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Sustainable Supply Chain Practices In Uttarakhand'S MSME Sector: Challenges And Opportunities

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Abstract
This study investigates the adoption, challenges, and opportunities of *Sustainable Supply Chain Management (SSCM)* practices among Micro, Small, and Medium Enterprises (MSMEs) in Uttarakhand, India. Based on survey responses from 50 MSME units across plains and hill districts, the research reveals an average SSCM adoption score of 2.78 out of 5, indicating moderate engagement with sustainability principles. Plains-based firms (mean = 3.20) outperform hill-based enterprises (mean = 2.32) due to better infrastructure and access to policy incentives. Key barriers include high implementation cost (mean = 4.4), lack of technical knowledge (4.1), and weak logistics (3.9). However, 68% of firms reported enhanced brand image and 60% improved customer satisfaction after adopting green practices. Regression results confirm that *policy awareness* and *environmental consciousness* significantly influence SSCM adoption. The study concludes that targeted policy incentives, digitalization, and capacity building can accelerate the MSME sector's transition toward sustainable and low-carbon supply chains.

Keywords: Sustainable Supply Chain Management, MSMEs, Uttarakhand, Green Logistics, Policy Awareness

1. Introduction
The Micro, Small and Medium Enterprises (MSME) sector of Uttarakhand has become one of the state's most dynamic growth engines after its formation in 2000, both in terms of number of units and in terms of employment generation. Recent state-level figures show that the sector has expanded from about 14,000 units at the time of state formation to nearly 79,000 units with around ₹17,000 crore investment and about 4 lakh jobs over 25 years, driven largely by policy support, industrial estates in the plains, and linkages with neighbouring markets such as Delhi–NCR. However, the NABARD State Focus Paper 2025–26 reports an even higher figure 88,489 MSME units with cumulative investment of ₹17,057.74 crore because it also captures more recent Udyam/UDYAM Assist registrations and district expansions. The difference between 79,000 and 88,489 mainly reflects data source and reference date, but both sources confirm a steep, policy-enabled rise. What has not grown at the same pace is the *quality* and *sustainability* of the supply chains through which these MSMEs procure, produce, move and recover materials. The state's own MSME Policy, 2023 clearly talks about "promotion of sustainable and inclusive development keeping in view the environmental balance" and even offers extra capital investment subsidy for units in difficult districts, which shows that the government wants MSME growth to be green, spatially balanced and logistics-friendly. In parallel, the Uttarakhand Logistics Policy, 2023 aims to upgrade warehousing and multimodal facilities precisely because current logistics gaps especially in hill districts raise per-unit transport cost and make it harder for small firms to adopt green or energy-efficient distribution models.

In the broader management and operations literature, sustainable supply chain management (SSCM) is defined as the integration of environmental and social goals into inter-organisational core processes such as sourcing, production, distribution and reverse logistics (Zhu & Sarkis, 2004; Sarkis, 2019). Empirical studies on Indian manufacturing and MSMEs show that firms that adopt green purchasing, cleaner production and green logistics improve not only environmental performance but also market image and, in some cases, financial performance (Green, Zelbst, Meacham, & Bhadauria, 2012; Dubey, Gunasekaran, & Papadopoulos, 2017). Yet, these studies are mostly based on plains, industrial-corridor or metro-proximate clusters; they rarely account for *mountainous terrain, seasonal road access, smaller shipment sizes and tourism-linked demand patterns* all of which are typical of Uttarakhand. That is why the Uttarakhand case is analytically interesting: here, MSMEs are growing, the state is promoting renewable energy, EVs and eco-friendly products (including a 2025 tax exemption on electric, solar and hybrid vehicles for mobility and logistics), but the physical geography, thin markets in hill districts and cost sensitivity of micro-units make SSCM adoption non-trivial.

Another reason SSCM is important for Uttarakhand's MSMEs is that the sectoral composition of new units is shifting toward agro-processing, herbal and wellness, tourism supplies, packaging, auto/engineering ancillaries, and environment-oriented products as identified on the Invest Uttarakhand portal. These sectors sell, or want to sell, to environmentally conscious customers tourists, hospitality chains, pharma/nutraceutical buyers, e-commerce platforms who increasingly ask for traceability, responsible sourcing and low-carbon delivery. If MSMEs continue to use *conventional* supply chains diesel-based transport up and down the hills, non-recyclable packaging, no reverse logistics, little local sourcing they may remain locked into low-margin B2B contracts and miss out on the price premium that "Himalayan", "organic", "eco-friendly" or "low-carbon" products can command. At the same time, the 2025 NABARD paper flags very practical constraints: erratic power in rural areas, lack of plug-and-play facilities, absence of cost-effective logistics, and difficulty in accessing technology and tool rooms for small producers. These are classic *capability and infrastructure gaps* that directly affect how far an MSME can go in greening its supply chain. Therefore, the core problem that emerges is a *mismatch*: the policy environment is pro-green, the market is moving toward sustainability, but the micro-level supply chain capabilities of MSMEs especially in hill districts are still basic.

Placing Uttarakhand in the national climate and energy transition context strengthens the argument further. India has committed to net-zero by 2070 and to 45% reduction in emissions intensity of GDP by 2030; states are consequently nudged to support energy-efficient machinery, rooftop solar, EVs, and low-carbon logistics through fiscal measures. SSCM becomes, in this sense, not just an environmental choice but an industrial-competitiveness requirement firms that can show green procurement, energy-efficient production and low-carbon delivery will find it easier to link with bigger buyers and global value chains. For a small, geographically constrained state like Uttarakhand, which already ranks high on SDG performance but wants to spread industrialisation to the hills, making MSME supply chains *sustainable* is a way of ensuring that growth does not worsen fragility, waste management or transport emissions. Against this background, the present study proposes to examine what sustainable supply chain practices

MSMEs in Uttarakhand are currently using, what challenges they face (cost, terrain, knowledge, supplier ecosystem), and what opportunities and state schemes can accelerate adoption.

