Sustainable Supply Chain Management and Green Logistics Practices in the Automobile Industry: A Study of Sonalika Tractors

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Abstract— This capstone examines how Sustainable Supply Chain Management (SSCM) and green logistics can be applied in the Indian tractor industry, using International Tractors Limited (ITL), maker of Sonalika tractors, as a case study. It explores whether a vertically integrated OEM can meet rising environmental requirements while remaining cost-effective for small farmers. ITL's Hoshiarpur plant produces about three lakh tractors annually, and the company sold 153,764 tractors in FY2025, with a 14.8% domestic market share and exports to over 150 countries. The study is framed by India's TREM IV and proposed TREM V emission norms, along with the EU's Carbon Border Adjustment Mechanism (CBAM). Using secondary sources, one dealer interview, and a pilot questionnaire, the study finds that ITL has strengths such as vertical integration, low-VOC robotic paint systems, export-oriented assembly, and partial rail connectivity. Key challenges remain in Scope 3 emissions tracking, reverse logistics, and infrastructure for electric and CNG/CBG tractors. The study recommends better digital emissions monitoring, stronger rail and intermodal transport, circular economy initiatives, alternative fuel adoption, and supplier development.

Keywords: Sustainable Supply Chain Management, green logistics, Sonalika tractors, Indian tractor sector, TREM IV, TREM V, CBAM, Scope 3 emissions, circular economy

I. Introduction

A. Background of the Study

Agricultural machinery often does not feature prominently in mainstream discussions about sustainability. However, there is a clear environmental rationale for examining tractors. A tractor bought in rural Punjab today may still be in use twenty-five years from now, and every litre of diesel it consumes contributes to emissions that cannot be fully offset by factory efficiency improvements. India reached ten lakh annual tractor sales in 2024, making it the world's largest tractor market by volume, surpassing China and the United States (TMA, 2024).

The market is highly concentrated. Mahindra & Mahindra leads by volume, while TAFE, ITL Sonalika, Escorts Kubota, and John Deere share the rest. Two regulatory changes have sharply increased sustainability pressures. Domestically, TREM IV standards are now mandatory for tractors above 50 HP. Draft TREM V regulations under consideration would extend similar rules to the 25-50 HP range. Internationally, the EU's CBAM entered its transitional reporting phase in October 2023. Starting in 2026, importers of iron, steel, aluminum, and related products into the EU will need to pay a carbon price aligned with the EU Emissions Trading System.

B. Theoretical Framework

Resource-Based View (Barney, 1991): According to Barney, a firm gains a lasting competitive edge through resources that are valuable, rare, hard to copy, and non-substitutable - the VRIN criteria. In this context, ITL's plant meets all four conditions when aligned with sustainability goals.

Institutional Theory (DiMaggio & Powell, 1983): The three pressures identified by DiMaggio and Powell - coercive (from regulators like TREM and CBAM), normative (from international buyers and ESG-focused lenders), and mimetic (from global OEM norms) - all influence ITL at the same time, affecting how it responds to sustainability demands.

Stakeholder Theory (Freeman, 1984): Different groups within Sonalika's value chain have competing sustainability interests. Farmers need affordable, fuel-efficient machines, regulators want lower emissions, and export buyers require carbon disclosures that comply with CBAM. Effective SSCM needs to balance these various interests rather than maximize just one.

Dynamic Capabilities (Teece, Pisano & Shuen, 1997): Examples of ITL's dynamic capabilities include shifting logistics from road to rail, piloting alternative-fuel tractors, and redesigning products to meet TREM and CBAM standards.

C. Research Problem and Questions

The central research question is: How can a top Indian tractor manufacturer design and run its supply chain and logistics system to meet global sustainability standards while maintaining the cost competitiveness that small and marginal farmers rely on? Four related questions follow:

- RQ1: How are ITL's inbound, in-plant, and outbound logistics organized, and what are the main environmental impacts?
- RQ2: How do TREM IV, draft TREM V, and EU CBAM influence sourcing, production, and export logistics decisions for Sonalika?
- RQ3: What green logistics and SSCM practices are in place, and what are the biggest remaining opportunities?
- RQ4: How do dealers and logistics managers view sustainability opportunities and challenges in the tractor value chain?

