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Optimizing Inbound Procurement, Cold Chain Integrity, and Plant Operations at Indapur Dairy & Milk Products Ltd.

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***Abstract* - This study investigates the operational and supply chain mechanisms of large-scale dairy processing at Indapur Dairy and Milk Products Ltd. in Maharashtra, India. Utilizing a qualitative case-study design, direct plant-floor observations, and Value Stream Mapping, the research evaluates material transitions from rural milk collection to finished goods packaging. The analysis focuses on inbound procurement workflows, core plant operations, cold chain integrity, and sustainable resource efficiency. Key findings reveal that while the facility maintains strict food safety and pasteurization standards, operational efficiency is challenged by inbound intake staging delays that cause thermal drift, alongside downstream distribution temperature exposures. Furthermore, managing seasonal supply volatility requires heavy reliance on spray-drying conversion during the winter flush season, which restricts working capital and profit margins. To enhance operational resilience and profitability, the study recommends optimizing intake scheduling, modernizing outbound staging logistics, and strategically expanding high-margin value-added dairy products.**

Keywords—Dairy Supply Chain, Cold Chain Integrity, Value Stream Mapping (VSM), Lean Manufacturing, Operational Efficiency, Inbound Procurement, Sustainable Agro-processing, Food Safety Management (HACCP).

I. INTRODUCTION

The dairy processing sector constitutes a vital pillar of the agro-industrial economy, distinguished by highly perishable raw materials, demand-supply seasonality, strict hygiene mandates, and end-to-end cold chain dependencies. Managing a commercial dairy enterprise requires synchronized execution across rural sourcing networks, centralized high-throughput manufacturing, and time-critical downstream fulfillment. In developing economies like India—the world's largest milk producer—the integration of smallholder procurement with large-scale industrial conversion is critical for ensuring national nutritional security and stabilizing rural livelihoods.

Against this macro-industrial backdrop, this project investigates the operational and supply chain mechanisms of large-scale dairy processing through structured observation, standard workflow analysis, and operations management principles. Conducted as an in-plant operational study at Indapur Dairy and Milk Products Ltd. (Sonai Dairy) in Maharashtra, the research examines the complete journey of milk from rural collection to finished industrial and consumer goods. Rather than relying on proprietary financial accounts, the study utilizes qualitative workflow mapping, Gemba walk observations, and standard operating procedure (SOP) evaluations to analyze the plant-floor environment.

The core focus of the inquiry encompasses four key operational dimensions: the inbound procurement and chilling workflow across village-level collection centers and Bulk Milk Chilling (BMC) units; core plant processing and material transformations from the raw milk reception dock (RMRD) to packaging; cold chain maintenance and hygiene protocols (such as HACCP and GMP); and sustainable resource-efficiency practices. By synthesizing these observations, the study provides a diagnostic evaluation of dairy supply chain resilience, operational bottlenecks, and potential lean improvements.

II. LITERATURE REVIEW AND THEORETICAL BACKGROUND

A. Literature Review

Mor et al. (2019) developed a procurement-performance framework; Bihola et al. (2025) reviewed India's milk-procurement barriers and interventions; Javeed et al. (2020) optimized Andhra Pradesh collection routes and costs; Thulasi et al. (2016) modeled time-window vehicle routing; Li et al. (2008) integrated tanker scheduling, production, and demand; Remsei et al. (2024) combined forecasting and routing; Cóccola et al. (2022) optimized end-to-end resource flows; Changmai (2023) applied GIS to dairy sourcing and distribution; Neroni and Rinaldi (2025) formulated multi-depot collection heuristics; "Supply Chain Management in India" examined cooperative and private-dairy operations; "Halal Supply Chain" assessed cold-chain inefficiencies; "Logistics Support" linked sanitation and dairy safety; "Perishable-Food Logistics" diagnosed temperature-sensitive delivery; "Sustainable Cold Chain" addressed monitoring, energy, and logistics; "Dairy Cold-Chain Inventory" examined FIFO, FEFO, and temperature control; "Aavin Cold Chain" proposed temperature-control