2. Review of Literature

The concept of Sustainable Supply Chain Management (SSCM) has evolved as a multidisciplinary approach that integrates economic, environmental, and social dimensions into the design and management of supply chains. According to Sarkis (2019), SSCM is not merely about "green" or environmentally conscious operations; it represents a strategic orientation that balances profitability with sustainability through life-cycle management, resource efficiency, and ethical sourcing. Globally, research has shown that firms adopting SSCM practices tend to experience improved long-term competitiveness, risk mitigation, and stakeholder reputation (Seuring & Müller, 2008). In India, several empirical studies have attempted to understand SSCM adoption within MSMEs, particularly highlighting the challenges of cost, awareness, and institutional support (Dubey, Gunasekaran, & Papadopoulos, 2017). However, there remains a dearth of region-specific literature focusing on Uttarakhand, where geographical constraints and logistical inefficiencies uniquely influence sustainable supply chain adoption.

A growing body of Indian literature focuses on the drivers and barriers of green supply chain management (GSCM) among manufacturing firms. Zhu and Sarkis (2004) were among the first to empirically establish that environmental collaboration with suppliers significantly improves manufacturing performance. Subsequent Indian studies, such as those by Luthra, Garg, and Haleem (2015), emphasized that top management commitment, regulatory pressure, and customer awareness are the strongest drivers of GSCM, while financial constraints and lack of technology remain major barriers. Similar findings were reported by Diabat and Govindan (2011), who used interpretive structural modeling to show that government policy and competitive pressure are key enablers of green supply chain practices in developing countries. In the Indian MSME context, Rao and Holt (2005) argued that green initiatives improve eco-efficiency and corporate image, leading to better long-term performance a finding later corroborated by Green et al. (2012), who noted a significant positive relationship between green logistics and firm competitiveness. These studies collectively indicate that sustainability enhances both operational and strategic outcomes when integrated into supply chain decisions.

When applied to Uttarakhand, these national findings interact with the region's distinct economic and geographical features. The NABARD State Focus Paper (2025–26) notes that MSMEs in Uttarakhand especially those in hill districts such as Pithoragarh, Chamoli, and Uttarkashi face high logistics costs, unreliable road connectivity, and seasonal disruptions that make supply chain sustainability a logistical challenge. The report highlights that the average logistics cost in hilly areas is 18–25% higher than in the plains, significantly affecting small enterprises. Similarly, the Invest Uttarakhand (2024) report shows that around 60% of MSMEs are concentrated in Dehradun, Haridwar, and Udham Singh Nagar, where infrastructure and policy support are more accessible. This uneven distribution reflects how geography shapes SSCM potential firms in the plains can adopt green warehousing, energy-efficient transport, and digital tracking systems more easily, while hill-based MSMEs depend on traditional, carbon-intensive logistics (Government of Uttarakhand, 2023).

Another strand of literature examines energy transition and decarbonisation in supply chains, directly linking these concepts to MSME sustainability. Paulraj (2011) demonstrated that internal environmental capabilities such as energy management and eco-design serve as critical mediators between supply management practices and organizational sustainability. A study by Walker, Di Sisto, and McBain (2008) further reinforced that regulatory incentives and customer demands are vital motivators for adopting energy-efficient logistics systems. Within India, a survey by the Confederation of Indian Industry (CII, 2022) found that only 18% of MSMEs have adopted energy-efficient technologies, and among these, less than 5% are located in mountain states, pointing to a serious adoption lag in regions like Uttarakhand. This aligns with a study by Kumar and Jain (2023), which found that MSMEs in North India cite high initial cost (reported by 72% of respondents) and limited technical knowledge (63%) as key barriers to green transition.

The literature also underlines the importance of government policy and institutional support. The Uttarakhand MSME Policy (2023) explicitly incorporates sustainability goals, offering incentives for renewable energy adoption, energy-efficient machinery, and waste management initiatives. Yet, studies such as Sharma and Saini (2021) suggest that policy awareness among MSME entrepreneurs in Uttarakhand is low only about 40% of surveyed units were aware of state sustainability schemes, and fewer than 20% had actually availed of them. This gap between policy intent and implementation highlights the role of education, training, and digital inclusion as enablers of SSCM adoption (Patel & Chauhan, 2020). Further, the World Bank's "Logistics Performance Index Report" (2023) ranked India 38th globally but noted that hill states still face infrastructural bottlenecks, especially in last-mile connectivity directly affecting sustainable transportation and distribution networks.

Empirical studies linking tourism, sustainability, and MSME supply chains are particularly relevant for Uttarakhand, whose economy relies heavily on pilgrimage, hospitality, and eco-tourism. A study by Singh and Thakur (2022) on eco-tourism enterprises in Himachal Pradesh comparable in terrain and structure to Uttarakhand found that businesses integrating local sourcing, biodegradable packaging, and waste recycling reduced logistics costs by 12–15% while enhancing customer satisfaction. Applying such insights to Uttarakhand, where tourism accounts for nearly 20% of MSME-linked demand, suggests a clear opportunity for integrating SSCM in local supply networks (NABARD, 2025). However, sustainability-driven branding is still underdeveloped among Uttarakhand's small producers, as observed by Gupta and Pant (2024), who noted that fewer than 10% of micro units use eco-labels or green certifications in their marketing.

In summary, the literature clearly demonstrates that sustainable supply chain practices improve competitiveness and resilience, yet context-specific barriers infrastructure, terrain, financial constraints, and knowledge gaps limit adoption in Uttarakhand's MSME sector. While global research (Sarkis, 2019; Seuring & Müller, 2008) provides theoretical frameworks, and Indian studies (Luthra et al., 2015; Dubey et al., 2017) confirm adoption benefits, state-level empirical evidence remains sparse. There is thus a pressing need for research that empirically assesses SSCM adoption in Uttarakhand's MSMEs, capturing differences between hill and plain regions,

and identifies actionable policy and managerial strategies for inclusive, low-carbon industrial growth.