D. Scope and Limitations

This study focuses on ITL's operations in India and its export logistics from Hoshiarpur, particularly involving higher-horsepower and export-oriented models. It is exploratory and qualitative and does not include a full lifecycle assessment or quantitative carbon-footprint analysis. Financial modeling and profitability assessment are beyond the scope of this capstone.

II. Review of Literature

1. Srivastava (2007) organized GSCM scholarship by identifying three main themes in the literature: product and process design, operational procurement and logistics, and end-of-life waste management and reverse-flow activities. This three-cluster framework is Srivastava's unique contribution to the field. The structure also reflects Sonalika's green initiatives throughout this report. Notably, reverse-logistics research was the weakest cluster in 2007, and nearly two decades later, formal end-of-life infrastructure for tractors in India is still largely absent.

2. Zhu & Sarkis (2004) studied Chinese manufacturers facing conditions similar to those of Indian tractor makers. They found that lean culture and quality management systems improve GSCM performance, and that investment recovery and internal environmental management provide the most consistent returns. These results inform the prioritization of plant-level and circular-economy initiatives in the recommendations.

3. Seuring & Müller (2008) reviewed a large body of SSCM literature and distilled it into two practical strategic directions: one focuses on managing supplier-side risks and environmental standards, while the other centers on designing sustainability criteria into products from the outset. For ITL, vertical integration merges these pathways into one operation, explaining the company's above-average performance in production but weaker traceability when dealing with suppliers.

4. Carter & Rogers (2008) defined SSCM as "the strategic, transparent integration and achievement of an organization's social, environmental, and economic goals in the systemic coordination of key interorganizational business processes." This definition is used throughout the report. ITL's diagnostic question is whether its green initiatives represent a coherent strategic plan or a collection of independently motivated projects.

5. Pagell & Wu (2009) studied ten globally recognized sustainable supply chains and found that the most advanced organizations often go beyond what commercial logic would suggest. For example, they invest in supplier relationships beyond immediate needs and treat sustainability targets as essential organizational goals rather than optional trade-offs. This serves as a benchmark for ITL.

6. Sarkis (2003) used analytic network process methodology to evaluate strategic options in green supply chain management. Using this framework, this report identifies a key imbalance at ITL: its forward logistics are quite developed (export containerization, partial rail), while its reverse logistics (no formal tractor end-of-life take-back) are essentially absent. Addressing this imbalance is necessary for creating a coherent GSCM strategy 7. Linton, Klassen & Jayaraman (2007) argued that a genuinely sustainable supply chain must consider the entire product lifecycle. This provides the intellectual basis for the analysis in Chapters 6 and

7, which looks beyond ITL's factory gate to examine use-phase fuel emissions, embedded carbon in upstream steel, and informal scrap markets where most old Indian tractors end up.

8. Min & Kim (2012) confirmed that most published empirical GSCM work focuses on large firms in developed economies and that agricultural sectors in emerging markets receive little attention. This justifies this capstone's emphasis on an Indian tractor OEM.

9. Ahi & Searcy (2013) compared definitions in the literature and found that GSCM and SSCM are meaningfully different concepts. The former mainly addresses environmental outcomes, while the latter includes social and economic performance alongside environmental goals. This distinction helps separate ITL's logistics decarbonization efforts from its CSR programs, avoiding exaggeration of environmental progress.

10. Ashby, Leat & Hudson-Smith (2012) found that environmental management at the manufacturing level is relatively strong, while management of end-of-life issues is the least developed. They also found that coordination across different levels is the most influential factor for comprehensive SSCM. This aligns closely with Sonalika's situation.

11. Beske & Seuring (2014) discovered that sustained SSCM engagement fosters adaptive, absorptive, and innovative capabilities as direct outcomes of the activity. This reframes ITL's investments in electric tractors, rail logistics, and CBAM preparedness as capability assets with future competitive value.