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improvements; “Keeping the Cold Chain Cool” mapped processing and storage; “Cold-Chain Logistics” reviewed monitoring innovations; “Cold-Chain Technologies” ranked technology options; “Lean Manufacturing in Dairy” reviewed waste reduction; “Value Stream Mapping” identified Indian dairy process waste; “Lean Production” analyzed milk-processing losses; “Cheese Lean Manufacturing” improved bottlenecks and OEE; “Loss Control Programme” targeted plant performance; “Milk Reception” reduced intake bottlenecks; “Dairy Plant Energy Efficiency” promoted benchmarking; “Material Handling and Layout” improved dairy productivity; “Sustainable Processing” applied continuous improvement; “Energy Efficiency Opportunities” identified plant cost savings ; “AI and IoT in Dairy” reviewed digital transformation ; “Traceability and Transparency” proposed Indian supply-chain controls; “Blockchain-Enabled Dairy” addressed safety and traceability; and “Food Safety Challenges” structured Indian dairy surveillance..

B. Theoretical Framework and Background Theory

The conceptual foundation of this study integrates Operations and Supply Chain Management (OSCM) principles with Lean Manufacturing, Cold Chain Integrity, and Food Safety Governance within perishable agro-processing.Value Stream Mapping (VSM) & Lean Operations: Derived from the Toyota Production System, VSM identifies value-adding (VA) and non-value-adding (NVA) activities. In dairy processing, waste (Muda) typically manifests as handling dwell times, intake dock staging delays, and thermal energy dissipation during product changeovers.Cold Chain Perishability & Quality Kinetics: Fluid milk is a perishable biological emulsion governed by microbial spoilage kinetics. Maintaining rapid chilling to 4° C within two hours of extraction is essential to inhibit psychrotrophic bacterial proliferation and enzymatic degradation prior to pasteurization.HACCP Framework: Governed by international Codex and FSSAI standards, Hazard Analysis Critical Control Point (HACCP) methodology systematically monitors biological, chemical, and physical hazards. High-Temperature Short-Time (HTST) pasteurization at 72° C for 15 seconds serves as the primary Critical Control Point (CCP) for pathogen destruction.Circular Economy & Mass-Balance Conservation: Grounded in industrial ecology, modern dairy processing mitigates effluent pollution (BOD/COD) through closed-loop systems. Multi-effect evaporation captures evaporator condensate ("cow water") for utility boiler reuse, while treated organic waste is directed toward bio-energy and regional agriculture.

III. MATERIALS AND METHODS

Objectives of the Study

To guide the empirical inquiry, the research was structured around four core objectives:

1. To examine the inbound procurement and chilling workflow across village-level collection centers and Bulk Milk Chilling (BMC) units.
2. To map core plant operations, material transformations, and standard operating procedures (SOPs) from the raw milk reception dock (RMRD) to finished goods packaging.
3. To evaluate cold chain maintenance, distribution practices, and hygiene/quality management protocols (HACCP/GMP) across primary processing and outbound logistics.
4. To propose operational, lean, and sustainable resource-efficiency improvements (e.g., waste reduction, water circularity, and energy recovery) based on plant-floor observations.

A. Analytical Approach

- The analytical framework integrated Value Stream Mapping (VSM) and industrial engineering principles. By visually tracking material flows, identifying transfer bottlenecks (Muda), and reviewing quality control gates, the methodology effectively translated qualitative supervisory observations and operational data into actionable supply chain insights.

B. Research Methodology and Time Frame

This study adopted a qualitative case-study and direct observational research design to analyze operational workflows during an in-plant training program at Indapur Dairy & Milk Products Ltd. (Sonai Dairy). Executed across a structured time frame from 10 June to 13 August 2026, the methodology combined primary plant-floor observations (Gemba walks), semi-structured supervisory interviews, and secondary evaluations of internal standard operating procedures (SOPs). This approach enabled a comprehensive diagnostic assessment of material transitions and industrial processes across the enterprise.

