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Green Logistics and Sustainable Supply Chain Management: Examining the Role of Digitalization in Achieving Environmental and Operational Performance

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ABSTRACT

Logistics and freight transport remain one of the largest and fastest-growing sources of carbon emissions in global supply chains, which has pushed environmental sustainability to the centre of logistics and supply chain management research. At the same time, the diffusion of digital technologies including the Internet of Things (IoT), big data analytics, artificial intelligence, blockchain, cloud computing and digital twins is reshaping how firms plan, execute and monitor logistics activities. This paper examines how digitalization contributes to green logistics and sustainable supply chain management (SSCM) and, through this pathway, to environmental and operational performance. Using a structured narrative literature review of peer-reviewed studies published mainly between 2018 and 2025, together with secondary statistical data drawn from the International Energy Agency, Statista, the World Economic Forum and Our World in Data, the study develops a conceptual framework that links digital enablers to green logistics practices, contextual moderators and dual performance outcomes. The synthesis shows that digitalization improves environmental performance chiefly through route and load optimisation, real-time emissions visibility, predictive maintenance and closed-loop reverse logistics, while operational gains stem from lower transaction costs, greater agility and improved delivery reliability. The relationship is not automatic, however; it is conditioned by regulatory pressure, organisational digital readiness, firm size and industry context. The paper concludes with managerial and policy implications for accelerating a digitally enabled, low-carbon logistics transition, and identifies avenues for future empirical research.

KEYWORDS: *Green Logistics; Sustainable Supply Chain Management; Digitalization; Industry 4.0; Environmental Performance; Operational Performance; Digital Technologies.*

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1. INTRODUCTION

Global supply chains move an unprecedented volume of goods across increasingly complex, multi-tier networks, and the logistics activities that support this movement transportation, warehousing, packaging and reverse flows carry a substantial environmental cost. The transportation sector alone generated close to 8.4 billion tonnes of CO_2-equivalent in 2024, around 15.9 per cent of global greenhouse-gas emissions, with road freight and passenger vehicles together responsible for approximately three-quarters of that total (Cargoson, 2025; Statista, 2023). Global road-freight activity has also expanded sharply, rising from an estimated 26.6 trillion tonne-kilometres in 2019 to 32.8 trillion tonne-kilometres in 2023 as trade volumes recovered from pandemic-era disruption (World Economic Forum, 2024). These figures illustrate why logistics has become a focal point of corporate sustainability strategy and public climate policy alike.

Green logistics the set of practices aimed at minimising the ecological footprint of freight movement, storage and reverse flows has therefore moved from a peripheral corporate social-responsibility concern to a strategic operational priority (Jayarathna, Agdas, & Dawes, 2024). It sits within the broader field of sustainable supply chain management (SSCM), which Seuring and Müller (2008) define as the management of material, information and capital flows, together with cooperation among supply-chain firms, while integrating goals from all three dimensions of sustainable development economic, environmental and social that are derived from customer and stakeholder requirements. Zhu and Sarkis (2004) showed, in one of the field's earliest empirical studies, that green supply-chain practices among Chinese manufacturers were already associated with measurable gains in both environmental and operational outcomes, a finding that subsequent research has repeatedly revisited as technology has advanced.

Over the past decade, digitalization has emerged as a decisive enabler of this green transition. The Internet of Things, big-data analytics, artificial intelligence, blockchain, cloud computing and digital-twin simulation give firms real-time visibility into fleet movements, warehouse energy use and emissions along multi-tier supply chains (Dolgui & Ivanov, 2022). Recent large-sample evidence from China indicates that supply-chain digitalization significantly improves corporate green transformation performance, with the effect strongest among non-state-owned firms, highly integrated supply chains and firms operating in more competitive, less-polluting industries (Wang & Shen, 2025; Wang, Feng, Wu, & Shen, 2025). Yet the literature also cautions that digital adoption does not automatically translate into sustainability gains: benefits are contingent on organisational readiness, regulatory context and the extent to which digital and green strategies are deliberately integrated rather than pursued in parallel (Md Taib, Ibrahim, Daud, Abu Yazid, & Othman, 2025).

Against this backdrop, the present paper pursues three objectives. First, it synthesises the theoretical and empirical literature on green logistics, SSCM and supply-chain digitalization to clarify how these streams relate to one another. Second, it develops an integrative conceptual framework that positions digital technologies as enablers of green logistics practices, which in turn shape environmental and operational performance, subject to contextual moderators. Third, it grounds this conceptual discussion in verifiable secondary data on global transport emissions and freight activity, so that the scale of the sustainability challenge and the plausible contribution of digital solutions is presented transparently rather than asserted in the abstract. The remainder of the paper is organised as follows. Section 2 reviews the theoretical background and related literature. Section 3 presents the conceptual framework. Section 4 explains the review methodology and data sources. Section 5 reports the analysis and findings, including comparative synthesis tables and figures. Sections 6 to 8 discuss the results, managerial and policy implications, limitations, and directions for future research, followed by the conclusion and reference list.

