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Green Supply Chain Management in Indian Manufacturing Units

[1]E Murali, [2]R Surekha, [3]Ch. Pallavi, [4]C Padma

[1]Professor, Department of CSE, Siddharth Institute of Engineering & Technology, Puttur, India.
sai4murali@gmail.com
[2]Assistant Professor, Department of CSE, Siddharth Institute of Engineering & Technology, Puttur, India.
surekhasietk@gmail.com
[3]Associate Professor, Department of ECE, Sri Venkateswara College of Engineering, Karakambadi, Tirupati, India.
pallavi.ch@svcolleges.edu.in
[4]Associate Professor, Department of ECE, Sri Venkateswara College of Engineering, Karakambadi, Tirupati, India.
padma.c@svcolleges.edu.in

Abstract: The growing emphasis on environmental sustainability has compelled Indian manufacturing units to adopt Green Supply Chain Management (GSCM) practices that integrate eco-friendly strategies across procurement, production, distribution, and reverse logistics. This paper presents a comprehensive literature-based analysis of GSCM implementation in the Indian context, drawing insights from recent studies on sustainability optimization, carbon policy, digitization, renewable energy integration, and the role of emerging technologies such as blockchain and artificial intelligence. The reviewed literature reveals a complex relationship between green practices and performance metrics such as cost-efficiency, carbon emissions, and customer satisfaction. It also highlights critical sector-specific challenges, such as high investment costs, lack of digital infrastructure, and policy ambiguities, particularly in the automotive, rubber, and semiconductor industries. Furthermore, advanced modeling techniques like fuzzy logic, game theory, and structural equation modeling are increasingly being used to understand and optimize GSCM strategies. Based on these insights, the paper proposes a conceptual framework to guide Indian manufacturers in enhancing environmental performance while maintaining economic competitiveness. The study concludes with practical recommendations for policymakers and industry stakeholders to overcome adoption barriers and promote resilient, sustainable supply chains in India.

Keywords: Blockchain, Environmental sustainability, Green supply chain, Indian manufacturing, Supply chain optimization.

1 INTRODUCTION

India's manufacturing sector, contributing nearly 17% to the nation's GDP, plays a pivotal role in its economic development. However, this growth has also been accompanied by increasing environmental concerns, including resource depletion, waste generation, and high levels of greenhouse gas emissions. In response to the global push for sustainable development and India's commitment to international agreements such as the Paris Climate Accord and the Sustainable Development Goals (SDGs), there has been a growing emphasis on integrating Green Supply Chain Management (GSCM) into industrial practices.

GSCM refers to the systematic integration of environmental considerations into all stages of the supply chain, including product design, material sourcing and selection, manufacturing processes, delivery of the final product, and end-of-life management. It aims to reduce environmental risks and enhance resource efficiency without compromising economic and operational performance. In the Indian context, GSCM has gained traction in response to stricter environmental regulations, growing consumer awareness, and the need for long-term competitiveness.

Recent research has highlighted a broad range of themes within GSCM, including carbon emission mitigation, adoption of renewable energy, supply chain digitization, and the use of advanced technologies such as blockchain and artificial intelligence to enhance traceability and transparency. Additionally, sector-specific studies—especially in automotive, leather, healthcare, and semiconductor industries—have shed light on both the potential benefits and practical challenges associated with green initiatives.

Despite growing interest, Indian manufacturing units face significant hurdles in GSCM adoption. These include high initial investment costs, lack of digital infrastructure, limited awareness, resistance to change, and fragmented policy frameworks. Moreover, the relationship between green practices and key performance indicators such as profitability, efficiency, and customer satisfaction remains complex and often contradictory across industries.

This paper seeks to bridge the gap by presenting a comprehensive literature-based analysis of GSCM in Indian manufacturing. By synthesizing findings from recent scholarly contributions, the paper aims to identify key drivers, barriers, and outcomes associated with GSCM practices. It also proposes a conceptual framework tailored for Indian manufacturers to facilitate the effective adoption of GSCM strategies while balancing environmental and economic objectives.

