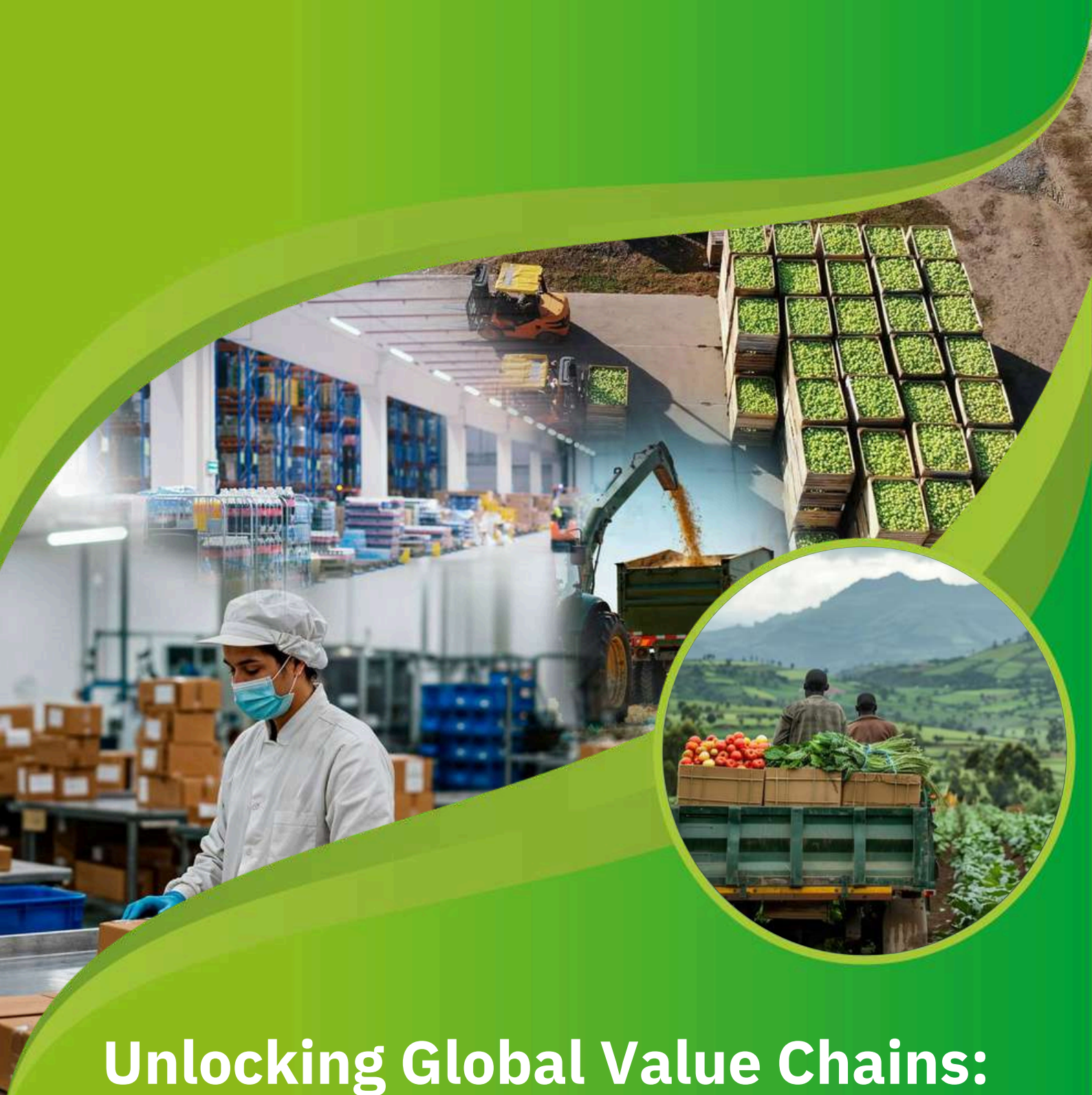


Unlocking Global Value Chains: The Role of Sustainable Agri-Logistics in India

ASSOCHAM
Ideate · Innovate · Impact

synergy TECHNOFIN

Foreword

Mr Saurabh Sanyal
Secretary General
ASSOCHAM

India's agricultural transformation is increasingly shaped not just by production volumes, but by the efficiency, resilience, and sustainability of the systems that move produce from farm to market. While India has emerged as a leading cereal producer and major agricultural exporter, this scale has intensified pressure on logistics infrastructure.

As the apex chamber representing over 450,000 enterprises across India, ASSOCHAM has always believed in catalyzing industrial excellence through collaboration, policy advocacy, and actionable insight. The 3rd Edition of the Agri logistics Conclave delves on emerging national priorities such as the pivot towards high value crops, Bharat VISTAAR, AgriStack digital infrastructure, and the World's Largest Grain Storage Plan, positioning agri logistics within the broader vision of Viksit Bharat.

The report provides a forward-looking assessment of India's agri-logistics ecosystem integrating national policy architecture with regional insights from Maharashtra and Nashik and linking infrastructure gaps to supply volatility, inflation pressures, and export restrictions. Moving beyond policy description, the report highlights ecosystem transformation driven by both public initiatives and private innovation. It examines structural challenges alongside emerging trends such as multi-temperature cold storage, electrified reefer transport, drone enabled logistics, blockchain-based traceability, AI driven planning, and ESG-aligned green warehousing. By shifting the focus from capacity expansion to sustainable, energy-aware digital infrastructure, the report presents a concise roadmap for strengthening India's farm to market continuum and enhancing long term competitiveness.

ASSOCHAM is pleased to present to you this pivotal report on "Unlocking Global Value Chains: The Role of Sustainable Agri-Logistics in India", drafted by knowledge partner, Synergy Technofin Private Limited and launched at ASSOCHAM's 3rd Edition of Agri Logistics Conclave at Nashik. We hope this document helps the stakeholders navigate the future of India's agriculture and logistics sector, which stands poised for unprecedented growth.

Foreword

Mr. Sunil Kumar
Managing Director
Synergy Technofin Pvt. Ltd

India's agricultural sector is no longer constrained by production alone; its next phase of growth will be determined by how efficiently value is preserved, transmitted, and sustained across increasingly complex supply chains shaped by climate change, sustainability imperatives, and global market requirements. Across value chains, the gap between farm output and market realization is driven less by production and more by inefficiencies in aggregation, storage, logistics coordination, and quality preservation particularly in high-value and perishable segments.

Despite expanded infrastructure investments, a gap persists between asset creation and effective utilization. Weak integration, limited demand alignment, and lack of real-time coordination continue to drive inefficiencies and environmental costs. The priority must shift from expansion to optimization through digital integration, climate-resilient design, and low-carbon logistics.

An equally critical dimension is the strengthening of governance and operational quality through standardized processes, compliance mechanisms, and certification frameworks. Global agri-logistics systems are increasingly guided by traceability protocols, food safety standards, and sustainability certifications such as GlobalG.A.P., ISO 22000, HACCP, GS1, and carbon accounting frameworks. Adoption of standardized processes and compliance-led logistics management will be essential to enhance export competitiveness and align with evolving international requirements.

The report analyses how logistics systems operate in practice, identifying key bottlenecks and their economic and environmental impacts. It incorporates insights from Maharashtra and the Nashik cluster, underscoring the role of traceability, digital monitoring, and quality assurance in export-oriented supply chains. The findings reflect a shift toward integrated, demand-responsive systems enabled by AI and digital technologies, alongside a growing focus on energy-efficient cold chains and sustainable infrastructure to enhance resilience and align with the vision of Viksit Bharat.

As Knowledge Partner, Synergy Technofin is honoured to contribute to this report titled "Unlocking Global Value Chains: The Role of Sustainable Agri-Logistics in India," launched at the 3rd Edition of the Agri Logistics Conclave organized by ASSOCHAM. We sincerely thank ASSOCHAM for providing us the opportunity to serve as Knowledge Partner for this timely and important initiative. We hope the insights presented will support informed decision-making and enable stakeholders to design agri-logistics systems that are efficient, traceable, climate-resilient, and aligned with long-term value creation and global sustainability benchmarks.

Executive Summary

India’s agriculture sector is undergoing a structural transformation, driven by rising demand, diversification of produce, and the need for efficient farm-to-market linkages. However, fragmented logistics systems, post-harvest losses, inadequate storage, and weak last-mile connectivity continue to constrain farmer incomes and overall supply chain efficiency. This report positions agri-logistics as a critical enabler of productivity, competitiveness, and food security, emphasizing that logistics is no longer a supporting function but a core pillar of agricultural value creation.

The analysis highlights that agri-logistics is an integrated ecosystem spanning storage, cold chains, warehousing, aggregation, transportation, packhouses, and digital platforms. While policy reforms and infrastructure investments are accelerating modernization, persistent structural inefficiencies including limited cold-chain penetration, first-mile bottlenecks, and fragmented coordination continue to generate avoidable losses and raise transaction costs. Addressing these constraints is essential to improving price realization for farmers and strengthening supply chain resilience.

Regional production clusters demonstrate how targeted logistics planning can unlock significant economic value. In particular, Maharashtra illustrates the strategic importance of aligning logistics infrastructure with high-value agricultural zones, where improved cold-chain systems, aggregation networks, and export connectivity can directly enhance market access, reduce wastage, and stabilize supply chains.

The report underscores the need for coordinated action among government institutions, industry stakeholders, and farmer organizations to build integrated logistics ecosystems. Investments in modern storage, multimodal connectivity, digital traceability, and cluster-based infrastructure supported by policy incentives and private participation are critical to transforming India’s agri-value chains. Strengthened agri-logistics will play a decisive role in reducing post-harvest losses, improving farmer incomes, and enhancing India’s competitiveness in global agricultural markets, ultimately supporting a more resilient and inclusive agricultural economy.

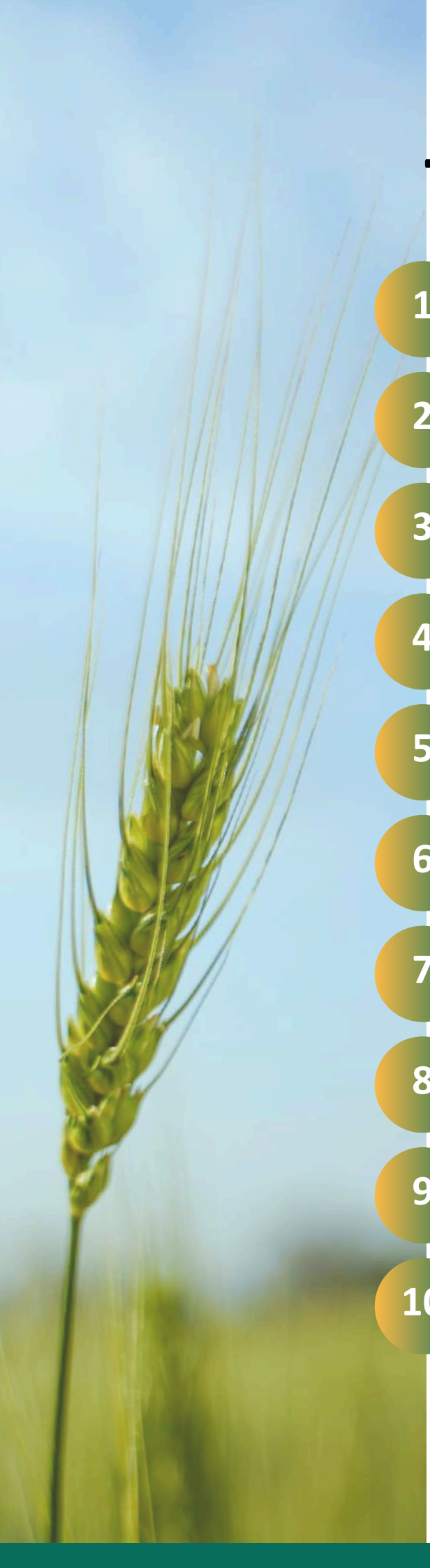


Table of Contents

Introduction: The Context

The Indian agricultural sector, often dubbed the "backbone" of the national economy, is undergoing a profound structural transformation. Traditionally production-centric, India is now moving toward a value-chain-driven model where agri-logistics the network of activities involved in moving agricultural produce from the farm to markets is emerging as a critical enabler. Efficient agri-logistics is vital for connecting India's vast rural production areas with domestic urban consumers and global markets, thereby determining the shelf life of perishable produce and the economic resilience of millions of farming households [1] [2]. In early 2026, India's agri-logistics networks have expanded significantly through investments in highways, multimodal corridors, warehousing, digital platforms, and cold-chain infrastructure. However, structural gaps persist. High logistics costs, fragmented supply chains, inadequate rural connectivity, insufficient pack-house capacity, and low cold-chain penetration continue to generate substantial post-harvest losses and reduce value realization. The challenge today is not merely expanding infrastructure, but rebalancing production scale with logistics intelligence.

Recognizing these structural constraints, the Government of India has introduced an integrated reform framework including the National Logistics Policy, PM GatiShakti, the Agriculture Infrastructure Fund, AgriStack, and the cooperative-led Grain Storage Plan aimed at modernizing logistics systems, strengthening multimodal integration, and aligning agricultural value chains with the broader vision of Viksit Bharat. This report examines the current state of agri-logistics in India, the structural bottlenecks that constrain efficiency, and the policy and technological transitions shaping the sector's forward trajectory, with particular relevance for high-value production clusters such as Maharashtra and the Nashik region.

Economic Catalyst: Driving Competitiveness and Global Integration

Efficient agri-logistics acts as a fundamental multiplier for India's agricultural economy. By reducing the cost and time to move goods from farm gate to consumer, it narrows the "economic distance" between producers and markets.[3] In India, logistics costs have historically been high often around 13-14% of GDP which is significantly above the global benchmark of 7-8% in developed economies.[4] High logistics costs erode the competitiveness of Indian agricultural products. However, by streamlining cold chain networks and specialized transit, the sector can substantially lower costs and enhance price competitiveness. This is crucial for Indian exporters to meet the stringent price and quality standards of global markets.[5] As noted in a DPIIT report, reducing logistics costs will make Indian goods more competitive and promote economic growth.[6] In fact, estimates suggest that improving logistics efficiency could reduce indirect logistics costs by 10% and boost exports by 5–8%.[7]

Beyond cost reduction, advanced agri-logistics is a prerequisite for productivity enhancement and deeper integration into global value chains (GVCs). When supply chains are reliable and timely, farmers are incentivized to invest in higher-value crops such as horticulture and floriculture, which require specialized handling and faster delivery to maintain quality.[8] For example, India's rapidly growing fruit and vegetable exports depend on efficient cold chain logistics to transport perishables to distant markets.

Efficient logistics also provide the necessary traceability and quality assurance that international trade partners demand. This transforms India from a bulk-commodity exporter into a reliable supplier of high-value processed and fresh agri-products. In summary, agri-logistics acts as an economic catalyst, driving competitiveness, enabling growth in higher-value segments, and facilitating India's integration into global markets. [9] [10]

Structural Friction: Navigating India's Logistical Hurdles

Despite recent progress, India's agri-logistics landscape remains characterized by significant structural friction inefficiencies and bottlenecks that impede the smooth flow of produce from farm to fork. Key challenges include:

Inadequate Rural Infrastructure and First-Mile Connectivity

Fragmented Supply Chains

Over-Reliance on Road Transport

Last-Mile Delivery and Urban Congestion

- **Inadequate Rural Infrastructure and First-Mile Connectivity:** A major hurdle is the poor state of rural infrastructure, especially in the "first-mile" connectivity from farm fields to main roads. While the national highway network has expanded rapidly (from ~91,000 km in 2014 to over 146,000 km by 2023)[11], rural and farm-level roads are often narrow, unpaved, or non-existent. This fragmentation in last-mile connectivity results in significant post-harvest losses. Farmers frequently have to transport the produce long distances on poor roads, leading to spoilage and quality deterioration. According to studies, post-harvest losses in India range from 4.6% to 15.9% across different commodities, with an estimated annual economic loss of over ₹92,000 crore (approximately $11 billion) due to inadequate cold storage and handling.[12] In fact, India suffers a food loss of about 177 million tonnes per year[13], a large portion of which is attributed to poor infrastructure and handling during transport and storage. This not only reduces farmer incomes but also impacts food security.
- **Fragmented Supply Chains:** The agri-supply chain in India is highly fragmented, involving an average of 5–7 intermediaries between the farmer and the consumer.[14] This fragmentation creates several problems. First, farmers often lack direct access to end markets, forcing them to sell their produce at lower prices through intermediaries. Second, information asymmetry is prevalent farmers may not know the best prices or demand, while consumers may pay higher prices due to multiple markups. Third, fragmentation increases transaction costs and delays, as each intermediary adds to the journey time and cost. The result is inefficient price discovery and suboptimal value realization for farmers. Additionally, fragmentation makes the supply chain less responsive to market signals and less resilient to shocks.
- **Over-Reliance on Road Transport:** India's transport sector is heavily skewed toward roadways, and agri-logistics is no exception. Road transport accounts for roughly 60% of all cargo movement in the country.[15] While road transport offers flexibility and "first-mile" reach, it is also vulnerable to factors like fuel price volatility and seasonal disruptions (e.g., monsoons, traffic jams). Moreover, the dominance of road transport can lead to congestion in urban areas and longer transit times for perishable goods. There is a need to diversify and integrate modes of transport such as railways and inland waterways to reduce dependency on roads and improve efficiency. However, the lack of seamless inter-modal connectivity is a significant challenge in India's logistics system.
- **Last-Mile Delivery and Urban Congestion:** The "final-mile" challenge in urban areas further exacerbates logistics inefficiencies. Many Indian cities suffer from traffic congestion and a shortage of micro-warehousing and distribution centers at the local level. This leads to higher delivery costs, especially for e-commerce and perishable goods. Studies have found that congestion and lack of last-mile infrastructure can drive up delivery costs by nearly 30% for e-commerce firms in urban centers.[16] Inadequate last-mile logistics also means that consumers in some areas may not get fresh produce in a timely manner, contributing to food waste and suboptimal market integration.

These structural challenges together undermine the effectiveness of India's agri-logistics. They contribute to high costs, low farmer incomes, and significant food losses. Addressing them is essential for India to fully harness the potential of its agricultural sector. The next section discusses how the Indian government is responding with a series of policy reforms aimed at modernizing agri-logistics and overcoming these hurdles.

Indian Agriculture Production Scenario

India's agricultural sector continues to demonstrate robust growth, solidifying its position as a global powerhouse in food production. This sustained output, particularly in staple cereals, creates significant logistical demands and shapes its export dynamics on the international stage.