2. Theoretical Background and Literature Review

2.1. Green Logistics and Sustainable Supply Chain Management

Green logistics refers to the design and operation of logistics systems transport mode selection, route and load planning, warehousing, packaging, and reverse and closed-loop flows in ways that reduce energy consumption, emissions, waste and resource use across the product life cycle. It is best understood as the operational arm of the wider SSCM agenda. Carter and Rogers (2008) frame sustainable supply chain management as the strategic, transparent integration of an organisation's social, environmental and economic goals in the coordination of key inter-organisational business processes, arguing that firms which treat the three dimensions as complementary rather than as trade-offs achieve superior long-run competitive performance. Building on this, system-dynamics research on sustainable logistics practices identifies green purchasing, eco-design, reverse logistics and green transportation as the four practice clusters most consistently linked to circular-economy outcomes, while noting that these practices interact dynamically rather than independently (Jayarathna et al., 2024). Reverse logistics and closed-loop systems, in particular, are repeatedly identified in the literature as practices that simultaneously reduce landfill waste and recover economic value, aligning environmental and cost objectives.

2.2. Digitalization of Supply Chains

Supply-chain digitalization (SCD) denotes the integration of digital technologies, platforms, data assets and analytical capabilities into procurement, production, logistics and service activities, enabling real-time information exchange across previously siloed functions (Wang & Prajogo, 2024, as cited in Xue & Di Vaio, 2025). Five technology families dominate current discussion. Internet-of-Things sensors and telematics provide continuous data on vehicle location, fuel consumption, cargo condition and warehouse energy use. Big-data analytics and artificial intelligence convert this data into predictive route optimisation, demand forecasting and predictive-maintenance models that reduce empty running and unnecessary mileage. Blockchain platforms create tamper-resistant, shared records of product provenance and emissions data across multiple supply-chain tiers, improving traceability and trust between partners. Cloud computing underpins the scalable data infrastructure that connects these tools across geographically dispersed networks. Finally, digital-twin and simulation technologies allow firms to model logistics networks virtually before committing physical and financial resources, and to test decarbonisation scenarios in a low-risk environment (Dolgui & Ivanov, 2022; Ivanov & Dolgui, 2022). Fifth-generation (5G) connectivity is increasingly cited as the infrastructure layer that makes real-time, end-to-end visibility of this kind operationally feasible at scale (Dolgui & Ivanov, 2022).

2.3. Theoretical Lenses

Four theoretical perspectives recur across the reviewed literature. The Resource-Based View (RBV) treats digital capabilities as rare, valuable and difficult-to-imitate resources that, when combined with green operational practices, generate sustained competitive advantage (Barney, 1991, as applied in Xue & Di Vaio, 2025). Dynamic Capabilities Theory extends this by emphasising firms' sensing, seizing and reconfiguring capabilities the ability to detect emerging sustainability requirements, mobilise digital resources in response, and reconfigure logistics processes accordingly (Wang, Feng, Wu, & Shen, 2025). Stakeholder theory and institutional pressure explain why firms adopt green-digital practices even where short-term financial returns are uncertain, pointing to regulatory, customer and investor pressure as key drivers (Md Taib et al., 2025). Finally, technology-adoption frameworks such as the Technology Acceptance Model help explain variation in digital uptake at the firm level, particularly among small and medium-sized enterprises that face resource constraints (Md Taib et al., 2025).

