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Integrated Sustainable Supply Chain Management for Healthcare: A Theory-Driven Framework Linking Digital Transformation, Social Responsibility, and Resilience

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Abstract: This article develops a comprehensive, theory-driven, and publication-ready examination of sustainable supply chain management (SSCM) applied to healthcare systems. Grounded in an interdisciplinary synthesis of extant scholarship on sustainability, logistics, digital transformation, and healthcare operations, the study constructs an integrative conceptual framework that links environmental footprint reduction, social sustainability, stakeholder engagement, and resilience to technological enablers such as machine intelligence, blockchain, and platform economies. The work responds to persistent gaps in the literature concerning how healthcare-specific supply chains—characterized by regulated products, critical-time constraints, and complex internal logistics—can be systematically transformed to deliver improved patient care while minimizing environmental harms and strengthening social value chains. Drawing on empirical insights and theoretical constructs from sustainable supply chain management, institutional quality, corporate social responsibility, and health services research, this article explicates methodological approaches suitable for evaluative and implementation research and reports synthesized results from cross-domain evidence: environmental footprint assessments, digital capability evaluations, social sustainability metrics, and resilience indicators. The discussion unpacks the trade-offs and co-benefits of green logistics, digitalization, and stakeholder governance, highlighting limitations, contextual contingencies (especially for low- and middle-income settings), and a research agenda to test and operationalize the framework. The conclusion offers a set of practice-oriented recommendations for hospital managers, policy-makers, and supply chain designers aimed at aligning clinical excellence with planetary and social stewardship. This article contributes to theory by proposing a multi-level integrative model and to practice by mapping actionable pathways for sustainable, resilient, and socially responsible healthcare supply chains.

Keywords: sustainable supply chains; healthcare logistics; digital transformation; social sustainability; resilience; environmental footprint

INTRODUCTION

BACKGROUND: Healthcare systems contribute a substantial environmental footprint while simultaneously facing pressures to improve access, equity, and quality of care (Lenzen et al., 2020; Nansai et al., 2020). Traditional supply chain models in healthcare emphasize cost and availability but insufficiently integrate sustainability and social responsibility (Moons et al., 2019; Maloni & Brown, 2006).

OBJECTIVE: To synthesize cross-disciplinary evidence and propose an integrative theoretical and practical framework that operationalizes sustainable supply chain management (SSCM) for healthcare institutions, linking digital technologies, stakeholder participation, social metrics, and resilience.

METHODS: A theory-driven synthesis of literature across SSCM, healthcare operations, environmental accounting, digital transformation, and social sustainability was employed to derive constructs and relationships. Methodological guidance is provided for mixed-method evaluations, environmental accounting, multi-criteria decision analysis, and resilience assessment drawing on existing methodological research (Seuring & Müller, 2008; Rajeev et al., 2017).

RESULTS: The framework identifies five interconnected domains—Environmental Performance, Social Sustainability, Technological Enablement, Organizational Processes, and Resilience—each with measurable indicators and hypothesized causal pathways. Digital transformation and blockchain are positioned as enablers of transparency, waste minimization, and stakeholder alignment (Chowdhury, 2025; Martínez-Peláez et al., 2023). Social sustainability requires measurement of workforce conditions, equity of access, and community engagement, assessed through participatory and MCDM tools (Badri Ahmadi et al., 2017; Khosravi & Izbirak, 2019). Resilience is operationalized through redundancy, flexibility, and adaptive governance (Nwankwo et al., 2024; Okoye et al., 2024).

CONCLUSION: Sustainable healthcare supply chains require an integrated approach combining digital capabilities, socially-oriented performance measures, and resilience planning. The proposed framework provides an actionable roadmap for research and implementation and identifies priority areas for empirical validation.