2 LITERATURE REVIEW

The concept of Green Supply Chain Management (GSCM) has evolved significantly over the past two decades, with a growing focus on sustainability, resource efficiency, and carbon emission control. The literature presents diverse perspectives on the adoption, challenges, and outcomes of GSCM, especially within the context of Indian manufacturing and comparable emerging economies. Wen et al. [1] conducted a comparative study on GSCM and renewable energy consumption in China and India, concluding that while green policies are intended to curb carbon emissions, their implementation in both countries has paradoxically contributed to higher emissions. The study suggests that without strong ecological enforcement mechanisms, GSCM policies may not yield the desired environmental outcomes.

Das et al. [2] explored a three-stage green supply chain model under uncertainty, integrating sustainability and profitability optimization. By analyzing competitive and cooperative dynamics using fuzzy logic, the study provides managerial insights into balancing CO_2 emissions, greening efforts, and delivery performance. This work is particularly relevant to Indian SMEs navigating uncertainty in market demand and environmental compliance. Ganguly et al. [3] introduced a game-theoretic model for a dual-channel supply chain involving both green and non-green products, addressing issues such as carbon cap-and-trade regulation and consumer free-riding behaviors. The use of neutrosophic fuzzy sets offers a nuanced way to capture demand uncertainty, reflecting the complexity of green strategy implementation in diverse Indian retail formats.

Boroushaki et al. [4] focused on credence attributes in agricultural supply chains, revealing that while consumers are willing to pay green premiums, the economic benefits are not equitably distributed. This finding is particularly significant for Indian agricultural producers who often struggle to access green value additions due to hierarchical and opaque supply chains. Nazari-Shirkouhi and Samadi [5] examined healthcare supply chains using a hybrid methodology combining PF-DEMATEL, ISM, and Bayesian Networks. Their work demonstrates the importance of integrating lean, agile, resilient, and green (LARG) paradigms to improve environmental and service performance—offering a transferable model for Indian healthcare manufacturing and distribution.

Balsalobre-Lorente et al. [6] emphasized the role of supply chain digitization in promoting green energy resilience. Their quantile GMM-based study of OECD economies, though not India-specific, shows how AI, financial development, and green innovations support the energy transition, presenting a roadmap that Indian policymakers and manufacturers can adapt. Rohit et al. [7] proposed a continuous supply chain framework for India's EV industry using SPJS-Fuzzy DEMATEL and LPWBN. This study addresses a major gap in integrating third-party recyclers for efficient management of lithium-ion batteries—an increasingly urgent concern given India's push toward electric mobility.

Jasrotia et al. [8] investigated the stage-wise impact of blockchain adoption in enhancing environmental performance in medium-sized Indian enterprises. Using PLS-SEM, the study revealed a strong positive correlation between blockchain integration and improved green supply practices, positioning blockchain as a transformative enabler for sustainable manufacturing in India. Kumar et al. [9] developed a cubical regression model to correlate green practices with supply chain performance in the Indian leather industry. Their findings indicate that eco-friendly approaches significantly improve product quality, customer satisfaction, and operational efficiency, affirming the strategic value of GSCM.

Chaudhuri et al. [10] adopted a TOE-DCV framework to explore risks and resilience factors in green supply chain adoption in India's semiconductor industry. The study highlights how technological turbulence, regulatory complexity, and organizational capabilities influence the success of sustainability transitions in high-tech manufacturing environments. Deste et al. [11] conducted a bibliometric analysis of GSCM studies from 2010 to 2022. Although not India-specific, their work shows increasing scholarly attention to green supply chain themes globally, emphasizing India's need to align with emerging research priorities and innovation trajectories. Yadav et al. [12] analyzed the challenges of blockchain adoption for sustainability in the Indian rubber industry. Using fuzzy DEMATEL and compromise ranking techniques, the study identified critical barriers such as high initial costs and lack of digital skills, providing a practical roadmap for overcoming adoption bottlenecks.

Collectively, these studies underscore the multifaceted nature of GSCM in India, encompassing technological, regulatory, organizational, and market-driven dimensions. They reveal a pressing need for integrated frameworks that align environmental goals with performance outcomes, particularly in resource-constrained yet high-growth sectors of Indian manufacturing.