2.1. India's Global Standing in Cereal Production

India occupies a significant position in global cereal production and is the world's second-largest producer of major cereals such as rice, wheat, and maize. In terms of global share, India contributes approximately 25.79% of total rice production, 13.84% of wheat production, and 3.07% of maize production worldwide. This substantial production base, combined with rising demand for cereals in the international market, has created a highly favorable environment for the export of Indian cereal products. Cereals form the backbone of India's agricultural sector, both in terms of food security and economic importance. The major cereals cultivated across the country include wheat, paddy (rice), sorghum, millet (bajra), barley, and maize. These crops are grown across diverse agro-climatic regions, reflecting their central role in Indian agriculture and consumption patterns.

As per the Ministry of Agriculture, Government of India, during the financial year 2024–25, the production of key cereals reached substantial levels. Rice production stood at 150.18 million tonnes, while wheat production was recorded at 117.95 million tonnes. Maize and bajra production during the same period amounted to 43.41 million tonnes and 11.21 million tonnes, respectively. Collectively, the total production of cereals in India for the financial year 2024–25 was reported to be 332.05 million tonnes[17]. These figures highlight the scale and consistency of cereal production in India and underscore the country's critical role in meeting both domestic requirements and international market demand.

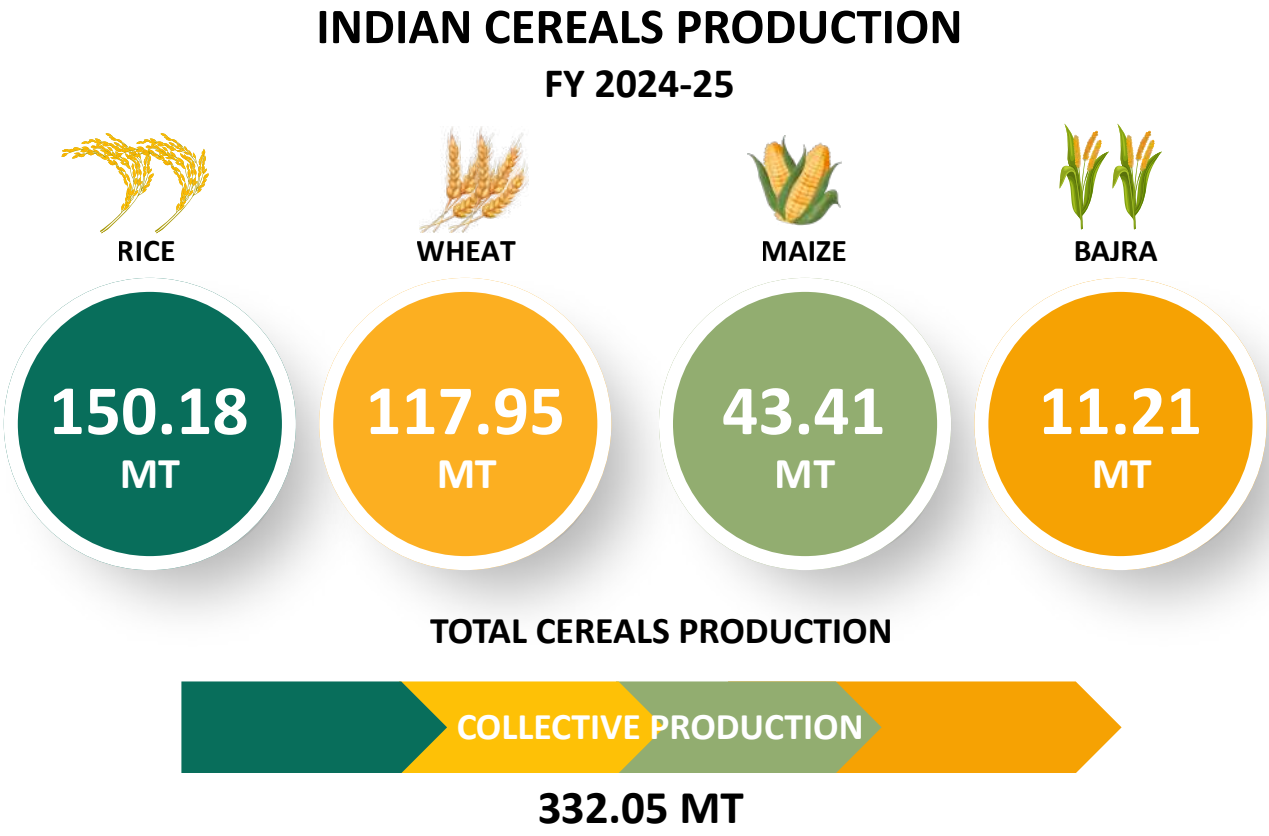


Figure 1: Production of Cereals for Fiscal Year 2024–25

Agri-logistics in India involves the efficient movement and storage of agricultural produce from farm to market. The Indian government has invested heavily in improving road, rail, air, and port infrastructure, as well as customs procedures and agro-processing facilities, to reduce post-harvest losses and enhance export competitiveness.

2.2. Horticulture Production in India

During the period from 2014–15 to 2023–24, India's horticultural sector recorded steady growth in both production and productivity. Total fruit production increased from 866 lakh metric tonnes to 1129.7 lakh metric tonnes, representing an overall growth of nearly 30 percent.

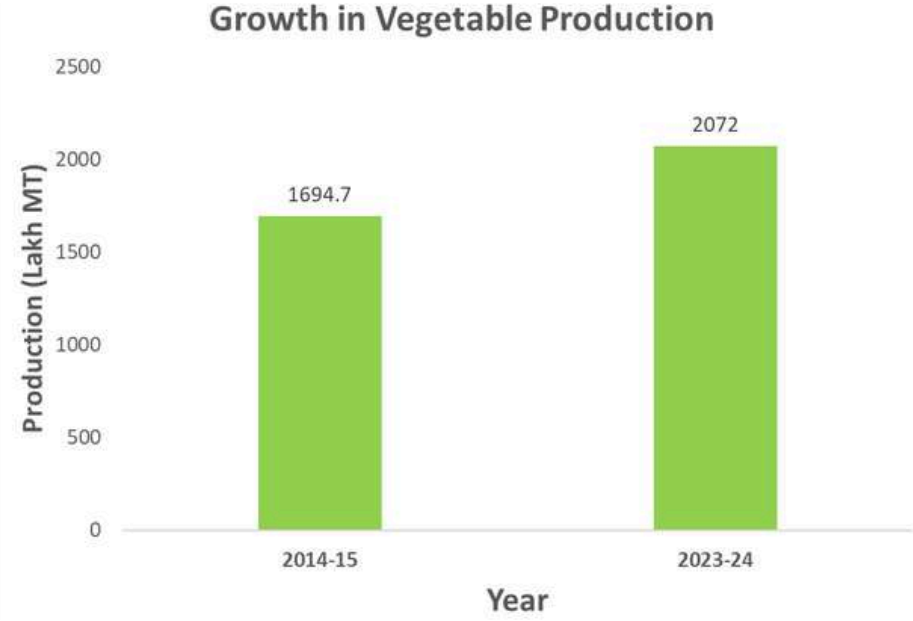


Figure 2: Growth in Vegetable Production (https://www.pib.gov.in)

Similarly, vegetable production rose from 1694.7 lakh metric tonnes to 2072 lakh metric tonnes, registering an increase of approximately 22 percent over the same period.

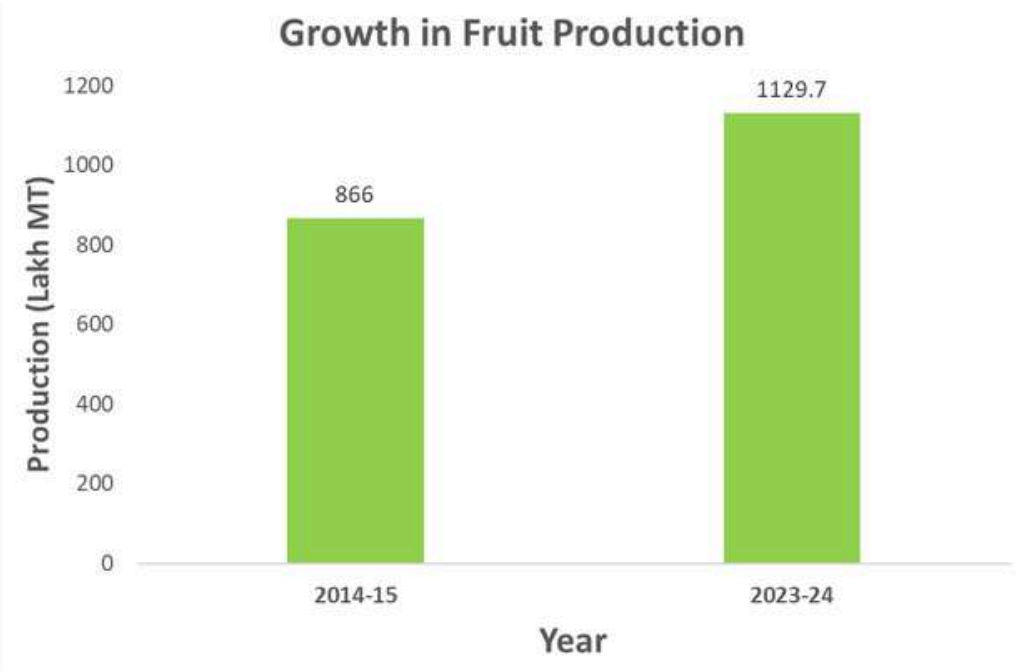


Figure 3: Growth in Fruit Production (https://www.pib.gov.in)

Productivity levels also showed measurable improvement. Average fruit yields increased from 14.17 metric tonnes per hectare to 15.80 metric tonnes per hectare, while vegetable productivity improved from 17.76 to 18.40 metric tonnes per hectare. These trends indicate sustained expansion in output alongside gradual gains in per-hectare efficiency.

2.3. Maharashtra's Strategic Position in Indian & Global Agriculture

Maharashtra stands as a significant contributor to India's agricultural economy, demonstrating robust growth and a pivotal role in national output and exports. The state has emerged as a leader in agro-food exports, achieving a 15% increase and reaching an all time high of ₹47,017 crore in the financial year 2024-25[18] . This performance underscores Maharashtra's integral role within the broader Indian agricultural landscape. Maharashtra encompasses diverse agro-climatic zones that dictate regional cropping patterns. The Nashik district, for instance, is situated within the Western Ghat Zone, specifically its western part, alongside districts like Nandurbar, Satara, Kolhapur, and Pune[19]. This diverse geography supports a variety of agricultural practices. During the Kharif season of 2021-22, sowing was completed across 155.15 lakh hectares in Maharashtra[20]. Key production statistics for the state highlight its agricultural diversity, contributing various commodities including rice, wheat, and numerous specialty crops recognized for their geographical indication, such as Nashik Valley Wine, Sangli Turmeric, and Jalgaon Banana[21].

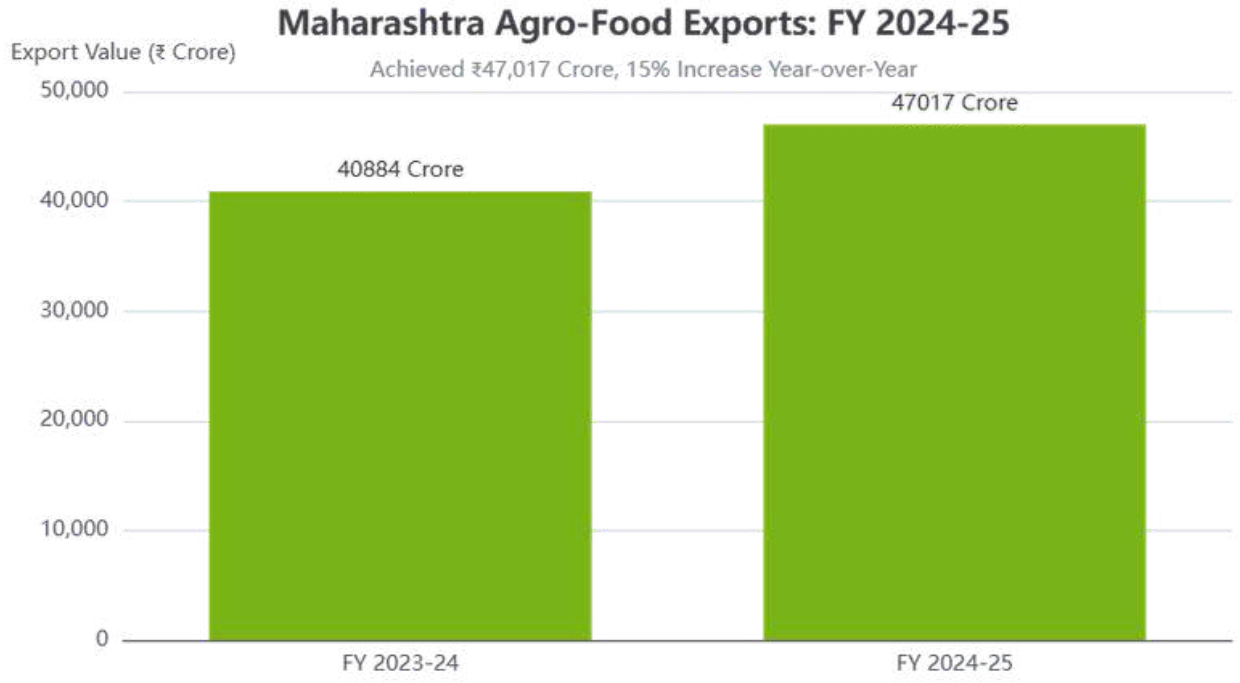


Figure 4: Maharashtra Agro-Food Exports for Fiscal Year 2024–25

2.4. Nashik Region: A Hub for Specialized Horticultural Production

The cropping pattern of Nashik district reflects a balanced and diversified agricultural structure combining staple cereals, commercial field crops, and high-value horticulture. Maize and bajra together account for a substantial share of the cultivated area, indicating the continued importance of food grains in ensuring regional food security and fodder availability. Paddy cultivation remains concentrated in higher rainfall western talukas such as Trimbakeshwar and Surgana.

Among horticultural crops, onion occupies a significant share of the gross cropped area, reinforcing Nashik's role as a major onion-producing and exporting district in India. Grapes, though occupying a comparatively smaller percentage of the total cultivated area, represent one of the most economically significant crops due to their export orientation and linkages with wine production and agro-processing industries. Pomegranate and tomato further strengthen the district's horticultural profile.

Oilseed and cash crops such as soybean, cotton, and groundnut contribute to income diversification and risk management for farmers. The coexistence of cereals, oilseeds, pulses, and horticultural crops highlights the absence of monoculture and demonstrates a resilient mixed farming system. This diversified cropping structure enhances climate adaptability, spreads market risk, and supports Nashik's emergence as both a food grain producer and a high-value horticultural hub within Maharashtra.

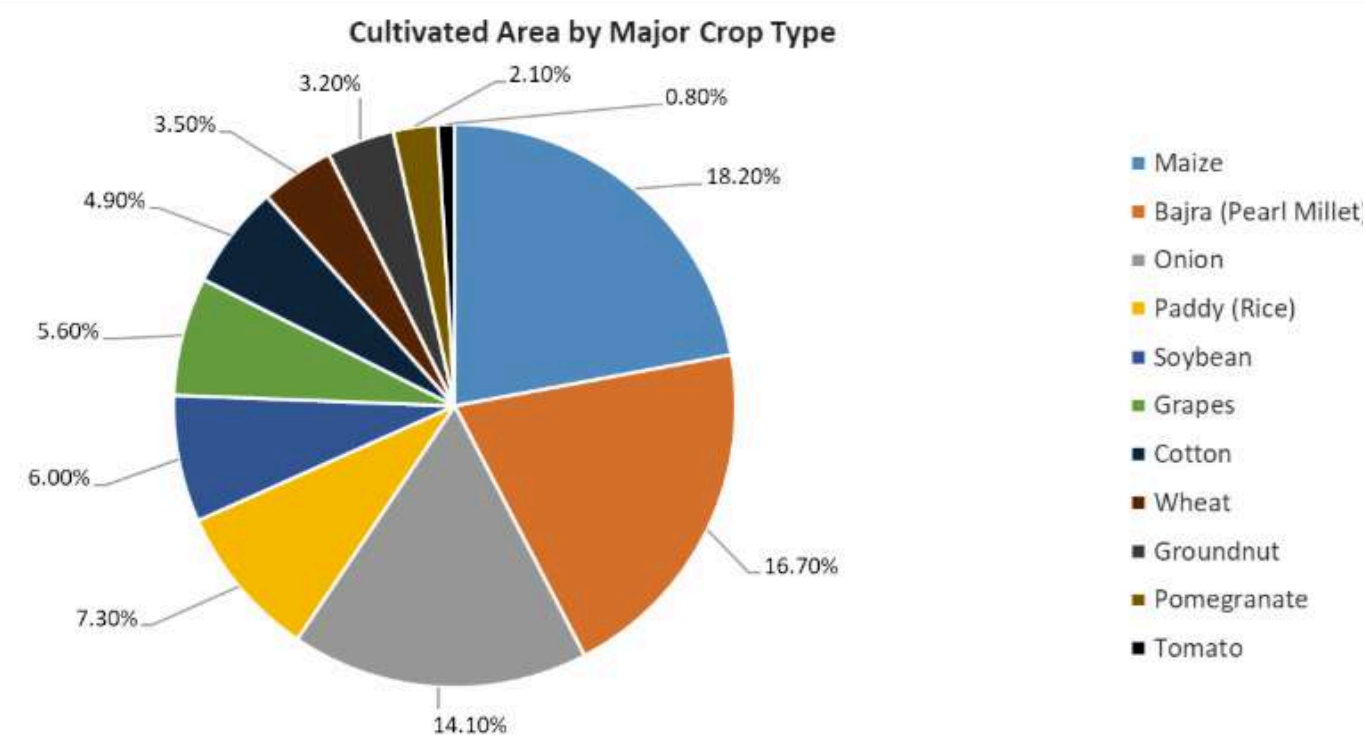


Figure 5: Cultivated Area by Major Crop Type in Nashik, Maharashtra[22]

Nashik is the undisputed leader in India's wine production. Maharashtra produces 90% of India's total wine, with approximately 1.4 crore liters produced in 2022. Of the 40-45 operational wineries in Maharashtra, around 29 are located in Nashik, accounting for about 80% of India's wine output[23]. This concentration has fostered a thriving wine tourism industry, attracting over 3.5 lakh visitors annually to its vineyards and wineries.

Formal market structures are facilitated by 17 Agricultural Produce Market Committees (APMCs) across the district, which handle major commodities such as maize, bajra, tomato, gram, onion, wheat, pomegranate, melons, grapes, and soybean. The district also has 623 godowns, 70 cold storages, and 7,610 agro service centers to support agricultural activities[24].

2.5. Structural Bottlenecks and Their Impact on Trade Restrictions

The sheer scale of India's agricultural output, while a testament to its farming capabilities, simultaneously exerts immense pressure on its agri-logistics infrastructure. Despite significant advancements in production, the country faces persistent challenges in post-harvest management, storage, and transportation. High volumes of produce, particularly cereals, often outstrip the available modern storage and warehousing capacity. For instance, in December 2025, rice and paddy stocks in government warehouses were approximately 7-8 times higher than buffer norms, indicating a significant demand for efficient storage and movement solutions.