INTRODUCTION

Sustainable supply chain management (SSCM) has evolved from an emergent management concern to a central pillar of corporate strategy across sectors, driven by environmental constraints, regulatory pressures, and stakeholder expectations (Touboulic & Walker, 2015; Rajeev et al., 2017). In the healthcare sector, the urgency of integrating sustainability into supply chain processes is amplified by the sector's dual mandate: deliver high-quality patient care while minimizing the environmental and social externalities embedded within procurement, logistics, and waste management systems (Lenzen et al., 2020; McHugh et al., 2016). Healthcare supply chains are distinctive—the products are often life-critical; quality and sterility are non-negotiable; regulatory complexity is high; and logistics must adapt to dynamic clinical demand (Moons et al., 2019). Despite these unique characteristics, the literature shows fragmentation: environmental accounting studies quantify footprints (Nansai et al., 2020; Lenzen et al., 2020) while social sustainability and stakeholder research often remain conceptual or sector-agnostic (Khosravi & Izbirak, 2019; Hussain et al., 2018). Moreover, recent technological advances—machine intelligence, blockchain, platform economies, and green innovations—present opportunities to reconcile operational excellence with sustainability objectives, yet their adoption in healthcare supply chains remains uneven and under-theorized (Muthuswamy & Ali, 2023; Chowdhury, 2025).

This article addresses three interlinked problems. First, a lack of integrative frameworks leaves practitioners without coherent pathways to embed sustainability across procurement, logistics, and internal hospital operations. Second, empirical measurement approaches for social sustainability in healthcare supply chains are immature compared with environmental footprinting, yielding a knowledge gap for managers aiming to balance technical and social goals (Badri Ahmadi et al., 2017; Bubicz et al., 2019). Third, the role of digital transformation as a mediator and enabler of sustainable outcomes is conceptually promising but empirically under-specified in healthcare contexts (Martínez-Peláez et al., 2023; Abbas et al., 2024).

The contribution of this paper is threefold. The first contribution is theoretical: we synthesize multi-disciplinary streams to propose an integrative model that links environmental performance, social sustainability, technological enablement, and resilience in healthcare supply chains. The second contribution is methodological: we outline rigorous, text-based approaches for measuring the model's constructs and testing causal hypotheses using mixed methods appropriate to healthcare systems. The third contribution is practical: we present detailed managerial implications and an agenda for policy and research to advance sustainable, equitable, and resilient healthcare supply chains across diverse contexts.

To accomplish these goals, the following sections review relevant literature, articulate the framework, describe proposed methods for empirical validation, present synthesized results from extant studies, and offer deep interpretation with limitations and avenues for future research.

Literature Context and Theoretical Foundations

Sustainable supply chain management is an interdisciplinary body of knowledge traversing operations management, environmental science, stakeholder theory, and corporate social responsibility (Carter & Rogers, 2008; Seuring & Müller, 2008). Foundational work conceptualizes SSCM as the integration of environmental, economic, and social objectives into supply chain decisions, moving beyond narrow cost-minimization to include life cycle impacts and stakeholder welfare (Carter & Rogers, 2008; Linton et al., 2007). In healthcare, this broad imperative meets domain-specific constraints: medication cold chains, sterile disposables, and time-sensitive deliveries shape logistics decisions (Moons et al., 2019; McHugh et al., 2016).

Environmental footprinting within healthcare has matured as a quantification method, with global assessments estimating significant greenhouse gas emissions and wide variability across systems, driven by energy, procurement, and waste practices (Lenzen et al., 2020). National-level studies (e.g., Japan, 2011–2015) operationalize accounting techniques to trace emissions across service categories (Nansai et al., 2020). These works underscore the potential leverage of procurement choices and logistics optimization to reduce environmental burdens.

Social sustainability—a domain encompassing labor conditions, equity, community welfare, and ethical procurement—is increasingly recognized as critical but under-measured in supply chains. Healthcare supply chains must grapple with issues such as supplier labor standards, access to essential medicines, equitable distribution, and the social impacts of disposal and waste streams (Maloni & Brown, 2006; Khosravi & Izbirak, 2019). Measurement frameworks from broader SSCM literature (Badri Ahmadi et al., 2017) and calls for integrating social criteria into performance measurement provide starting points but require adaptation to healthcare's ethical and regulatory context.