12. Brandenburg et al. (2014) reviewed quantitative methods in SSCM and found that optimizationbased modeling represented most of the published work, while social sustainability and circulareconomy issues received

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minimal analytical attention. This acknowledges that the freight emissions modeling originally proposed is a research frontier beyond the current scope.

13. Tseng et al. (2019) conducted a bibliometric review that traced how GSCM research has shifted from a primary focus on regulations and compliance to more forward-looking themes, especially circular economy design and the use of digital tools for supply chain transparency. The most significant improvements ITL can make are investments in digital Scope 3 traceability and formalized component remanufacturing.

14. Dubey et al. (2017) found that regulatory mandates, buyer-driven norms, and competitive benchmarking are necessary but not sufficient drivers of SSCM. Organizations that also use advanced data analytics are better positioned to turn these external pressures into measurable sustainability performance on a large scale.

15. Fahimnia, Sarkis & Davarzani (2015) confirmed that GSCM has become part of mainstream strategy, with the automotive and electronics sectors leading empirical contributions. This indicates that tractor manufacturing operates within a well-established GSCM framework while remaining an under-researched sub-sector. Section 2: Automotive Industry Supply Chain and Green Practices (Citations 16-30)

16. Luthra, Kumar, Kumar & Haleem (2011) applied interpretive structural modeling in the Indian automotive context and found that managers usually see cost and awareness issues as the main barriers to GSCM. However, the ISM analysis revealed that these are just surface-level symptoms. The deeper structural factors, including consistent policy support, IT infrastructure, and commitment from top management, are the real root causes. Addressing dealer-level awareness of CBAM is unlikely to succeed until these deeper factors are in place. 17.

Shukla, Deshmukh & Kanda (2009) found that regulatory pressure and OEM-driven demands are the main drivers of GSCM, while financial limitations and lack of awareness are significant obstacles. These structural characteristics of Indian automotive supply chains reflect themes from the Sonalika dealer interview.

18. Jabbour et al. (2013), studying Brazilian automotive companies, found that ISO 14001 certification and eco-design adoption were linked to improvements in productivity, quality, and delivery reliability. This provides empirical support for the idea that investments in Scope 3 traceability do not necessarily compromise the reliability that dealers and farmers rely on.

19. Olugu, Wong & Shaharoun (2011) developed a green supply chain indicator set covering both forward and reverse chain activities. For ITL, the company performs relatively well on eco-design and production but poorly on suppliers' environmental commitments and lacks a formal tractor endof-life recovery program.

20. Mitra & Datta (2014) showed that green purchasing and eco-design yield the most measurable performance returns among Indian manufacturers, with reverse logistics practices lagging significantly. This supports the identification of the reverse logistics gap at Sonalika

III. Research Objectives and Methodology

A. Research Objectives

- Map and analyze ITL's inbound, in-plant, and outbound logistics setup for sustainability opportunities and challenges.
- Examine how TREM IV, draft TREM V, and EU CBAM affect sourcing, production, and export logistics decisions.
- Identify SSCM and green logistics practices already in place at Sonalika and compare them to relevant literature and industry examples.
- Understand stakeholder views from dealers, logistics managers, and tractor users about green logistics, affordability, and regulatory pressures.
- Provide practical, context-specific strategic and operational recommendations for advancing SSCM without losing cost competitiveness.

B. Research Design and Data Collection

The study uses an exploratory qualitative case-study design. ITL/Sonalika was chosen because it blends large-scale, highly integrated manufacturing with a strong position in a cost-sensitive emerging market. This creates tension between environmental goals and affordability, making it an insightful case. The focus of analysis is the ITL supply chain centered on the Hoshiarpur plant.

Secondary data: Company disclosures, the ITL corporate website, press releases, and publicly available CSR reports were used for plant configuration, product portfolio, export footprint, and sustainability initiatives. Industry reports from ICRA (2024) and the Tractor and Mechanization Association (2022, 2024) provided market and regulatory context. Policy documents from the European Commission (2023) and the Ministries of Petroleum and Natural Gas and Jal Shakti (both 2018) outlined the regulatory framework. Fifty peer-reviewed works form Chapter 2.