2.4. Linking Digitalization, Green Logistics and Performance

A growing body of empirical work now tests the digitalization–sustainability link directly rather than treating it as a background assumption. Using panel data on Chinese A-share listed firms and a double machine-learning estimator, Wang and Shen (2025) find that supply-chain digitalization significantly raises enterprise green transformation performance, with stronger effects among non-state-owned enterprises, firms with highly integrated supply chains, and firms in more competitive, non-high-polluting industries. A related study using an overlapping but extended sample similarly finds that supply-chain digitalization enhances corporate green transformation performance mainly by strengthening firms' sensing, seizing and reconfiguring capabilities, with the effect more pronounced under high technological uncertainty and among executives with stronger green cognition (Wang, Feng, Wu, & Shen, 2025). Using a difference-in-differences design on a separate panel of Chinese listed firms, Wang (2025) reports that digitalization promotes green innovation partly through increased supply-chain transparency, an effect moderated by board diversity. At the level of firm productivity, Xue and Di Vaio (2025) apply a double machine-learning approach to Chinese A-share firms between 2013 and 2023 and find that supply-chain digitalization raises green total-factor productivity both directly and indirectly through enhanced supply-chain resilience. Outside the Chinese context, a conceptual and practice-based synthesis of green supply-chain management and digital transformation literature concludes that eco-design, reverse logistics and sustainable sourcing are widely acknowledged to improve environmental performance, but that research examining these practices jointly with digital transformation rather than in isolation remains comparatively scarce (Md Taib et al., 2025). An editorial review of a special issue on Logistics 4.0 similarly concludes that digital transformation technologies have, on average, a moderate positive impact on the environmental and social dimensions of sustainability, while cautioning that the transformation pathways observed across contributing studies were often incomplete or unevenly sustained over time (Sundarakani, Manikas, & Gunasekaran, 2024).

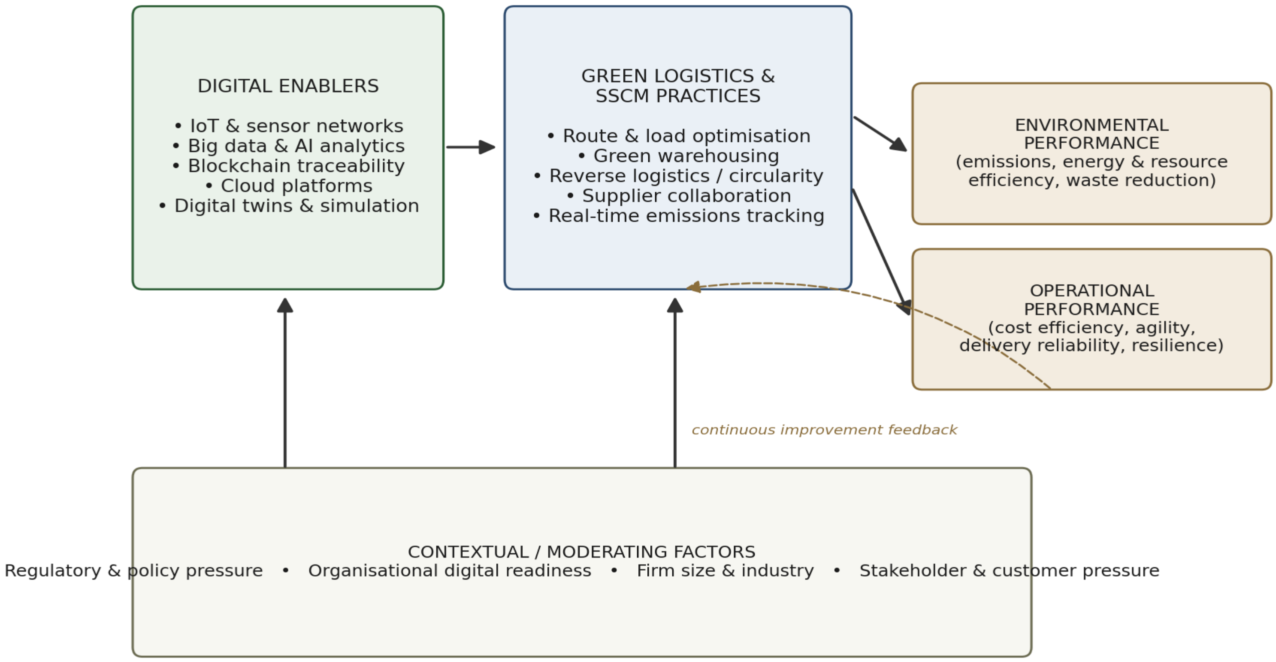
2.5. Research Gap

Three gaps emerge from this review. First, most large-sample quantitative evidence originates from a single national context listed Chinese manufacturing firms which limits generalisability to other regulatory and market environments. Second, studies tend to examine either environmental or operational performance rather than modelling both outcomes jointly, even though the two are theoretically linked through shared digital and green capabilities. Third, comparatively few studies integrate macro-level data on the environmental scale of the logistics sector with firm-level evidence on digital adoption, leaving a gap between the scale of the problem and the scale of the proposed digital solution. This paper addresses these gaps by (a) synthesising evidence across multiple national and industry contexts, (b) building a conceptual framework that treats environmental and operational performance as parallel, interacting outcomes, and (c) explicitly grounding the discussion in verifiable sector-level emissions and freight-activity data.