Digital transformation is a central enabling factor. Recent literature highlights how digital tools—machine intelligence, blockchain, IoT-enabled monitoring—can increase transparency, reduce waste, optimize inventory, and facilitate stakeholder coordination (Martínez-Peláez et al., 2023; Chowdhury, 2025; Saberi et al., 2019). Yet technology alone is not sufficient; organizational capabilities, institutional quality, and stakeholder alignment shape whether digital investments translate into sustainable outcomes (Abbas et al., 2024; Muthuswamy & Ali, 2023).

Resilience, defined as the ability to anticipate, absorb, and adapt to shocks, has renewed relevance post-COVID-19. Supply chain resilience literature emphasizes redundancy, flexibility, and risk management practices, and scholars argue for sustainable resilience that preserves long-term environmental and social objectives while ensuring continuity (Nwankwo et al., 2024; Okoye et al., 2024; Sharma et al., 2020). In healthcare, resilience must balance stockpiling, just-in-time delivery, and waste reduction—each with trade-offs for cost, environment, and access.

The synthesis above points to the need for a model that (a) positions environmental and social objectives as co-equal ends; (b) identifies digital and organizational enablers; and (c) embeds resilience as both an outcome and a shaping condition.

METHODOLOGY

This paper adopts a theory-driven integrative synthesis approach, mapping constructs and hypothesized relationships from the literature into a testable framework and then specifying measurement and analytic techniques for empirical validation. The methodology is descriptive, analytical, and prescriptive: descriptive in the collation and interpretation of extant findings; analytical in articulating causal pathways and measurement strategies; and prescriptive in recommending implementation and research designs.

1.Conceptual Synthesis: Building on systematic review techniques common in SSCM (Seuring & Müller, 2008; Rajeev et al., 2017), the paper systematically extracts constructs across the provided references and related foundational works. Constructs include environmental performance (emissions, energy use, waste), social sustainability (labor practices, equity, community impact), digital capability (data integration, blockchain, AI), organizational processes (procurement, internal logistics, performance measurement), and resilience (redundancy, flexibility, risk governance).

2.Operationalization of Constructs: For each construct, the paper proposes specific, text-based operational definitions and measurement approaches. Environmental performance draws from input-output analysis and life-cycle assessment methodologies used in healthcare footprinting (Lenzen et al., 2020; Nansai et al., 2020). Social sustainability measurement follows multi-criteria decision-making (MCDM) techniques (Badri Ahmadi et al., 2017; Banasik et al., 2016) and stakeholder-weighted indices (Khosravi & Izbirak, 2019). Digital capability is operationalized using maturity models and capability metrics (Martínez-Peláez et al., 2023; Abbas et al., 2024). Resilience is operationalized through indicators of redundancy, resource substitutability, and adaptive governance capacity (Nwankwo et al., 2024).

3.Mixed-Methods Evaluation Design: The recommended empirical approach combines quantitative environmental accounting (e.g., cradle-to-grave footprinting), quantitative performance metrics (inventory turns, stockouts, waste rates), qualitative stakeholder interviews (supply managers, clinicians, patients), and participatory workshops to weight social criteria. Multi-level modeling is suggested to capture organizational-level drivers and supplier-level effects, with structural equation modeling (SEM) used to test hypothesized mediations (e.g., digital capability mediating between organizational processes and environmental performance).

4.Data Sources and Sampling: Suggested data sources include hospital procurement records, energy and waste logs, supplier disclosures, and national environmental accounts. Sampling strategies recommend purposive sampling of hospitals across income settings to capture institutional quality heterogeneity (Abbas et al., 2024; Owusu & Asumadu-Sarkodie, 2016).

5.Ethical and Practical Considerations: The methodology emphasizes ethical procurement of data, protection of patient-related information, and participatory methods for social measures to ensure legitimacy and contextual sensitivity (Khosravi & Izbirak, 2019).

The methodology section deliberately avoids numerical formulas or tables to comply with the constraint of text-only exposition and instead focuses on clear, replicable text-based procedures.

RESULTS

The following results derive from an integrative synthesis of the referenced empirical and conceptual literature; they present consolidated evidence and emergent patterns rather than a single empirical dataset.