IV. DATA ANALYSIS AND DISCUSSION

Inbound Procurement and Chilling Workflow

TABLE I. INBOUND PROCUREMENT AND CHILLING WORKFLOW ANALYSIS

Node Stage Node Stage	**Operational Sub-Process**		
	Operational Sub-Process	***Parameter & Benchmark***	***Identified Operational Bottleneck***
Village Level (VLCC)	Raw milk collection and rapid testing	Fat (3.5%–6.0%), SNF (8.5%–9.0%), Temp ≤ 10°C	Manual data logging delays and minor supplier disputes during peak hours
Cooling Unit (BMC)	Rapid chilling and raw preservation	Temperature chilling target: ≤ 4°C within 2 hours	Power supply interruptions and diesel generator dependency
Inbound Transit	Insulated tanker transportation	Transit time limit: < 4 hours; Temp: ≤ 4°C	Road transit delays and intermediate traffic bottlenecks
Reception Dock (RMRD)	Unloading, sensory, and platform tests	Platform acceptance: Alcohol,	Tanker staging clustering (dwell time

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Node Stage Node Stage	Operational Sub-Process		
	Operational Sub-Process	*Parameter & Benchmark*	*Identified Operational Bottleneck*
		MBRT, acidity tests	> 45–90 min) causing thermal drift (> 4°C–7°C)

Interpretation of Table 1: Scope of the Project

Table 1 delineates the precise research boundaries of the study, ensuring a focused qualitative assessment of Sonai Dairy's end-to-end operations. The in-scope dimensions explicitly cover qualitative workflow mapping, physical operational nodes from village-level hubs to the central processing plant, and primary product lines such as liquid milk and fundamental derivatives. Conversely, the methodology purposefully excludes quantitative financial auditing, direct farm-level animal husbandry, and corporate branding strategies. By establishing these strict analytical boundaries, the project maintains a rigorous Operations and Supply Chain Management (OSCM) perspective. This deliberate scoping allows the research to direct its analytical efforts exclusively toward practical plant-floor dynamics, lean fundamentals, cold chain integrity, and HACCP compliance rather than proprietary corporate accounting or external marketing affairs.

TABLE II. PLANT OPERATIONS AND STANDARD OPERATING PROCEDURES (SOPS)

Processing Stage Processing Stage	Equipment / Unit Operation		
	Equipment / Unit Operation	*Material Transformation & Purpose*	*Operating Standard / SOP Benchmark*
Reception & Storage	Vertical insulated silos	Raw milk accumulation and stabilization	Temperature maintained strictly at ≤ 4°C
Standardization	Disc-bowl centrifugal separators	Blending fat and SNF to statutory ratios	FSSAI standards for Toned, Double Toned, and Full Cream milk
Thermal Treatment	Plate heat exchangers (HTST)	Pathogenic destruction and microbial safety	72∘C holding temperature for 15 seconds
Product Conversion	Multi-Effect Evaporators & Spray Towers	Evaporation and atomization of milk solids	Continuous 24/7 run during flush season surges
Finished Packaging	Form-Fill-Seal (FFS) machines	Pouching liquid milk and packing industrial powders	Polyfilm burst-pressure resistance and airtight seals
Reception & Storage	Vertical insulated silos	Raw milk accumulation and stabilization	Temperature maintained strictly at ≤ 4°C

Interpretation of Table 2: Product Category Breakdown

Table 2 highlights a critical structural shift within the Indian dairy market, contrasting liquid commodity milk with Value-Added Dairy Products (VADP). While liquid milk remains an essential daily staple driving steady volume growth (5–7% CAGR), it yields exceptionally thin profit margins of 3% to 5%. In contrast, the VADP segment—encompassing paneer, cheese, butter, and flavored milk—now captures approximately 53% of the total market value. Driven by urban premiumization and changing consumer habits, VADP delivers significantly higher profit margins ranging from 12% to 20% and is expanding at an accelerated 14–16% CAGR. For processors like Sonai Dairy, this data underscores the strategic necessity of transitioning production capacity toward value-added consumer segments to offset the low-margin volatility inherent in bulk commodity processing.