This situation leads to considerable post-harvest losses, which are among the highest globally, exacerbated by inadequate cold chain facilities and fragmented retail networks. The movement of agricultural commodities within India is further complicated by regulatory hurdles, including inter state and even inter-district restrictions that impede efficient supply chain flow. While regions like Punjab, Haryana, and Andhra Pradesh benefit from robust infrastructure and irrigation, other rain-dependent areas in central and eastern India continue to struggle, leading to regional disparities that strain logistical networks attempting to balance supply and demand across the vast nation. The primary challenge is not production itself, but rather the efficient management of storage, liquidity, and movement of these massive outputs.

As a primary driver of India’s industrial output, Maharashtra faces unique structural constraints that hinder its full export potential. According to the NITI Aayog Trade Watch Report**,** structural bottlenecks and competitiveness gaps remain primary targets for corrective policy action to ensure global trade integration[25].

- **High Operational and Logistics Costs:**

  Maharashtra grapples with some of the highest operational costs in the country. Reports from the IMF 2025 Article IV Consultation suggest that lifting non-tariff barriers and addressing burdensome administrative requirements are essential to bolster the competitiveness of states like Maharashtra. The cost of industrial land in hubs like Mumbai and Pune, combined with high energy tariffs, often pushes manufacturing units to relocate to neighboring states with more favorable cost structures.

- **Regional Development Imbalances:**

  Economic activity is heavily concentrated in the Mumbai-Pune-Nashik triangle. While Nashik district is a global leader in horticultural exports, many other districts lack the necessary cold-chain infrastructure and proximity to major logistics nodes. According to the Official District Website of Nashik, the region's reliance on specific horticultural crops requires specialized agro-logistics that are not always consistently available across the state[26].

- **Energy and Utility Reliability:**

  Infrastructure reliability, specifically power quality and water supply for food processing units, remains a bottleneck. While the Economic Survey of Maharashtra highlights agricultural production growth, the value addition process is often hampered by these foundational structural gaps.

  Trade restrictions, such as sudden export bans or the imposition of Minimum Export Prices (MEP), act as immediate trade barriers. In Maharashtra, these restrictions most acutely affect the onion and grape sectors in the Nashik region. The Maharashtra State Agricultural Marketing Board (MSAMB) notes that while it strives to develop unified markets through schemes like the National Agriculture Market (eNAM), sudden policy shifts often lead to domestic price crashes and supply chain volatility[27]. For example, a ban on onion exports frequently results in a glut at the APMC markets in Nashik, leading to significant financial losses for farmers and eroding India's reliability as a stable trade partner in international markets.

2.6. Nashik as a High-Value Logistics Corridor

Within Maharashtra's agricultural framework, Nashik occupies a distinctive position as a high-value production and export cluster. The district's prominence in grapes, onions, pomegranates, and wine production situates it directly within the diversification trajectory envisaged at the national level. This production profile requires a logistics architecture that differs fundamentally from bulk grain systems.

Export-oriented grape and pomegranate supply chains depend on temperature-controlled handling, synchronized pre-cooling and packhouse operations, and seamless port connectivity. Seasonal concentration of harvest cycles generates sharp spikes in freight demand, necessitating flexible logistics deployment. In contrast, onion supply chains are characterized by price volatility and periodic export restrictions, requiring storage systems capable of absorbing policy shocks without destabilizing local markets. Climate variability further reinforces the need for adaptive logistics planning. Shifts in rainfall patterns and temperature regimes influence harvest timing and yield volumes, creating uncertainty in dispatch cycles. Infrastructure in Nashik must therefore be modular and responsive, capable of scaling operations during peak export windows while maintaining cost efficiency during lean periods.

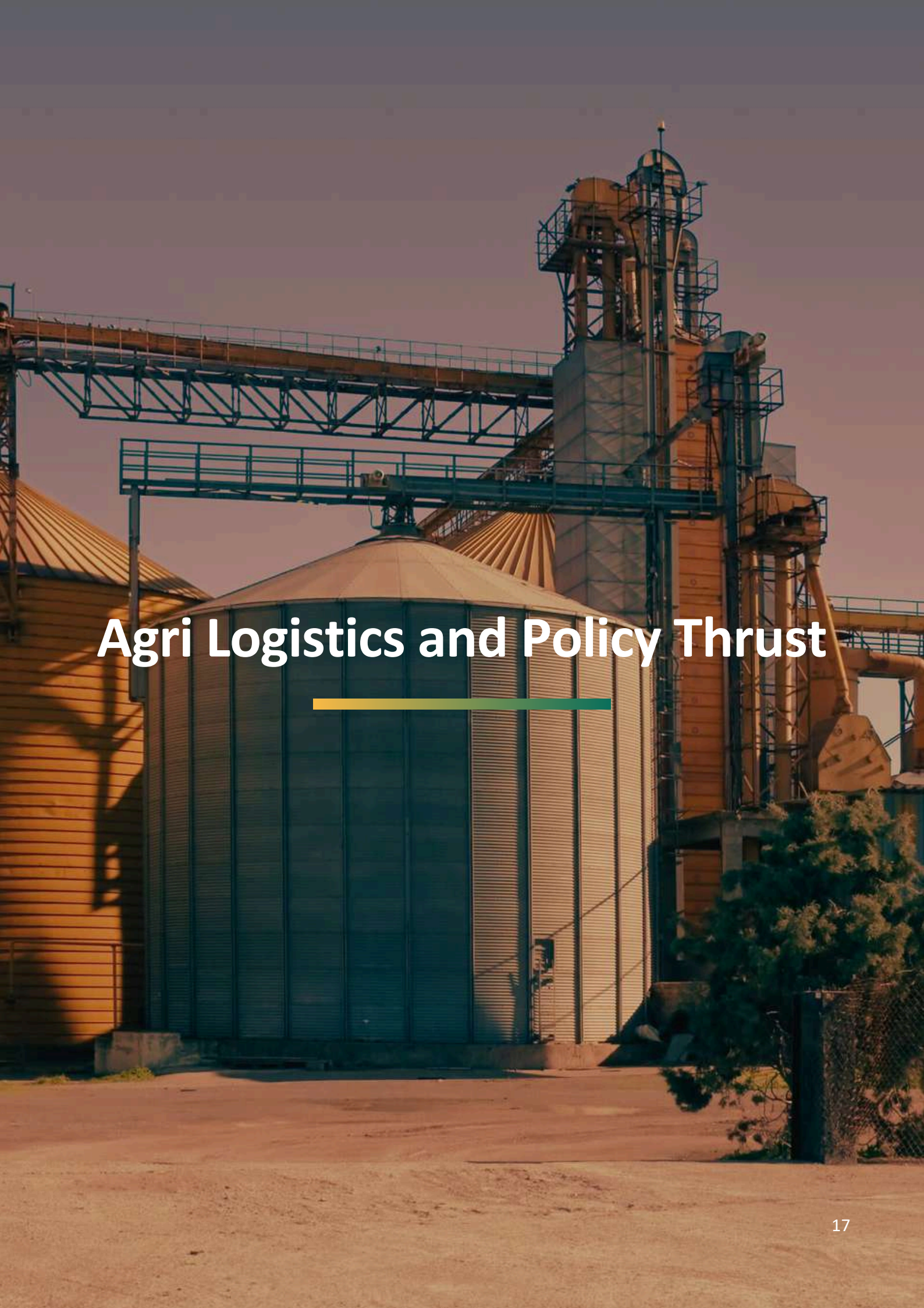
The district's proximity to major transport corridors and access to containerized export routes provide structural advantages. However, infrastructure utilization remains sensitive to coordination gaps among producers, aggregators, and transport operators. Integrating digital crop intelligence, freight scheduling, and export demand signals will be essential to unlocking Nashik's full potential as a specialized logistics corridor. Positioning Nashik in this manner aligns regional infrastructure planning with national objectives of enhancing agricultural competitiveness and export resilience. It shifts the discourse from production dominance to supply-chain sophistication.

2.7. Cereals and the Export Demand Nexus

India's burgeoning agricultural output has direct implications for its presence in international markets, driving both export opportunities and policy challenges. For FY 2024-25, agricultural exports demonstrated robust growth, reaching an annual value of $52 billion, an increase of 6.4% year-on-year, significantly outperforming the modest 0.1% growth in total merchandise exports.

Rice remains the largest exported agricultural product, contributing over 30% to the total agri-exports. Both Basmati and non-Basmati rice varieties are crucial drivers, with Basmati exports experiencing a notable 15-20% year-on-year growth trend in FY 2025-26. India maintains its position as the world's largest rice exporter, with key destinations including Saudi Arabia, Benin, Iraq, Iran, Guinea, and Cote D Ivoire.

However, the link between production and export demand is not without complexities. Domestic policy decisions, often aimed at controlling inflation or ensuring food security, can introduce restrictions on exports of critical commodities such as wheat, rice, sugar, and onions. These interventions, while addressing internal needs, can impact India's reliability and competitiveness in the global market. Furthermore, challenges persist from global price sensitivity, trade barriers, and inherent supply-side constraints, including agricultural productivity variations and inadequate logistics infrastructure. To fully leverage its production surplus and become a global agri-trade powerhouse, India must continue to invest in infrastructure upgrades, diversify its export markets, promote value-added processing, and enhance technology adoption across the agricultural supply chain.



Agri Logistics and Policy Thrust

India's agri-logistics ecosystem is entering a structurally transformative phase under the Union Budget 2026-27. Unlike earlier policy cycles that emphasized infrastructure creation in isolation, the current framework integrates diversification toward high-value crops, digital agricultural infrastructure, and decentralized storage reform. This coordinated thrust aligns with the long-term vision of Viksit Bharat, where agricultural growth is driven not only by production expansion but by systemic efficiency, export competitiveness, and value-chain sophistication.
The policy direction through 2026 and beyond signals a transition from volume-centric logistics to value-sensitive, data-enabled, and regionally adaptive supply chains.

3.1 High-Value Crop Diversification and Specialized Logistics Systems

The Budget 2026-27 introduces targeted financial support for high-value agriculture, including coconut, cashew, plantation crops, spices, and horticulture commodities. This marks a strategic shift from cereal dominated logistics planning toward commodity specific supply chain architecture.
Coconut and cashew supply chains require moisture-controlled storage, shelling and grading units, fumigation protocols, and export-grade packaging. Plantation crops such as tea, coffee, and spices demand lot-based traceability, quality testing, and humidity-regulated warehousing to meet international standards. Horticultural commodities including grapes, pomegranates, bananas, and vegetables necessitate pre cooling, integrated packhouse operations, temperature-controlled aggregation, and rapid multimodal evacuation to ports or airports.

These requirements imply a logistics transformation along four dimensions:

- **Commodity-Specific Infrastructure:** Cold storages, ripening chambers, grading lines, scientific drying yards, and export-certified packhouses.
- **Quality Preservation Protocols:** Digital grading, phytosanitary compliance, residue monitoring, and lot traceability.
- **Multimodal Synchronization:** Alignment of road, rail, and port schedules with harvest windows.
- **Export-Oriented Handling Standards:** Containerization, reefer deployment, and certification based dispatch.

As agricultural exports crossed approximately USD 52 billion in FY 2024-25, driven increasingly by horticulture and value-added products, the logistics system must prioritize perishability management and compliance-led movement rather than bulk grain throughput alone[31].

3.2. Bharat-VISTAAR, AgriStack and Integrated Traceability Architecture

The allocation of ₹150 crore for Bharat-VISTAAR under Budget 2026-27 builds upon the AgriStack digital infrastructure under the Digital Agriculture Mission[32]. AgriStack integrates farmer registries, geo-referenced land records, and crop-sown databases to create a foundational digital public infrastructure for agriculture.

Traceability and Compliance:

Digital farm and crop identification enables end-to-end traceability, critical for exports to regulated markets such as the European Union and Gulf countries. Lot-level tracking can reduce rejection risks and enhance credibility in global trade.

Quality Assurance and Packhouse Integration:

Harvest forecasts can be synchronized with packhouse scheduling, ensuring optimal utilization of grading and pre-cooling facilities. Digital crop records can support quality certification and inspection protocols, reducing delays at export gateways.

Logistics Advisory Protocols:

AI-enabled advisory systems can extend to dispatch optimization suggesting ideal harvest windows, storage durations, nearest cold storage availability, and alternate freight routes during congestion. For Farmer Producer Organizations (FPOs) and cooperatives, such intelligence improves coordination between production and movement.

Freight Forecasting and Capacity Allocation:

Real-time crop-sown data can inform seasonal demand projections for reefer containers, dry vans, and rail wagons. This shifts logistics planning from reactive booking to predictive deployment. By linking AgriStack with national logistics platforms such as the Unified Logistics Interface Platform (ULIP), the agricultural supply chain can evolve into a data-integrated ecosystem[33]. Through 2026, the effectiveness of agri-logistics will increasingly depend on the interoperability of farm intelligence, storage systems, and transport networks.

3.3. World's Largest Grain Storage Plan and Structural Decentralization

India's central foodgrain stocks continue to remain substantially above prescribed buffer norms. As per Food Corporation of India (FCI) stock bulletins in early 2026, rice and wheat stocks significantly exceeded buffer requirements, generating high carrying costs and repeated freight cycles between centralized depots and distribution points.

The initiative to create the "World's Largest Grain Storage Plan" in the cooperative sector, approved in 2023 and implemented through the Ministry of Cooperation, aims to decentralize storage capacity to Primary Agricultural Credit Societies (PACS). The plan converges with schemes such as the Agriculture Infrastructure Fund to establish scientific storage facilities at the grassroots level.This reform represents structural logistics rationalization rather than simple capacity addition.

Modern mechanized silo infrastructure provides a relevant illustration. Extending silo-based or scientific storage models across cooperative networks can reduce redundant long-haul transportation, lower congestion at central depots, and enable localized stock management. However, decentralization must be digitally integrated with inventory monitoring and synchronized procurement-release systems. Without real-time visibility, decentralized capacity risks becoming static warehousing rather than dynamic logistics infrastructure.

3.4. Forward Looking Alignment Through 2026 and Beyond

The policy thrust emerging from Budget 2026-27 must be evaluated not as a short-term intervention cycle but as the foundation of a structural transformation in agri-logistics through 2026 and beyond. Three interconnected transitions commodity diversification, digital integration, and decentralized storage modernization are expected to reshape freight flows, infrastructure utilization patterns, and export competitiveness.

Commodity Rebalancing and Freight Pattern Shifts: India's agricultural export basket is gradually diversifying from bulk cereals toward horticulture, processed foods, plantation crops, and high-value commodities. While rice continues to dominate export volumes, value-added segments such as fruits, vegetables, spices, marine products, and plantation crops are contributing increasingly to export earnings. This implies a structural shift in freight composition:

- Greater share of temperature-controlled movement
- Higher reliance on containerized transport
- Increased demand for time-bound dispatch cycles
- Reduced tolerance for port dwell times

For example, horticultural exports require shipment within tightly defined harvest windows, whereas plantation crop exports are quality sensitive and certification driven. This shift will require logistics operators to recalibrate asset allocation reefer container fleets, packhouse capacity, cold-chain nodes, and rail-linked inland container depots must expand proportionally to value-sensitive cargo.

Digital Convergence and Predictive Logistics: The scaling of AgriStack and Bharat-VISTAAR through 2026 enables predictive logistics coordination. With digitized farmer registries and crop-sown databases expanding coverage, production forecasting can increasingly inform transport scheduling and warehouse utilization.
The forward-looking potential lies in integrating:

- Crop-sown data with freight booking systems
- Weather alerts with dispatch planning
- Market price signals with storage duration decisions
- Export demand forecasts with container allocation

Such convergence reduces speculative movement, avoids last-mile congestion, and enhances supply-chain transparency. Over time, digital interoperability between agricultural data systems and logistics platforms can support near real-time tracking of commodity flows, strengthening both domestic distribution efficiency and export reliability.

Decentralized Storage and Transport Rationalization: Persistently elevated grain stocks highlight the fiscal and logistical strain of centralized storage systems. Decentralized storage under the cooperative-led Grain Storage Plan can significantly alter freight flows by reducing repetitive long-distance transport cycles.
Through 2026, the impact of decentralized storage will depend on:

- Integration with procurement and PDS distribution schedules
- Scientific storage standards across PACS networks
- Digital inventory visibility for coordinated evacuation
- Silo-based modernization reducing handling losses

If effectively implemented, decentralized storage can reduce transport congestion, lower fuel consumption, and shorten turnaround times for wagons and trucks. In turn, this frees logistical bandwidth for high-value commodity corridors that require rapid evacuation capacity.

Multimodal Infrastructure and Export Gateways: The expansion of dedicated freight corridors, modernization of container terminals, and port capacity augmentation are expected to reshape agricultural logistics flows. Improved rail connectivity to ports such as JNPT and western gateways can enhance the competitiveness of containerized agricultural exports.
However, forward looking alignment requires not merely infrastructure expansion but utilization optimization. Container dwell time reduction, yard congestion management, and synchronized port scheduling must accompany capacity creation. For perishable cargo, even marginal improvements in turnaround time can significantly enhance price realization.

Climate Resilience and Adaptive Logistics: Climate variability erratic rainfall, temperature extremes, and shifting harvest cycles introduces unpredictability into production patterns. Forward-looking logistics planning must therefore incorporate adaptive capacity:

- Flexible cold-chain modules
- Modular warehousing systems
- Climate-controlled transport
- Dynamic route optimization during extreme weather events

The integration of weather intelligence with crop forecasting and logistics advisory systems will become critical to maintaining supply continuity and minimizing losses.

Institutional Convergence and Efficiency Metrics: The convergence of FPOs, PACS, digital agricultural infrastructure, and logistics operators will define the next phase of value-chain coordination. Through 2026, measurable performance indicators should include:

- Reduction in post-harvest losses
- Decline in grain carrying costs
- Improved container turnaround times
- Reduction in logistics cost as a share of agricultural GDP
- Increased share of value-added exports

The success of the policy thrust will not be measured solely by infrastructure additions but by efficiency gains across the supply chain.

Strategic Outlook

By 2026, India's agri-logistics ecosystem is expected to reflect a hybrid architecture: decentralized grain storage for stability, digitally integrated high-value corridors for export growth, and multimodal infrastructure for rapid evacuation. The alignment of these transitions with the Viksit Bharat objective positions logistics not merely as a support function, but as a growth multiplier for agricultural transformation. The challenge ahead lies in ensuring that digital systems, physical infrastructure, and institutional reforms evolve in coordination rather than isolation.

