



TNPL's Approach for Future-Ready Paper Manufacturing



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Abstract: *The global pulp and paper industry is undergoing a major transformation driven by environmental regulations, resource constraints, changing customer expectations, climate concerns, and rapid technological advancement. Traditional paper manufacturing, which has historically been associated with high energy demand, intensive water use, and dependence on virgin forest-based fibres, is steadily shifting toward sustainable, circular, and technology-enabled manufacturing systems. In this context, the concept of a future-ready paper industry has emerged as a strategic imperative, with emphasis on policy alignment, sustainability integration, and technology convergence. This paper presents a case study of Tamil Nadu Newsprint and Papers Limited (TNPL), India's pioneering bagasse-based integrated paper manufacturer, and highlights its transition toward sustainable manufacturing through circular economy practices, renewable energy integration, and digital transformation. The study examines TNPL's SEQPC framework—Safety, Eco-Friendly, Quality, Productivity, and Conservation—as a holistic operational philosophy that supports manufacturing excellence. The paper also discusses the role of ERP integration, wireless predictive monitoring, AI-enabled workforce systems, automated quality testing, and digital supply chain management in building operational resilience and competitiveness.*

Keywords: Digital Twin, Artificial Intelligence, Process Optimisation, Break Reduction, Paper Machine.

Introduction

The pulp and paper industry plays a significant role in socio-economic development by supporting education, packaging, healthcare, hygiene, and a wide range of industrial applications. Despite increasing digitalization, paper products remain indispensable because of their recyclability, biodegradability and versatility [1]. However, the sector continues to face challenges associated with high resource consumption, carbon emissions, environmental compliance, and sustainability pressure [2]. As a result, future competitiveness increasingly depends on the integration of sustainability, policy alignment, and advanced technologies into manufacturing systems. In India, the industry is witnessing a major transition driven by demand for sustainable packaging, plastic substitution, and circular economy initiatives [3]. In this evolving landscape, TNPL stands out as a pioneer in eco-friendly papermaking through Bagasse-based production, renewable energy adoption, and sustainable raw material sourcing. TNPL also envisions achieving a production capacity of over one million MT per annum by 2030 through continuous innovation, operational excellence, employee inclusivity, environmental stewardship, and technology convergence.

TNPL's SEQPC Policy Framework as a model for a Future-Ready Industry

Sustainable industrial growth requires a balanced approach that simultaneously emphasizes employee safety, environmental responsibility, product quality, operational efficiency, and conservation of natural resources. Recognizing the interdependence of these dimensions, TNPL has institutionalized an integrated operational philosophy known as SEQPC: Safety, Eco-Friendly, Quality, Productivity, and Conservation. The framework forms the foundation of TNPL's operational excellence and sustainability strategy. Rather than functioning as independent priorities, these five pillars are embedded in day-to-day manufacturing operations to improve process reliability, environmental performance, operational efficiency, and long-term competitiveness.

Safety: Building a Proactive Safety Culture

Industrial safety has evolved from a compliance requirement into a strategic business priority that directly affects productivity, employee well-being, operational continuity, and sustainability performance. At TNPL, safety is regarded as a long-term investment, as reflected in the principle: "Safety is not an

expense; it is an investment.” This philosophy underscores the organization’s commitment to accident prevention, employee well-being, and workplace safety excellence.

Occupational Health and Safety Management

To strengthen workplace safety standards and enhance compliance readiness, TNPL implemented and obtained certification under ISO 45001:2018 Occupational Health and Safety Management System [4] within a short period of time, demonstrating strong commitment toward safety excellence. The system supports hazard identification and risk assessment, risk mitigation and preventive controls, workplace safety improvement, regulatory compliance, incident prevention, and continual improvement.

Internal Safety Audits

A strong internal audit culture is essential for identifying operational risks before they develop into incidents. TNPL conducts periodic internal safety audits to evaluate workplace hazards, equipment safety, procedural compliance, and opportunities for risk reduction. These assessments

strengthen preparedness, improve compliance, and help reduce accident probability through preventive intervention.