Semi-structured interview: An in-depth interview was conducted with an authorized Sonalika dealer at Ghuman Automobiles, Hoshiarpur (J.S. Ghuman, personal communication, 2024), covering inbound and outbound logistics, inventory management, views on sustainability, and perceptions of electric and alternative-fuel tractors. Pilot questionnaire: A structured questionnaire targeted dealers, logistics partners, and tractor users on sustainability drivers and barriers. Fifteen responses were collected and analyzed qualitatively. The results cannot be statistically generalized but offer supportive evidence for the interview themes.

C. Data Analysis and Limitations

Document and content analysis: Secondary data were organized thematically around regulatory drivers, logistics configuration, green practices, and digital initiatives. Thematic analysis of interview and questionnaire responses identified recurring themes, such as cost sensitivity, infrastructure gaps, and limited awareness of advanced regulatory instruments through repeated readings. Analytical triangulation compared themes from primary data with secondary sources and literature findings.

Primary data are limited to one detailed dealer interview and fifteen pilot questionnaire responses. These do not capture the full diversity of dealers, farmers, or logistics partners across India. Access to ITL's internal emissions data, logistics cost breakdowns, and proprietary digital systems was not available. Quantitative emissions modeling is used for illustration rather than as a definitive measure.

IV. Indian Tractor Industry and Company Context

Annual domestic tractor sales exceeded eleven lakh units in 2024, making India the largest tractor market by volume (TMA, 2024). The growth from the previous year was about twenty percent, driven by government mechanisation subsidies, increasing rural wages, and more custom-hiring centres (ICRA, 2024). The market is dominated by a few players: Mahindra and Mahindra lead, while TAFE (Massey Ferguson and Eicher brands), ITL Sonalika, Escorts Kubota, and John Deere hold most of the remaining share. In FY2025, ITL sold 1,53,764 tractors and claimed a 14.8 percent all-India market share.

India's TREM standards have gradually become stricter, moving from basic limits on particulate and NOx emissions to alignment with international standards. TREM IV norms, which apply to tractors over 50 HP, now require electronic fuel injection and better exhaust management similar to EU Stage IIIB. Draft TREM V norms, currently being discussed as of early 2026, will likely impose similar standards on the 25-50 HP segment and align with EU Stage V and US Tier 4 Final. This might include requirements for common-rail direct injection (CRDi), electronic control units (ECUs), diesel particulate filters (DPF), and selective catalytic reduction (SCR) systems (TMA, 2024). Analysts predict that meeting full TREM V standards for smaller tractors could increase retail prices by fifteen to twenty percent (ICRA, 2024; TMA, 2024).

CBAM (EU Regulation 2023/956) began its transitional phase in October 2023, mandating quarterly reports on embedded emissions without financial consequences. Financial obligations will start in 2026. For ITL, whose Solis-branded tractors enter European markets, CBAM has indirect yet important implications. Although tractors are not on the initial CBAM product list, iron, steel, and aluminium are included. These materials make up a large part of tractor bill-of-materials. As ITL's European customers face CBAM costs for steel-intensive inputs, the demand for lower embedded-carbon supply chains will shift upstream. Accurate product-level carbon tracking and clear coordination with steel and aluminium suppliers are becoming essential for maintaining access to the competitive European market.

International Tractors Limited (ITL), the main company within the Sonalika Group, was founded in 1969. It sells tractors under the Sonalika brand in India and parts of Asia, and as Solis in Europe, the Americas, and parts of Africa, reaching over 150 countries. In FY2025, it reported sales of 1,53,764 tractors, a 14.8 percent all-India market share, and solid export volumes, maintaining its title as Asia's top tractor exporter for fourteen years in a row (ITL, 2024; self-reported).