Policy Architecture Supporting Agri-Logistics

The Government of India has recognized the pivotal role of logistics in agricultural development and has formulated a comprehensive policy framework to address the challenges outlined above. Key initiatives include the National Logistics Policy, the PM GatiShakti National Master Plan, the Agriculture Infrastructure Fund, and the Logistics Ease Across Different States (LEADS) index. These measures collectively aim to modernize India's logistics infrastructure, streamline operations, and reduce costs.

As of early 2026, the focus has shifted from mere policy description to a dynamic ecosystem transformation, where the private sector comprising agritech startups and established logistics firms acts as the primary engine for implementing these reforms. By leveraging state-backed digital platforms and financial incentives, these firms are building a tech-enabled supply chain that aligns with the "Viksit Bharat" objectives of a developed and self-reliant India. Below is an overview of each major reform:

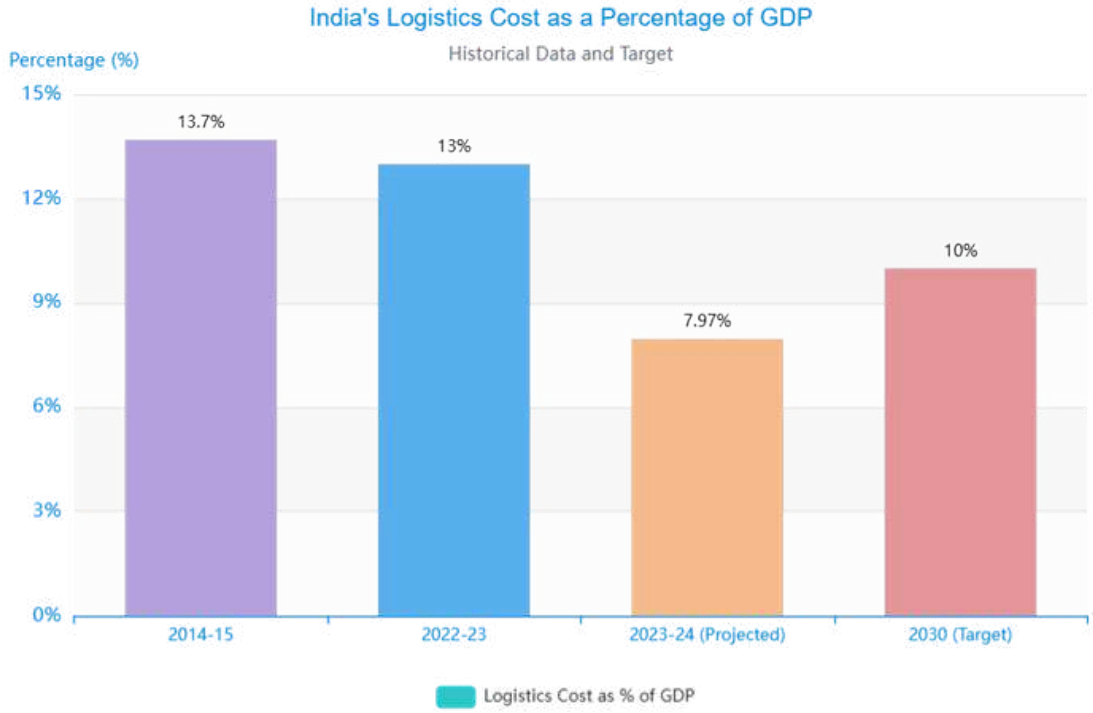


Figure 6: India's Logistics Cost[34]

4.1. National Logistics Policy (NLP) 2022 and Private Sector Integration

Launched in September 2022, the National Logistics Policy (NLP) is a landmark initiative to create a unified and efficient logistics ecosystem. Its primary objective is to reduce logistics costs to under 10% of GDP by 2030[35]. In early 2026, India's logistics cost stands at approximately 7.97% of GDP, a significant decline from 13% a decade ago[36 37].

A cornerstone of the NLP is the Unified Logistics Interface Platform (ULIP), which integrates over 30 digital systems across various ministries[38]. While the government provides the platform, private players like Rivigo and Ninjacart have pioneered its adoption to enhance supply chain transparency. Rivigo utilizes ULIP data to optimize its "relay trucking" model, reducing transit times by matching real-time vehicle movement with e-way bill data. Ninjacart integrates ULIP's digital infrastructure to provide end-to-end traceability for fresh produce, ensuring that the journey from farm-gate to retailer is documented and optimized for speed, which is critical for reducing perishability losses.

The NLP encourages the use of IoT, AI, and blockchain. Agritech leaders like Ag-Next and Vigro are leveraging these policy-driven standards to build quality-centric supply chains.

Ag-Next utilizes AI-based spectral analytics to provide instant quality assessments at collection centers, while Vigro employs blockchain-enabled tracking to meet stringent international phytosanitary requirements, directly improving India's standing in the World Bank's Logistics Performance Index[39].

4.2. PM GatiShakti National Master Plan (2021) and Site Selection

The PM GatiShakti initiative represents a transformative approach to integrated infrastructure planning using a GIS-based platform that synchronizes 16 central ministries[40]. By 2026, the focus has evolved from building roads to optimizing the location of logistics hubs. Private developers and agritech firms now use the PM GatiShakti National Master Plan (NMP) portal to identify "Logistics Dark Zones."

WayCool and DeHaat utilize the GIS layers of PM GatiShakti to identify optimal locations for their distribution centers and collection hubs. By overlaying data on existing rail-road connectivity and proximity to Multi-Modal Logistics Parks (MMLPs), these firms ensure that their physical assets are positioned for maximum last-mile efficiency. Ayekart leverages GatiShakti data to build regional hubs that bridge the gap between rural production clusters and urban demand, ensuring that infrastructure investments are data-driven rather than speculative.

By integrating projects like rural feeder roads into the master plan, GatiShakti allows firms like DeHaat to extend their service reach to previously inaccessible remote farm-gates. This integration reduces transit times and allows for the data-driven optimization of routes, a move highlighted by the World Bank as essential for modern business destinations.

4.3. Agriculture Infrastructure Fund (AIF) (2020) and Ecosystem Growth

The Agriculture Infrastructure Fund (AIF) provides medium-to-long term debt financing for investments in viable post-harvest infrastructure projects[41]. With a corpus of ₹1 lakh crore, it has become the primary financial vehicle for private-sector expansion into rural logistics. Leading private entities and agritech firms have actively tapped into the AIF to scale their physical operations:

Arya.ag (Arya Collateral) and StarAgri have leveraged AIF to build and upgrade thousands of warehouses across India. By utilizing the 3% interest subvention and credit guarantee schemes, these firms have transformed traditional storage into "Phygital" warehouses that offer both physical storage and digital financial services like e-NWRs (Electronic Negotiable Warehouse Receipts).

Superplum has utilized AIF incentives to invest in a tech-driven cold chain, specifically focusing on "on-farm" pre-cooling and refrigerated transport, which has significantly extended the shelf life of high-value fruits.

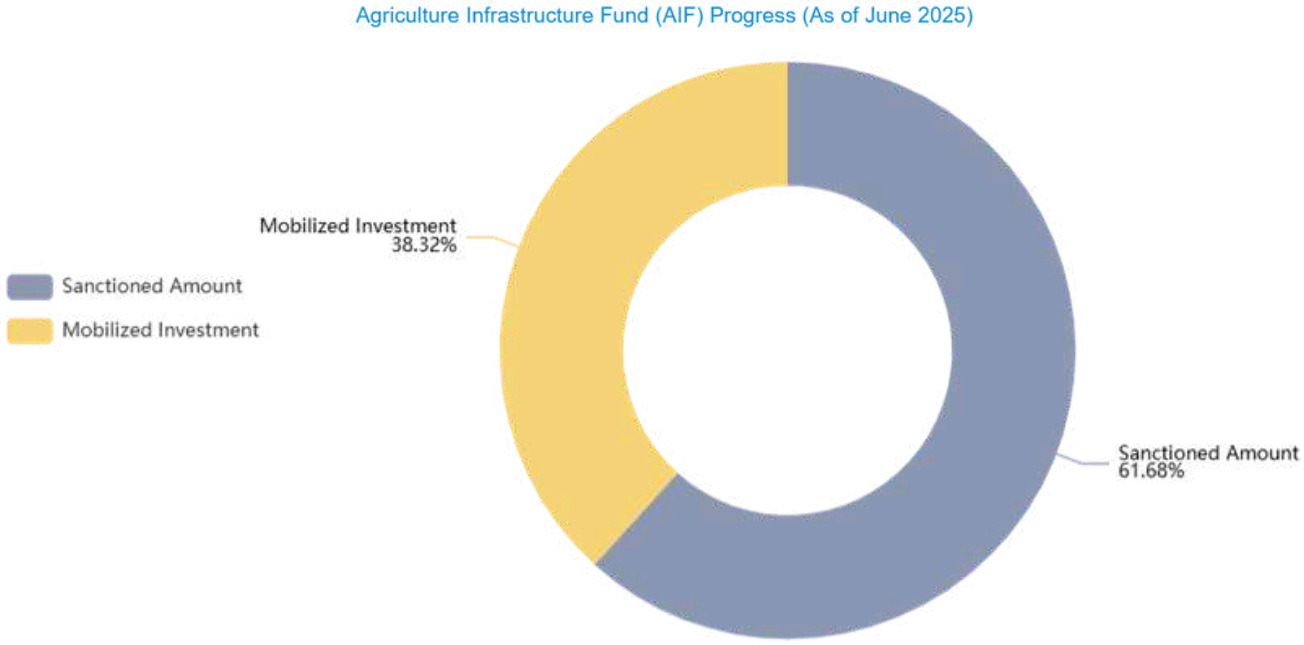


Figure 7: Agriculture Infrastructure Fund (AIF) Progress[42]

As of February 2026, over ₹66,310 crore has been sanctioned under AIF for more than 1.13 lakh projects[43]. The involvement of agritech firms has been critical in this progress, as they often aggregate smallholder farmers through FPOs (Farmer Producer Organizations) to access these funds collectively, enabling the construction of solar-powered cold storage units and automated grading centers[44].

4.4. Logistics Ease Across Different States (LEADS) Index

The LEADS index benchmarks the logistics performance of Indian states, encouraging competitive federalism[45]. By 2026, the index has evolved to include metrics for digital logistics and Environmental, Social, and Governance (ESG) compliance[46]. Firms like StarAgri and WayCool prioritize their expansion in states identified as "Achievers" in the LEADS report (such as Gujarat, Maharashtra, and Tamil Nadu). By aligning state-level logistics performance with the innovative capacity of the private sector, the LEADS index ensures that the transformation of the agri-logistics ecosystem is inclusive, sustainable, and technologically advanced. While national policies provide the overarching framework, the Nashik region in Maharashtra serves as the primary laboratory for the tech-enabled ecosystem transformation described in this report. As the "Horticulture Hub" of India, Nashik's integration of private-sector innovation with government digital infrastructure (ULIP and PM GatiShakti) and financial incentives (AIF) offers a scalable model for the objectives of Viksit Bharat 2047.

4.4.1. Private Sector Players and Technology Utilization

The concentration of high-value crops (HVCs) such as grapes, onions, and pomegranates in Nashik has attracted a high density of agritech and logistics firms. These entities have transitioned from traditional service providers to infrastructure orchestrators by leveraging the following frameworks:

- **Site Selection via PM GatiShakti and NLP:** Firms such as Ninjacart, and DeHaat utilize the PM GatiShakti National Master Plan (NMP) to identify optimal nodes for collection centers. In Nashik, this involves mapping proximity to the upcoming Multi-Modal Logistics Parks (MMLPs) and ensuring seamless connectivity to the Jawaharlal Nehru Port Authority (JNPA) for export-bound produce.
- **AIF-Driven Infrastructure Scaling:** Arya.ag (Arya Collateral) and StarAgri have significantly expanded their footprint in the Nashik-Pimpri belt. By leveraging the Agriculture Infrastructure Fund (AIF), these firms have established "Phygital" warehouses that utilize Electronic Negotiable Warehouse Receipts (e-NWRs) to provide instant liquidity to farmers, thereby preventing distress sales during the onion harvest glut.
- **ULIP Integration for Export Resilience:** Rivigo and Ayekart have integrated their fleet management systems with the Unified Logistics Interface Platform (ULIP). This integration is critical for Nashik's grape exporters, as it provides real-time visibility through the "Green Corridor" from farm-gate to port, reducing transit delays that previously compromised the cold chain integrity of perishable shipments.

4.4.2. Tech-Enabled Supply Chain Enhancements

The application of cutting-edge technologies by private players in the Nashik cluster has redefined storage and quality assurance standards:

- **AI and Quality Traceability:** Ag-next and Vigro have deployed AI-driven "Agentic" planning and spectral analytics at Nashik collection points. This allows for instant non-destructive testing of onion moisture content and grape brix levels, ensuring that only export-quality produce enters the high-cost refrigerated supply chain.
- **Specialized Cold Chain Solutions:** Superplum has utilized AIF incentives to build a multi-commodity cold chain in Nashik that employs "quick-switch" evaporator technologies. This allows the facility to handle Nashik's seasonal shifts moving from ambient storage for onions to precisely controlled chilled environments for pomegranates maximizing year-round capacity utilization.

4.5. The Maharashtra Agri-AI Policy[47]

The Maharashtra Agri-AI Policy (2025–2029) represents a strategic sub-national advancement in digital infrastructure, positioning the state as a leading hub for Artificial Intelligence (AI) and Generative AI (GenAI) in agriculture. Formulated to align with the national "IndiaAI" and "AgriStack" frameworks, the policy allocates an initial budget of ₹500 crore to revolutionize productivity, resilience, and farmer incomes through a shared Digital Public Infrastructure (DPI). This policy serves as a critical bridge between physical logistics and intelligent data-driven orchestration, ensuring that Maharashtra's vast agricultural output including cotton, soybean, and high-value horticulture is integrated into a modern, tech-enabled supply chain.

A fundamental pillar of the policy is the establishment of a Shared Digital Public Infrastructure (DPI) for data exchange. This includes the creation of the Agricultural Data Exchange (ADeX), which consolidates credible public datasets (farmer registries, soil health, and weather) with private sector data (market intelligence and credit systems). To support the logistics ecosystem, the policy provides a secure "sandbox" environment where agritech startups and logistics providers can validate AI models and digital tools before statewide deployment. This DPI-led approach ensures that data silos are eliminated, allowing for more precise planning in the movement of goods and market arrivals.

Expanding on the national focus on quality-centric supply chains, Maharashtra is implementing a statewide AI-enabled Agri-Food Traceability and Quality Certification Platform. Utilizing AI, Blockchain, and QR-code technology, the platform tracks produce from "farm to fork," documenting cultivation practices, harvest data, and quality certifications digitally.

- **Export Competitiveness:** Initially targeting export-oriented crops such as grapes, pomegranates, bananas, and specialty rice, the platform integrates with Farmers Producer Organizations (FPOs), exporters, and logistics providers.
- **Market Reliability:** By enabling AI-driven anomaly detection and real-time validation, the state aims to reduce rejection rates in international markets and improve price realization for farmers, strengthening Maharashtra's position as a trusted source for agri-exports.

4.5.1. The VISTAAR Initiative and Remote Sensing

The policy operationalizes the "Virtually Integrated System to Access Agricultural Resources" (VISTAAR) initiative, which leverages GenAI for real-time, hyperlocal, and multilingual advisory services. Complementing this is a shared Remote Sensing and Geospatial Intelligence Engine. This engine analyzes multi-source spatial data including satellite imagery, drones, and IoT devices to provide real-time insights into crop health and yield forecasting. For the logistics sector, these predictive analytics allow for better anticipation of surplus volumes, enabling transport providers to optimize fleet deployment and reduce post-harvest waste through precision-targeted interventions.

4.5.2. Institutional Framework and Phased Implementation

To ensure the sustainable delivery of AI solutions, the policy establishes a three-tiered governance structure:

- **State-Level Steering Committee (SLSC):** Chaired by the Chief Secretary for strategic oversight and fund approval.
- **State-Level Technical Committee (SLTC):** Responsible for evaluating the technical and commercial feasibility of AI use cases.
- **AI and Agritech Innovation Centre:** Serving as the operational program management unit, this center facilitates hackathons, manages the AI sandbox, and supports the scaling of proven technologies through Direct Benefit Transfer (DBT) for hardware like IoT sensors.

The implementation follows a four-phase roadmap through 2029, transitioning from foundational institutional setup to statewide scale-up and eventual cross-sector replication. By fostering collaboration between State Agriculture Universities (SAUs), industry leaders, and startups, the Maharashtra Agri-AI Policy ensures that the state's agri-logistics framework evolves into a sustainable, energy-aware, and data-intelligent ecosystem.

Case Study: Zespri and Avoco : Unified Cloud Based Quality Monitoring

New Zealand cooperatives Zespri (Kiwifruit) and Avoco (Avocados) provide a practical demonstration of how connected logistics standards can transform quality management. Both organizations utilize the QuantumLeap cloud platform to ensure GLOBALG.A.P. compliance and quality assurance from the grower through to in-market distribution.

Stage 1: Farm-Level Compliance and Process Traceability

At the grower level, compliance is treated as a digitally documented process rather than a static certification. Using the cloud platform, farmers and auditors capture origin data via code numbers and barcoding. Evidence of adherence to operational standards is uploaded through digital capture, including images, voice recordings, and documents. This ensures that not only is the product origin traceable, but the specific processes used to produce it such as harvesting methods and handling procedures are documented and verifiable.

Stage 2: In-Market Product Quality Feedback Loop

The critical innovation in this model is the synchronization of data at the destination. At in-market distribution centers, auditors conduct statistically valid sampling of fruit quality using the same cloud platform.

Data Capture: Auditors record producer codes, packhouse codes, and specific quality metrics, including visual defects and grading data, supported by photographic evidence.

Immediate Visibility: Reports are uploaded instantly to the cloud database, allowing the cooperative head office to view data in real time from anywhere in the world.

Root Cause Analysis: By matching product quality data (rejection rates and defects) with process quality data (harvesting and handling records), the organizations can identify systemic weaknesses and trace defects back to specific packhouses or growers.

