.329	0.049	0.068	<0.001
SER1	−0.222	−0.002	−0.284	**0.744**	0.281	0.066	<0.001
SER2	−0.059	−0.073	−0.148	**0.829**	0.114	0.065	<0.001
SER3	−0.089	−0.049	−0.046	**0.797**	0.096	0.065	<0.001
SER4	−0.041	−0.36	−0.173	**0.714**	0.374	0.067	<0.001
SER5	−0.109	0.006	−0.062	**0.823**	0.179	0.065	<0.001
SER6	0.212	0.128	0.036	**0.488**	0.242	0.07	<0.001
SER7	0.073	−0.182	0.186	**0.633**	−0.564	0.068	<0.001
SER8	0.077	−0.247	0.124	**0.668**	−0.34	0.067	<0.001
SER9	−0.283	−0.203	0.237	**0.619**	−0.584	0.068	<0.001
REO1	−0.029	−0.13	0.099	0.148	**0.738**	0.066	<0.001
REO2	−0.236	−0.011	−0.159	0.078	**0.777**	0.066	<0.001
REO3	−0.081	−0.13	0.066	−0.007	**0.801**	0.065	<0.001
REO4	0.296	−0.117	−0.08	−0.455	**0.727**	0.066	<0.001

Notes: Loadings are unrotated and cross-loadings are oblique-rotated. Standard error (SE) and p-values are for loadings. p-values < 0.001 for reflective indicators.

Appendix D. Demographic Profile of the Respondents

Variable	Description	Frequency	%
Gender	Female	43	26%
	Male	124	74%
Company Size	Medium (50 to 250 Employees)	57	34%
	Large (251 to 1000 Employees)	89	53%
	Conglomerate (More than 1000 Employees)	21	13%
Role in Company	Executive/Asst. Manager	32	19%
	Manager/Sr. Manager	94	56%
	GM/VP/EVP	29	17%
	Director/CEO/MD	12	7%
Experience	1 to 3 years	30	18%
	4 to 10 years	86	51%
	11 to 15 years	31	19%
	More than 15 years	20	12%
Industry	Manufacturing	22	13%
	Logistics	79	47%
	Packaging	27	16%
	Environmental Tech	39	23%

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