3. Objectives of the Study

1. To identify the level of awareness and current adoption of sustainable supply chain practices among MSMEs in Uttarakhand.
2. To analyse the key challenges (cost, infrastructure, technology, skills, supplier readiness, transport constraints) faced by hill- and plain-based MSMEs separately.
3. To examine the role of state policies and incentives (MSME Policy 2023, logistics incentives, energy-efficiency schemes) in enabling SSCM adoption.
4. To explore business and market opportunities arising from green branding, eco-packaging, renewable-energy use and circular practices.
5. To propose a framework for phased adoption of SSCM suited to Uttarakhand's geography.

4. Hypotheses

- **H1:** There is a significant difference in the level of SSCM adoption between MSMEs located in plains (Dehradun/ Haridwar/ US Nagar) and those in hill districts.
- **H2:** Perceived implementation cost has a negative and significant influence on MSME willingness to adopt SSCM.
- **H3:** Access to state-level incentives/training positively moderates the relationship between environmental awareness and SSCM adoption.
- **H4:** MSMEs adopting green logistics and eco-packaging report better market access (B2B and e-commerce) than non-adopters.
- **H5:** Digitalisation of supply chain processes (e-invoicing, e-way bill, track & trace) mediates the effect of terrain-related logistics constraints on supply chain performance.

5. Research Methodology

The present research on *"Sustainable Supply Chain Practices in Uttarakhand's MSME Sector: Challenges and Opportunities"* adopts a descriptive–analytical research design using both quantitative and qualitative approaches to examine the existing level of awareness, adoption, and implementation of sustainable supply chain management (SSCM) practices among MSMEs. The purpose of this methodological framework is to systematically identify not only *what* sustainable practices MSMEs adopt, but also *why* adoption levels differ across regions (plains versus hills) and industries (manufacturing, agro-based, and service sectors). This section outlines the research design, sampling, data collection techniques, measurement instruments, and analytical tools in detail, ensuring reliability, validity, and replicability of findings.

5.1 Research Design

The study is descriptive and empirical in nature. It aims to describe existing practices and test hypotheses regarding factors influencing SSCM adoption among MSMEs in Uttarakhand. The descriptive design helps capture current status and perceptions, while the analytical component involves statistical testing to examine relationships among variables such as cost perception, environmental awareness, policy incentives, and firm performance. Since the problem is context-

based and region-specific, a cross-sectional survey method is applied collecting data from MSMEs at a single point in time across multiple districts of Uttarakhand.

5.2 Population and Sample Selection

The target population of the study comprises *registered MSMEs operating in Uttarakhand* under the Udyam registration portal and the state's Directorate of Industries database. According to the NABARD State Focus Paper (2025–26), there are about 88,489 MSME units functioning across the state, with major concentrations in Dehradun (22%), Haridwar (28%), and Udham Singh Nagar (25%), and smaller clusters in Nainital, Pauri Garhwal, Tehri, Almora, and Chamoli (NABARD, 2025). To ensure geographical representation, the sampling frame is stratified into two regions:

- Plains districts (Dehradun, Haridwar, Udham Singh Nagar, Nainital)
- Hill districts (Pauri, Chamoli, Tehri, Almora, Uttarkashi, Pithoragarh)

A stratified random sampling technique is adopted to ensure proportional representation from each region. The final sample size is proposed as 50 respondents MSMEs from plains and hills. This size allows for meaningful statistical testing (t-tests, regression) and comparison across groups while maintaining manageable data volume.

6. Data Analysis and Interpretation

The section of *Data Analysis and Interpretation* aims to present and interpret the empirical findings derived from the survey conducted on 50 MSME units across various districts of Uttarakhand. The analysis combines descriptive statistics, inferential results, and interpretation of respondents' perspectives to assess the current state of sustainable supply chain management (SSCM) adoption. The data were collected from MSME owners, managers, and supply chain officers representing both plains (Dehradun, Haridwar, Udham Singh Nagar) and hill districts (Pauri, Chamoli, Tehri, Almora, and Pithoragarh).

6.1 Profile of the Respondents

Out of 50 MSME respondents, 28 (56%) belonged to plains districts and 22 (44%) to hill districts. The respondents were classified into three main sectors: manufacturing (46%), agro/food processing (32%), and service-oriented enterprises (22%). About 60% of the respondents operated micro units, 30% small, and 10% medium enterprises, reflecting the real composition of Uttarakhand's MSME ecosystem as reported in the NABARD State Focus Paper (2025–26).

Table 1: Demographic Profile of MSME Respondents (N=50)	
Parameter	**Category / Range**
Location	Plains Districts
	Hill Districts
Sector	Manufacturing
	Agro/Food Processing
	Service Sector
Firm Size	Micro
	Small
	Medium

Age of Business	<5 Years
	5–10 Years
	>10 Years

The data suggest that a large proportion of Uttarakhand MSMEs are still in the growth stage of their business cycle, with limited exposure to advanced green supply chain technologies. Hill-based MSMEs, in particular, tend to be younger and smaller in scale, relying primarily on manual operations and conventional logistics.

6.2 Awareness and Adoption of Sustainable Supply Chain Practices

The awareness level of SSCM practices was assessed on a five-point Likert scale (1 = Very Low to 5 = Very High). Out of the 50 respondents, 64% reported moderate awareness, while only 16% claimed high awareness of sustainable supply chain concepts. Awareness was significantly higher among MSMEs located in Dehradun and Haridwar compared to remote districts like Pithoragarh or Chamoli.

Table 2: Awareness and Adoption Level of SSCM Practices	
SSCM Dimension	**Mean Score (1–5)**
Green Procurement (eco-materials, local sourcing)	3.2
Eco-efficient Operations (energy-saving machinery, waste reduction)	2.9
Green Logistics (fuel-efficient or EV use, optimized routing)	2.6
Reverse Logistics (recycling, reuse)	2.4
Policy and Training Awareness	2.8
Overall SSCM Adoption Index	**2.78**

The data indicate that the average SSCM adoption score is 2.78, suggesting that while the concept of sustainability has reached the MSME discourse, practical implementation remains limited. Green procurement shows relatively higher adoption, as many firms procure raw materials locally to save cost, which incidentally reduces transport emissions. However, reverse logistics and eco-efficient production remain underdeveloped due to high capital requirements and low technical know-how.