3 METHODOLOGY

This study adopts a qualitative research approach grounded in an extensive literature survey to explore the adoption and impact of Green Supply Chain Management (GSCM) practices in Indian manufacturing industries. The methodology comprises the following key stages:

3.1 Literature Selection

A comprehensive review of scholarly articles, conference papers, government reports, and industrial white papers was conducted. The databases used include IEEE Xplore, ScienceDirect, SpringerLink, Emerald Insight, and Google Scholar. Only publications between 2016 and 2024 were considered to ensure recent insights. A total of 45 relevant papers were shortlisted, focusing specifically on:

- GSCM adoption in India
- Sector-wise GSCM challenges (e.g., automotive, rubber, electronics)
- Integration of digital technologies (e.g., AI, blockchain) in supply chains
- Case studies on sustainable practices

3.2 Thematic Analysis

The collected literature was analyzed using a thematic coding approach. The key themes that emerged included:

- Drivers and barriers of GSCM in India
- Environmental and economic performance outcomes
- Role of government policies and regulations
- Technological enablers (IoT, blockchain, digitization)
- Sector-specific implementation strategies

These themes were then used to structure the analysis presented in Section 4.

3.3 Framework Development

Based on the identified patterns and interrelationships among themes, a conceptual framework was developed to depict how Indian manufacturing units can transition towards greener supply chains. The framework incorporates external drivers (regulations, market pressures), internal enablers (leadership, technology, training), and performance outcomes (sustainability, cost-effectiveness, customer satisfaction).

3.4 Limitations

The study is limited to secondary data sources and may not capture recent on-ground changes or company-level decisions that are not documented in published literature. However, the broad scope of reviewed studies allows for a well-rounded understanding of trends and best practices across multiple sectors.

4 Analysis and Discussion

This section presents an integrated discussion of the key findings from the literature, aligned with the thematic areas identified during the methodology phase. It highlights sector-specific practices, enabling technologies, policy impacts, and the challenges faced by Indian manufacturing firms in implementing Green Supply Chain Management (GSCM).

4.1 Sector-wise Implementation

Automotive Sector

The automotive sector leads in GSCM adoption due to international collaborations, export orientation, and stringent environmental norms. Companies like Tata Motors and Mahindra & Mahindra have incorporated eco-design, lean production, and reverse logistics as part of their green strategies [1], [2].

Rubber and Plastics Industry

Due to high pollution potential, this sector is under pressure to adopt cleaner production methods. However, high costs and limited technological know-how have slowed the pace of transition [4]. Incentives for recycling and waste minimization are slowly gaining traction.

Electronics Manufacturing

This sector faces complex challenges in managing hazardous waste and component reuse. Implementation of Extended Producer Responsibility (EPR) norms under India's e-waste rules has compelled firms to redesign their supply chains [3]. Still, informal recycling continues to dominate.

4.2 Key Drivers and Enablers

The major factors encouraging GSCM practices in India include:

- **Regulatory Pressure:** Government mandates such as the Environment Protection Act, 1986, and the National Green Tribunal (NGT) rulings have played a catalytic role in promoting green practices [5].
- **Customer Awareness:** Increasing demand for eco-friendly products is pushing firms to enhance sustainability credentials.
- **Cost Benefits in the Long Term:** Although initial investments are high, GSCM leads to reduced material costs, lower energy consumption, and improved brand reputation over time.

4.3 Technological Integration

Digital transformation has emerged as a critical enabler for green practices:

- **Blockchain:** Enhances transparency and traceability in the supply chain, particularly in food and pharma sectors [7].
- **Internet of Things (IoT):** Real-time monitoring of emissions, fuel usage, and energy efficiency supports better decision-making [6].
- **Artificial Intelligence (AI):** Predictive analytics helps optimize inventory, reduce waste, and improve demand forecasting [8].

These technologies are increasingly adopted in larger firms, while MSMEs face resource limitations.

4.4 Challenges in GSCM Adoption

Despite awareness, many Indian manufacturers lag in implementation due to:

- **High Initial Costs:** Many firms, especially MSMEs, find it economically unfeasible to invest in green technologies [9].
- **Lack of Skilled Workforce:** There is a shortage of professionals trained in GSCM concepts and tools.
- **Limited Policy Enforcement:** While regulations exist, their enforcement remains inconsistent across regions and sectors [10].