1.Environmental Footprint is Largely Driven by Procurement and Energy Use. Multiple cross-national assessments find that a significant share of healthcare emissions originates upstream in procurement (medical devices, pharmaceuticals) and in facility energy consumption (Lenzen et al., 2020; Nansai et al., 2020). The practical implication is that procurement strategies—favoring low-carbon suppliers, reusable devices where safe, and green energy procurement—offer substantial mitigation potential (Song et al., 2019; Azevedo et al., 2011).

2.Digital Technologies Reduce Waste and Improve Traceability When Paired with Organizational Change. Blockchain and IoT-enabled monitoring reduce loss, enable accurate cold-chain monitoring, and increase accountability across supplier networks (Chowdhury, 2025; Saberi et al., 2019). However, evidence indicates that technology adoption without complementary process redesign and stakeholder alignment yields limited sustainability gains (Martínez-Peláez et al., 2023; Abbas et al., 2024).

3.Social Sustainability Is Multi-Dimensional and Requires Participatory Measurement. Studies highlight the need to include workforce welfare, local community impacts, access equity, and ethical procurement within performance metrics (Maloni & Brown, 2006; Hussain et al., 2018; Khosravi & Izbirak, 2019). MCDM and participatory weighting methods have been effectively used in other sectors and show promise for healthcare adaptation (Badri Ahmadi et al., 2017; Banasik et al., 2016).

4.Resilience and Sustainability Can Align but Also Conflict—Trade-offs Require Governance Choices. Resilience measures like stockpiling can increase resource availability but may raise waste and emissions if inventory expires; conversely, lean practices reduce waste but may heighten vulnerability to disruptions (Sharma et al., 2020; Nwankwo et al., 2024). Sound governance and scenario planning can identify context-specific trade-offs.

5.Institutional Quality and Policy Context Shape Outcomes. Cross-country differences in institutional quality (regulatory effectiveness, enforcement) moderate the translation of SSCM practices into outcomes (Abbas et al., 2024; Raza et al., 2023). In contexts with weaker institutions, digital transparency tools and international contracting standards can partially mitigate governance gaps.

6.Supply Chain Actors' Orientations Matter. Firms and hospitals with proactive sustainability orientation tend to achieve better SSCM outcomes, mediated by investments in capabilities and stakeholder engagement (Mariadoss et al., 2016; Ageron et al., 2012). Leadership commitment, as seen in integrated health systems, contributes to operational alignment for sustainability (McHugh et al., 2016).

DISCUSSION

This section provides an in-depth interpretation of synthesized findings, explores theoretical implications, addresses limitations, and outlines a progressive research and practice agenda.

1.Theoretical Interpretation: Toward a Multi-Level Integration of SSCM in Healthcare. The integrated model proposed situates the hospital supply chain as nested within broader institutional and environmental systems. At the micro level, procurement policies and internal logistics determine direct operational impacts; at the meso level, supplier networks and regional infrastructures shape upstream environmental burdens; at the macro level, institutional quality and regulations set boundary conditions (Carter & Rogers, 2008; Seuring & Müller, 2008). Digital transformation functions as both a mediator and moderator: it mediates by improving information flows and moderates by amplifying organizational capabilities (Martínez-Peláez et al., 2023; Muthuswamy & Ali, 2023). Social sustainability must be embedded as a normative and measurable dimension alongside environmental metrics—this reflects an expansion of triple-bottom-line logic into practice-sensitive operational measures (Maloni & Brown, 2006; Khosravi & Izbirak, 2019).

2.Practical Implications and Managerial Pathways. For hospital leaders and supply chain managers, the integrated model suggests a phased approach:

○Phase 1—Assessment and Transparency: Establish baseline environmental footprints using life cycle and input-output methods and map social risk profiles across supplier networks (Lenzen et al., 2020; Badri Ahmadi et al., 2017).

○Phase 2—Capability Building: Invest in digital maturity—inventory management systems, cold-chain monitoring, and supplier portals—while developing organizational processes for data use in decision-making (Martínez-Peláez et al., 2023).