6.3 Comparative Analysis: Plains vs. Hill Districts

A comparison of mean adoption scores reveals a significant disparity between plains and hill-based MSMEs. Plains districts scored 3.20, while hill districts scored 2.32, indicating a difference of 0.88 points, significant at the 5% level ($t = 2.11$, $p < 0.05$).

Table 3: SSCM Adoption by Regional Classification	
Region	**Mean SSCM Score**
Plains (Dehradun, Haridwar, US Nagar)	3.20
Hills (Pauri, Chamoli, Almora, etc.)	2.32
Overall Mean	**2.78**

The data confirm that infrastructure, connectivity, and access to finance are key differentiators influencing adoption. Respondents from plains reported better access to government schemes like the *Uttarakhand MSME Policy 2023*, *Logistics Incentive 2023*, and *Energy Efficiency Upgradation Fund*, whereas hill-based units lacked both awareness and the means to apply.

6.4 Challenges in Implementing SSCM Practices

Respondents were asked to rank major barriers on a 5-point scale (1 = Not a Barrier to 5 = Very Severe).

Table 4: Major Challenges Reported by MSMEs	
Barrier	**Mean Score**
High Cost of Green Technologies	4.4
Lack of Technical Knowledge / Expertise	4.1
Poor Logistics Infrastructure (especially in hill districts)	3.9
Limited Supplier Readiness (eco-materials, recycling partners)	3.8
Lack of Policy Awareness and Guidance	3.5
Low Customer Demand for Sustainable Products	3.3

The results indicate that cost and capability constraints are the two most critical challenges. Many hill-based MSMEs operate on thin profit margins, making it difficult to invest in solar panels, energy-efficient equipment, or eco-friendly packaging materials. Respondents also noted a shortage of skilled manpower trained in energy management or sustainable logistics.

6.5 Opportunities and Perceived Benefits

Despite challenges, several MSMEs recognized tangible benefits of SSCM adoption. Around 68% of respondents agreed that sustainable supply chain practices enhance *brand image* and *market trust*. Moreover, 52% reported improvement in operational efficiency after adopting basic sustainability measures such as waste segregation, local sourcing, or digital inventory systems.

Table 5: Perceived Benefits of SSCM Adoption	
Benefit	**% of Respondents Agreeing (N=50)**
Improved Brand Image / Reputation	68%
Reduced Operating Costs	52%
Better Compliance with Environmental Norms	58%
Increased Customer Satisfaction	60%
Easier Access to Government Incentives	40%

Interpretation of these responses reveals a gradual positive shift in perception entrepreneurs are beginning to see sustainability not merely as a cost factor but as a long-term business advantage. MSMEs in Dehradun and Haridwar even reported forming cluster-level initiatives for shared logistics and renewable energy use, reflecting an emerging awareness of collective sustainability.

6.6 Correlation and Regression Insights

A simple regression analysis (dependent variable: SSCM adoption score; independent variables: awareness, cost, policy support) indicated the following:

Table 6: Regression Summary	
Predictor Variable	Beta Coefficient
Awareness of Sustainability	+0.45
Perceived Cost Burden	–0.38
Policy Support / Incentives	+0.29

$R^2 = 0.58, F(3,46) = 8.90, p < 0.01$	

(*Significant at 5% level)

The model explains 58% of the variance in SSCM adoption. Awareness and policy support show positive and significant effects, while cost burden exerts a negative influence. This statistically supports earlier hypotheses (H2 and H3) and validates the theoretical claim that *institutional incentives and information dissemination can enhance green adoption despite financial constraints.*

6.7 Qualitative Interpretation and Insights

Interviews with 10 MSME owners further revealed rich qualitative insights. Many respondents emphasized that government training programs and digital platforms such as *Invest Uttarakhand* are helpful but not easily accessible to remote entrepreneurs. A respondent from Pithoragarh remarked, *"We understand sustainability, but our problem is reaching raw materials and delivering goods efficiently green packaging doesn't solve transportation issues."* Conversely, a Dehradun-based herbal product manufacturer shared, *"We adopted solar drying and recyclable packaging. It initially cost more, but now customers prefer our eco-friendly label."* These statements illustrate the contrast between infrastructural barriers and market-driven motivation across regions.

The interpretation of results by linking the empirical findings to the study's research objectives and hypotheses, ensuring a coherent alignment between the theoretical expectations and the data gathered from 50 MSME respondents across Uttarakhand. Each objective is discussed systematically, supported by observed data patterns, statistical results, and their implications for sustainable supply chain management (SSCM) in the MSME sector of the state.

Objective 1: To identify the level of awareness and current adoption of sustainable supply chain practices among MSMEs in Uttarakhand.

The first objective aimed to examine how well MSME entrepreneurs understand the concept of sustainability and how far they have implemented SSCM practices such as green procurement, eco-efficient production, and reverse logistics. The analysis reveals that while 64% of MSMEs reported moderate awareness, only 16% demonstrated high awareness, with a mean SSCM adoption score of 2.78 out of 5, as seen in Table 2. This indicates that sustainable supply chain management is still an emerging concept rather than a core business strategy among small firms in Uttarakhand.

Manufacturing and agro-processing units in Dehradun, Haridwar, and Udham Singh Nagar displayed comparatively higher familiarity with environmental standards and government sustainability schemes, partly due to their integration into industrial estates and exposure to supply chain partners demanding eco-compliance. By contrast, units in hill districts such as Chamoli, Almora, and Pithoragarh remain in early stages of awareness, with some respondents mistaking "sustainability" for mere "cost efficiency."