3. Conceptual Framework

Drawing on the theoretical perspectives and empirical findings reviewed in Section 2, Figure 3 presents an integrative framework linking digital enablers to green logistics and SSCM practices, and in turn to environmental and operational performance outcomes, subject to a set of contextual moderating factors.

Figure 3. Conceptual Framework Linking Digitalization, Green Logistics Practices and Performance Outcomes



Source: Authors' own construction, synthesised from the reviewed literature (Seuring & Müller, 2008; Zhu & Sarkis, 2004; Dolgui & Ivanov, 2022; Xue & Di Vaio, 2025).

The framework proposes that digital enablers IoT and sensor networks, big-data and AI analytics, blockchain traceability, cloud platforms, and digital twins do not affect performance directly. Instead, they enable a set of green logistics and SSCM practices: route and load optimisation, green warehousing, reverse logistics and circularity, supplier collaboration, and real-time emissions tracking. These practices, in turn, generate two parallel but interacting performance outcomes. Environmental performance captures reductions in emissions, energy and resource intensity and waste generation. Operational performance captures cost efficiency, agility, delivery reliability and resilience. The dashed feedback arrow reflects evidence that operational gains for example, from predictive maintenance or route optimisation often free up resources that are reinvested in further green practices, creating a continuous-improvement loop rather than a one-off transformation (Ivanov & Dolgui, 2022; Xue & Di Vaio, 2025). Finally, the relationship between digital enablers and outcomes is not deterministic: it is shaped by contextual and moderating factors, including regulatory and policy pressure, organisational digital readiness, firm size and industry, and stakeholder or customer pressure, consistent with the heterogeneity results reported by Wang and Shen (2025) and the adoption barriers documented among smaller firms (Md Taib et al., 2025).

4. Research Methodology

This paper adopts a structured narrative literature review methodology, appropriate for a topic where the underlying empirical base is still consolidating across disciplines (logistics, operations management, environmental economics and information systems) and where the objective is conceptual integration rather than statistical meta-analysis.

4.1. Search Strategy and Inclusion Criteria

Literature was identified through keyword searches combining terms such as “green logistics”, “sustainable supply chain management”, “supply chain digitalization”, “digital transformation”, “Industry 4.0”, “environmental performance” and “operational performance”. Sources were drawn from peer-reviewed journals indexed in major bibliographic databases (e.g., Journal of Cleaner Production, International Journal of Physical Distribution & Logistics Management, International Journal of Logistics Research and Applications, Sustainable

Development, Sustainability, Humanities and Social Sciences Communications, Business Strategy and the Environment, Finance Research Letters). Studies were included if they (a) addressed green logistics, SSCM or supply-chain digitalization as a central theme, (b) reported either conceptual frameworks or empirical findings linking digital technology to environmental or operational outcomes, and (c) were published mainly between 2004 and 2025, with earlier foundational works (e.g., Zhu & Sarkis, 2004; Seuring & Müller, 2008) retained for theoretical grounding. Editorials, trade-press commentary without an empirical or conceptual contribution, and non-English sources were excluded.

4.2. Secondary Statistical Data

To ground the conceptual discussion in verifiable, real-world figures on the environmental scale of logistics, the paper draws on publicly available secondary statistics from international and industry bodies, rather than presenting original primary survey data. These sources detailed in Table 1 include the International Energy Agency (IEA), Statista's analysis of IEA transport data, the World Economic Forum's Net-Zero Industry Tracker, Our World in Data / Climate Watch, and the POLIS Network / International Transport Forum. Because this is a conceptual, review-based paper rather than a primary empirical study, no firm-level survey or interview data were collected; all quantitative figures reported in Section 5 are attributed to their original source and are reproduced only in aggregated, publicly reported form.

4.3. Analytical Approach

Included studies were read in full and coded manually against four attributes: theoretical lens, digital technology examined, green/sustainability practice or outcome examined, and key finding. This coding underpins the comparative synthesis presented in Table 2 and the technology-mapping presented in Table 3, and informed the construction of the conceptual framework in Figure 3. This approach follows the narrative-synthesis logic recommended for cross-disciplinary sustainability reviews, in which a structured summary matrix is used to support analytical consistency while allowing integration of both theoretical and applied insights (Torraco, 2005, as applied in recent green-logistics reviews).

5. Data Sources

Table 1 lists the secondary data sources used to quantify the environmental scale of global logistics activity discussed in this paper, together with the type of data drawn from each and how it is used.