Near-Miss and Unsafe Act/Condition Reporting Systems

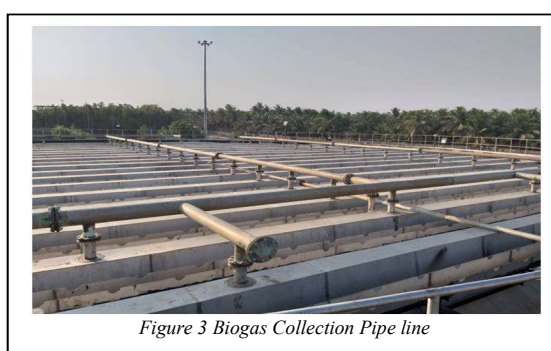
TNPL has institutionalized mill-wide reporting systems for identifying and addressing near-miss incidents, unsafe acts, and unsafe conditions. Near-miss events are those that could have caused injury, equipment damage, or operational disruption, while unsafe acts and conditions refer to human behaviors or workplace situations that may contribute to accidents. The reporting system supports early hazard detection, employee participation, preventive action, and continual improvement, reflecting a transition from reactive safety management to a predictive and preventive safety culture.

Eco-Friendly Paper Manufacturing Practice

Environmental sustainability is a major pillar of TNPL’s SEQPC philosophy. Unlike conventional paper manufacturing models that depend predominantly on virgin wood resources, TNPL follows a production approach centered on resource efficiency, circularity, renewable energy integration, and pollution minimization.

Table 1 – Details of Eco-friendly practices		
S.No	Particulars	GHG Emission reduction
1	Thermal Energy Saved by Bagasse Pith	89423t CO ₂ e/Annum
2	Furnace oil Saving by using Biogas in lime kiln	14837 t CO ₂ e/Annum
3	Lime Stone Conserved by Using 1 st lime sludge in Cement Plant	28898t CO ₂ e/Annum
4	Thermal Energy Conserved by CO ₂ Sequestration in PCC Plant	22000 t CO ₂ e/Annum
5	Usage of biogas in the heating equipment	6570 t CO ₂ e/Annum

The organization uses bagasse (Figure 1), recycled fibre, and optimized hardwood consumption to reduce dependence on forest-based resources. In parallel, TNPL promotes circular economy principles through waste utilization such as cement manufacturing (Figure 2) from industrial waste, chemical recovery systems, and enhanced resource reuse across operations. Sustainability performance is further strengthened through wind power generation, bio-fuel utilization, biogas-based energy systems (Figure 3) & (Figure 4), water reuse, energy-efficient operations, and carbon reduction initiatives (Table 1).



Quality Excellence: A Strategic Differentiator

In competitive paper markets, consistent product quality is a critical differentiator influencing customer satisfaction, product reliability, brand reputation, and long-term competitiveness. At TNPL, quality is treated as a strategic priority rather than only a manufacturing output parameter. The organization is committed to achieving nil customer complaints (Table 2) through continuous quality improvement, supported by process control, testing accuracy, root-cause analysis, and corrective action systems.

Quality Assurance through Technology

A future-ready paper industry requires testing systems that deliver rapid, reliable, and repeatable quality measurements to ensure process stability and product consistency. TNPL uses the Auto Paper Lab, one of the most advanced automated paper testing systems in the pulp and paper industry. It is employed for physical property testing, quality consistency monitoring, cross-directional analysis across the deckle, and real-time production feedback and correction. The system is aligned with ISO and BIS requirements, and regular calibration is coordinated with the Original Equipment Manufacturer to maintain accuracy and repeatability. The automated platform reduces manual intervention, increases test frequency, improves measurement confidence, and enables faster decision-making by transferring results directly to production teams. Output from all three paper machines can be evaluated in less than thirty minutes, and the results are integrated into an ERP-based online platform for immediate corrective action.