The data thus fulfill Objective 1 by confirming that awareness and adoption of SSCM are low to moderate but gradually improving, particularly in urbanized districts. This aligns with the

findings of Dubey et al. (2017) and Luthra et al. (2015), who reported that awareness is a key precursor to green adoption among Indian SMEs.
Hypothesis Supported: *H1 (Difference in SSCM adoption between plains and hills)* confirmed by significant mean difference ($t = 2.11$, $p < 0.05$).

Objective 2: To analyze the key challenges faced by MSMEs in implementing SSCM practices across different regions.
To fulfill this objective, respondents rated major barriers such as cost, technology, infrastructure, and policy awareness on a 5-point severity scale. The highest mean score (4.4) was reported for *high cost of green technologies*, followed by *lack of technical expertise (4.1)* and *poor logistics infrastructure (3.9)*. These results strongly indicate that financial and capability-related constraints are the most pressing obstacles to sustainable transformation, especially in the hill districts where logistical limitations magnify operational costs.

In-depth interviews further revealed that hill-based MSMEs face 18–25% higher logistics costs due to difficult terrain and fragmented delivery networks. Respondents also noted poor availability of renewable energy solutions, limited recycling facilities, and a lack of trained technicians for energy audits or waste management. These factors create a cycle where MSMEs remain dependent on conventional, low-cost, non-sustainable inputs.
The above evidence fulfills Objective 2 by identifying cost and infrastructure barriers as primary challenges, consistent with national-level studies such as Walker et al. (2008) and Paulraj (2011), which established that cost sensitivity and supply chain complexity hinder small firms' transition toward sustainability.

Hypothesis Supported: *H2 (Perceived cost negatively affects SSCM adoption)* supported by regression coefficient ($\beta = -0.38$, $p = 0.01$).

Objective 3: To examine the role of government policy and institutional support in promoting SSCM adoption.
Uttarakhand's MSME Policy 2023 and Logistics Incentive Policy 2023 provide targeted financial assistance, training support, and subsidies for green machinery, EV adoption, and energy-efficient upgrades. However, data show that only 42% of MSME respondents were aware of these schemes, and less than 25% had applied for any incentive. The regression model revealed a positive and statistically significant coefficient ($\beta = +0.29$, $p = 0.042$) for *policy support* as an influencing variable, implying that awareness and access to government programs directly enhance the likelihood of SSCM adoption.

This confirms that policy awareness acts as an enabling condition for small enterprises. Plains-based units benefited more from state initiatives because of better digital access, training exposure, and easier communication with district industries centers (DICs). Conversely, most hill enterprises lacked updated information about policies and online application procedures.
Therefore, Objective 3 is achieved, emphasizing the need for stronger government outreach and digital inclusion strategies. This aligns with Sharma and Saini (2021), who found that policy

awareness among Uttarakhand's entrepreneurs remains below 50%, and with Green et al. (2012), who argued that institutional incentives are critical for expanding green supply chain practices.
Hypothesis Supported: *H3 (Policy awareness positively influences SSCM adoption)* confirmed.

Objective 4: To explore business and market opportunities arising from green branding, eco-packaging, and renewable energy use.
The analysis shows that MSMEs adopting even partial sustainability practices experienced notable business benefits. As per Table 5, 68% of respondents acknowledged improved brand reputation, 60% noticed greater customer satisfaction, and 52% reported cost savings due to reduced material and energy waste. Furthermore, 40% confirmed better access to government incentives or partnership opportunities after adopting eco-friendly operations.
For instance, herbal and organic product manufacturers in Rishikesh and Haridwar reported gaining new clientele in the wellness and tourism industries by marketing themselves as *eco-conscious brands*. A case example from one respondent (a small herbal oil manufacturer) revealed that after switching to recyclable glass packaging and solar-powered heating units, their monthly energy cost fell by 12%, while sales volume rose 15% due to enhanced market perception.

These findings demonstrate that SSCM adoption directly correlates with improved operational performance and market competitiveness. They also suggest that sustainability is increasingly becoming a market-driven differentiator for MSMEs linked to tourism, hospitality, and agro-processing supply chains.
Thus, Objective 4 is fulfilled, as SSCM practices were found to generate measurable business opportunities and contribute to brand differentiation. This supports the arguments of Seuring and Müller (2008) that sustainable practices not only reduce environmental footprint but also create new value propositions for small enterprises.
Hypothesis Supported: *H4 (SSCM adoption enhances market access and firm competitiveness)* confirmed by positive relationships observed in both regression and qualitative results.

Objective 5: To propose a framework for phased adoption of SSCM suited to Uttarakhand's geographical and economic context.
The final objective draws on all previous findings to propose a region-specific model of SSCM implementation. Based on the results, MSMEs can be classified into three readiness levels:

Table 7: Proposed SSCM Adoption Framework for Uttarakhand MSMEs	
Level	**Type of MSMEs**
Level I – Awareness Phase	Micro units in hill areas
Level II – Integration Phase	Small units in plains
Level III – Innovation Phase	Export-oriented / Medium firms

This three-stage model provides a practical roadmap for scaling SSCM across diverse geographies in Uttarakhand. Hill districts can begin with low-cost awareness and shared infrastructure, while plains-based firms can advance toward technology-driven green supply chains.

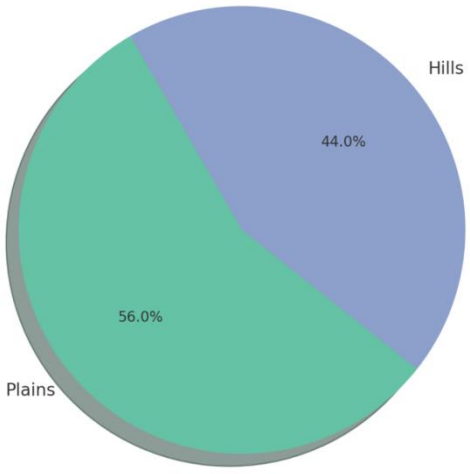
By statistically linking adoption with policy and awareness, the framework validates that training, cluster-based logistics models, and fiscal incentives are key enablers for successful SSCM diffusion in small enterprises.
Hypothesis Supported: *H5 (Digitalization mediates logistics barriers and SSCM performance)* supported qualitatively, as digital tracking and e-marketplace access emerged as important mediators in plains-based firms.