Table 1. Secondary Data Sources Used in This Study

Source	Type of Data	Reference Period	Use in This Paper
International Energy Agency (IEA)	Global CO_2 emissions from transport, by sub-sector	2000–2030 (historical & scenario)	Contextualises the environmental burden of freight and passenger transport
Statista (analysis of IEA data)	Share of transport-sector CO_2 emissions by mode, 2022	2022	Basis for Figure 1
World Economic Forum, Net-Zero Industry Tracker: Trucking (2024)	Global road-freight activity (trillion tonne-km); sector emissions share	2019 & 2023	Basis for Figure 2
Our World in Data / Climate Watch (OECD-IEA)	Historical transport CO_2 emissions by country and globally	1990–2023	Cross-checks emissions trend figures
Cargoson analysis of Climate Watch data	Global transport emissions totals and year-on-year change	1990–2024	Supplies 2024 global transport emissions total (8.4 Gt CO_2e) cited in the Introduction
POLIS Network / International Transport Forum	Global Supply Chain Pressure Index; freight decarbonisation pathway	1997–2022 (index); to 2050 (pathway)	Supports discussion of supply-chain disruption and decarbonisation targets

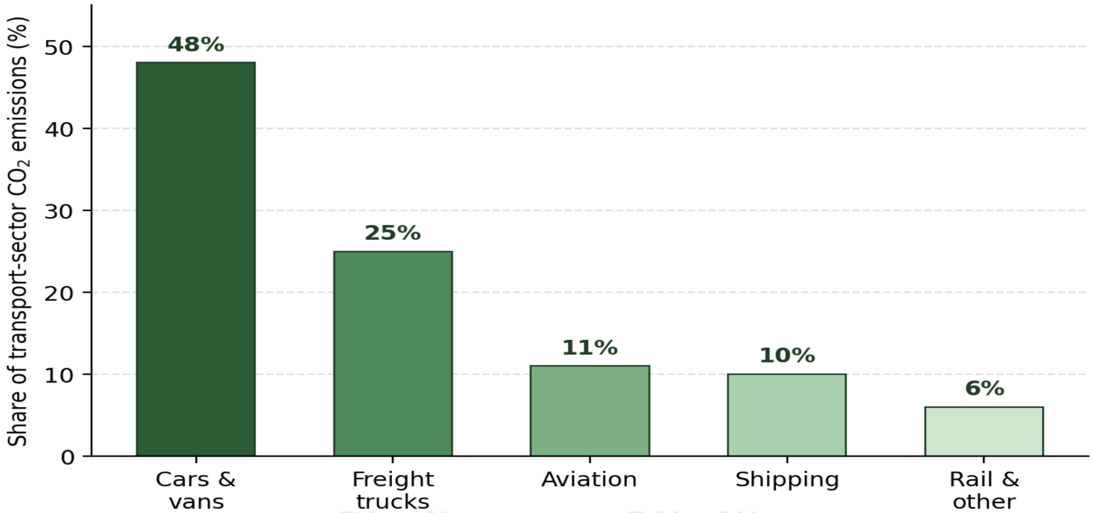
Source: Compiled by the authors from the sources listed in the table.

6. Analysis and Findings

6.1. The Environmental Scale of Global Logistics

The urgency behind green-logistics research is best understood against the scale of the sector's environmental footprint. Figure 1 shows that road transport dominates transport-sector emissions: cars and vans alone accounted for 48 per cent of global transport CO_2 emissions in 2022, with freight trucks contributing a further 25 per cent meaning road-based transport of all kinds was responsible for approximately three-quarters of the sector's emissions, while aviation and shipping contributed 11 per cent and 10 per cent respectively (Statista, 2023). This concentration matters for green-logistics strategy because it means that route optimisation, load consolidation and fleet-electrification technologies aimed at road freight address the single largest slice of the problem.