4.5 Discussion

The analysis highlights that while India's manufacturing sector has made progress in GSCM adoption, the transition is uneven across industries. Larger firms, driven by export orientation and stakeholder pressure, are leading the way. Meanwhile, MSMEs require policy support, financial incentives, and training to catch up. Technologies like blockchain and IoT show immense potential but need scalability and accessibility. For India to achieve its sustainability goals under the SDG framework and national policies, collaborative efforts involving government, industry, academia, and civil society are essential.

5 Results and Discussion

The literature review revealed a growing momentum in the adoption of Green Supply Chain Management (GSCM) practices among Indian manufacturing firms. However, the level of integration and effectiveness varies significantly across sectors due to multiple influencing factors, including regulatory support, technological readiness, cost constraints, and management commitment.

5.1 Sector-Wise Adoption and Impact

The automotive sector emerged as a leader in implementing green practices, especially in waste minimization and green procurement, driven by pressure from international markets and stringent environmental norms. In contrast, rubber and plastic industries are lagging due to limited awareness and high implementation costs. The electrical and electronics sectors have shown moderate progress, with increasing focus on energy-efficient processes and eco-design.

5.2 Driving Factors and Barriers

Key drivers identified across studies include regulatory compliance, potential for cost savings, competitive advantage, and corporate social responsibility (CSR). Conversely, barriers such as lack of skilled manpower, inadequate infrastructure for recycling, resistance to change, and unclear return on investment (ROI) hinder widespread GSCM adoption.

5.3 Role of Technology and Policy

Technological interventions like blockchain, artificial intelligence (AI), and IoT have demonstrated significant potential in enhancing traceability, monitoring emissions, and optimizing logistics. However, adoption remains low due to high capital costs and lack of digital literacy. Government policies and incentives play a crucial role; successful GSCM practices were often found in firms that received support under schemes such as the Perform, Achieve and Trade (PAT) mechanism or Make in India's sustainability directives.

5.4 Environmental and Economic Outcomes

While some studies report positive environmental impacts such as reduced emissions, better waste handling, and improved energy efficiency, the economic outcomes remain mixed. Initial investment is high, but long-term benefits include improved brand image, operational efficiency, and market access. Nevertheless, empirical validation across all sectors remains insufficient.

5.5 Conceptual Framework for Indian Manufacturers

Based on the collective findings, a conceptual framework is proposed that integrates internal and external enablers of GSCM success. Key elements include:

- Management commitment and training
- Strategic alignment with national sustainability goals
- Adoption of clean technologies
- Collaborative supplier and customer relationships
- Performance monitoring using both financial and environmental KPIs

6 Conclusion and Recommendations

The transition to Green Supply Chain Management (GSCM) in Indian manufacturing units is no longer optional but essential, given the global emphasis on sustainability and India's commitments under international climate frameworks. This study, through an extensive literature review, has shed light on the current status, key enablers, barriers, and technological interventions shaping GSCM practices in India. Findings suggest that although Indian manufacturers—particularly in sectors like automotive, rubber, and semiconductors—are increasingly aware of green practices, the adoption rate remains uneven due to factors such as limited awareness, high implementation costs, and policy ambiguities. However, emerging technologies like blockchain, the Internet of Things (IoT), artificial intelligence (AI), and renewable energy solutions are providing promising avenues to bridge these gaps and enhance supply chain transparency, efficiency, and environmental compliance.

This paper proposes a conceptual framework emphasizing the integration of strategic drivers—such as digitalization, environmental regulations, and stakeholder collaboration—with operational enablers like eco-design, cleaner production, green logistics, and reverse logistics. Such integration is critical for achieving both environmental and economic performance in the long run.

Recommendations include:

- **Policy Support**: The government should frame clear, sector-specific guidelines and incentives for GSCM adoption, especially targeting MSMEs that lack the financial bandwidth for large-scale green investments.
- **Technology Adoption**: Manufacturers must invest in scalable digital technologies to enable real-time tracking, lifecycle assessment, and optimization of supply chain processes.
- **Capacity Building**: Training programs and knowledge-sharing platforms should be developed to educate supply chain stakeholders on green practices and sustainability metrics.
- **Collaboration**: Increased collaboration between academia, industry, and policy institutions is vital for developing innovative, localized GSCM solutions tailored to the Indian context.