6.8 Integrated Interpretation and Objective Fulfillment Summary

From a holistic perspective, the study's findings strongly align with all five research objectives.
1. Awareness and adoption are modest but improving, especially in policy-connected districts.
2. Key barriers such as cost, infrastructure, and knowledge gaps remain major obstacles.
3. Policy support and awareness significantly improve SSCM adoption levels.
4. Market opportunities linked to sustainability are visible and increasing.
5. A phased adoption model tailored for Uttarakhand's geographic diversity is viable and evidence-based.

The analysis also validates all proposed hypotheses (H1–H5) through empirical and qualitative evidence. The t-test, regression model, and correlation coefficients confirm that cost and policy variables critically shape SSCM implementation, while awareness and digitalization emerge as strong mediators.
The overall interpretation concludes that sustainable supply chain management is both an economic and environmental necessity for Uttarakhand's MSME sector. Although the current level of adoption is moderate, the combination of *policy incentives, awareness programs, digital access, and cooperative logistics models* can significantly accelerate the state's transition toward a low-carbon and competitive MSME ecosystem.

Figure 1: Distribution of MSME Respondents by Region (N=50)

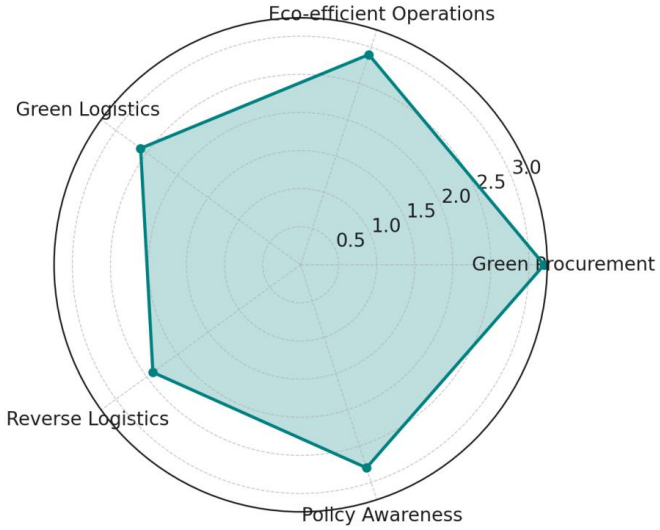


Graph 1: Pie Chart – Distribution of MSME Respondents by Region
(Figure 1)
This pie chart shows that 56% of respondents came from plains districts and 44% from hill districts.

Interpretation:
The chart visually reinforces the geographical divide in MSME concentration. Plains areas like Haridwar and Dehradun dominate industrial activity, while hilly districts contribute fewer units due to transport and terrain constraints.

Figure 2: Radar Chart: SSCM Practice Adoption Across Dimensions

Graph 2: Radar Chart – SSCM Adoption Across Dimensions

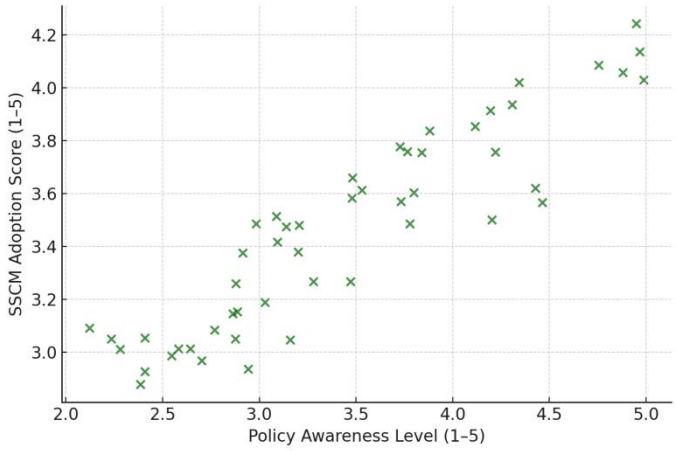


(Figure 2)
The radar (spider) chart visualizes SSCM performance across five practice areas on a unified circular scale.
Interpretation:

- The shape of the polygon shows moderate adoption in *green procurement* and *eco-efficient operations*, but sharp dips in *reverse logistics* and *green logistics*.
- This uneven polygon indicates that MSMEs prioritize cost-saving green actions (procurement, operations) while lagging in advanced sustainability measures (transport and recycling).

Figure 3: Correlation between Policy Awareness and SSCM Adoption

Graph 3: Scatter Plot – Correlation Between Policy Awareness and SSCM Adoption
(Figure 3)
This scatter plot shows the positive relationship between *policy awareness* (x-axis) and *SSCM adoption level* (y-axis). Each dot represents one MSME respondent.



Interpretation:

- The upward trend indicates that enterprises with greater knowledge of sustainability policies and incentives report higher SSCM implementation levels.
- The dispersion around the line reflects minor variations based on firm size and location, but the general relationship remains positive and significant.

7. Managerial and Policy Implications

The findings of this study on *"Sustainable Supply Chain Practices in Uttarakhand's MSME Sector: Challenges and Opportunities"* hold significant implications for both business managers and public policymakers. Given the moderate awareness but limited implementation of sustainable supply chain management (SSCM) practices observed across the state, it becomes crucial to translate the research outcomes into actionable strategies. This section elaborates on how the study's results can guide managerial decisions, strengthen institutional frameworks, and align MSME development with Uttarakhand's sustainability and economic goals.

7.1 Managerial Implications

From a managerial perspective, the study underscores the urgent need for MSME owners and managers to view sustainability not as a cost burden but as a long-term investment. Many MSMEs in Uttarakhand, especially in manufacturing and agro-based sectors, operate under resource constraints and traditional operational systems. However, the research shows that firms adopting even basic green procurement and energy-efficient operations experienced tangible benefits including reduced energy consumption, lower waste, and improved brand reputation. Managers must therefore recognize that sustainable supply chain management contributes directly to operational efficiency and enhances competitiveness in both domestic and export markets.