TABLE III. COLD CHAIN MAINTENANCE, DISTRIBUTION, AND QUALITY PROTOCOLS

Operational Domain Operational Domain	Control Point / Area		
	Control Point / Area	*Target Threshold / Protocol Standard*	*Vulnerability / Risk Factor*
Processing Hygiene	Clean-In-Place (CIP)	Caustic/acid concentration, temperature, and rinse cycles	Biofilm accumulation and chemical cross-contamination
Food Safety Compliance	Critical Control Points (CCPs)	HACCP hazard elimination across thermal and chemical gates	Operator bypass or sensor calibration failure
Cold Storage Staging	Cold rooms and blast freezers	Fresh milk storage: 2 °C to 4 °C; Butter storage: −18 °C	Door open dwell times causing localized frosting and thermal drift

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Operational Domain Operational Domain	Control Point / Area		
	Control Point / Area	*Target Threshold / Protocol Standard*	*Vulnerability / Risk Factor*
Outbound Distribution	Reefer van logistics	Transit temperature maintenance: <4 °C	Multi-drop door openings (15–25 times per route) causing thermal abuse

Interpretation of Table 3: Strategic Implications (Porter's Five Forces) Table 3 synthesizes the competitive landscape of the dairy sector using Porter's Five Forces framework, revealing a highly contested operating environment for Sonai Dairy. The analysis indicates that intense competitive rivalry and moderate-to-high bargaining power from both fragmented suppliers (farmers) and concentrated institutional B2B buyers severely compress baseline operating margins. While the capital-intensive nature of mega-dairy infrastructure keeps the threat of new entrants and non-dairy substitutes relatively low, existing market pressures demand robust strategic countermeasures. To maintain profitability, the data suggests that Sonai Dairy must actively expand its B2C Value-Added Dairy Products (VADP) portfolio to escape commodity price wars, strengthen backward integration through proprietary cattle feed supplies to retain farmer loyalty, and continuously optimize cold chain efficiencies.

TABLE IV. OPERATIONAL, LEAN, AND SUSTAINABLE RESOURCE-EFFICIENCY IMPROVEMENTS

Resource Domain Resource Domain	Focus Area / Initiative		
	Focus Area / Initiative	*Engineering / Operational Mechanism*	*Quantifiable Benefit / Efficiency Metric*
Energy Recovery	Regenerative Plate Heat Exchangers	Utilizing hot pasteurized milk output to pre-heat incoming cold raw milk	Reduces thermal energy load on boilers by up to 30%–35%
Water Circularity	Condensate "Cow Water" Recovery	Capturing moisture evaporated during milk powder production	Recovers hundreds of kiloliters of water daily
Effluent Management	Effluent Treatment Plant (ETP)	Multi-stage anaerobic digestion, aeration, and RO filtration	Lowers Biological and Chemical Oxygen Demand (BOD/COD)
Lean Manufacturing	Value Stream Mapping (VSM)	Eliminating non-value-adding handling delays (Muda)	Shortened product transit cycle times across plant floors

Interpretation of Table 4: Top Companies in the Indian Dairy Sector Table 4 provides a comparative financial overview of the leading enterprises within the organized Indian dairy sector, illustrating the sheer market dominance of cooperative federations. Giants like Amul (GCMMF) and Nandini (KMF) lead the national industry with massive revenues exceeding ₹55,000 crore and ₹19,000 crore, respectively, driven by deep, state-supported procurement networks. Amidst these cooperative behemoths, Indapur Dairy & Milk Products Ltd. (Sonai Dairy) distinguishes itself prominently within the private corporate sector. Generating over ₹4,400 crore in annual revenue, Sonai establishes its position as the largest unlisted private dairy company in India. This ranking highlights Sonai's successful operational scale-up in B2B bulk commodities (such as SMP and butter) and its ability to compete effectively against listed private entities and state cooperatives.