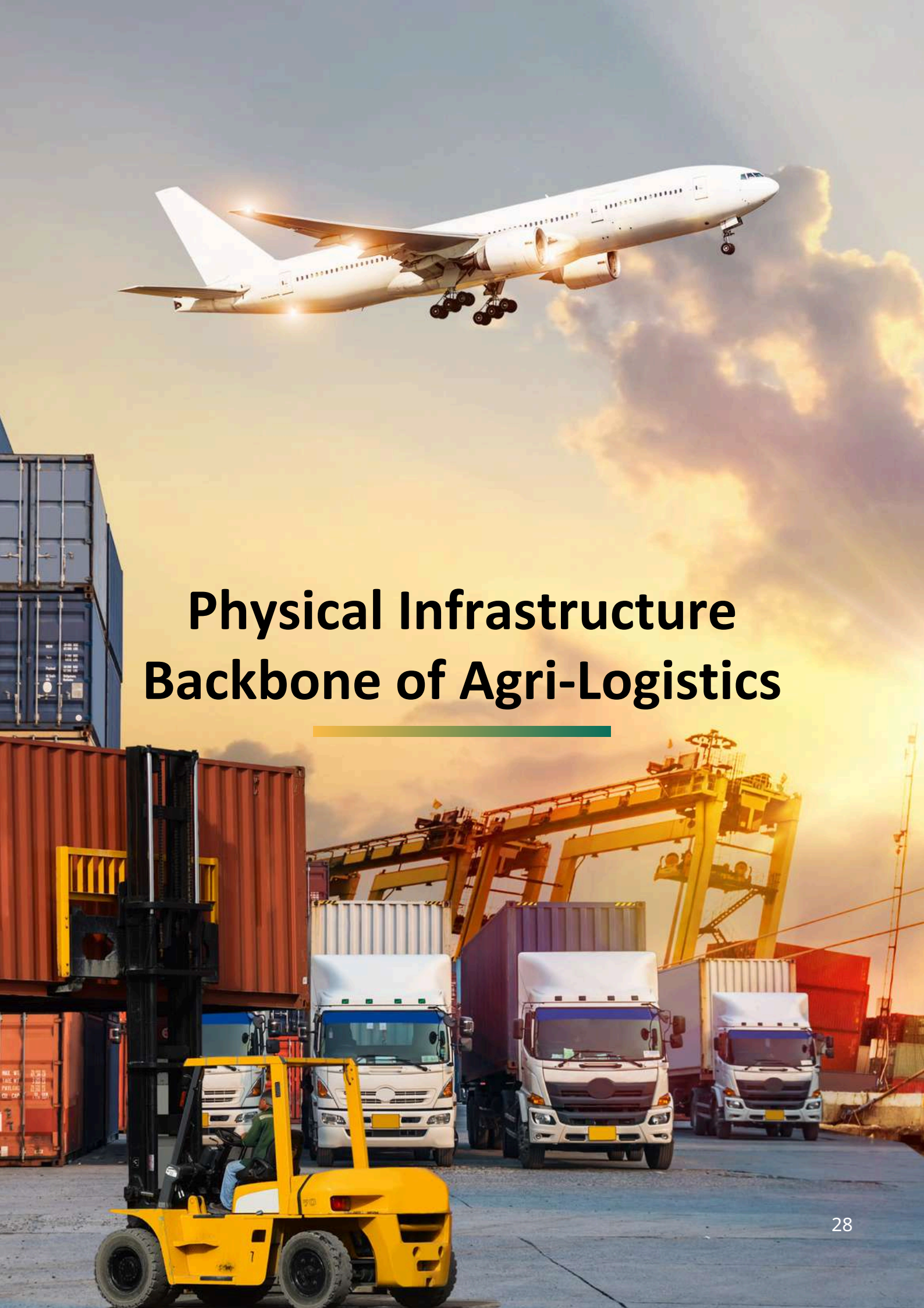
4.5.3. The Supply Chain Data Lake and Predictive Logistics

The experience of these global cooperatives highlights the emergence of the "Supply Chain Data Lake." When every stage of the logistics chain is digitally audited on a single integrated platform, it prevents data silos and enables the transition from reactive correction to predictive assurance. The integration of digital evidence capture and video monitoring systems strengthens logistics standards by providing behavioral confirmation of documented processes. For Indian clusters like Nashik, adopting such unified platforms would allow for:

Trend Analysis and Early Warning: Identifying recurring patterns and "solving a quality problem before it happens" by detecting early deviations in process adherence.

Verification of Cold Chain Integrity: Using digital tools and video verification to confirm correct handling and temperature maintenance, which is essential for perishable exports.

Dispute Resolution: Providing verifiable digital evidence (time-stamped images and video) to resolve claims and reduce waste.



Physical Infrastructure Backbone of Agri-Logistics

India's agri-logistics physical infrastructure is built upon an expanding network of storage and transportation assets. This includes over 8,689 cold storage facilities with a total capacity of 39.6 million metric tonnes as of August 2024, though a shortfall of approximately 10 million tonnes remains[48] [49]. General warehousing is also developing, with initiatives supporting block-level and WDRA-compliant facilities, often leveraging Public-Private Partnership (PPP) models, contributing to an agricultural warehousing capacity that grew at a 4.4% compound annual growth rate over the last decade[50] [51]. Transportation relies predominantly on an extensive road network, handling over 71% of the country's freight, complemented by significant investments in Dedicated Freight Corridors (DFCs) for rail, with the Eastern DFC now fully operational and the Western DFC 85% operational as of April 2024[52] [53]. Furthermore, multi-modal logistics parks (MMLPs) are being established to integrate various transport modes, while "Krishi Udan" supports air cargo for agricultural produce, and port infrastructure upgrades under programs like Sagarmala enhance maritime connectivity[54] [55] [56].

5.1. Road Connectivity (Domestic & Rural)

National Highways and Expressways: India’s national highway network spans over 142,000 km, connecting major cities and ports. The government’s Bharatmala Pariyojana (launched 2017) is modernizing and expanding highways, with a focus on high-speed corridors and connectivity to industrial and agricultural zones. By February 2025, projects covering 26,425 km of new highways had been awarded, with 19,826 km already constructed. The scheme aims to complete Phase-I by 2027–28, adding about 24,800 km of highways and 10,000 km of balance NHDP roads[57]. These new roads are improving connectivity between agricultural production centres and ports/consumption hubs. In addition, new expressways like the Delhi-Mumbai Expressway (approx. 1,350 km) are reducing travel time between India’s economic heartlands, benefiting farmers and traders by speeding up delivery of perishable goods.

Rural Roads: The Pradhan Mantri Gram Sadak Yojana (PMGSY) has been a game-changer for rural connectivity. Since its launch in 2000, PMGSY has constructed over 789,600 km of rural roads[58], connecting nearly all unconnected villages This massive expansion of rural road infrastructure has improved market access for farmers, allowing them to transport produce to markets and procurement centres more easily which significantly boosts agricultural GDP growth and reduces post-harvest losses by enabling timely transport of perishables. Better rural roads also enhance connectivity to nearby urban centres and national highways, facilitating the movement of agricultural inputs and outputs.

Logistics Parks and Corridors: To support efficient freight movement, the government is developing Multi-Modal Logistics Parks (MMLPs) at strategic locations. A policy for MMLPs was launched in 2021, aiming to establish 100 such parks nationwide. As of 2025, 10 MMLPs are under development (with 4 operational), aggregating 1,000+ acres of land[59]. These parks will integrate rail, road, and sometimes air transport, acting as hubs for cargo aggregation and distribution. Additionally, the PM Gati Shakti National Master Plan coordinates infrastructure planning across ministries. Gati Shakti has identified critical gaps in logistics corridors and aims to improve last-mile connectivity for goods, including agricultural commodities. This unified approach helps in planning highways, railways, and ports in tandem, ensuring seamless movement of farm produce from villages to ports/warehouses. For example, Gati Shakti is accelerating the construction of dedicated freight corridors and multimodal terminals to reduce transit times and congestion in the logistics chain.

5.2. Airport Infrastructure (Domestic & International)

Domestic Airports: India’s domestic aviation network has expanded rapidly, with a focus on regional connectivity. The UDAN (Ude Desh ka Aam Naagrik) scheme, launched in 2016, has opened over 150 new air routes to remote and hilly areas, connecting 90 airports across the country[60]. UDAN flights now serve even tribal and northeastern regions, making it easier to transport perishable agricultural products to markets. The government has also introduced Krishi UDAN (launched 2020), a special initiative to facilitate air transport of perishable farm produce. Krishi UDAN offers subsidized air freight rates and operational support to transport fruits, vegetables, fish, and meat from inland farms or tribal areas to major consumption or export centres.

By reducing transit time and spoilage, Krishi UDAN aims to improve value realization for farmers and expand agricultural exports. Under Krishi UDAN 2.0 (2021), airports are now involved in handling agri-cargo, with special focus on airports in the Northeast, hills, and tribal regions. This scheme has been successful in reducing post-harvest losses and increasing the share of air transport in the modal mix for perishables.

Air Cargo Terminals: While passenger traffic dominates, India's airports are also investing in cargo infrastructure. Major airports like Delhi, Mumbai, Chennai, Bangalore, and Hyderabad have dedicated cargo terminals. However, capacity constraints remain an issue, currently, India's total cargo handling capacity is around 6.5 million tonnes annually[61]. Several new cargo terminals and cold storage facilities are being built to meet the goal under National Infrastructure Pipeline for airport expansion. For instance, new facilities at airports in Pune, Guwahati, and Coimbatore are being are being developed to handle fresh perishable cargo, particularly fresh produce, reflecting a policy shift toward supporting high-value agricultural exports.

A notable regional example is Nashik Airport, which has emerged as a critical node for horticulture exports, especially grapes, onions, and other perishable vegetables. The airport is being equipped with dedicated perishable cargo handling infrastructure, including cold storage and pack-house linkages, enabling direct farm-to-airport connectivity. This reduces dependency on Mumbai as a consolidation hub and minimizes transit time and spoilage losses. The Nashik model illustrates the importance of decentralized air cargo infrastructure in strengthening agri-logistics value chains, particularly for export-oriented clusters.

Looking ahead, growth in air cargo is expected to accelerate in tandem with broader aviation sector modernization. The PM Gati Shakti framework further reinforces this trajectory by envisioning integrated, multimodal logistics systems where airport cargo terminals are seamlessly connected with road and rail networks, thereby enhancing efficiency, reducing turnaround times, and enabling end-to-end supply chain optimization.

International Airports: India's international airports (like Delhi, Mumbai, Chennai, Bangalore, etc.) are major gateways for agricultural exports. These airports handle high-value perishable shipments such as fruits, vegetables, and flowers. To support exports, the government has improved customs and warehousing at international airports. Many airports now have cold storage facilities and quarantine zones to handle perishables. The Customs Single Window Interface for Facilitating Trade (SWIFT) system, launched in 2018, provides a single platform for cargo clearance, benefiting exporters by reducing the time to clear shipments at airports. India's international airports have also upgraded cargo handling equipment and adopted modern IT systems for better efficiency. Overall, while air transport in India is still relatively small compared to road and rail, the improved infrastructure and schemes like UDAN and Krishi UDAN are steadily increasing its role in agri-logistics.

5.3. Rail Infrastructure

India's rail network forms a critical backbone for long-distance agricultural freight movement, particularly for bulk commodities such as cereals, pulses, sugar, and oilseeds. In recent years, Indian Railways has expanded its role in agri-logistics through targeted policy interventions aimed at improving accessibility, affordability, and efficiency. The introduction of Kisan Rail (2020) marked a significant shift toward integrating perishables into rail transport. These trains operate on fixed schedules and connect major production clusters with consumption centres, enabling faster movement of fruits, vegetables, dairy, and fish. Subsidized freight rates and operational support have further incentivized farmers, FPOs, and aggregators to utilize rail for time-sensitive shipments.

In parallel, national programmes such as PM Gati Shakti and the National Logistics Policy are reinforcing rail's role within a multimodal logistics framework, emphasizing seamless integration with road, ports, and airports. The development of Dedicated Freight Corridors (DFCs) particularly the Eastern and Western corridors is expected to significantly enhance freight capacity, reduce transit time, and improve reliability for agricultural cargo.

Agri-Freight Operations and Commodity Movement:

Rail provides a cost efficient mode for transporting large volumes over long distances, making it well suited for non-perishable and semi-perishable commodities. Initiatives like Kisan Rail have enabled aggregation and movement of horticultural produce from key states to major urban markets, improving supply efficiency and reducing post-harvest losses. However, reliance on centralized loading points and limited decentralized aggregation infrastructure restrict smallholder participation, often necessitating intermediaries or FPO-led aggregation.

Rail Freight Terminals and Infrastructure:

Indian Railways is expanding Private Freight Terminals (PFTs), goods sheds, and multimodal logistics parks with improved handling and warehousing infrastructure. Despite this, gaps persist in reefer-compatible facilities, pack-house linkages, and temperature-controlled handling at railheads, limiting effectiveness for perishables. In clusters such as Nashik, while rail supports bulk movement, inadequate cold-chain integration at loading points continues to constrain its role in high-value export supply chains.

5.4. Seaport Infrastructure (Major & Minor)

Major Ports: India has 13 major ports (including new ones like Deendayal Port (Kandla), Chennai, Ennore, V.O. Chidambaranar (Tuticorin), Visakhapatnam, Mormugao, New Mangalore, Cochin, Kolkata-Haldia, Paradip, JNPT (Mumbai), Jawaharlal Nehru Port Trust (Nhava Sheva), and Port Blair), which handle about 65% of the country's maritime trade[62]. These ports are being modernized and expanded under the Sagarmala Programme (launched 2015), with a focus on deepening berths, adding new terminals, and improving hinterland connectivity.

Recent developments include new container terminals at JNPT and Mundra, expansion of coal and iron ore handling facilities, and the commissioning of the new Paradip Port in Odisha. Major ports have also improved operational efficiency, for example, Jawaharlal Nehru Port (Nhava Sheva) has introduced advanced technologies to reduce dwell times and improve turnaround of ships. The government has set ambitious targets to enhance port capacity and throughput. For instance, by 2025-26, major ports aim to handle about 855 million tonnes of cargo[63]. The PM Gati Shakti initiative is further aligning port projects with road and rail projects to ensure seamless multimodal connectivity. This means new ports and terminals are being built in conjunction with new rail links and highways, thereby cutting inland transit times for agricultural exports.

Vadhavan Port (New Major Port):

In addition to existing major ports, Vadhavan Port is a greenfield deep-draft major port approved by the Union Cabinet and planned on the west coast at Vadhavan near Dahanu in Palghar district, Maharashtra. It will be developed by Vadhavan Port Project Limited (VPPL), a Special Purpose Vehicle formed by Jawaharlal Nehru Port Authority (JNPA, majority stake) and the Maharashtra Maritime Board (MMB). The project with an estimated investment of around ₹76,220 crore is being constructed under a public-private partnership (PPP) and landlord model framework.

Key features include:

- All-weather deep draft port with around 20 m depth suitable for ultra-large container vessels, enabling efficient handling of mega ships.
- **Capacity:** projected to handle up to 298 million tonnes per annum (including about 23–23.2 million TEUs of container volume), making it one of the largest ports in India once fully developed.
- **Infrastructure:** nine 1000 m container terminals, four multipurpose berths, four liquid cargo berths, a Ro-Ro berth, and a Coast Guard berth, along with extensive breakwaters and container/cargo storage areas.
- **Connectivity:** dedicated road and rail links to national highways and the Dedicated Freight Corridor are planned to ensure smooth hinterland logistics, including potential direct freight corridors to central and northern markets. isting major ports like JNPT.

- **Strategic Significance:** the port is expected to support major trade corridors such as the India-Middle East-Europe Economic Corridor (IMEEEC) and the International North-South Transport Corridor (INSTC), enhancing India's global maritime connectivity.

Phased development is planned, with initial terminals projected to begin operations in the coming few years, and full build-out by the early 2030s. Once operational, Vadhavan is expected to significantly augment India's container handling capacity, reduce dependence on foreign transshipment hubs, and ease congestion at existing major ports like JNPT.

Minor (Non-Major) Ports: There are over 200 non-major ports (minor ports) along the coast, which handle a variety of cargo including agricultural produce, fish, and bulk goods. These ports are managed by state governments and play a crucial role in local and regional trade. The Sagarmala Programme also includes projects for developing non-major ports, for example, the Coastal Berth Scheme provides grant-in-aid to state governments to develop berths and associated infrastructure (like dredging, breakwaters, and mechanization) at minor ports[64]. By improving facilities at these ports, the government aims to reduce the load on major ports and bring agricultural products from smaller ports closer to the farms. Additionally, many non-major ports have started handling containerized cargo in recent years. For instance, ports in Tamil Nadu (Tuticorin, Chennai), Andhra Pradesh (Vizag, Krishnapatnam), and Odisha (Paradip) are increasingly handling export containers, including those carrying agricultural commodities.
The PM Gati Shakti plan also identifies minor ports as potential nodes for regional logistics hubs, which will be connected via improved road and rail networks. Overall, the non-major ports complement the major ports by providing last-mile connectivity to local agricultural clusters and fishing villages, thereby strengthening the entire agri-logistics chain.

Port Infrastructure for Agro Exports: Recognizing the importance of ports in agri-trade, the government has prioritized port infrastructure for agro commodities. Many major ports have dedicated facilities for handling agricultural products. For example, Mundra Port (operated by Adani) has state-of-the-art terminals for grains and edible oils, with modern silos and bagging facilities.

Chennai Port has dedicated terminals for sugar and grains, and Kandla Port is a bulk grain trade leader. Additionally, cold storage facilities are being set up at ports to store perishable exports like fruits and vegetables before shipment. In 2025, the government announced plans to develop specialized cold storage units at ports (e.g., at JNPT) to extend the shelf life of agricultural exports[65]. Furthermore, ports are implementing green initiatives (like solar power, waste management) to improve sustainability. The Harit Sagar guidelines, issued under Sagarmala, encourage ports to adopt green technology and reduce their carbon footprint. These measures not only make ports more efficient but also ensure compliance with international environmental standards for exporting perishable goods.

Customs procedures and Automation (Import/Export)

The Indian government has made significant strides in simplifying customs procedures to reduce trade logistics costs. Under the Ease of Doing Business reforms, the Customs Department introduced the Single Window Interface for Facilitating Trade (SWIFT) system. SWIFT allows exporters and importers to file all necessary trade documents (for customs, DGFT, etc.) through a single portal. This has drastically cut down the time and paperwork for clearance. For instance, exporters can now file documents online and get them approved within a few hours, compared to days or weeks earlier. The introduction of Electronic Bill of Entry (eBOE) and eSanchar Net (an electronic communication platform) has further streamlined the export process. These digital systems have reduced documentation requirements and delays, making it easier for small and medium exporters to handle shipments[66]. Additionally, the Customs Act, 1962 was amended to introduce a "Self-Sealing" facility for exporters. Under this scheme, exporters are permitted to seal their own containers, and customs officials do not need to manually seal each container for export. This measure, introduced in 2017, has eliminated the need for exporters to wait for customs personnel at the factory gate, thus saving time and reducing costs[67]. The government has also been working on a National Customs Portal to integrate various customs systems and provide real-time tracking of shipments, further enhancing transparency and efficiency.

Automation is a key focus in customs operations. The Indian Customs has implemented e-filing of all major documents, including Bill of Entry, Shipping Bill, and certificates. The use of EDI (Electronic Data Interchange) and ANX (Advance Numeric X-ray) technology has improved the screening of cargo.