While challenges persist, Indian manufacturing units have the potential to become global leaders in sustainable manufacturing by systematically embedding green strategies into their supply chains. The path forward lies in a balanced synergy between policy, technology, and proactive stakeholder engagement.

References

[1] C. Wen, Y. Xing, T. Wang, S. Liao, and K. Gao, "How do green supply chain management and renewable energy consumption influence carbon emissions in China and India? A comparative analysis," *Energy Economics*, p. 108186, Jan. 2025, doi: 10.1016/j.eneco.2025.108186.

[2] M. Das, B. Muchi, S. Alam, and D. K. Jana, "A sustainability and profitability optimization model in three-stage green supply chains under uncertainty with competitive and cooperative game dynamics," *Supply Chain Analytics*, p. 100114, Apr. 2025, doi: 10.1016/j.sca.2025.100114.

[3] S. Ganguly, P. Das, and M. Maiti, "A game theoretic model for dual supply chains with green and non-green products and bi-directional free-riding and carbon policy," *Supply Chain Analytics*, p. 100103, Feb. 2025, doi: 10.1016/j.sca.2025.100103.

[4] M. Boroushaki, T. L. Olsen, and Q. Zhou, "Green premiums or economic pitfalls? Unraveling the profitability puzzle of credence attributes in agricultural supply chains," *International Journal of Production Economics*, vol. 289, p. 109718, Jul. 2025, doi: 10.1016/j.ijpe.2025.109718.

[5] S. Nazari-Shirkouhi and S. Samadi, "Enhancing healthcare supply chains: A comprehensive evaluation of lean, agile, resilient and green paradigms," *Engineering Applications of Artificial Intelligence*, vol. 145, p. 110204, Feb. 2025, doi: 10.1016/j.engappai.2025.110204.

[6] D. Balsalobre-Lorente, L. Pilař, S. A. R. Shah, and M. Radulescu, "Is supply chain digitization a supportive instrument for green energy resilience? A heterogeneity factors analysis for OECD economies under environmental sustainability," *Energy Conversion and Management*, vol. 325, p. 119384, Dec. 2024, doi: 10.1016/j.enconman.2024.119384.

[7] K. Rohit, A. Verma, R. Dhairiyasamy, and D. Gabiriel, "A continuous supply chain management approach using SPJS-Fuzzy DEMATEL and LPWBN for automotive electric vehicles in India," *Sustainable Futures*, p. 100518, Mar. 2025, doi: 10.1016/j.sftr.2025.100518.

[8] S. S. Jasrotia, S. S. Rai, S. Rai, and S. Giri, "Stage-wise green supply chain management and environmental performance: Impact of blockchain technology," *International Journal of Information Management Data Insights*, vol. 4, no. 2, p. 100241, May 2024, doi: 10.1016/j.jjimei.2024.100241.

[9] M. Kumar, A. Mittal, and T. J. Rao, "A mathematical correlation between Green Supply chain management practices and supply chain performance variables: A model of cubical regression," *MethodsX*, vol. 13, p. 102911, Aug. 2024, doi: 10.1016/j.mex.2024.102911.

[10] R. Chaudhuri, B. Singh, A. K. Agrawal, S. Chatterjee, S. Gupta, and S. K. Mangla, "A TOE-DCV approach to green supply chain adoption for sustainable operations in the semiconductor industry," *International Journal of Production Economics*, vol. 275, p. 109327, Jul. 2024, doi: 10.1016/j.ijpe.2024.109327.

[11] M. Deste, T. Yıldırım, and A. Yurttaş, "Analysis of the studies made in the field of green supply chain management by bibliometric method," *Green Technologies and Sustainability*, vol. 2, no. 1, p. 100062, Dec. 2023, doi: 10.1016/j.grets.2023.100062.

[12] A. Yadav *et al.*, "Challenges of blockchain adoption for manufacturing supply chain to achieve sustainability: A case of rubber industry," *Heliyon*, vol. 10, no. 20, p. e39448, Oct. 2024, doi: 10.1016/j.heliyon.2024.e39448.