# Three-Layer Framework for Sustainable Digital Supply Chains: A Systematic Literature Review and Case Study Validation

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**Abstract**

This study proposes a novel three-layer framework for developing Sustainable Digital Supply Chains (SDSCs) by integrating Industry 4.0 technologies with circular economy (CE) principles. Through a mixed-methods approach combining a systematic literature review (SLR) and empirical case studies, the research designs a structure to enhance environmental, social, and operational sustainability. The framework's three interconnected layers—Technology, Governance & Compliance, and Circular Integration—enable real-time tracking, stakeholder collaboration, and closed-loop resource flows. Empirical evidence demonstrates significant improvements in material recovery, waste reduction, and emissions savings. While expert validation confirms the framework's adaptability, the study also identifies key implementation barriers such as high costs and regulatory challenges. This work provides an actionable pathway for operationalizing sustainable supply chains and contributes to the Industry 5.0 vision of resilient, human-centric industrial ecosystems.

**Keywords:** sustainability, digitalization, supply chain, circular economy, systemic barriers, case studies.