Advanced Paper Testing Modules

The Auto Paper Lab (Figure 5) incorporates 12 testing modules and can evaluate more than 33 physical paper properties across the deckle within approximately 7–9 minutes. Major modules include basis weight, caliper, burst strength, tear strength (MD and CD), tensile strength (MD and CD), tensile stiffness, fiber orientation analysis, smoothness testing by the Bendtsen method, porosity testing, and UV color measurement. This capability provides valuable insight for process optimization, defect identification, and quality consistency improvement.



Figure 5 Image of Auto Paper Lab

Productivity: Driving Operational Excellence

Productivity is a critical determinant of manufacturing competitiveness and operational excellence in the pulp and paper industry. Sustained productivity improvement enhances operational efficiency, profitability, market responsiveness, and long-term business sustainability. During the recent financial year, TNPL achieved its highest-ever paper and board production levels across Unit I and Unit II, (Table 3) reflecting strong operational discipline, efficient resource utilization, technology-enabled process optimization, and workforce commitment. This performance demonstrates TNPL's ability to maximize asset utilization while maintaining quality and sustainability standards.

Conservation: Resource Stewardship for Sustainable Growth

Resource conservation forms the final pillar of the SEQPC philosophy and reinforces TNPL's commitment to sustainable resource management and long-term environmental stewardship.

Table 2 – Details of Customer Complaint Index

S.No	Year	(No. of Complaints/1000 MT)
1	2014 - 2015	0.20
2	2015 - 2016	0.17
3	2016 - 2017	0.14
4	2017 - 2018	0.12
5	2018 - 2019	0.09
6	2019 - 2020	0.10
7	2020 - 2021	0.05
8	2021 - 2022	0.05
9	2022 - 2023	0.06
10	2023 - 2024	0.07
11	2024 - 2025	0.07
12	2025 – 2026	0.07

Table 3 – Details of Production in MT

S.No	Year	Unit-1	Unit -2
1	2021-22	388881	183770
2	2022-23	420793	168035
3	2023-24	422742	195437
4	2024-25	425166	189406
5	2025-26	434294	200075

The organization actively implements initiatives for conserving water, steam, power, raw materials, and carbon footprint. Water conservation is supported by reuse and recycling systems, steam efficiency by heat recovery and process integration, and power conservation by energy-efficient operational practices. Raw material optimization and carbon reduction initiatives further improve environmental performance and cost efficiency [5]. Micro-level operational improvements across the mill also support overall resource efficiency and long-term sustainability.

TNPL's Sustainability through product Evolution and Market Diversification

TNPL's product sustainability journey reflects the organization's ability to adapt to changing market expectations while maintaining its commitment to environmentally responsible manufacturing. Originally established for newsprint production, TNPL diversified into copier paper and writing and printing grades in response to customer requirements. The portfolio was later expanded to include sublimation paper, packaging boards, and tissue paper, reflecting strategic foresight and market responsiveness. The

establishment of Unit II for packaging board manufacturing enabled TNPL to capitalize on the growing demand for sustainable packaging solutions, while tissue paper production marked another step toward future-ready, sustainability-driven growth. TNPL's growth trajectory has been supported by continuous investment in sustainability, renewable energy, circular manufacturing, and capacity expansion. Major milestones include:

- 1979 – Incorporation of TNPL
- 1982 – Issuance of Industrial License
- 1984 – Commencement of Trial Production
- 1985 – Commencement of Commercial Production
- 1993 – Deployment of 15 MW Wind Farm, strengthening renewable energy adoption
- 1996 – Doubling of production capacity to 180,000 tonnes per annum (TPA)
- 2000 – Achievement of self-sufficiency in power generation
- 2007 – Expansion of wind energy capacity to 35.5 MW
- 2008 – Commissioning of Mill Development Plan for modernization & improvement
- 2010 – Enhancement of annual production capacity to 400,000 MT/Year
- 2013 – Installation of a 300 TPD Deinked Pulp (DIP) Plant and cement plant,
- 2016 – First paperboard reeling
- 2026 – Commencement of Tissue paper production

Collectively, these developments illustrate TNPL's transformation into a diversified, sustainability-oriented, and future-ready paper manufacturer [6].