For example, many airports and ports use X-ray scanners and AI-based systems to detect suspicious shipments, ensuring security without slowing down legitimate trade. The Customs department has also rolled out the ITC-TradeNet system, which integrates multiple departments (Customs, DGFT, RBI, etc.) and provides a unified platform for trade facilitation. The PM Gati Shakti plan's digital platform is expected to further integrate customs data with other logistics data (road, rail, port, etc.), enabling end-to-end visibility of goods in transit. This digital integration will help in identifying bottlenecks and optimizing clearance processes. Another notable development is the use of blockchain and IoT (Internet of Things) in trade. The government has been exploring blockchain-based trade finance and shipping documents to reduce fraud and paperwork. Some pilot projects have used blockchain to share shipping manifests and bills of lading in real-time among customs, banks, and shipping lines, improving the speed of clearance. These technological advancements are gradually transforming India's customs into a more efficient, data-driven system that supports agrilogistics by reducing delays and ensuring compliance.

Transportation Infrastructure for Agricultural Logistics in India

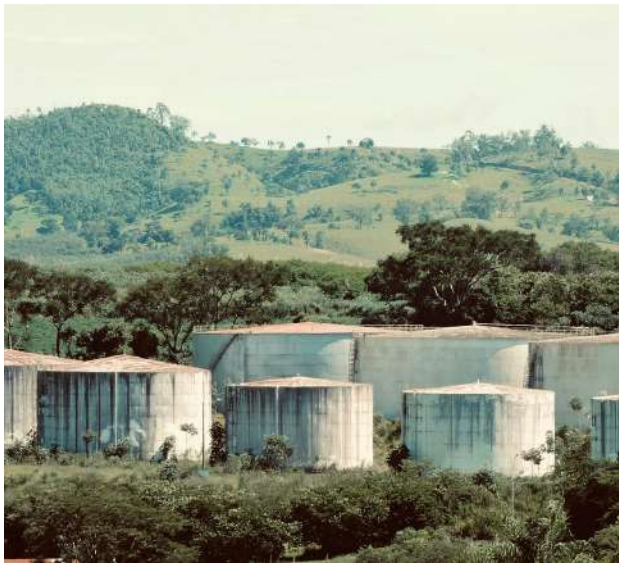
Road transportation is the backbone of India's agricultural supply chains. An estimated 4 million trucks ply Indian roads, carrying about 70% of the country's total domestic freight volume[68]. Agriculture forms a significant share of this freight roughly 22% of freight tonnage consists of agricultural goods[69]. The vast majority of farm produce, particularly perishables, moves via highways and rural roads. According to the National Centre for Cold-chain Development (NCCD), fully 97.4% of fruits and vegetables in India are transported by road, with only 2.6% moving via rail[70]. This heavy reliance on trucking is partly due to flexibility and first-mile connectivity that road transport offers. However, it also reflects limited development of alternative modes and a historically fragmented logistics network.

Infrastructure expansion: In recent years, government programs like Bharatmala have expanded the highway network to improve connectivity from farm regions to markets. The National Highway network grew from ~91,000 km in 2014 to 1,46,560 km by 2025[71], including over 3,000 km of new expressways. Modern logistics parks are being planned (35 Multimodal Logistics Parks under Bharatmala) to handle 700+ million tonnes of cargo with better multimodal facilities[72]. These investments are gradually improving long-haul transport efficiency for agri-produce. Nonetheless, the **"first-mile" and rural road connectivity** remain a bottleneck in moving produce from farm-gates to these main transport corridors, necessitating reliance on smaller trucks and intermediaries.

6.1 Trucking Capacity and Utilization

India's agri-trucking sector is characterized by high fragmentation and capacity inefficiencies. Over 80% of truck operators run fleets of fewer than 10 trucks[73], and a large portion are single-truck owners. This unorganized structure limits economies of scale many small operators cannot afford specialized vehicles or advanced fleet management. As a result, trucking capacity is often under-utilized. Studies indicate Indian trucks run empty for up to 30-40% of their total kilometers[74], especially on return legs after delivering produce. Such high empty backhaul rates effectively reduce available capacity and drive up costs. The average load factors are suboptimal, meaning trucks often don't carry full loads on outbound trips either. These inefficiencies contribute to India's logistics costs being ~14% of GDP (versus ~8-10% in developed economies)[75].

A related constraint is the shortage of truck drivers and skilled labor. Nearly 28% of the trucking fleet may be idle at a given time due to lack of drivers[76]. Difficult working conditions, low pay, and long transit times discourage new entrants to truck driving. This manpower gap effectively caps usable trucking capacity even when vehicles are available. Seasonal spikes (e.g. during harvest gluts) further strain capacity, often resulting in localized truck shortages or price surges for hiring transport at peak times. In sum, while absolute trucking numbers are high, effective capacity for agri-logistics is curtailed by fragmentation, under-utilization, and workforce limitations. Addressing these will be key to lowering freight costs for farmers and ensuring timely evacuation of produce from production clusters



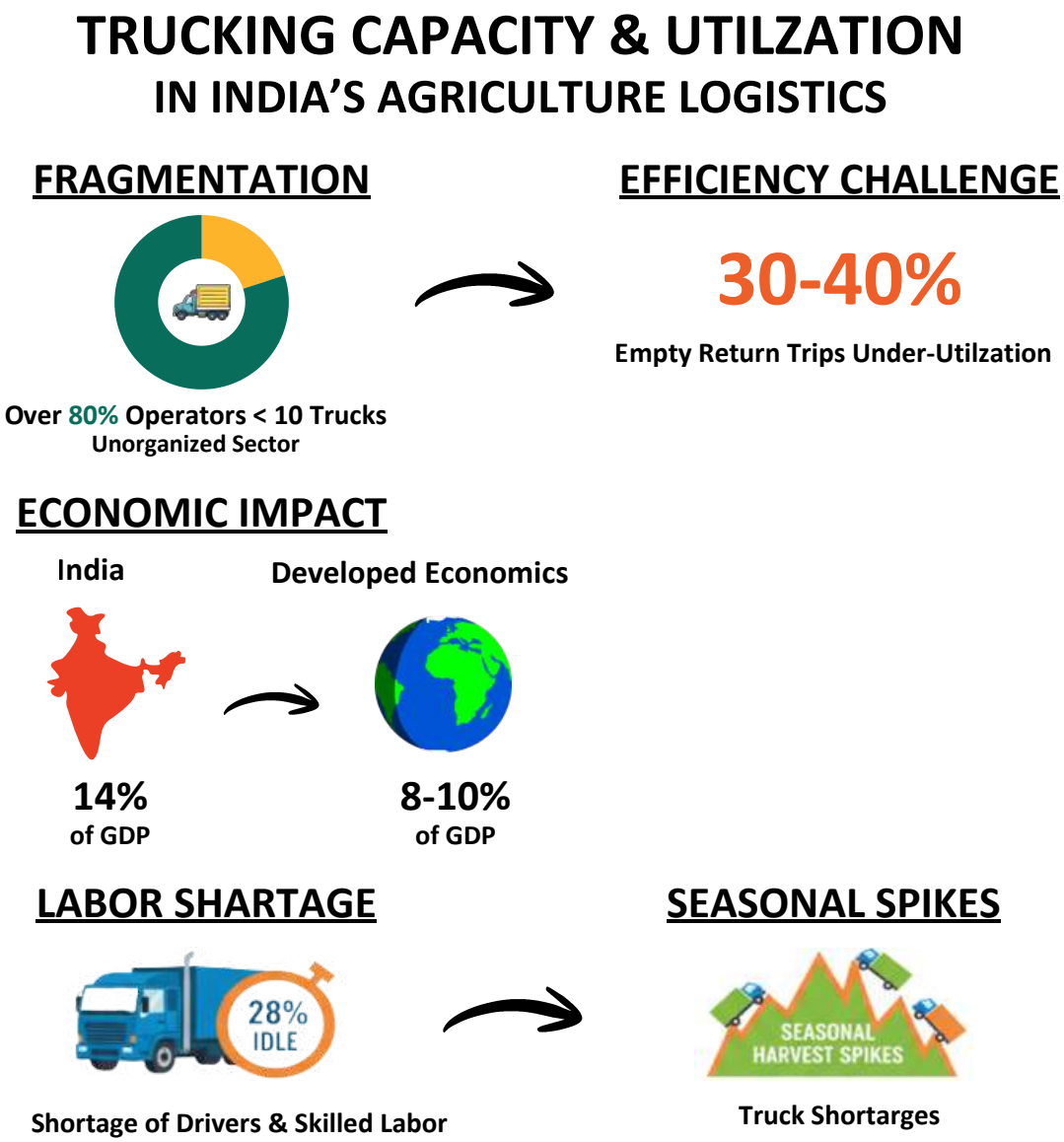


Figure 8: Trucking Capacity and Utilization

6.2 Vehicle Quality and Standards

The quality and fitness of vehicles used in agricultural transport have direct implications on efficiency, safety, and produce quality. A large segment of trucks on Indian roads are older vehicles with outdated technology. Traditionally, trucks in India have a first useful life of around 8–12 years with primary owners, after which many enter a "second-life" of 5+ years in lighter or regional operations[77]. This means it's not uncommon to see 15-year-old or older trucks carrying agricultural goods. Such aging vehicles often suffer frequent breakdowns, poor fuel efficiency, and higher spoilage risk for cargo (due to unreliable cooling or ventilation). In recent years, the government has acknowledged this issue: as of late 2025, over 3.5 lakh old vehicles had been scrapped under new vehicle scrappage and fitness policies, and 123 automated testing stations were operational for periodic fitness checks[78]. These measures aim to phase out unroadworthy trucks and modernize the fleet. However, enforcement remains a challenge, and many old, polluting trucks remain in service especially with small operators in remote areas.

Overloading and compliance: Another quality concern is the prevalent practice of overloading trucks beyond prescribed weight limits. Overloading not only damages road infrastructure but also stresses vehicles, leading to higher breakdown rates and unsafe handling. While laws exist against overloading, enforcement is inconsistent

enforcement is inconsistent across states and highway checkpoints. This undermines vehicle longevity and road safety. Furthermore, basic safety features and driver amenities in trucks have been historically minimal though new trucks are now required to include features like ABS and various aids, much of the existing fleet lacks advanced safety or driver comfort features. The Ministry of Road Transport has strengthened standards (e.g. mandating certain ADAS – Advanced Driver Assistance Systems in new heavy vehicles), but it will take time for such improvements to permeate the entire fleet.

Specialized agri-transport equipment: The quality issue is also about suitability most agricultural produce is still hauled in general purpose trucks not designed for perishables. Open-top trucks or non-insulated cargo spaces remain common for fruits and vegetables, exposing them to heat, dust, and rain. A lack of crating or palletization means produce is often heaped in jute sacks or loose piles, causing bruising and unsanitary conditions. Only the dairy and meat sectors have widely deployed insulated or purpose-built vehicles for horticulture, the norm is still conventional diesel trucks with no refrigeration[79]. This "one-size-fits-all" approach to vehicles is a weak link in maintaining quality across the supply chain. In short, the vehicle fleet for agri-logistics requires an upgrade newer, well-maintained trucks, adherence to load and safety norms, and more specialized vehicles (reefers, ventilated vans, etc.) for transporting sensitive produce. Without this, inefficiencies and losses persist from farm to market.

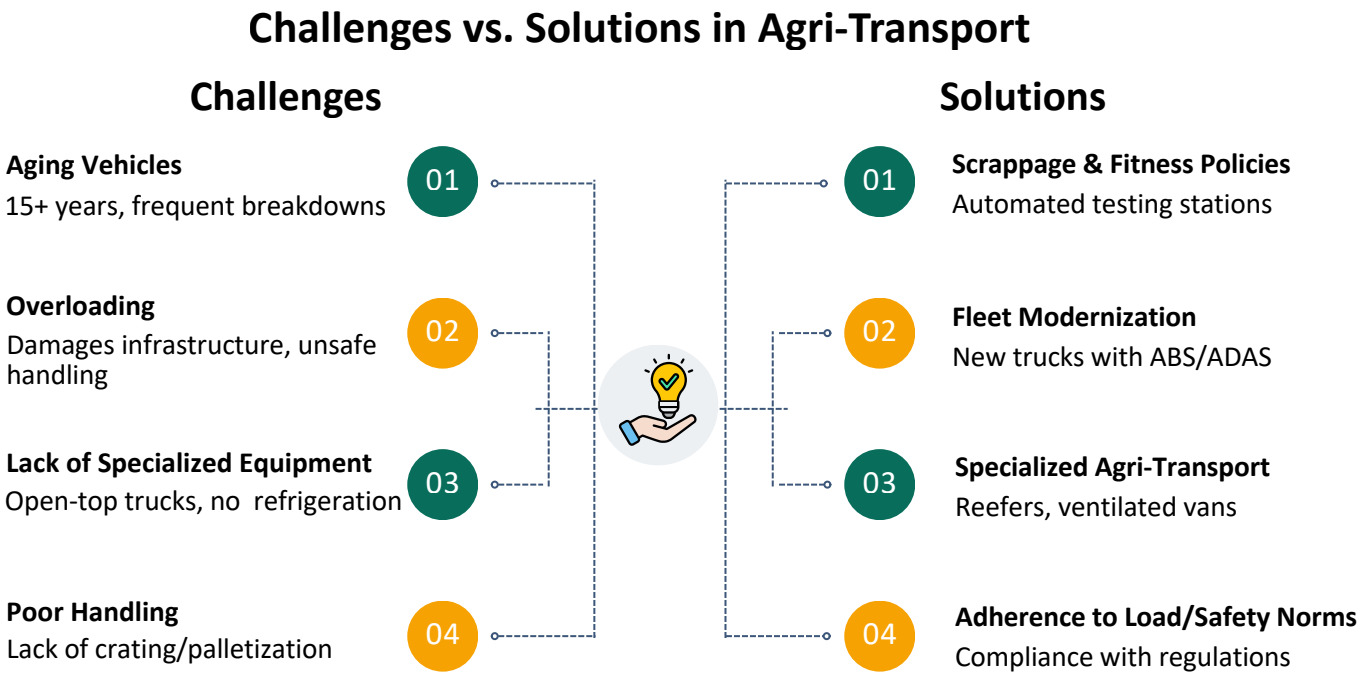


Figure 9: Strategy towards Agri-Transport in India

6.3 Cargo Visibility and Tracking

Real-time visibility of agricultural cargo movements in India is generally limited. In the current state, once produce leaves the farm gate, stakeholders (farmers, traders, buyers) often have little visibility on its exact location or condition until it reaches the destination. This is largely due to the sector's fragmentation – small fleet operators rarely invest in advanced telematics or IT systems. In fact, 80% of Indian trucking firms (mostly small operators) do not log detailed operational data as larger companies do[80]. Consequently, the supply chain operates with information gaps: delays, route deviations, or end-route mishandling often go untracked. Lack of visibility also impedes coordination for example, a market yard may not know when exactly a produce-laden truck will arrive, affecting auction timing and cold storage prep. However, there are signs of change. The government has introduced regulatory mandates to improve tracking. Since 2019, Automotive Industry Standard AIS-140 requires GPS-based vehicle tracking devices in all commercial vehicles (N2 and N3 category trucks)[81]. Compliance with this mandate has accelerated with states like Uttar Pradesh linking GPS device installation to vehicle registration[82].

Moreover, the widespread implementation of FASTag (RFID toll tags) on over 1,000 highway toll plazas means that truck movements are being digitized to some extent. These toll systems capture data on truck transit which, if aggregated, can provide macro-level visibility of freight flows[83]. Going forward, MoRTH plans to introduce GPS-based tolling (to eventually replace physical toll booths), which would further streamline real-time location data for vehicles.

In the private sector, new logistics tech startups and 3PL companies are offering solutions for fleet tracking, route optimization, and cargo monitoring (e.g. smartphone apps for truck drivers, IoT sensor packages for refrigerated loads). Some agribusinesses and food processors have begun equipping contracted trucks with IoT sensors that monitor temperature and humidity, transmitting alerts if cold chain parameters are breached. Pilot projects (such as in spice export supply chains) have demonstrated the value of GPS-enabled tracking combined with blockchain based logging for end-to-end transparency. These initiatives remain in nascent stages relative to the millions of small shipments moving daily. Policy support for digitization is growing: the National Logistics Policy (2022) explicitly calls for "global-standard tracking and tracing systems" and greater digital integration across the logistics sector[84]. Over time, as device costs fall and digital literacy improves, even smaller operators may adopt basic tracking for competitive advantage. In summary, cargo visibility in agri-logistics is currently an area of weakness characterized by low technology adoption and information silos but is poised to improve through mandatory GPS devices, logistics data platforms, and the entry of tech-driven fleet aggregators.

6.4 Hygiene and Food Safety in Transportation

Maintaining hygiene and food safety during transport is critical for agricultural commodities, yet it remains an under addressed aspect of India's agri-logistics. Produce is often handled and shipped in ways that expose it to contamination and spoilage. Inadequate pre-cooling and packaging at the farm level mean fruits and vegetables may carry field heat, soil, and microbes into the supply chain. When such produce is loaded onto trucks without proper cleaning or packing, the risk of rot and food safety hazards increases. Pack-houses facilities for sorting, grading, and hygienic packing at the farm gate – are glaringly scarce (India has only a few hundred modern pack-houses against a requirement of ~70,000). This gap forces much produce to bypass hygiene steps and go straight onto transport. The NCCD's gap assessment bluntly noted that the cold-chain gap is "not as much cold storage capacity as other components" like pack-houses and reefer transport[85]. In other words, missing first-mile infrastructure results in produce being moved in non-ideal conditions, breaching cold-chain integrity and hygiene standards.

Conditions during transport: Field surveys often find that trucks carrying fruits, vegetables or grains are not sanitized between loads. It's common for the same truck that hauled fertilizer or livestock feed on one trip to carry food produce on the next, without thorough cleaning leading to cross-contamination risks. Most small transporters are unaware or dismissive of Good Hygiene Practices (GHP) in logistics. Few trucks have washable cargo interiors or food-grade container linings. Temperature-sensitive items like dairy, meat, or fish are frequently transported with inadequate ice or no refrigeration, causing bacterial growth. The result is high spoilage: post-harvest losses in fruits and vegetables still range from ~6% up to 15% by volume, much of which is attributed to spoilage during handling and transit in unsafe conditions[86]. The economic loss from such wastage is enormous one estimate put total post-harvest food losses at ₹89,000 crore annually (nearly 1% of GDP)[87].

On the regulatory side, the Food Safety and Standards Authority of India (FSSAI) has issued guidelines for safe food transport (e.g. recommended temperature ranges, cleanliness, pest control, driver hygiene)[88]. But enforcement of these standards in the unorganized transport sector is minimal. There are no routine inspections of produce trucks for sanitary conditions, except occasionally at major market yards. This represents a policy blind spot while considerable attention has been given to food processing hygiene, the transportation link has not seen equivalent oversight. Improving hygiene will require measures such as: incentivizing use of plastic crates or liners instead of gunny sacks (to reduce physical damage and contamination), training transporters on basic food safety, and potentially certifying or rating logistics providers on hygiene compliance. In essence, the hygiene bottleneck in agri-logistics continues to undermine food quality and safety, and addressing it is crucial for delivering farm produce to consumers in wholesome condition.

