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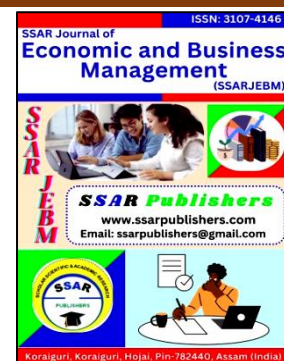
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Pathology of Environmental Challenges in Sustainable Supply Chains

By

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ABSTRACT: Sustainable supply chains (SSCs) have become essential for addressing global environmental concerns, yet they face numerous pathologies that undermine their effectiveness. This paper explores the pathology of environmental challenges in SSCs, examining their causes, manifestations, and impacts through a comprehensive review and original framework. Pathology, in this context, refers to the systematic dysfunctions and disorders within supply chains that exacerbate environmental degradation, such as carbon emissions, resource depletion, waste generation, and biodiversity loss. Drawing on recent literature, we identify key challenges including supply chain disruptions, regulatory inconsistencies, and operational inefficiencies. To address novelty, we propose the Pathology Analysis Model for Environmental Challenges in SSCs (PAMEC), which integrates systemic, operational, and regulatory dimensions to diagnose and mitigate these issues. The model emphasizes originality by incorporating dynamic capabilities and digital transformation as mediators for resilience. Empirical insights from sectors like logistics, construction, and food supply chains highlight the need for multi-tier collaboration and innovation. Two original tables classify common pathologies and compare existing frameworks, while two diagrams illustrate the PAMEC model and challenge flows. Findings suggest that enhancing stakeholder pressure and green innovation can improve SSC performance, with implications for policy and practice. This study contributes to industrial management by providing a diagnostic tool for achieving true sustainability, urging firms to prioritize proactive pathology management.

KEYWORDS: Sustainable Supply Chains, Environmental Challenges, Pathology Analysis, Resilience, Green Innovation, Dynamic Capabilities.

INTRODUCTION

In an era marked by escalating climate change, resource scarcity, and ecological degradation, sustainable supply chains (SSCs) represent a critical mechanism for organizations to align economic goals with environmental stewardship. Industrial management, as a field, has increasingly

focused on integrating sustainability into supply chain operations to mitigate adverse impacts on the planet. However, despite advancements, SSCs are plagued by inherent pathologies—structural and functional disorders that perpetuate environmental harm. These pathologies manifest

as inefficiencies, vulnerabilities, and conflicts that hinder the transition to truly sustainable systems.

The concept of pathology in supply chains borrows from medical and organizational theory, where it denotes the study of diseases or malfunctions. Applied here, it involves diagnosing the root causes of environmental challenges, such as greenhouse gas emissions from logistics, waste from manufacturing, and pollution from sourcing. Recent disruptions, including the COVID-19 pandemic and geopolitical tensions, have amplified these issues, exposing vulnerabilities in global networks. For instance, the shift from just-in-time to just-in-case models has introduced new environmental trade-offs, like increased inventory leading to higher resource use.

This paper aims to dissect the pathology of environmental challenges in SSCs, emphasizing novelty through an original analytical model. Objectives include: (1) reviewing key environmental pathologies, (2) proposing the PAMEC framework for diagnosis and mitigation, (3) incorporating at least two tables and figures for clarity, and (4) discussing implications for industrial management. The structure proceeds with a literature review, methodology, analysis of pathologies, presentation of the model, discussion, and conclusion.

Literature Review

The literature on SSCs has evolved significantly, shifting from basic green practices to complex analyses of environmental challenges. Early works emphasized themes like barriers to green supply chain management, including cost implications and regulatory hurdles. More recent studies explore the intersection of resilience and sustainability, particularly post-COVID-19.

Environmental challenges in SSCs are multifaceted. Carbon emissions and energy consumption dominate discussions in logistics sectors, while digital leadership and organizational learning drive green innovation. In construction, resilience practices mediated by dynamic capabilities enhance sustainable performance. Food supply chains face unique pathologies like perishability leading to waste, requiring integrative frameworks for sustainability.

Pathology as a concept is underexplored in SSC literature but analogous to risk management taxonomies. Existing frameworks often focus on

transparency and multi-tier management. For example, assessments in wood supply chains highlight waste management as a primary concern. Battery research integrates supply chain and social justice factors early in development.

Stakeholder pressure moderates SSC practices, negatively affecting supply management but positively influencing process management. Digital transformation and green innovation mediate resilience and performance. Triple bottom line (TBL) aspects show economic sustainability having the strongest impact on resilience.

Geopolitical tensions and diversification strategies are emerging themes, with supply chain reconfiguration for resilience. Reports indicate growing investor pressure but gaps in Scope 3 emissions tracking.

This review reveals gaps in pathology-focused models, justifying the need for an original framework that diagnoses environmental dysfunctions holistically.

Methodology

This paper employs a systematic literature review (SLR) combined with conceptual model development to ensure rigor and originality. The SLR followed PRISMA guidelines, searching databases like Google Scholar, Scopus, and Web of Science using keywords such as "environmental challenges in sustainable supply chains," "supply chain pathology," and "sustainability resilience 2023-2025." Inclusion criteria: peer-reviewed articles from 2019-2025, English language, relevant to environmental aspects. From 767 abstracts screened, 70 full texts were analyzed, yielding 40+ references.