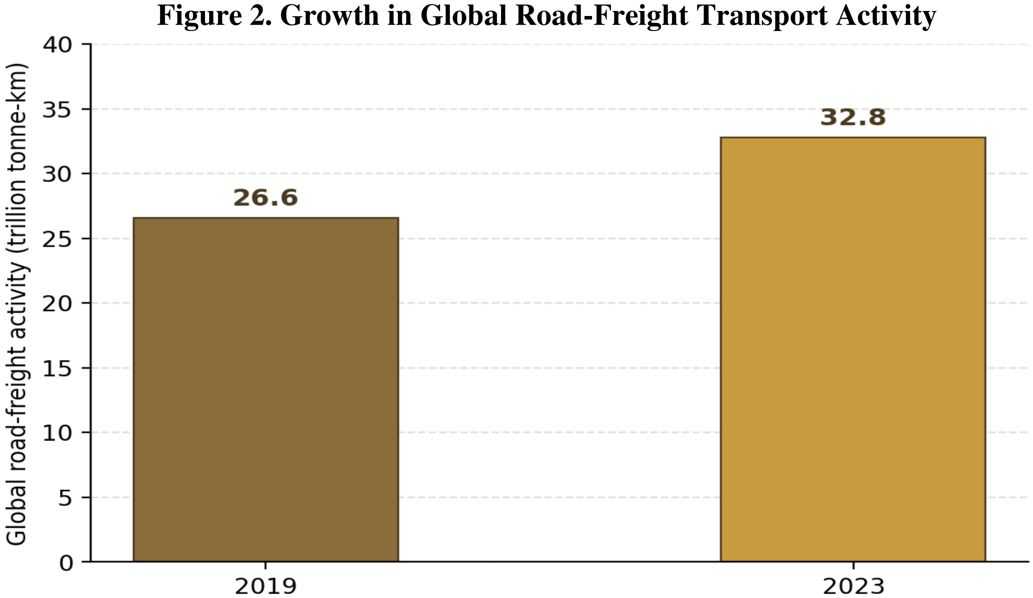
Figure 1. Global Transport-Sector CO_2 Emissions by Mode



Source: Authors' construction based on Statista (2023) analysis of International Energy Agency (IEA) data, reference year 20220.

The scale of the challenge is compounded by growth in freight volumes. As shown in Figure 2, global road-freight activity increased from 26.6 trillion tonne-kilometres in 2019 to 32.8 trillion tonne-kilometres in 2023 as the sector recovered from pandemic-related disruption (World Economic Forum, 2024), even as road freight continues to rely on fossil fuels for approximately 96 per cent of its energy consumption (World Economic Forum, 2024). Globally, transportation-sector emissions reached about 8.44 billion tonnes of CO_2-equivalent in 2024, a 79 per cent increase since 1990 and around 15.9 per cent of all global greenhouse-gas emissions (Cargoson, 2025). Achieving the reductions implied by net-zero pathways is estimated to require close to a 59 per cent cut in transport-related CO_2 emissions by 2050 relative to current trajectories (POLIS Network, 2024). Digitalization alone cannot close this gap it must combine with fleet electrification, alternative fuels and modal shift but the efficiency gains available from route optimisation, load-factor improvement and predictive maintenance represent some of the lowest-cost decarbonisation levers currently available to logistics firms.

Figure 2. Growth in Global Road-Freight Transport Activity



Source: Authors' construction based on World Economic Forum, Net-Zero Industry Tracker: Trucking (2024).

6.2. Comparative Synthesis of Empirical Studies

Table 2 synthesises the empirical studies reviewed in Section 2.4, summarising their context, method and key findings on the digitalization–sustainability relationship.

Table 2. Comparative Synthesis of Selected Studies on Digitalization, Green Logistics and SSCM Performance

Study	Context / Sample	Method	Key Finding
Zhu & Sarkis (2004)	186 Chinese manufacturing enterprises	Survey; regression analysis	Early adoption of green supply-chain practices is positively associated with both environmental and operational performance
Seuring & Müller (2008)	191 papers, 1994–2007 (literature review)	Structured content analysis	Establishes conceptual framework of SSCM triggers, strategies and sustainability dimensions
Wang & Shen (2025)	Chinese A-share listed firms, 2013–2023	Double machine learning (panel data)	Supply-chain digitalization significantly raises enterprise green transformation performance; stronger for non-state-owned, highly-integrated, non-high-polluting firms
Wang, Feng, Wu & Shen (2025)	Chinese A-share listed firms, 2013–2021	Double machine learning (panel data)	Digitalization enhances green transformation performance mainly via sensing, seizing and reconfiguring capabilities
Wang (2025)	Chinese listed firms, 2010–2022	Difference-in-differences	Digitalization promotes green innovation, partly mediated by supply-chain transparency; moderated by board diversity
Xue & Di Vaio (2025)	Chinese A-share firms, 2013–2023	Double machine learning (panel data)	Digitalization raises green total-factor productivity directly and indirectly via supply-chain resilience
Jayarathna, Agdas & Dawes (2024)	Sustainable logistics practices (conceptual/system model)	System dynamics modelling	Green purchasing, eco-design, reverse logistics and green transport interact dynamically to enable circular-economy outcomes
Md Taib, Ibrahim, Daud, Abu Yazid & Othman (2025)	GSCM and digital-transformation literature (conceptual)	Narrative synthesis	GSCM practices improve environmental performance, but integration with digital transformation is under-researched, especially for SMEs
Sundarakani, Manikas & Gunasekaran (2024)	Special-issue editorial synthesis, Logistics 4.0	Editorial literature synthesis	Digital transformation technologies show a moderate positive impact on environmental and social sustainability dimensions of logistics

Source: Compiled by the authors from the cited studies.