6.5 Cold-Chain Transportation for Perishables

Perhaps the most critical weakness in India's agri-transport infrastructure is the lack of adequate cold-chain transport i.e. refrigerated trucks and vans for perishable commodities. Despite being the world's second-largest producer of fruits and vegetables, India has a shockingly low cold-chain penetration. Only an estimated 4% of India's fresh food produce travels through a cold chain (refrigerated storage and transport). In contrast, well-developed supply chains like that of the UK see about 70% of food moving under cold-chain conditions[89]. This gap explains the high spoilage rates and short market reach of Indian perishables. Produce like tomatoes, grapes, or leafy greens often start deteriorating soon after harvest due to exposure to ambient heat in transit. By the time they reach distant urban markets, a significant portion is unsellable. Some high-value export-oriented supply chains (e.g.for mangoes, pomegranates) do use reefers and cold storage, but these are the exception rather than the norm domestically.

Capacity vs. requirement: A landmark 2015 study by NCCD quantified the cold-chain deficit: India needed about 62,000 refrigerated vehicles to serve its consumption demand but had less than 10,000 in operation[90]. Updated estimates in 2020 show some improvement roughly 12,700 refrigerated trucks were in use yet this is still a small fraction of the >70,000 that would be required to fully cater to the nation's perishables[91].

This severe undercapacity means that even when cold storage facilities exist, the "mobile" part of the cold chain is a weak link. Notably, India has created large cold storage spaces (India has 8,815 cold storages with a combined capacity of 402.18 lakh metric tonnes (MT)[92]. But without sufficient refrigerated transport and pack-houses, much of that storage is utilized for products like potatoes or dried chili items that can tolerate non-refrigerated transport rather than for a seamlessly chilled farm-to-fork supply chain. As one official quipped, "the gap in India's cold-chain is less about cold stores than about the connective tissue pack-houses and reefer trucks"[93].

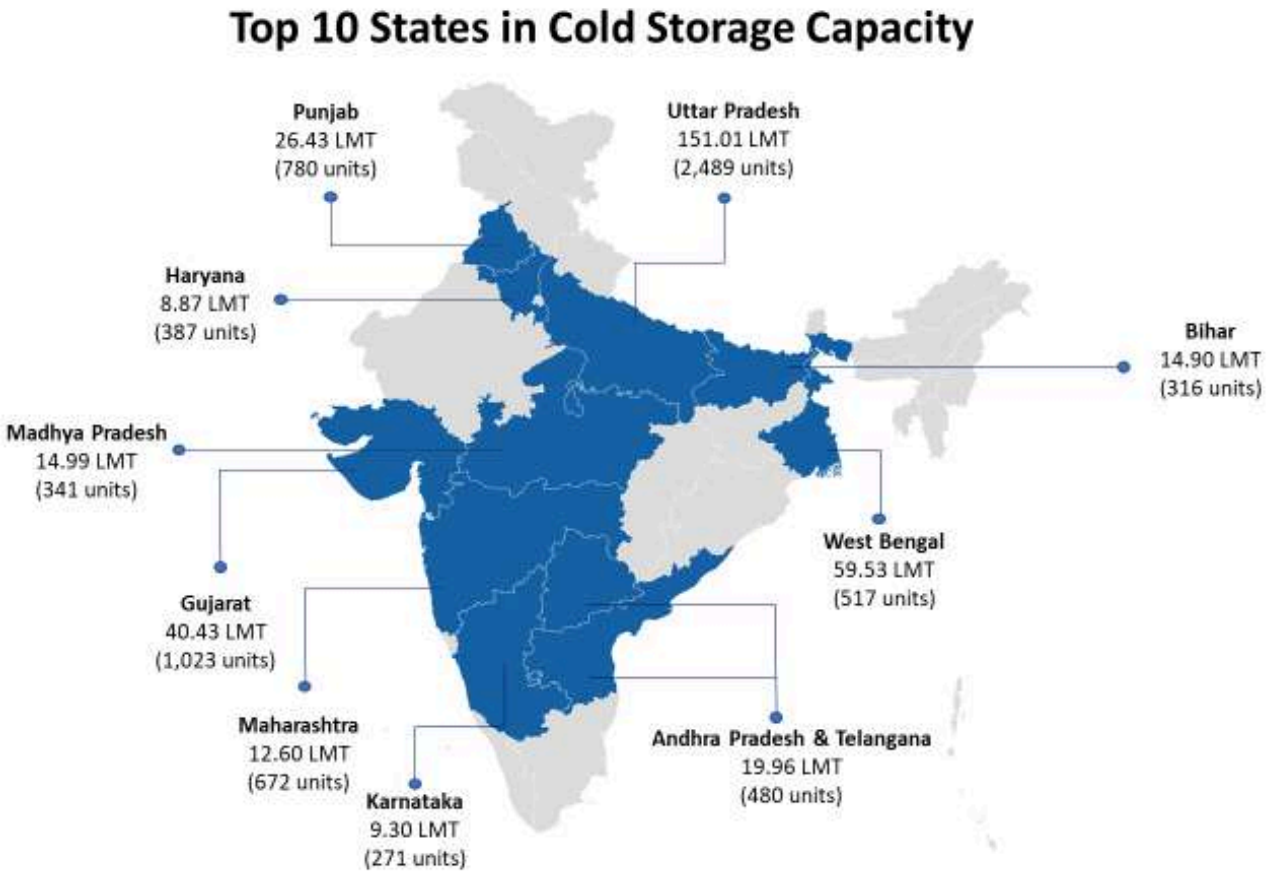


Figure 10: Cold Storage Capacity in India[94]

Impacts and current initiatives: The shortage of reefers and poor temperature control in transit contribute to high post-harvest losses (often 20-30% in value for perishables). It also limits farmers' market options without cold-chain, farmers must sell quickly to nearby markets before spoilage, often at distressed prices. The government has launched schemes to tackle this: the Mission for Integrated Development of Horticulture (MIDH) and the PM Kisan Sampada Yojana (Cold Chain scheme) subsidize purchase of refrigerated vans and the setting up of pack-houses. Under these schemes, as of FY2024 about 1,482 refrigerated vehicles have been supported (with another ~380 in pipeline)[95]. While helpful, these numbers are relatively small clearly, large-scale private sector investment is needed to bridge the tens of thousands gap in reefer trucks. The "Kisan Rail" initiative (running special reefer rail trains from production zones to cities) has also been introduced, but rail's share remains minuscule (just 2-3% of produce movement)[96]. In summary, cold-chain transport is a glaring bottleneck and policy blind spot historically one that demands urgent attention to reduce food waste and extend the shelf life and reach of India's agricultural produce.

6.6 Emerging Trends and Expected Developments

Looking ahead, India's agri-logistics transportation is poised for significant change. Several emerging trends are expected to reshape the trucking segment, improving efficiency, reducing losses, and modernizing the sector. Notably, these changes are being driven both by policy incentives and by market forces (including adoption of global best practices). Key expected trends include:

- **Expansion of Refrigerated Fleet:** The coming years should see a rapid increase in the number of reefer trucks and vans. Government initiatives under MoFPI and MIDH continue to provide capital subsidies for refrigerated vehicles, recognizing the critical gap. The India Cooling Action Plan (2019) projects the country's fleet of refrigerated vehicles to grow from roughly 13,000 in 2018 to 300,000 by 2037-38, underlining the scale of ambition[97].

While this projection is aspirational, it signals strong policy intent. Factors driving reefer growth include rising demand for fresh and processed foods in urban areas, the expansion of organized retail and e-commerce grocery (which require cold-chain for quality), and the push to reduce post-harvest losses. Private sector participation is rising: major logistics firms and supermarket chains are investing in their own cold-chain fleets or partnering with startups. For example, e-commerce grocers like Amazon and BigBasket reportedly added over 500 refrigerated vehicles to their distribution networks recently to reach more cities[98]. This trend is expected to continue, aided by global best practices in cold-chain management (such as adoption of multi-temperature vehicles, smaller reefer vans for last-mile delivery, and use of renewable energy-based refrigeration like solar-powered "reefers"). The why is clear with cold-chain use correlated to improved farmer incomes and lower waste, there is both political and economic incentive to build out this capacity.

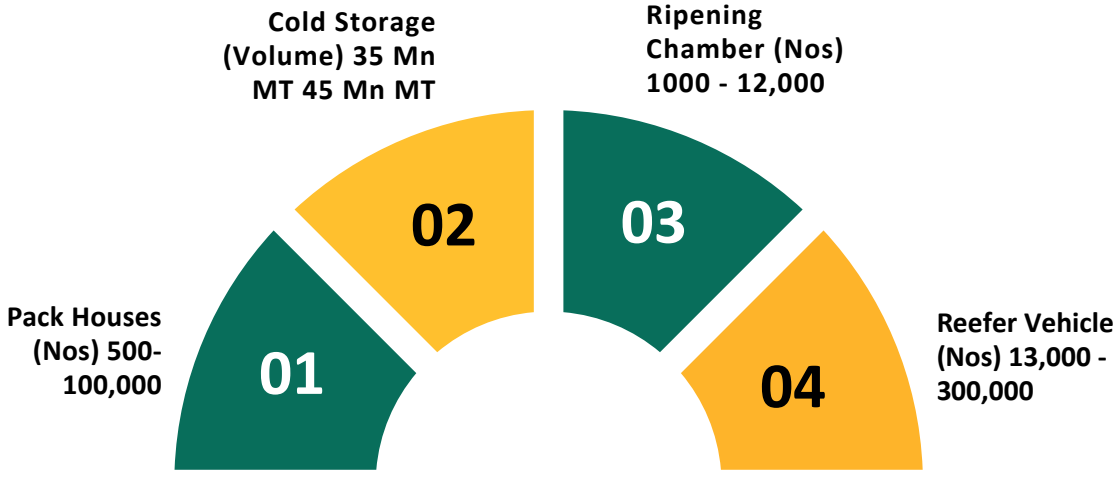


Figure 11: Envisaged growth in cold-chain infrastructure from 2017-18 to 2037-38

- **Fleet Electrification and Green Trucks:** The freight transport sector is on the cusp of an electric vehicle (EV) revolution, and agricultural logistics will benefit from this broader shift. In 2025, the Government launched the PM E-DRIVE scheme, India's first dedicated incentive program for electric trucks[99]. The scheme provides upfront purchase incentives up to ₹9.6 lakh per truck, targeting the deployment of about 5,600 electric heavy trucks in an initial phase. This move is driven by environmental urgency diesel trucks comprise only ~3% of vehicles but contribute 42% of transport-sector greenhouse emissions[100] as well as the need to reduce diesel costs and pollution in cities. Several states are complementing this push: for instance, Maharashtra's EV policy aims for 20% of new truck sales to be electric by 2030[101], with purchase subsidies and tax waivers to encourage adoption. While current electric truck pilots in India are focusing on short-range and fixed-route operations (e.g. within port areas, steel plants, or urban deliveries), improvements in battery technology and charging infrastructure over the next decade are expected to make e-trucks viable for medium-haul agri transport. Additionally, trials of hydrogen fuel-cell trucks have begun (the first hydrogen heavy-duty truck trials were flagged off in 2025)[102], indicating a move toward multiple zero-emission technologies. The expectation is that by 2030 and beyond, a noticeable share of the trucks carrying produce from mandis to markets could be electric reducing fuel costs, and with simpler refrigeration options (electric reefers integrated with the EV powertrain). Policy support and global trends (many multinational companies pledging zero-carbon supply chains) reinforce this electrification trend as inevitable.
- **Digitalization and Real-Time Visibility:** Building on the current gradual improvements, the future will see digital tracking and coordination become standard in agri-logistics. The National Logistics Policy's emphasis on digitization is likely to translate into integrated digital platforms that connect farmers, FPOs, transporters, warehouses, and buyers. We anticipate wider use of telematics, route optimization software, and IoT sensors in even mid-tier logistics operations. Why is this change expected? Firstly, cost of technology is dropping basic GPS trackers and temperature sensors are now affordable even for small fleet owners. Secondly, large institutional buyers (exporters, food processing companies, modern retailers) are demanding traceability and compliance data from farm to fork.

  This creates a ripple effect where even upstream transporters must adopt tracking to remain part of certain supply chains. We can expect government to potentially mandate track-and-trace systems for certain high-value or sensitive commodities (for example, pharmaceuticals already have such requirements, similar could happen for meat or dairy transport). Also, the proliferation of smartphones and improved rural connectivity will bring even small truckers onto digital freight marketplaces. Digital freight matching platforms are already in use to reduce empty backhauls; their adoption will grow, improving asset utilization. Real-time visibility tools, coupled with analytics, will enable dynamic rerouting (to avoid traffic or to redirect produce to demand-surplus markets) and better inventory management in transit. In essence, the agri-trucking segment is expected to become far more data-driven. The why is tied to both efficiency gains (lower wastage, lower fuel use) and external pressures like food safety regulations and export quality standards that require documentation of cold-chain integrity throughout transit.
- **Improved Quality and Compliance Regime:** Future developments are likely to address the quality and hygiene gaps through a stronger compliance framework. We foresee stricter enforcement of fitness and safety norms; the number of automated vehicle testing stations is set to increase, meaning unfit trucks will be more regularly flagged and phased out. The scrappage policy (which mandates deregistration of commercial vehicles after a certain age unless they pass stringent fitness tests) will eliminate many old polluting trucks over the next 5–10 years, resulting in a younger fleet with better technology (e.g. all new trucks now are BS-VI emission standard, which also generally have improved engines and reliability). On the hygiene front, it's expected that food safety authorities may extend their oversight to transport links. This could involve audit checkpoints for reefer trucks (ensuring proper temperature logs are maintained) or certification for logistics providers who handle food. Global best practices like Hazard Analysis and Critical Control Points (HACCP) are likely to be increasingly applied to logistics and transport operations for food products, not just processing units.

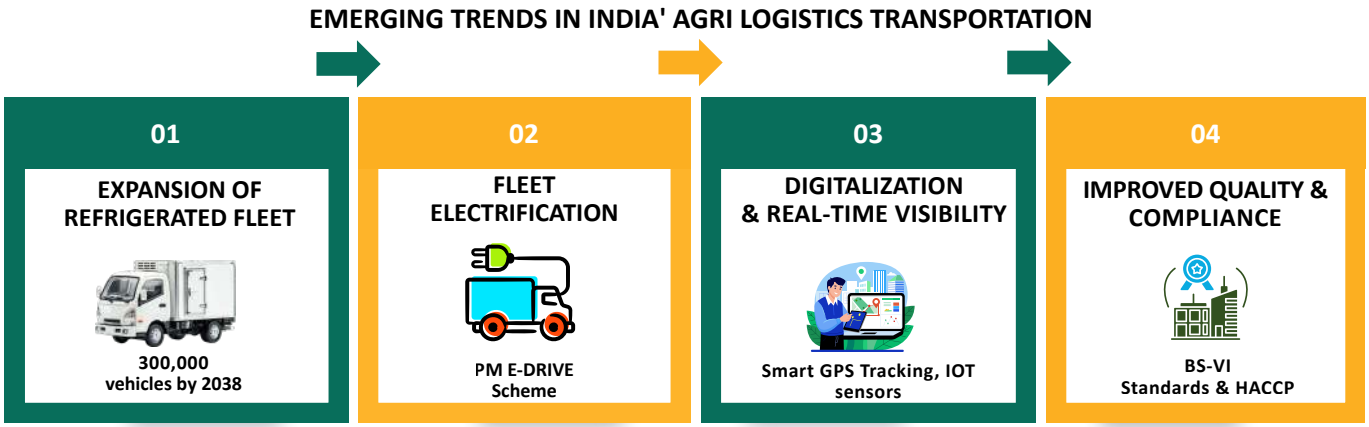


Figure 12: Emerging trends in India's Agri Logistics Transportation

The transportation segment of Indian agri-logistics is at a pivotal transition. The current state is marked by a mix of strengths (extensive road networks, entrepreneurial trucking community) and pronounced weaknesses (capacity shortfalls, poor cold-chain and hygiene, low tech adoption). The analysis highlights how these weaknesses from trucking inefficiencies to cold-chain gaps act as bottlenecks in realizing better farmer incomes and lower consumer prices. Importantly, none of these challenges are insurmountable. With targeted policy measures and increased private sector innovation, the next decade should witness an evolution toward a future-ready agri-transport system: one with adequate refrigerated trucks, cleaner and electric vehicles, digital visibility from farm to market, and adherence to quality standards. Such a transformation is vital if India is to drastically cut post-harvest losses, integrate its farmers with national and global markets, and ensure that the fruits of agricultural labour reach consumers efficiently and safely. The trends outlined backed by both government initiatives and market drivers provide reason for measured optimism, even as we maintain a critical eye on the persistent gaps and the need to address them with urgency. Each of these expected developments not only describes what may change but is underpinned by a clear why: be it climate commitments forcing greener trucking, economics pushing for reduced waste via cold-chains, or technology enabling solutions to age-old logistical problems. The transportation backbone of India's agriculture is set to strengthen, and with it, the prospects of India's farmers and the efficiency of its food supply will significantly improve.

Warehousing Landscape in India: Driving Growth Through Innovation

7.1 Dynamic Market Trends and Growth Catalysts

The Indian warehousing sector is undergoing a profound transformation, moving beyond its traditional role as mere storage into a pivotal enabler of the nation's economic growth. As of 2024, India's total warehousing stock had reached an impressive 533.1 million square feet, with emerging Tier II and Tier III cities contributing approximately 100 million square feet, representing a remarkable fourfold increase in their share. This decentralization reflects a strategic shift towards bringing logistics closer to consumption centers and manufacturing hubs across the country. The market's financial trajectory is equally robust; the India Warehouse Market is projected to grow from an estimated USD 38.99 billion in 2025 to USD 59.34 billion by 2030, exhibiting a Compound Annual Growth Rate (CAGR) of 8.76%. This sustained growth is underpinned by steady economic expansion, sustained industrial activity, and significant policy support. The industry's focus has decisively shifted from simply adding capacity to extracting maximum productivity per square foot, driven primarily by the escalating demands of e-commerce, the "quick-commerce" phenomenon requiring 10-minute fulfillment, and the evolving needs of the manufacturing sector, particularly under government Production-Linked Incentive (PLI) schemes[104.]

7.2 Strategic Expansion & Technological Integration in Warehousing

The Indian warehousing infrastructure has undergone a significant qualitative shift, primarily spurred by the implementation of the Goods and Services Tax (GST) in 2017. This policy reform eliminated disparate state-level taxes, removing the need for numerous small, state-specific warehouses and catalyzing a consolidation trend. Consequently, the average facility size jumped from approximately 50,000 square feet in 2023 to over 200,000 square feet by 2025. This shift has cemented the economic case for larger, more efficient Grade A facilities, which are expected to constitute 400 million square feet of the total warehousing stock by 2027. These modern facilities are designed with higher clear heights (11-12 meters) and flat floors, prerequisites for advanced material handling equipment.