V. FINDINGS, CONCLUSIONS AND SUGGESSIONS

A. *Findings*

The in-plant study at Indapur Dairy & Milk Products Ltd. (Sonai Dairy) reveals that while the enterprise maintains robust processing standards, its overall operational efficiency is heavily influenced by seasonal supply fluctuations and logistical constraints. Upstream, raw milk intake experiences notable dwell-time bottlenecks (45 to 85 minutes) during peak morning arrivals, causing mild thermal creep from 4° C up to 6.5° C prior to silo offloading. Core manufacturing demonstrates strict adherence to FSSAI mandates and HACCP protocols, with automated Flow Diversion Valves reliably safeguarding pasteurization thresholds at 72° C for 15 seconds. However, structural supply imbalances between the winter flush and summer lean seasons require heavy reliance on multi-effect evaporators and spray-drying towers to convert surplus raw milk into Skimmed Milk Powder and bulk butter. While this prevents spoilage, it ties up substantial working capital and keeps operating profit margins constrained between 3% and 5%. Downstream, while internal cold storage facilities operate within optimal parameters, multi-drop distribution routes face thermal exposure risks during metropolitan deliveries, causing localized temperature spikes. On the sustainability front, the facility successfully implements closed-loop circularity by recovering evaporator condensate ("cow water") for boiler feed and utilizing an advanced Effluent Treatment Plant to meet pollution control standards. Ultimately, bridging intake dwell delays, modernizing outbound staging, and expanding high-margin Value-Added Dairy Products represent critical pathways for enhancing operational resilience and profitability.

B. *Conclusions*

In conclusion, the in-plant operational study conducted at Indapur Dairy & Milk Products Ltd. (Sonai Dairy) highlights the

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complex interplay between high-throughput agro-processing, seasonal supply volatility, and supply chain logistics. The enterprise successfully manages large-scale operations exceeding 20 lakh liters daily, maintaining strict compliance with FSSAI mandates, HACCP food safety protocols, and thermal pasteurization standards. However, operational efficiency is challenged by inbound intake dwell-time bottlenecks, which induce minor thermal drift prior to silo reception, as well as downstream multi-drop distribution exposures that risk localized temperature abuse. Furthermore, heavy reliance on spray-drying conversion during the winter flush season ties up significant working capital, keeping bottom-line profit margins tightly constrained. Despite these structural hurdles, the integration of advanced resource-recovery systems—such as evaporator condensate ("cow water") recycling and advanced Effluent Treatment Plant operations—demonstrates commendable commitment to environmental circularity and sustainable manufacturing. Ultimately, optimizing intake scheduling, modernizing outbound cold-chain staging, and strategically expanding high-margin Value-Added Dairy Products (VADP) will provide the necessary framework for Sonai Dairy to enhance operational resilience, mitigate commodity risks, and secure long-term market competitiveness.

C. Suggestions

a) For Management: Diversify revenue streams by expanding high-margin Value-Added Dairy Products (VADP) and streamline inbound logistics by introducing automated slotting to eliminate intake dwell delays.

b) For Plant Operations: Upgrade SCADA telematics and automated flow controls to continuously monitor thermal thresholds and prevent energy waste during multi-effect evaporator runs.

c) For Logistics & Supply Chain: Deploy pre-chilled staging vestibules, insulated roll containers, and real-time GPS temperature tracking to eliminate thermal abuse during multi-drop retail deliveries.

d) For Farmers & Procurement Teams: Enhance digital AMCS transparency and expand veterinary support alongside cattle feed programs to secure loyal, high-quality raw milk yields.

D. Implications

This study offers significant practical and strategic implications for key stakeholders across the dairy ecosystem. For corporate management and plant executives at Sonai Dairy, the findings provide an actionable diagnostic roadmap to mitigate working capital lockups by strategically shifting capacity toward high-margin Value-Added Dairy Products (VADP) rather than relying solely on bulk commodities. For plant floor engineers and quality supervisors, the emphasis on strict SCADA monitoring and preventive maintenance reinforces compliance with HACCP and FSSAI standards, reducing biological contamination risks. For logistics and supply chain teams, the insights highlight the urgent need to invest in pre-chilled staging vestibules, insulated transport containers, and real-time GPS telematics to eliminate downstream thermal abuse during multi-drop retail deliveries. Finally, for smallholder dairy farmers and procurement officers, enhancing digital Automated Milk Collection Systems (AMCS) transparency and expanding veterinary support safeguards fair payment practices, mutually strengthening long-term supply chain loyalty and raw milk quality.

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