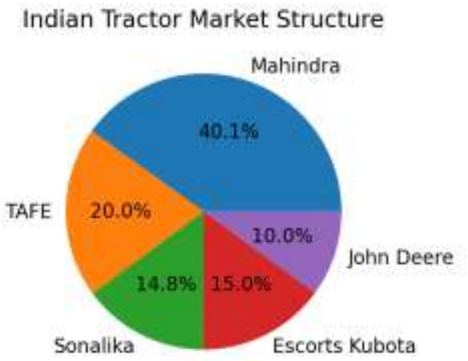

Figure 1: Market Share

The Hoshiarpur plant is known as the most integrated tractor manufacturing facility in the world (ITL, 2024), with an annual capacity of about three lakh tractors and an assembly rate of approximately one tractor every two minutes. The facility includes ten manufacturing departments: R&D, heavy machine shop, automated engine assembly, press shop, robotic PT-CED paint shop, transmission assembly, robotic gear shop, light machine shop, export tractor assembly, and final assembly. About 86 percent of tractor components - including crankcases, gear-box housings, gears, shafts, hydraulic valves, and sheet-metal parts - are produced on-site (J.S. Ghuman, personal communication, 2024). External suppliers provide tyres, bearings, driver seats, wiring harnesses, and certain electronics.

Sonalika's product line ranges from about 20 to 120 HP, including compact orchard tractors, standard agricultural and haulage models, and high-horsepower heavy-duty machines. ITL launched the Tiger Electric in 2020, promoted as India's first field-ready electric tractor. In European markets, the Solis 26 Electric was introduced. ITL has also announced and tested models running on compressed natural gas and compressed bio-gas, in line with the SATAT and GobarDhan initiatives, and the company makes straw-management tools that help integrate or collect post-harvest crop residue, reducing the economic reasons for open burning in Punjab and Haryana.

V. Supply Chain Mapping and Interpretation

Due to high vertical integration at Hoshiarpur, a significant portion of ITL's inbound logistics is internal, as components move between the plant's own departments rather than coming from outside vendors. External flows include tyres, bearings, wiring harnesses, selected electronics, seats, and specialized subsystems, which typically arrive by road in full truckloads from domestic suppliers or through ports at Nhava Sheva or Mundra. As upstream steel and aluminium come from Indian mills or international sources, ITL's Scope 3 Category 1 emissions (WBCSD/WRI, 2004) - resulting from purchased materials - may be considerable. However, no publicly available ITL disclosures provide detailed carbon-intensity data for the steel supply chain, which will be required for CBAM reporting.

Within Hoshiarpur, production follows a sequence through specialized departments. Heavy components are cast and machined in the foundry and heavy machine shop, gears and shafts in the robotic gear shop, sheet-metal parts in the press shop, engines in the automated engine plant, and transmissions in their dedicated assembly area. Chassis and body components move through the robotic PT-CED paint shop, which uses cathodic electrodeposition with lead-free, low-VOC coatings, offering environmental and quality benefits compared to standard spray painting. Having all manufacturing on one site cuts down on inter-facility freight but concentrates energy and emission impact at Hoshiarpur. This makes energy efficiency and renewable energy use crucial factors.

For domestic sales, finished tractors travel from Hoshiarpur to dealers by road. Within roughly 200-250 kilometres of the plant, covering all of Punjab, Himachal Pradesh, Jammu and Kashmir, and parts of Haryana, tractors are driven to dealerships by company drivers. For longer distances, multi-axle trailers transport eight to twelve tractors per load. Most long-haul domestic transport is managed by third-party logistics providers, including Holysoal and Bharat Transport. Last-mile delivery to rural dealerships relies entirely on road transport, reflecting the widespread geography of Sonalika's dealer network. Seasonal demand peaks during Kharif and Rabi sowing seasons create fluctuating patterns that make load planning challenging and lower average vehicle utilization.

ITL's export logistics are structured around a dedicated export assembly line and container dispatch. Tractors heading to international markets are either partially disassembled or configured to fit more efficiently into containers, usually accommodating eight tractors in a forty-foot container. A rail link within the Hoshiarpur plant allows containers to be loaded directly onto trains for transport to ports at Mundra and Kandla, avoiding long-haul road transport for most of the journey. The dealer estimates that daily export dispatch at full production involves 30 to 40 containers and one to three train trips. Rail transport provides lower per-tonne-kilometre emissions than road transport and offers price stability against diesel cost fluctuations.

