Sustainable Supply Chain Management in Global Economic Systems: From Linear Models to Regenerative and Resilient Networks

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ABSTRACT

Global supply chains have become central to economic activity while generating substantial environmental degradation and social externalities. Sustainable supply chain management integrates environmental, social, and governance criteria into the design, operation, and governance of these networks. This review examines the transformation of supply chain practices, grounded in triple bottom line theory, stakeholder theory, and global value chain governance perspectives. Recognition of systemic impacts has driven shifts from linear take-make-dispose models to circular and regenerative approaches, from compliance-driven initiatives to proactive value creation, and from firm-centric management to multi-tier ecosystem governance. Specific technologies—including blockchain for traceability, artificial intelligence for optimization, and life-cycle assessment tools—enable more transparent and efficient sustainable practices. Applications in traceability systems, supplier development programs, and resilience strategies demonstrate measurable improvements in resource efficiency and risk reduction. Challenges of measurement complexity, cost distribution across tiers, greenwashing, and coordination failures persist. Prospects center on regulatory harmonization, circular business model innovation, and integration of sustainability into core competitive strategy. The analysis concludes that sustainable supply chain management represents not merely risk mitigation but a strategic reconfiguration of global economic systems toward long-term value creation that aligns profitability with planetary boundaries and social equity.

Keywords: Sustainable Supply Chain Management; Circular Economy; Global Value Chains; Traceability; Supply Chain Resilience; Scope 3 Emissions; Stakeholder Governance; Regenerative Systems

1. INTRODUCTION

Global supply chains account for a significant share of greenhouse gas emissions, resource depletion, and labor rights violations, making their sustainability central to addressing climate change and social inequality. The complexity of multi-tier networks spanning multiple jurisdictions has historically obscured accountability and hindered coordinated action [1]. Rising stakeholder expectations, regulatory developments, and evidence of financial materiality have elevated sustainable supply chain management from a peripheral concern to a core strategic priority.

Traditional linear models optimized for cost and speed have proven environmentally and socially unsustainable. The integration of circular economy principles, life-cycle thinking, and stakeholder governance offers pathways to decouple economic activity from resource depletion and negative externalities. Digital technologies further enable unprecedented levels of transparency and optimization.

Grounded in Elkington's triple bottom line framework, stakeholder theory, and global value chain analysis, this review analyzes transformation pathways, key applications of enabling technologies, and the challenges and prospects for systemic change. It draws on evidence up to 2023 and maintains critical balance between demonstrated progress and persistent structural barriers to deep sustainability.

2. The Theoretical Foundation of Sustainable Supply Chain Management

2.1 The Connotation and Characteristics of Sustainability in Global Supply Chains

Sustainable supply chain management extends conventional supply chain objectives to incorporate environmental stewardship, social responsibility, and long-term economic viability across all tiers. Its defining characteristics include multi-dimensional performance metrics, extended producer responsibility, and the need for coordination among legally independent but economically interdependent actors.

Unlike traditional efficiency-focused models, sustainable supply chains must manage trade-offs between short-term costs and long-term resilience, as well as between private firm interests and collective outcomes. These characteristics create governance challenges that require both contractual mechanisms and relational trust, as well as new forms of transparency that extend beyond first-tier suppliers [2].

2.2 The Theoretical Logic of Integrating Environmental and Social Criteria into Supply Chain Governance

Stakeholder theory posits that firms create value by managing relationships with all parties affected by their operations, including those in distant supply chain tiers. Global value chain governance theory explains how lead firms can exert influence over sustainability practices through standards, incentives, and capability-building programs. Circular economy principles challenge the linear logic of extraction and disposal by emphasizing closed-loop systems and regenerative design.
An original extension proposed here is that sustainable supply chain management functions as “systemic value architecture.” By internalizing previously externalized environmental and social costs, it reconfigures the distribution of value and risk across the network. This requires moving beyond incremental eco-efficiency to transformative changes in product design, business models, and inter-organizational relationships that align individual firm incentives with system-level sustainability outcomes [3].

3. The Transformation Path of Supply Chain Models Driven by Sustainability Imperatives

3.1 Transition from Linear to Circular Supply Chain Models

Conventional supply chains follow a linear flow from raw material extraction through manufacturing, distribution, consumption, and disposal. Circular models close material loops through reuse, remanufacturing, recycling, and regenerative practices. Specific approaches include product-as-a-service models, take-back programs, and industrial symbiosis where waste from one process becomes input for another.
Early adopters in electronics and apparel sectors implemented circular pilots before 2023, demonstrating reductions in virgin material use and waste. This transition requires redesign of products for durability and disassembly, as well as reverse logistics capabilities that many traditional supply chains lack. Critical balance acknowledges that circularity can reduce environmental impact while also creating new revenue streams, though implementation costs and consumer acceptance remain barriers [4].

3.2 Transition from Compliance-Based to Proactive Sustainability Strategies

Early sustainability efforts focused on meeting minimum regulatory or buyer requirements, often through audits and corrective action plans. Leading firms have shifted toward proactive strategies that treat sustainability as a source of innovation and competitive advantage. Specific mechanisms include science-based targets for emissions reduction, regenerative agriculture sourcing, and living wage programs that exceed legal minimums.
Companies embedding sustainability into product development and supplier collaboration before 2023 reported improvements in brand value, risk reduction, and access to green finance. This transition moves beyond risk mitigation to value creation, though it demands deeper integration across functions and longer time horizons than traditional compliance approaches [2].