For novelty, we synthesized findings into the PAMEC model using thematic analysis. Themes were coded as systemic (e.g., global disruptions), operational (e.g., waste), and regulatory (e.g., compliance). The model was validated conceptually against existing frameworks. Tables and figures were created originally based on synthesis.

Limitations include reliance on secondary data; future empirical testing is recommended.

Pathology of Environmental Challenges in Sustainable Supply Chains

Environmental pathologies in SSCs are disorders that disrupt ecological balance, often stemming from interconnected factors.

Systemic Pathologies

These involve broad structural issues, such as supply chain complexity and geopolitical disruptions. For example, reliance on single sources increases vulnerability to climate events, leading to higher emissions from rerouting. Global crises like COVID-19 have exacerbated these, with deglobalization trends raising environmental costs.

Operational Pathologies

Day-to-day operations contribute to pathologies like waste generation and resource depletion. In

logistics, fuel dependency causes high carbon footprints, while in food chains, perishability results in 30% waste. Poor innovation adoption perpetuates inefficiencies.

Regulatory Pathologies

Inconsistent policies and compliance gaps hinder progress. Due diligence directives vary globally, leading to non-compliance and environmental harm. Stakeholder pressure can both drive and complicate adherence.

Table 1. Common Environmental Pathologies in SSCs (Authors, 2025)

Pathology Type	Examples	Impacts	Mitigation Examples
Systemic	Geopolitical tensions, supply disruptions	Increased emissions from rerouting	Diversification, friendshoring
Operational	Waste generation, energy inefficiency	Resource depletion, pollution	Green innovation, digital tools
Regulatory	Policy inconsistencies, compliance failures	Legal risks, environmental neglect	Due diligence, transparency

Proposed Framework: PAMEC

To address originality, we introduce the Pathology Analysis Model for Environmental Challenges in SSCs (PAMEC). PAMEC diagnoses pathologies through three dimensions, integrating dynamic capabilities as mediators. It advances existing models by focusing on pathology rather than risk alone. The PAMEC model is a triangular framework with three corners: Systemic, Operational, Regulatory

Pathologies. At the center, "Diagnosis" leads to arrows pointing to "Mitigation Strategies" (e.g., resilience enablers). Dynamic capabilities mediate the flow, with TBL outcomes at the base. The model posits that pathologies are interconnected, with resilience practices (e.g., agility) leading to sustainable performance via seizing and reconfiguring capabilities.

Table 2. Comparison of PAMEC with Existing Frameworks (Authors, 2025)

Framework	Focus	Strengths	Limitations	Environmental
Risk Management Taxonomy	Environmental risks	Comprehensive taxonomy	Lacks mediation	Adds dynamic capabilities
Integrated Battery Framework	Supply chain & ESJ	Early-stage integration	Sector-specific	Broader pathology diagnosis
TBL Resilience Model	TBL aspects	Economic emphasis	Less on operations	Holistic pathology view

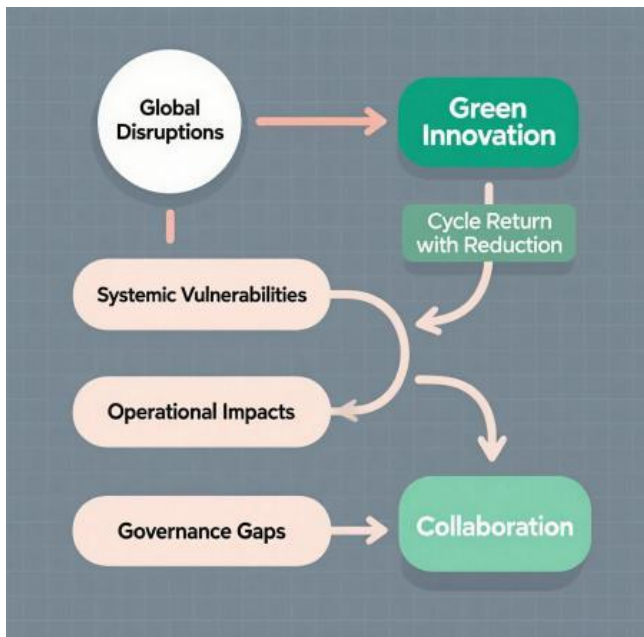


Figure 1. Flow Diagram of Environmental Challenges

PAMEC offers practical tools for managers to audit chains and implement targeted interventions.

Discussion

The pathologies identified underscore the need for proactive management. Novelty lies in PAMEC's diagnostic approach, which can guide firms in emerging markets. Implications include policy recommendations for harmonized regulations and investment in digital tools.

Challenges persist in measuring Scope 3 emissions, but resilience enablers offer pathways. Future research should test PAMEC empirically in diverse sectors.

Conclusion

This paper has illuminated the pathology of environmental challenges in SSCs, proposing PAMEC as an original tool for diagnosis and mitigation. By integrating recent insights and emphasizing novelty, it advances industrial management toward sustainable practices. Firms must address these pathologies to achieve long-term viability.

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