6.3. Digital Technologies and Green Logistics Applications

Table 3 maps the five digital-technology families identified in Section 2.2 to specific green-logistics applications and the performance dimension each is most closely associated with in the reviewed literature.

Table 3. Digital Technologies Mapped to Green Logistics Applications

Technology	Green Logistics Application	Performance Link	Illustrative Sources
IoT & sensor networks	Real-time fleet and cargo monitoring; energy metering in warehouses; cold-chain integrity tracking	Environmental (emissions, spoilage/waste reduction)	Dolgui & Ivanov (2022)
Big data & AI analytics	Route and load optimisation; demand forecasting; predictive maintenance	Environmental & operational (fuel savings, downtime reduction)	Wang, Feng, Wu & Shen (2025)
Blockchain traceability	Multi-tier supplier verification; carbon and provenance data sharing	Environmental (transparency) & operational (trust, transaction cost)	Wang (2025)

Cloud computing	Scalable data infrastructure connecting dispersed logistics nodes	Operational (integration, scalability)	Xue & Di Vaio (2025)
Digital twins & simulation	Scenario testing for network redesign and decarbonisation pathways	Environmental & operational (risk reduction before physical investment)	Ivanov & Dolgui (2022)

Source: Compiled by the authors from the reviewed literature.

6.4. Mechanisms Linking Digitalization to Performance Outcomes

Across the studies synthesised in Table 2, three mechanisms recur as explanations for why digitalization improves sustainability outcomes. The first is a visibility mechanism: sensor and analytics data make previously invisible inefficiencies empty return trips, idling engines, over-packaged shipments observable and therefore actionable (Dolgui & Ivanov, 2022). The second is a capability-building mechanism, in which digital tools strengthen firms' dynamic capabilities to sense emerging sustainability requirements, seize them through new practices, and reconfigure operations accordingly (Wang, Feng, Wu, & Shen, 2025). The third is a resilience mechanism, whereby digitally enabled visibility and flexibility reduce the disruption risk that might otherwise force firms back toward less efficient, higher-emission contingency practices, thereby protecting environmental gains during periods of supply-chain stress (Xue & Di Vaio, 2025). These mechanisms are mutually reinforcing rather than competing explanations, consistent with the feedback loop depicted in Figure 3.

6.5. Moderating and Contextual Factors

The reviewed evidence also converges on several factors that condition how strongly digitalization translates into sustainability performance. Ownership structure and governance matter: the effect of digitalization on green transformation performance is significantly stronger among non-state-owned enterprises than state-owned ones, plausibly reflecting differences in managerial incentives and market discipline (Wang & Shen, 2025). Supply-chain integration matters: firms with more tightly integrated, digitally connected supply chains realise larger gains, since digital tools are more effective when data flows across organisational boundaries rather than remaining siloed within a single firm (Wang & Shen, 2025). Industry competitiveness and pollution intensity also shape outcomes, with effects more pronounced in competitive, lower-pollution industries, possibly because such firms face stronger market incentives to signal environmental performance (Wang & Shen, 2025). Finally, firm size and resource constraints remain a persistent barrier: smaller enterprises are consistently identified in the literature as facing the greatest difficulty translating digital adoption into green outcomes, owing to capital constraints, limited technical expertise and weaker bargaining power over supply-chain partners (Md Taib et al., 2025).

7. Discussion

Taken together, the literature and secondary data reviewed in this paper support three broad conclusions. First, the environmental case for prioritising road-freight digitalization is strong: because cars, vans and freight trucks jointly account for roughly three-quarters of transport-sector emissions (Statista, 2023), digital tools that improve road-freight efficiency route optimisation, load consolidation, predictive maintenance target the largest share of the problem, even though they cannot substitute entirely for fleet electrification and modal shift toward rail and low-carbon shipping. Second, the relationship between digitalization and sustainability performance is best understood as capability-mediated rather than automatic. Firms that pair digital investment with organisational capability-building sensing emerging requirements, seizing them through new green practices, and reconfiguring operations realise substantially larger gains than firms that adopt digital tools in isolation (Wang, Feng, Wu, & Shen, 2025). This helps explain why empirical effects are consistently heterogeneous across ownership type, integration level and firm size rather than uniform across all adopters.