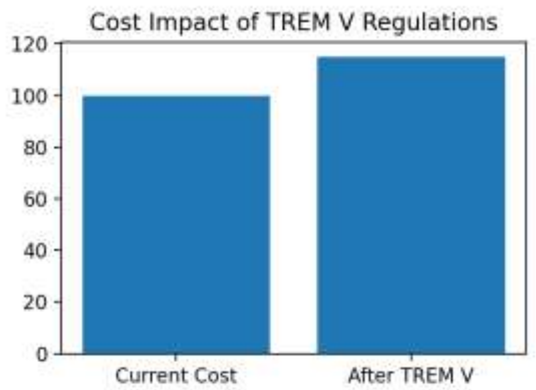

Figure 2: TREM Cost Impact

At the dealership level, inventory management largely depends on seasonal shifts and credit cycles rather than environmental factors. Some dealers have implemented green practices, such as solar power, waste-oil management, and water conservation, but these are not uniform or required by ITL. An interview with Ghuman Automobiles revealed that formal sustainability measures are still developing rather than established (J.S. Ghuman, personal communication, 2024).

ITL shows green logistics practices in several areas. Vertical integration is a structural environmental benefit. Fewer external supply relationships lead to fewer freight movements and reduced risk from supplier-related environmental issues. The robotic PT-CED paint shop stands out as a documented investment aimed at reducing emissions. The export assembly line and containerization strategy improve freight efficiency for international shipments. The rail connection at Hoshiarpur moves some export trunk-haul away from road transport. Crop-residue management and CBG tractor announcements contribute to reducing agricultural emissions at the product level. What is missing is just as important: there is no formal accounting of Scope 3 emissions for the upstream steel and aluminum supply chain, no systematic program promoting dealer-premises sustainability, and no structured system for recovering or remanufacturing tractors at the end of their life.

TREM IV and draft TREM V required redesigning engines for the over-50 HP category and will significantly increase material costs. Industry forecasts predict a 15-20 percent increase in retail prices (ICRA, 2024). CBAM focuses on embedded emissions in steel and aluminum, meaning ITL will need to document the carbon intensity of the steel used in tractors and attribute it at the product level for European customers. Together, these two regulatory pressures create a strong need for investments in digital emissions tracking and sourcing green steel to maintain access to the European market.

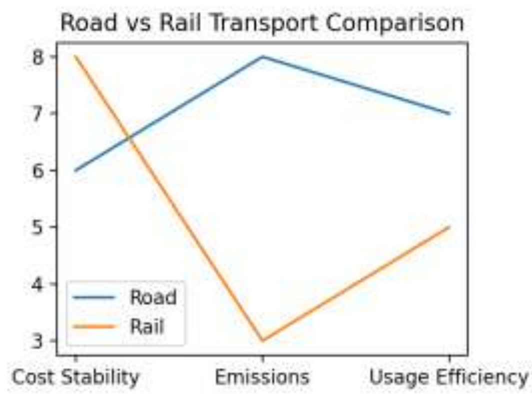

Figure 3: Road vs Rail

The rail connection at Hoshiarpur is likely underutilised for domestic trunk movements. The current configuration allows for eight tractors per forty-foot container, indicating room for improvement through better packing design and using high-cube containers. Adding transport-management system requirements into logistics provider contracts could help reduce emissions and costs without needing to replace vehicles or shift transport modes.

Tractors in India generally last between fifteen and twenty-five years, passing through several owners before entering the informal used-equipment market (TMA, 2022). High-value components, such as engines, transmissions, and hydraulic assemblies, retain considerable residual value throughout their lifespan and can be remanufactured to original specifications (Guide & Van Wassenhove, 2009). Three specific mechanisms can work: establishing regional remanufacturing hubs at or near high-volume service dealerships; creating structured trade-in programs through dealers; and collaborating with authorized metal recyclers to recover steel, aluminum, and copper from tractors that have genuinely reached the end of their service life.