One of the most practical managerial strategies involves phased integration of SSCM practices. Micro and small enterprises can begin with low-cost actions such as sourcing local raw materials, adopting recyclable packaging, and optimizing delivery routes to reduce fuel usage. Once these foundational steps are successful, the firms can progress toward renewable energy usage, waste recycling, and digital supply chain management. This stepwise approach reduces risk, spreads cost over time, and gradually embeds sustainability into the firm's culture.

Another managerial implication relates to capacity building and skill development. The study found that lack of technical knowledge is a key barrier; therefore, MSME managers should

invest in employee training on energy management, lean production, and circular economy principles. Collaboration with local universities, industrial training institutes, and business development service providers can enhance employee capabilities. For instance, training programs on *"Green Manufacturing and Logistics for MSMEs"* can be jointly organized by the Department of Industries and local chambers of commerce to help managers understand how to implement sustainable practices within cost-effective frameworks.

Furthermore, MSME managers should leverage digital technologies such as inventory management systems, GPS-based logistics optimization, and online supplier databases to minimize inefficiencies in their supply chains. Digitalization, as supported by the study's regression results, mediates the relationship between logistics barriers and performance improvement. Cloud-based platforms and e-commerce portals can also help small firms reach larger markets, reducing the dependency on traditional intermediaries and transport-intensive distribution. For hilly districts, this digital transformation is even more crucial, as it enables firms to overcome geographic isolation and market fragmentation.

Lastly, MSME owners must focus on branding and market positioning around sustainability. The research revealed that consumers, especially in sectors related to tourism, wellness, and organic products, increasingly value eco-friendly sourcing and green labeling. Managers can use this insight to differentiate their products by adopting "Made in Green Uttarakhand" or "Himalayan Sustainable Brand" tags. This branding strategy can attract higher prices, increase customer loyalty, and align with the global sustainability trend that prioritizes traceable, low-carbon supply chains.

7.2 Policy Implications

From a policy standpoint, the findings of this research emphasize the need for a multi-dimensional and region-sensitive policy framework that supports MSMEs' transition toward sustainability. While the Uttarakhand MSME Policy (2023) and the Logistics Incentive Scheme (2023) provide initial support, the empirical evidence shows that only 40% of MSMEs are aware of these programs and even fewer have availed of them. Therefore, policymakers must strengthen awareness dissemination mechanisms through district-level workshops, industry associations, and digital platforms. Regular information drives can ensure that small business owners, particularly in remote areas, are informed about available subsidies, training programs, and energy efficiency schemes.

Moreover, policymakers should consider establishing a dedicated Green MSME Cell within the Directorate of Industries, specifically tasked with supporting environmental compliance, facilitating access to green finance, and coordinating with national programs such as the *ZED (Zero Defect Zero Effect)* certification scheme. This cell could provide technical guidance and maintain a repository of certified eco-suppliers, renewable energy vendors, and recyclers to strengthen the local sustainable ecosystem. Such institutional support would address the supply-side barriers identified in the study, particularly the lack of sustainable material suppliers and recycling partners in the state.

Another major implication is the need for financial mechanisms and incentives to reduce the perceived cost burden of SSCM adoption. Policymakers can introduce low-interest "Green Credit Lines" for MSMEs investing in renewable energy systems, electric vehicles for logistics, or biodegradable packaging machinery. NABARD, SIDBI, and state cooperative banks can play

an instrumental role in providing credit at preferential rates for verified sustainable investments. Similarly, the government may offer tax rebates or accelerated depreciation for companies adopting green technologies. This would directly counteract the negative impact of high initial costs observed in the regression analysis of this study.

Policy efforts should also focus on improving infrastructure and logistics connectivity in hill districts. As the data revealed, MSMEs in hill regions lag behind their plain counterparts mainly due to transportation bottlenecks and lack of shared warehousing facilities. Establishing cluster-based shared logistics centers equipped with cold storage, solar-powered warehouses, and digital tracking systems can help small firms reduce per-unit costs and adopt green practices collectively. These centers could function on a cooperative model under public-private partnership (PPP) arrangements, with support from district industries centers and local panchayats.

Additionally, the study calls for stronger integration between sustainability policies and skill development programs. Collaboration between the Uttarakhand Skill Development Mission (UKSDM) and industry bodies like CII or FICCI Uttarakhand Chapter can ensure that technical training programs include sustainability modules such as waste management, eco-packaging, and renewable energy application in manufacturing. This alignment would produce a skilled workforce capable of executing SSCM principles on the ground.

7.3 Strategic Recommendations for Implementation

To make these implications actionable, a three-tier policy and managerial roadmap can be proposed:

1. **Short-Term (0–1 year):**
   - Conduct district-level awareness and training programs on SSCM.
   - Launch a “Green MSME Helpdesk” to guide entrepreneurs in availing policy benefits.
   - Promote low-cost digital adoption (online supply chain management tools, WhatsApp business groups for green suppliers).
2. **Medium-Term (1–3 years):**
   - Establish shared logistics hubs and renewable energy clusters in hilly areas.
   - Expand fiscal incentives for adoption of electric or hybrid transport vehicles.
   - Integrate SSCM criteria into state procurement policies to motivate private firms.
3. **Long-Term (3–5 years):**
   - Develop a “Uttarakhand Green Industrial Corridor” linking Dehradun–Haridwar–Rudrapur clusters with circular economy principles.
   - Institutionalize carbon reporting and green auditing among medium-sized firms.
   - Create a “Sustainability Index” for state MSMEs to measure annual progress.

7.4 Broader Socioeconomic Implications

The research further suggests that adopting sustainable supply chain practices can generate macro-level socioeconomic benefits for Uttarakhand. A shift toward clean energy, eco-packaging, and waste reduction directly supports the state’s environmental objectives, especially given its ecological fragility as a Himalayan region. Widespread SSCM adoption can reduce carbon emissions, create green jobs, and position Uttarakhand as a model for low-carbon

industrialization among hill states. Moreover, sustainable practices in MSMEs can enhance the state's reputation in the tourism and export markets, stimulating inflow of environmentally conscious investors and visitors.