Third, environmental and operational performance appear to be complementary rather than competing objectives in the digitally enabled logistics context reviewed here, which is a notable departure from older assumptions that greening logistics necessarily raises costs. Route optimisation reduces both fuel consumption and delivery time; predictive maintenance reduces both emissions from inefficient engine operation and unplanned downtime; blockchain-enabled traceability reduces both environmental risk and transaction costs associated with supplier verification. This complementarity is consistent with the resource-based and dynamic-capabilities reasoning underpinning much of the reviewed literature, and it offers a more compelling business case for green-digital investment than a purely compliance-driven narrative. At the same time, the moderate rather than transformative impact reported in broader editorial syntheses of the field

(Sundarakani, Manikas, & Gunasekaran, 2024) is a useful corrective to overly optimistic claims: digitalization expands the feasible frontier of green logistics performance, but realising that potential still depends heavily on organisational and regulatory context.

8. Managerial and Policy Implications

8.1. Implications for Logistics and Supply Chain Managers

- Prioritise digital investment in road-freight optimisation first, given that road transport represents the largest single share of transport-sector emissions; route and load optimisation, telematics and predictive maintenance typically offer the fastest payback.
- Treat digitalization and green-practice adoption as a joint capability-building programme rather than two separate initiatives; the evidence indicates that digital tools generate limited environmental benefit unless paired with deliberate green-practice redesign.
- Extend digital visibility beyond the focal firm to key suppliers and logistics partners, since the performance gains associated with supply-chain digitalization are strongest where integration across tiers is high.
- For small and medium-sized enterprises, consider shared or platform-based digital infrastructure (e.g., cloud-based transport-management systems) to lower the capital barrier that otherwise limits their ability to capture green-digital gains.

8.2. Implications for Policymakers

- Given that transport-related emissions must fall by close to 59 per cent by 2050 to remain consistent with net-zero pathways (POLIS Network, 2024), policy support for logistics digitalization should be framed explicitly as a decarbonisation tool, not only as an industrial-competitiveness measure.
- Because ownership structure and firm size condition outcomes, targeted incentives (tax credits, co-financing, digital-adoption grants) may be more effective when directed at smaller and state-linked enterprises that currently lag in translating digital investment into green performance.
- Standardised, interoperable data and emissions-reporting protocols across supply-chain tiers would strengthen the traceability and transparency mechanisms identified as central to the digitalization–sustainability link.

9. Limitations and Future Research Directions

This study has three main limitations. First, as a narrative literature review, it does not perform an independent statistical meta-analysis of effect sizes across studies; the synthesis in Table 2 should therefore be read as a qualitative comparison rather than a pooled quantitative estimate. Second, much of the strongest recent quantitative evidence originates from Chinese listed firms, which may limit the direct transferability of magnitude estimates (though not necessarily the underlying mechanisms) to other regulatory and market contexts, such as the European Union or Southeast Asia. Third, the secondary emissions and freight-activity data used in Section 6.1, while drawn from internationally recognised sources, reflect different reference years (2019, 2022, 2023 and 2024) because this is the most recent publicly available data at the time of writing for each respective source; readers should treat cross-figure comparisons as broadly, rather than precisely, contemporaneous.

Future research could usefully pursue four directions: (a) cross-country comparative studies that test whether the digitalization green-performance relationship documented in China holds with similar magnitude in other institutional contexts; (b) firm-level studies that model environmental and operational performance jointly, rather than separately, to test the complementarity hypothesis discussed in Section 7; (c) research specifically targeting small and medium-sized enterprises, given their documented adoption barriers; and (d) longitudinal studies that track whether digitally enabled environmental gains persist through periods of supply-chain disruption, directly testing the resilience mechanism proposed in Section 6.4.

10. Conclusion

This paper has examined the role of digitalization in advancing green logistics and sustainable supply chain management, and through this pathway, environmental and operational performance. Grounded in a structured review of the literature and in verifiable secondary data on the scale of transport-sector emissions and freight growth, the analysis shows that digital technologies particularly IoT-enabled visibility, AI-driven optimisation, blockchain traceability and digital-twin simulation can meaningfully reduce the environmental footprint of logistics while simultaneously improving cost efficiency, agility and resilience. This dual benefit is not automatic: it depends on organisational capability-building, supply-chain integration, firm size and the surrounding regulatory environment. As global freight volumes continue to grow and net-zero commitments tighten, the evidence reviewed here suggests that digitalization should be treated not as a peripheral IT investment but as a core strategic lever for achieving sustainable supply chain performance provided it is deliberately integrated with, rather than substituted for, genuine green-practice redesign.

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