Interviews with dealers and pilot questionnaires show a consistent set of themes. Dealers see a growing interest in sustainability from export customers, certain government procurement programs, and media attention on stubble burning. However, they report that individual purchase decisions are mainly driven by price, horsepower, fuel economy, and the quality of after-sales service. CBAM has not yet reached the dealership or farm level. Electric tractors spark genuine curiosity, but farmers have ongoing concerns about battery life, charging access, and higher prices. CNG/CBG models are interesting to those near CBG plants but face distribution challenges. Residue management tools seem commercially promising, but smallholder economics are tight without subsidies or custom hiring options.

Figure 4: Stakeholder Factors

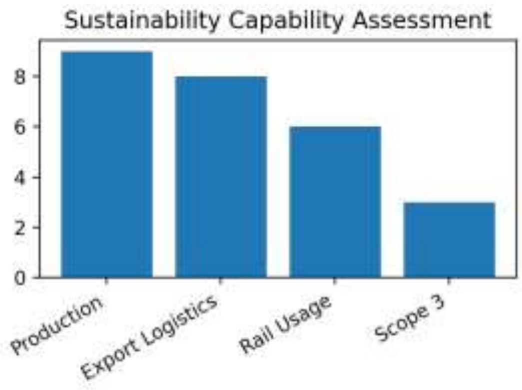

Figure 5: Sustainability Gap

VI. Findings, Discussion and Conclusion

The Sonalika case supports several ideas from the SSCM literature. Vertical integration, paired with intentional environmental management, provides supply chain environmental benefits that go beyond what individual supplier programs can achieve. This aligns with the resource-based view presented by Barney (1991). Coercive pressures, especially TREM IV and CBAM, are the main triggers for ITL's sustainability investments, confirming findings from institutional theory by Dubey et al. (2017). Stakeholder diversity is evident; regulators and European customers want lower embedded carbon, while Indian farmers focus on lower prices and better fuel efficiency. An effective strategy must manage this tension rather than suppress it. However, the case diverges from optimistic SSCM recommendations concerning the upstream and downstream chains. Vachon and Klassen (2006) showed that internal environmental management alone cannot yield comprehensive sustainability outcomes; collaboration with upstream and downstream partners is essential. Currently, ITL's sustainability efforts focus mainly on the Hoshiarpur plant.

Three constraints differentiate the Indian tractor context from the general manufacturing-sector SSCM literature. Price sensitivity is extremely high; even a five percent price increase can significantly affect affordability for marginal farmers who often finance purchases through costly agricultural credit. There is also a lack of charging infrastructure for electric vehicles in the districts where most tractors operate. Supplier capability is inconsistent. Many tier-two and tier-three vendors do not have the IT systems or management capacity to implement emissions reporting, much less determine carbon footprints at the product level. These constraints do not render green logistics investment unfeasible, but they do mean that recommendations should be gradual, starting with steps that offer immediate commercial benefits before moving to more transformative initiatives.

ITL's blend of an integrated plant, an export focus, rail connections, and early investments in electric and alternative-fuel technologies gives it a better position for the SSCM transition than a more fragmented competitor. Moving from this foundation to a truly integrated SSCM strategy requires three areas ITL has yet to fully develop: a product-level carbon accounting system to meet CBAM reporting needs, a formal program to engage upstream steel suppliers on emissions data, and a structured system for reverse logistics and remanufacturing that extracts value from the long life of tractors in the Indian market.

This study aimed to understand how a leading Indian tractor manufacturer can connect its supply chain and logistics with sustainability goals while maintaining cost efficiency for its main market. For ITL Sonalika, the foundational structure is solid, but the digital and circular-economy aspects are lacking. The Hoshiarpur plant, known for its high vertical integration, rail connections, containerized export assembly, and investments in low-emission manufacturing, is better suited for the transition to sustainable supply chain management than most Indian tractor manufacturers. Real challenges exist, such as the lack of Scope 3 carbon data, limited supplier involvement on emissions, insufficient reverse logistics, and gaps in rural infrastructure for electric tractors, but these can be addressed in a phased program over the next three to five years.