TNPL's Technology-Integrated Convergence: Defining Future Readiness

TNPL's technology convergence strategy emphasizes not only manufacturing efficiency but also enterprise-wide digital transformation through the integration of production systems, process monitoring, marketing, procurement, and finance, human resources, and data infrastructure. This holistic approach reflects the transition from conventional manufacturing toward smart industrial ecosystems.

Evolution from Manual Condition Monitoring to Real-Time Intelligent Asset Management

The reliability of critical rotating equipment is vital for uninterrupted paper manufacturing operations. Traditionally, machine condition assessment at TNPL relied on manual vibration measurements and periodic inspections. While effective for basic equipment monitoring, this approach was limited by infrequent data collection and delayed fault detection. In addition, conventional online monitoring systems required extensive cabling, resulting in complex installation and maintenance.

To address these challenges, TNPL has adopted advanced wireless 24×7 online vibration monitoring systems (Figure 6), enabling continuous equipment health assessment and predictive maintenance. The system integrates tri-axial vibration, temperature, and bearing noise monitoring (Figure 7) with wireless data transmission, eliminating the need for extensive cabling. Advanced AI and ML algorithms automatically configure ISO thresholds, analyze machine condition data, and identify potential defects at an early stage (Figures 8 & 9). Real-time processing, synchronous tri-axial measurements, and guided sensor positioning enhance monitoring accuracy and reliability.

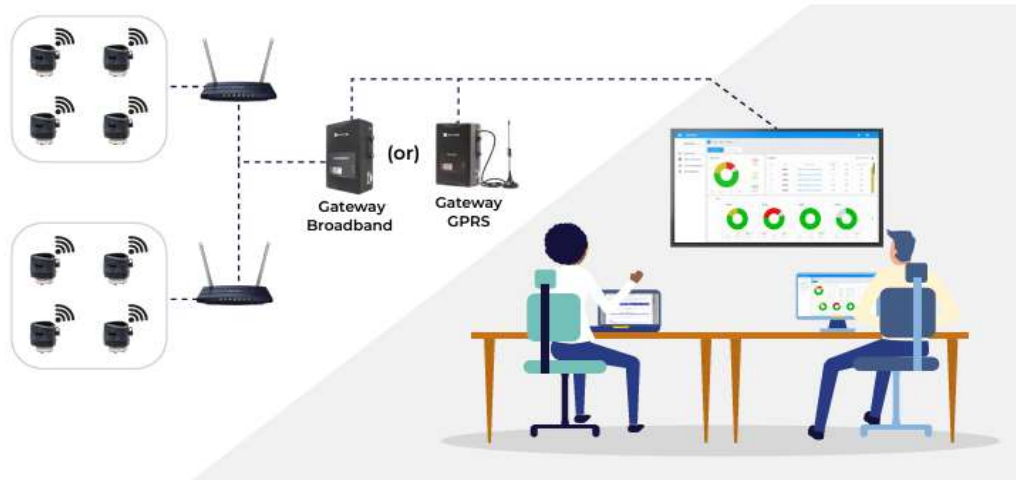
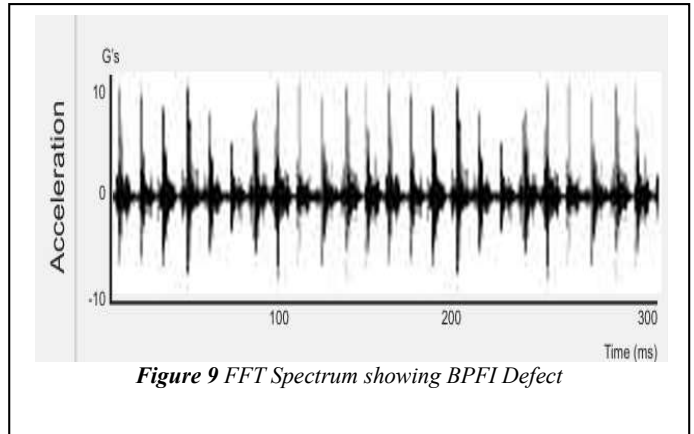
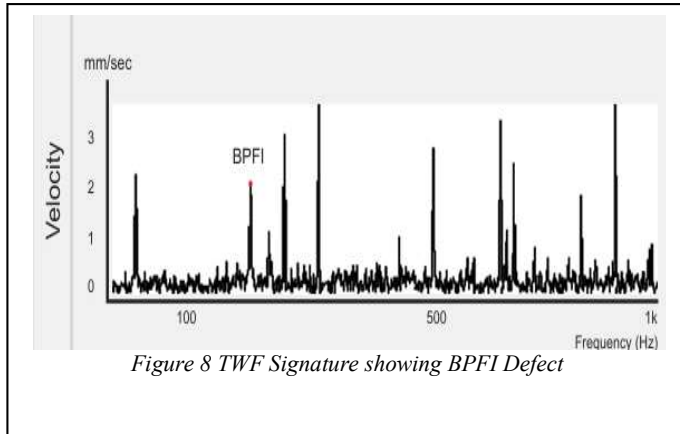