○Phase 3—Design and Governance: Implement procurement policies that incorporate environmental and social criteria, use MCDM tools for supplier selection, and create cross-functional sustainability committees involving clinical staff, procurement, and community representatives (Maloni & Brown, 2006; Banasik et al., 2016).

○Phase 4—Resilience and Adaptation: Develop scenario-based resilience plans that balance redundancy with sustainability; consider aggregating demand across networks to reduce waste and improve supplier continuity (Sharma et al., 2020; Nwankwo et al., 2024).

3.These pathways require leadership commitment and cross-functional collaboration—findings that echo the experience of integrated health systems that have successfully aligned quality and sustainability agendas (McHugh et al., 2016).

4.Measurement and Evaluation: Combining Rigor and Practicality. The balanced assessment model proposed blends robust environmental accounting with stakeholder-weighted social indices and digital capability metrics. Environmental metrics must be comparable across institutions, which suggests standardization efforts akin to those used in national footprint studies (Nansai et al., 2020). Social metrics require participatory weighting to reflect local priorities—this process builds legitimacy and facilitates behavioural change (Khosravi & Izbirak, 2019; Badri Ahmadi et al., 2017).

5.Trade-offs, Conflicts, and Ethical Considerations. Implementing SSCM raises unavoidable trade-offs: e.g., single-use devices reduce infection risk but generate waste; stockpiles improve readiness but increase expiration-related waste. Ethical frameworks should guide these choices, balancing clinical safety with long-term planetary health. Institutional transparency and stakeholder engagement are essential to negotiating these trade-offs. Moreover, equity concerns demand attention: sustainability initiatives should not disproportionately burden lower-income regions or disadvantaged patient groups.

6.Limitations of the Current Synthesis. This study synthesizes heterogeneous literature and is not a systematic meta-analysis. The findings draw heavily on conceptual work and national footprint studies; empirical causal claims require testing through multi-site longitudinal research. Measurement standardization remains a challenge, especially for social sustainability indicators where data availability varies widely.

7.Future Research Directions. Priority research areas include:

○Empirical Tests of the Integrated Model: Longitudinal multi-site studies to test hypothesized causal pathways, especially the mediating role of digital capability.

○Social Metrics Development: Co-created indicators for workforce welfare, supplier labor practices, and access equity, validated across contexts.

○Policy Experiments: Natural experiments of procurement policy changes to evaluate environmental and social outcomes.

○Technological Evaluations: Field trials of blockchain and IoT in healthcare supply chains with full cost-benefit and environmental impact analyses (Chowdhury, 2025; Saberi et al., 2019).

Limitations and Critical Reflection

A candid appraisal recognizes several limitations. First, while the integrative framework is theoretically grounded, it requires rigorous empirical validation. Second, variation across healthcare systems—public vs. private, high-income vs. low-income—means that contextualization is essential; a universal blueprint is neither feasible nor desirable. Third, data constraints, particularly for social indicators and supplier-level upstream emissions, present methodological hurdles that researchers must overcome through triangulation and partnerships with suppliers and governments (Lenzen et al., 2020; Badri Ahmadi et al., 2017). Fourth, technological fixes like blockchain and AI should not be viewed as panaceas; they are effective only when aligned with governance, incentives, and human capacities (Martínez-Peláez et al., 2023; Muthuswamy & Ali, 2023).

CONCLUSION

Healthcare supply chains sit at the intersection of clinical imperatives and planetary boundaries. The model and synthesis presented in this article argue that achieving sustainable, resilient, and socially responsible healthcare supply chains is possible through an integrated approach that combines environmental accounting, social metrics, digital capability, and adaptive governance. Practically, hospitals should begin with transparent assessments, invest in capability building, revise procurement and logistics for sustainability, and build resilience into planning without sacrificing efficiency or equity. Research must follow with rigorous, context-sensitive empirical work that validates pathways and refines measurement. The stakes are high: aligning healthcare delivery with sustainability goals can reduce the sector's environmental footprint, improve social outcomes across supply chains, and ultimately support better patient care in a world of constrained resources and rising health needs.

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