Evidence from dealer interviews and pilot questionnaires shows that the reality on the ground does not match the corporate sustainability message: purchasing decisions are primarily driven by price, and regulatory changes like CBAM are largely unknown to dealers. This gap between corporate objectives and supply chain operations reflects trends observed in the Indian automotive sector by Shukla, Deshmukh, and Kanda (2009).

Research Objective 1, which involved mapping ITL's logistics setup, was met through the analysis of secondary data and dealer interviews detailed in Chapters 5 and 6. Research Objective 2, examining how TREM and CBAM affect strategy, was covered through policy and industry report analysis in Chapter 4, with practical implications developed in Chapter 7. Research Objective 3, identifying existing sustainable supply chain management practices and benchmarks, was accomplished in the Chapter 7 mapping exercise, evaluating ITL's maturity against the Olugu, Wong, and Shaharoun (2011) indicator framework. Research Objective 4, gathering stakeholder views, was achieved qualitatively through the dealer interview and a pilot questionnaire with 15 respondents. Research Objective 5, offering appropriate recommendations, is addressed below.

A. Recommendations for Sonalika-ITL

Recommendation 1: Build Digital Emissions Visibility. ITL should implement transport management and telematics systems to track route efficiency, vehicle use, and fuel consumption for outbound logistics along domestic trunk routes. Simultaneously, ITL should start product-level carbon accounting for steel-heavy components by choosing two or three main steel suppliers and collaborating with them to measure and report embedded emissions per tonne. This manageable first step will help build supplier capability and provide insights before financial obligations related to CBAM take effect.

Recommendation 2: Scale Rail and Intermodal Freight. A detailed analysis should identify domestic corridors, likely in Maharashtra, Telangana, and Karnataka, where rail-based dispatch is more cost-effective than road transport. For export shipments, ITL should work with Indian Railways to increase the frequency of rake allocations and optimize rail scheduling to sync with port departures. Adjusting packing configurations should aim to fit nine or ten tractors into a forty-foot container whenever the model dimensions allow.

Recommendation 3: Pilot Circular Economy and Remanufacturing. ITL should launch a three-year pilot program focused on component remanufacturing, starting with engines and transmissions collected through dealer trade-ins at four or five high-volume dealerships in Punjab, Haryana, and western Uttar Pradesh. The economics of the pilot should be carefully monitored to assess its viability before scaling up. Additionally, ITL should engage with at least one certified metal recycler to create a clear and verifiable pathway for recovering steel, aluminum, and copper.

Recommendation 4: Target Electric and CNG/CBG Deployment. A specific focus strategy is more realistic than a widespread launch due to infrastructure challenges. Institutional buyers, such as state government farms, agricultural universities, sugar cooperatives, and peri-urban horticulture operations, should be the primary targets for electric tractor deployment, as they generally have the necessary charging infrastructure and stand to gain from lower operating costs with high usage rates. CNG/CBG tractor variants should be promoted in districts with a strong presence of CBG plants, including parts of Punjab, Haryana, Gujarat, and Maharashtra.

Recommendation 5: Deepen Supplier and Dealer Engagement. ITL should create a structured supplier engagement program focused on sustainability for its major steel and aluminum suppliers. This program should include a shared template for data on energy and process emissions, joint workshops to develop measurement methods, and a multi-year plan for reducing supplier emissions that aligns with ITL's own reporting needs for CBAM. For dealers, a sustainability certification program covering solar installations, waste oil collection, and water conservation could help bridge the gap between corporate sustainability goals and actual field operations.

B. Directions for Future Research

Four research pathways arise from the limitations of this study: (1) develop a quantitative model for freight emissions using actual vehicle fleet data for ITL's main domestic and export routes; (2) conduct a larger survey of dealers, logistics providers, and farmers, aiming for at least 200 respondents across three Indian states to gather statistically significant insights on sustainability awareness; (3) perform a techno-economic feasibility study on remanufacturing tractor engines and transmissions in India; and (4) conduct a comparative case study on sustainable supply chain management across several Indian tractor manufacturers, including Mahindra, TAFE, and Escorts Kubota, to facilitate benchmarking and identify opportunities for shared learning.

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