Figure 6 Wireless 24×7 online vibration monitoring systems



Figure 7 Installed wireless Monitoring Sensors



TNPL's condition monitoring journey can be summarized as:

Manual Monitoring → Online Monitoring → Wireless Real-Time Monitoring

This evolution has improved equipment reliability, enabled early fault detection, reduced unplanned downtime, optimized maintenance planning, and supported TNPL's vision of a smart and future-ready paper manufacturing operation.

Digital Transformation across Functional Domains

TNPL has deployed advanced digital technologies across multiple business functions to enable seamless information flow, process optimization, and data-driven decision-making.

Production: Smart Manufacturing and Process Optimization

TNPL has implemented total automation systems to support production planning and operational optimization. A robust Enterprise Resource Planning (ERP) system enables monitoring of production output, raw material consumption, and variable costs against annual operating plans. Digital systems also support continuous monitoring of treated effluents, emissions, and ambient air quality, thereby strengthening compliance and environmental sustainability [7]. Future initiatives include stronger raw

material optimization, ERP-integrated quality control, and big data analytics for process improvement and predictive decision-making.

Marketing: End-to-End Digital Dealer Ecosystem

TNPL has digitized its dealer management platform to improve market responsiveness and customer service efficiency. ERP integration enables dealers to place orders, reconcile invoices, submit complaints, and monitor transactions through a unified digital interface. Integration with GSTN and NIC platforms automates e-invoicing and e-way bill generation, while export activities are managed through ERP-based export and treasury modules. Future initiatives include deckle optimization software to reduce finishing losses and intelligent dispatch planning systems for logistics optimization.

Procurement: Digitally Integrated Supply Chain Management

TNPL has streamlined domestic and international procurement through e-tendering and e-auction platforms, achieving more than 90% end-to-end procurement digitization. This has improved transparency, efficiency, and supplier competitiveness. The pulpwood supply chain is also digitally managed from plantation planning and cultivation through harvesting and procurement using an integrated mobile application "TNPL FARM CONNECT" (Figure 10), improving traceability and supply chain visibility.