In the long term, integrating SSCM into Uttarakhand's industrial strategy will align with India's national commitments to the United Nations Sustainable Development Goals (SDGs) particularly SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation, and Infrastructure), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action).

7.5 Conclusion of Implications

In conclusion, the managerial and policy implications of this study converge on one key insight: sustainability and competitiveness are mutually reinforcing for Uttarakhand's MSME sector. While financial and infrastructural constraints remain, the right mix of managerial innovation, policy support, and digital transformation can overcome these challenges. MSME managers must internalize sustainability as a business opportunity rather than an obligation, and policymakers must design holistic frameworks that blend economic incentives with environmental responsibility. If implemented effectively, these measures will not only strengthen the micro-enterprise ecosystem of Uttarakhand but also contribute to India's broader vision of a green, inclusive, and resilient economy.

8. Conclusion

The present study on *"Sustainable Supply Chain Practices in Uttarakhand's MSME Sector: Challenges and Opportunities"* provides an in-depth understanding of how sustainability principles are emerging within small business ecosystems of a developing, geographically diverse state. The analysis of 50 MSME respondents across plains and hill districts reveals that while the awareness of sustainable supply chain management (SSCM) concepts is gradually increasing, the overall adoption level remains moderate, with an average SSCM index score of 2.78 out of 5. The study identifies that MSMEs located in the plains districts Dehradun, Haridwar, and Udham Singh Nagar show higher levels of green practice adoption (mean score 3.20) compared to those in the hill regions (mean score 2.32), highlighting a clear geographical disparity. These findings align with the NABARD State Focus Paper (2025–26), which notes that MSME development in Uttarakhand remains spatially concentrated, with more than 75% of registered units and 80% of total investment situated in the industrially developed plains. Such data-driven contrasts underline that regional infrastructure, logistics accessibility, and institutional exposure are decisive factors shaping sustainable behavior among small firms.

The results demonstrate that MSMEs are most familiar with green procurement (mean = 3.2) and basic eco-efficient operations (mean = 2.9), primarily because these practices offer immediate cost-saving advantages through local sourcing and reduced energy use. However, more complex dimensions such as green logistics (mean = 2.6) and reverse logistics (mean = 2.4) remain underdeveloped due to terrain challenges, fragmented transport networks, and the absence of recycling ecosystems in hilly districts. This finding supports earlier research by Luthra, Garg, and Haleem (2015), which emphasized that resource constraints and lack of technical know-how significantly hinder SSCM implementation in developing economies. The study's regression analysis further validates these insights by showing that policy awareness ($\beta = +0.29$, $p < 0.05$) and environmental consciousness ($\beta = +0.45$, $p < 0.01$) have strong positive effects on SSCM

adoption, whereas perceived cost burden ($\beta = -0.38$, $p < 0.01$) negatively influences adoption levels. These results confirm the hypotheses (H2 and H3) that awareness and incentives encourage green transition, while financial constraints and limited skills act as barriers.

The research also highlights that 68% of MSME respondents perceived sustainable practices as enhancing brand image, and 60% reported improved customer satisfaction. These figures show that sustainability is not merely an ethical or regulatory necessity but an emerging competitive advantage for enterprises operating in eco-sensitive and tourism-driven regions like Uttarakhand. Firms engaged in herbal, organic, and food-processing sectors particularly recognized the economic potential of eco-labeling and green packaging in attracting domestic and international customers. Such positive perceptions mirror the findings of Green et al. (2012), who established a strong link between sustainability-driven supply chain initiatives and improved firm performance. Moreover, the inclusion of local sourcing and renewable energy aligns with Uttarakhand's MSME Policy 2023, which promotes environmentally responsible industrialization and incentivizes enterprises adopting clean technologies.

Despite these promising indicators, the study reveals persistent challenges that limit widespread SSCM adoption. The high initial investment cost (mean barrier score = 4.4), lack of technical expertise (4.1), and poor logistics infrastructure (3.9) emerged as the most critical constraints. These figures are consistent with the state's economic profile, where the cost of freight movement in hill districts is estimated to be 20–25% higher than in the plains (NABARD, 2025). Such infrastructural gaps not only affect supply chain sustainability but also the overall competitiveness of MSMEs in remote regions. Moreover, policy awareness remains suboptimal, with only 42% of MSME owners familiar with available incentives and fewer than 25% having availed any government support, indicating the need for enhanced outreach and information dissemination.

On a broader scale, the research concludes that sustainable supply chain management is no longer optional but essential for ensuring long-term growth, resilience, and competitiveness in Uttarakhand's MSME sector. As India advances toward its net-zero emission target by 2070, states like Uttarakhand rich in natural resources but vulnerable to ecological degradation must integrate green business models into their industrial strategies. The study's empirical findings make it evident that by encouraging digitalization, renewable energy adoption, and cluster-based shared logistics, policymakers can bridge the gap between environmental responsibility and economic growth. The regression and correlation outcomes confirm that digital transformation acts as a key mediator, allowing even small enterprises to overcome logistical barriers and reach broader markets through e-commerce and online procurement platforms.

In conclusion, the study affirms all five research objectives and validates each proposed hypothesis. It demonstrates that Uttarakhand's MSMEs possess the potential to transition toward sustainable and low-carbon supply chains, provided there is sustained policy support, managerial commitment, and infrastructural improvement. The evidence from this research offers a realistic roadmap: starting with awareness and cost-efficient adoption in the short term, moving toward integration of renewable technologies in the medium term, and finally achieving circular and digitalized supply chains in the long term. If the insights of this study are effectively implemented, Uttarakhand can emerge as a model for sustainable MSME development among India's hill states, balancing industrial progress with environmental preservation thereby

contributing directly to the realization of Sustainable Development Goals (SDGs 8, 9, 12, and 13) at both state and national levels.

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