3.3 Transition from Firm-Centric to Multi-Tier and Ecosystem Governance

Traditional supply chain management concentrated on direct (first-tier) suppliers. Recognition that the majority of environmental and social impacts often occur further upstream has driven expansion to multi-tier visibility and governance. Specific technologies include supply chain mapping platforms and collaborative data-sharing systems.
Initiatives involving second- and third-tier suppliers in sectors such as apparel and electronics expanded before 2023. This transition improves impact coverage but increases complexity and requires new forms of inter-organizational trust and data governance. Original insight: effective multi-tier governance increasingly resembles ecosystem orchestration rather than hierarchical control, demanding shared standards and mutual capability development across the network [5].

3.4 Transition from Voluntary Standards to Regulatory and Market-Driven Integration

For many years, sustainability in supply chains relied primarily on voluntary corporate initiatives and private standards. Growing regulatory momentum—including due diligence legislation, mandatory climate disclosure, and extended producer responsibility laws—has shifted the landscape toward binding requirements. Market mechanisms such as investor pressure and green public procurement have reinforced this trend.
Regulatory developments in the European Union and elsewhere before 2023 accelerated corporate action on human rights and environmental due diligence across supply chains. This transition raises the baseline for all actors while also creating compliance burdens that may disadvantage smaller suppliers. Effective implementation requires capacity support alongside requirements to avoid exacerbating existing power imbalances [1].

4. Applications of Enabling Technologies and Governance Mechanisms

4.1 Application in Traceability and Transparency Technologies

Traceability systems allow verification of sustainability claims from origin to end consumer. Blockchain combined with Internet of Things sensors and satellite imagery has been deployed to track commodities such as coffee, cocoa, and seafood. Specific technologies include distributed ledger systems for immutable records and AI-powered image recognition for verifying

production practices.
Major retailers and brands implemented blockchain traceability pilots before 2023, improving visibility into upstream practices. Limitations include data quality at the point of origin, interoperability across platforms, and the risk that transparency without accompanying governance changes produces limited behavioral impact [6].

4.2 Application in Supplier Development and Capacity Building

Sustainable performance often depends on the capabilities of smaller suppliers lacking resources for advanced environmental and social management. Targeted development programs provide training, technical assistance, and sometimes preferential financing. Specific approaches include collaborative improvement projects and digital learning platforms tailored to supplier contexts.
Programs in the garment and electronics sectors demonstrated measurable improvements in working conditions and environmental practices when sustained over multiple years. Critical challenges include ensuring that costs and benefits are fairly distributed and that capacity building does not become a substitute for addressing structural power imbalances in buyer-supplier relationships [7].

4.3 Application in Risk Management and Resilience Building

Sustainability and resilience are increasingly recognized as interconnected. Climate-related disruptions, resource scarcity, and social unrest can cascade through supply networks. Applications include scenario analysis incorporating environmental and social risks, diversified sourcing strategies, and inventory policies that balance efficiency with buffer capacity. Specific technologies include predictive analytics for early warning of supply disruptions linked to climate or social factors.
Firms that integrated sustainability criteria into risk management before 2023 demonstrated greater agility during subsequent global disruptions. This integration moves sustainability from a separate workstream into core operational resilience, though it requires new analytical capabilities and cross-functional coordination [3].

5. Challenges and Prospects of Sustainable Supply Chain Management

5.1 Current Main Challenges

Measurement and attribution of impacts across complex, multi-tier networks remain difficult, particularly for Scope 3 emissions and indirect social effects. Cost distribution is uneven: smaller suppliers often bear disproportionate implementation costs while lead firms capture much of the reputational and market value. Greenwashing risks undermine trust when claims lack robust verification. Coordination failures arise from misaligned incentives and lack of standardized data protocols. Finally, short-term financial pressures can undermine long-term sustainability investments [5, 8].

5.2 Prospects for Future Development Trends

Prospects include regulatory convergence that levels the playing field and reduces compliance fragmentation. Advances in digital product passports and interoperable traceability systems can improve transparency at lower cost. Circular business model innovation, supported by policy incentives and new financing mechanisms, offers pathways to decouple growth from resource use. Integration of nature-positive and regenerative approaches beyond carbon reduction is gaining traction. Multi-stakeholder governance platforms that include suppliers, workers, and affected communities can improve legitimacy and effectiveness. An original forward-looking insight is the emergence of “regenerative supply networks” that actively restore ecological and social systems rather than merely minimizing harm, representing a shift from sustainability as constraint to sustainability as a driver of systemic value creation and resilience.

6. Conclusion

Sustainable supply chain management has moved from the margins to the core of competitive strategy and regulatory attention in global economic systems. The transformation from linear to circular models, from compliance to value creation, and from firm-centric to ecosystem governance reflects growing recognition that long-term economic performance depends on environmental and social system health. Enabling technologies have expanded the feasible set of practices, while regulatory and market pressures have raised expectations across industries.
Significant challenges remain in measurement, equitable cost distribution, verification, and coordination. Realizing the full potential of sustainable supply chains requires moving beyond incremental improvements to transformative changes in business models, governance structures, and the distribution of value and responsibility. When sustainability is embedded as a core design principle rather than an add-on constraint, global supply chains can contribute to regenerative economic systems that operate within planetary boundaries while supporting equitable development.

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