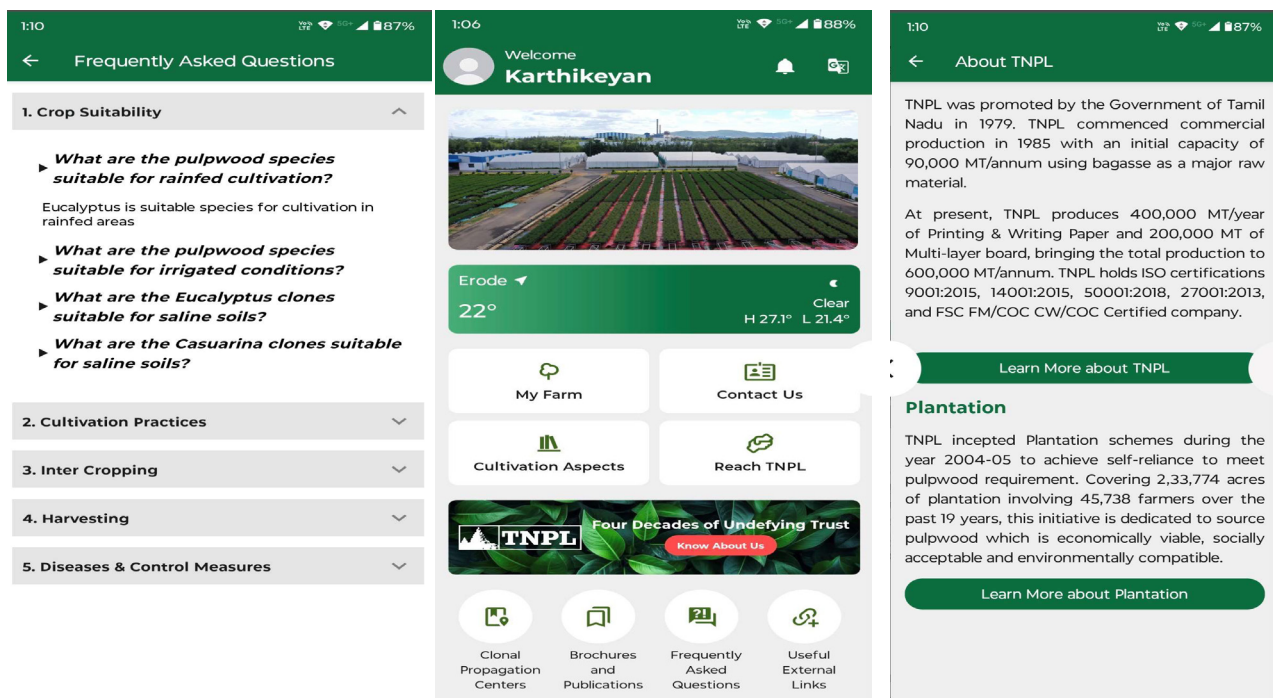


Figure 10 Dashboard of TNPL FARM CONNECT Mobile Application

Finance: Automated Financial Governance and Compliance

Digital integration extends to financial management through ERP-enabled systems supporting cash flow monitoring, treasury management, financial reporting, and statutory compliance. GSTN integration facilitates automated GST return filing, improving compliance accuracy and operational efficiency. Future initiatives include automated supplier payment systems, treasury integration with banking CMS platforms, and advanced planning tools for annual operating planning.

Human Resource Management: AI-Enabled Workforce Management

TNPL has deployed AI-enabled attendance management for contract workforce monitoring, improving attendance tracking accuracy and workforce visibility. The recruitment process has also been digitized to support efficient talent acquisition. In addition, the organization plans to transition from paper-based employee appraisal systems to digital performance management platforms to reduce subjectivity, improve transparency, and strengthen data confidentiality.

Conclusion

The case study of TNPL demonstrates that future-ready paper manufacturing can be achieved through the integration of sustainability practices, circular economy principles, operational excellence, and smart manufacturing technologies. TNPL's SEQPC framework, combined with digital transformation initiatives and product diversification, strengthens operational resilience, environmental sustainability, and long-term competitiveness in the evolving pulp and paper industry.

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