Geographically, the growth remains anchored in Western and Southern states, which account for over 60% of market deployments due to their established manufacturing bases, port connectivity, and robust logistics infrastructure. States like Maharashtra, Gujarat, Karnataka, and Tamil Nadu continue to attract substantial investment. However, the Eastern and Northeastern corridors are emerging as nascent but significant growth areas, poised for future expansion as government-backed initiatives improve multimodal connectivity. Programs like the PM GatiShakti National Master Plan and the Bharatmala Pariyojana are strategically enhancing road, rail, and port linkages, influencing future site selection and creating integrated logistics parks that will diversify the geographic spread of high-quality warehousing. Technology is rapidly transforming Indian warehousing, with automation moving from experimental pilot projects to widespread deployment. This shift is driven by the urgent need for enhanced speed, accuracy, and real-time visibility across increasingly complex supply chains.

Current grain stock positions further contextualize the urgency of structural storage reform. As of January 2026, central pool stocks remain substantially above prescribed buffer norms, particularly in rice. This stock accumulation not only increases fiscal carrying costs but also amplifies logistical redundancies arising from repeated long-haul movements between centralized warehouses and distribution nodes. In this context, the World’s Largest Grain Storage Plan assumes systemic importance. By decentralizing storage capacity to Primary Agricultural Credit Societies (PACS) and converging it with schemes such as the Agriculture Infrastructure Fund, the plan seeks to reposition storage closer to the production base.

For logistics systems, this represents a structural rebalancing rather than mere capacity addition. Decentralized storage reduces secondary transport cycles, shortens dispatch distances, and enhances inventory visibility at the local level. However, its long-term impact will depend on integration with digital inventory tracking and market-linked release mechanisms. Without such integration, decentralized capacity risks functioning as static warehousing rather than dynamic supply-chain infrastructure.

The integration encompasses both sophisticated hardware and intelligent software layers:

Hardware Automation: Advanced solutions such as Automated Storage and Retrieval Systems (AS/RS) and clad rack warehouses are being adopted to maximize vertical space efficiency, increasing pallet capacity and density within existing footprints. Autonomous Mobile Robots (AMRs), Automated Guided Vehicles (AGVs), robotic picking systems, and automated conveyor belts are becoming commonplace, streamlining material movement, reducing manual handling, and accelerating throughput. These systems are crucial for industries needing to handle high SKU counts and diverse order profiles.

Software Dominance: While hardware constituted 60.55% of the automation market in 2025, software's influence is rapidly expanding. AI-driven Warehouse Management Systems (WMS) are now central, orchestrating labor, inventory, and hardware. These platforms integrate with Enterprise Resource Planning (ERP) systems, provide real-time visibility dashboards, and leverage AI/Machine Learning for demand forecasting, predictive slotting, process optimization, and labor scheduling. The adoption of IoT devices (sensors, RFID tags) provides continuous real-time data on item location and ambient conditions, enabling smarter inventory management and proactive problem-solving[105].

Adoption rates vary by end-user, with e-commerce and Third-Party Logistics (3PLs) leading the charge, accounting for 35.10% of automation demand in 2025, due to their high throughput requirements and fragmented order profiles. However, pharmaceuticals and healthcare are expected to post the fastest growth, with a 26.80% CAGR through 2031, driven by stringent compliance, temperature control, and traceability mandates.

7.3 Cold Storage Sector: Capacity, Distribution, and Demand Drivers

India's cold storage sector is a critical component of its logistics infrastructure, particularly vital for a nation with vast agricultural produce. However, a significant gap persists; only about 2% of agricultural produce in India is currently held or transported using cold storage facilities, starkly contrasting with developed economies like the US, where this figure stands at 85%. Despite this, refrigerated warehouses are experiencing premium growth, with a projected CAGR of 12.11%, outpacing general warehousing in terms of revenue growth[106].

The existing cold storage capacity, which encompasses over 37 million metric tons, shows a notable geographic imbalance. Nearly 60% of the total cold storage capacity is concentrated in just two states: Uttar Pradesh and West Bengal. While these states are major agricultural producers, such high concentration creates regional supply imbalances and necessitates long-distance transport, increasing spoilage risks and logistics costs for other regions. Occupiers are increasingly demanding multi-chamber facilities equipped with advanced features like Supervisory Control and Data Acquisition (SCADA) systems and solar backup power, ensuring robust quality compliance and operational resilience for sensitive goods. These facilities attract higher rentals and secure longer lease tenures (above nine years), reflecting their strategic importance and predictable cash flows.

7.4. Advancing Cold Chain: Remote Monitoring and Predictive Analytics

The efficiency and reliability of cold storage facilities in India are being significantly enhanced through the integration of Industrial Internet of Things (IIoT)-based remote monitoring systems. These advanced solutions are specifically designed for cold rooms and freezers, offering critical capabilities that mitigate risks associated with perishable goods.

Key functional benefits of remote-controlled cold storage facilities include:

- **Real-time Alerts and Proactive Intervention:** Systems provide instant notifications for temperature deviations, humidity fluctuations, or power outages, allowing operators to address issues before product spoilage occurs. This is particularly crucial for high-value pharmaceutical exports and sensitive food products.
- **Optimized Energy Management:** Through continuous monitoring and data analysis, these systems enable optimized climate control, leading to substantial energy savings by adjusting cooling cycles based on internal and external conditions and inventory levels.
- **Enhanced Quality and Compliance:** Remote monitoring ensures adherence to strict temperature and humidity parameters, which is vital for maintaining product integrity and meeting regulatory compliance, especially for pharmaceutical and food safety standards. Automated data logging also simplifies audit trails.
- **Predictive Analytics and Strategic Siting:** Beyond real-time alerts, advanced systems leverage dynamic mapping and analysis tools. These tools can identify ideal future locations for cold storage facilities by simulating shelf-life gains for various perishable goods (e.g., potatoes, apples, bananas) under different storage scenarios. This data-driven approach helps in strategically placing new cold rooms within optimal market radii, considering factors like road access and network coverage, to maximize benefit for farmers and reduce post-harvest losses.

The increasing adoption of IoT-linked temperature probes, combined with sophisticated automation like shuttle-based pallet movement, is not only reducing spoilage but also significantly curbing energy consumption, making India's cold chain more robust, efficient, and sustainable.

7.5. The Evolving Landscape of Packhouses in India: A Supply Chain Analysis

India's agricultural landscape is undergoing a significant transition from traditional harvesting methods to integrated post-harvest management. Central to this transition are packhouses, specialized facilities that serve as the primary processing hub between the farm gate and the final consumer. The post-harvest ecosystem in India is structured as a hierarchical network designed to consolidate fragmented production from smallholder farmers into standardized, market-ready consignments. This network is composed of three primary tiers: collection, aggregation/processing, and distribution.

Collection & Aggregation Centres:

Collection centres act as the “first mile” infrastructure, usually located within a 10–15 km radius of production clusters. These centers facilitate the initial transition of raw produce from the field. Currently, Farmer Producer Organizations (FPOs) are being integrated into platforms like eNAM to streamline this stage. Aggregation centres follow this by pooling produce from multiple collection points to achieve the volumes required for industrial processing or bulk trade. In the current Indian landscape, these facilities are being revolutionized through the integration of Primary Agricultural Credit Societies (PACS) and the Gramin Agricultural Markets (GrAMs) initiative. The government has identified a massive need for localized points of sale and aggregation to prevent distress sales.

- **Gramin Agricultural Markets (GrAMs):** The government has mandated the development of 22,000 GrAMs across the country to act as local aggregation points and retail agricultural marketing hubs[107].
- **Decentralized Village Storage:** To support local aggregation, the "World’s Largest Grain Storage Plan" is utilizing Primary Agricultural Credit Societies (PACS).

- **Information Support Centres:** To facilitate data-driven aggregation and collection, the Indian Council of Agricultural Research (ICAR) has established 44 Agricultural Technology Information Centres (ATICs) across 28 states[108].
- **Private Sector Scale:** Large-scale private aggregators are also expanding the network; for instance, Ninjacart, India's largest agri-tech company, currently operates across 20 cities and collaborates with over 50,000 farmers for direct collection and aggregation[109].

Packhouse Facilities:

As of January 2026, the status of packhouse infrastructure in India is characterized by rapid modernization in export-oriented clusters, contrasted by a persistent shortage at the local farm-gate level. While the country has approximately 8,186 cold storage facilities with a capacity of 37.4 million tonnes[110], the number of integrated packhouses remains far below the estimated requirement. Modern packhouses are increasingly equipped with automated grading, sorting, and pre-cooling units. For specific high-value crops, such as grapes and mangoes, infrastructure has reached international standards. However, the National Centre for Cold Chain Development (NCCD) highlights an extreme deficit in rural packhouses, estimating a national requirement for 125,000 facilities, whereas currently, only around 500 such integrated units are operational[111].

The export of fresh fruits and vegetables from India is strictly regulated by the Agricultural and Processed Food Products Export Development Authority (APEDA). To access premium markets like the European Union (EU), USA, and Australia, produce must pass through APEDA-recognized packhouses that adhere to stringent phytosanitary standards. The Indian government has pledged that all food exports must be routed through recognized facilities to prevent interceptions due to harmful organisms. Currently, over 180 packhouses are approved by APEDA for various commodities[112]. Beyond domestic recognition, exporters increasingly seek international certifications. For instance, the government has recognized 220 laboratories to provide specialized testing and certification services for 50 agricultural products with high export potential[113].

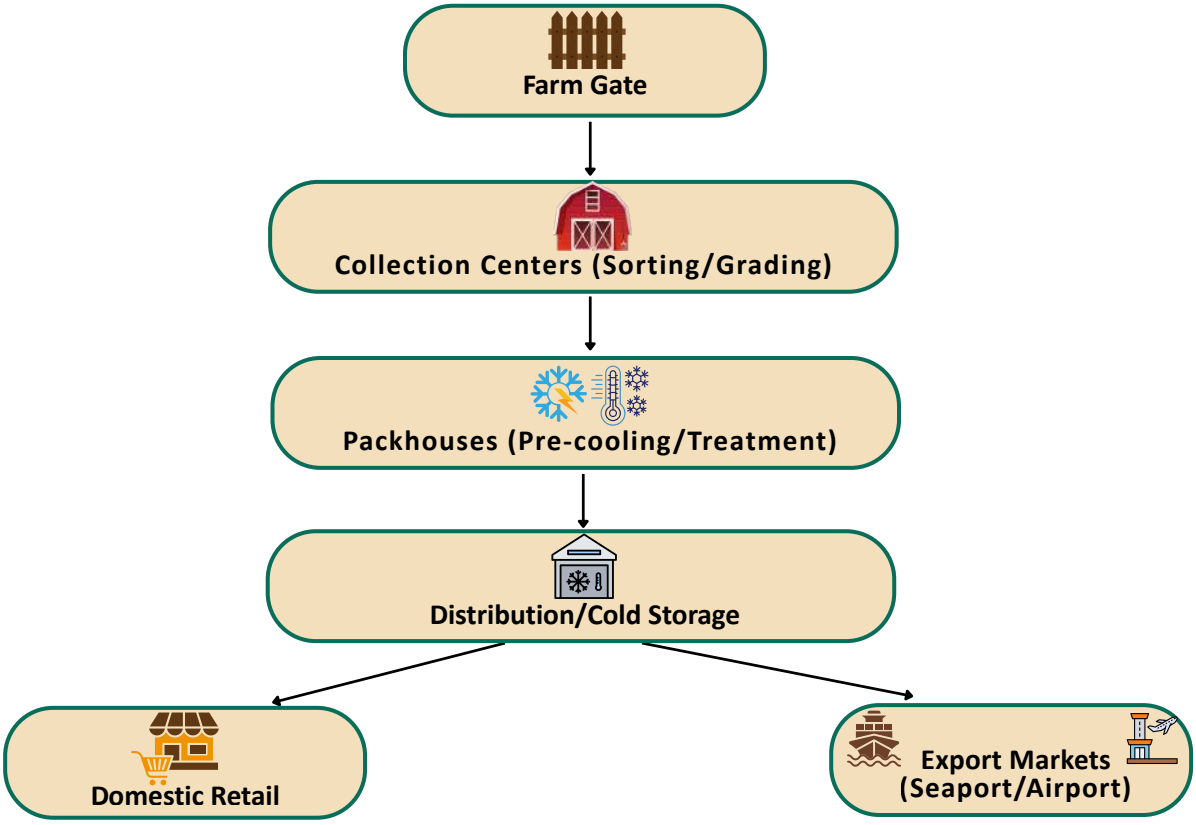


Figure 13: Packhouse facilities

Export Performance

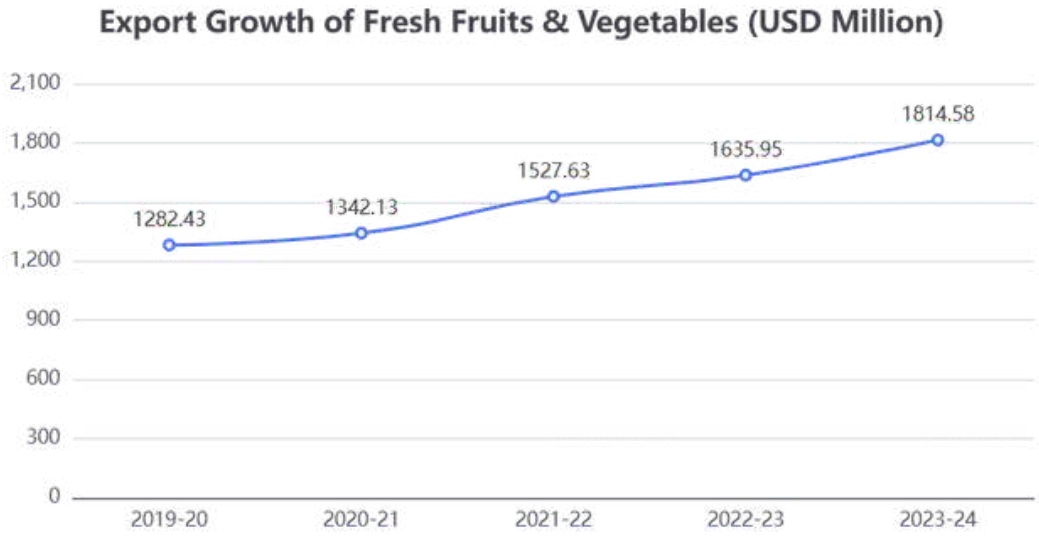


Figure 14: Export Growth of Fresh Fruits and Vegetables
Data Source: https://www.pib.gov.in/PressReleasePage.aspx?PRID=2099814&reg=3&lang=2

Recent financial assistance schemes have led to a 47.3% surge in the volume of fruit and vegetable exports between 2019-20 and 2023-24. In the 2023-24 fiscal year, the value of these exports reached US$ 1,814.58 million, representing a significant upward trend in global market penetration[114].

7.6. ESG Framework for Sustainable Agri-Logistics

As India's agri-logistics sector scales to accommodate record production levels and expanding export ambitions, the integration of Environmental, Social, and Governance (ESG) principles has transitioned from a corporate social responsibility initiative to a core operational necessity. The intensification of climate related disruptions, ranging from unpredictable heatwaves that threaten cold chain integrity to extreme rainfall affecting road transport has underscored the vulnerability of agricultural supply chains. In 2026, the Indian agri-logistics landscape is increasingly shaped by "Green" infrastructure mandates, driven by international trade requirements, domestic regulatory pressure, and the economic benefits of resource efficiency.

- **Certification Frameworks for Sustainable Warehousing and Logistics**

Sustainable warehousing and logistics certification frameworks are increasingly emerging as critical tools for embedding ESG principles into infrastructure development and operations. These frameworks provide structured, measurable approaches to assess and promote sustainability across logistics assets, including warehouses, logistics parks, and integrated supply chain facilities.

In this context, the ASSOCHAM GEM (Green and Eco-friendly Movement) Sustainable Warehouse and Logistics Certification offers an India-specific framework designed to evaluate sustainability across the entire lifecycle covering design, construction, and operational phases. It incorporates key Environmental, Social, and Governance (ESG) parameters such as energy efficiency, water conservation, material optimization, indoor environmental quality, waste management, and operational governance.

In the context of agri-logistics, its relevance is particularly significant given the energy-intensive nature of warehousing and cold-chain systems. The framework promotes the adoption of energy-efficient technologies such as optimized insulation, energy efficient HVAC systems, LED lighting, and integration of renewable energy sources including solar power. These measures contribute to both cost optimization and reduction in carbon footprint. Water management provisions such as rainwater harvesting, efficient usage systems, and wastewater recycling along with sustainable material usage and waste reduction practices, further enhance environmental performance across the infrastructure lifecycle.

Importantly, the certification extends beyond physical infrastructure to include governance and operational dimensions such as maintenance protocols, safety standards, performance monitoring, and compliance mechanisms.

Complementing this, the broader shift toward green warehousing in India is reflected in the growing adoption of global and national standards such as LEED (Leadership in Energy and Environmental Design) and IGBC Green Logistics Parks ratings. These certified facilities incorporate design features such as high-reflectivity roofing to reduce heat absorption, advanced insulation to minimize thermal loss, and rainwater harvesting systems to improve water efficiency. Evidence suggests that LEED certified warehouses can achieve energy savings of 20-30% compared to conventional structures, making them both environmentally and economically advantageous.
The integration of skylights for natural illumination and the use of low-VOC (Volatile Organic Compound) materials further enhance worker health and safety, addressing the social dimension of ESG. Increasingly, large logistics developers are prioritizing such “Grade A” green facilities to align with the sustainability commitments of global buyers, institutional investors, and export-oriented supply chains.
In this evolving landscape, certification frameworks such as ASSOCHAM GEM, alongside internationally recognized standards, are playing a critical role in enhancing the efficiency, credibility, and long-term resilience of India’s agri-logistics ecosystem.

- **Solar-Powered Infrastructure and Renewable Integration:**

A pivotal component of the sustainable transition is the "Solarization" of the agri-logistics backbone. Given the vast rooftop area of modern warehouses and cold storage units, solar photovoltaic (PV) integration has become a standard feature for new developments. By 2026, solar rooftops in logistics parks are no longer just for captive consumption but are increasingly integrated with the grid through net-metering, providing a secondary revenue stream. For cold storage facilities, which face high energy intensity, solar power provides a crucial hedge against fluctuating grid tariffs. Furthermore, the development of solar-powered micro-cold rooms at the farm gate—supported by schemes like the Agriculture Infrastructure Fund—is empowering smallholder farmers to preserve produce without relying on erratic rural power grids, thereby addressing both "Environmental" and "Social" ESG pillars.

- **Energy-Efficient Refrigeration and Low-GWP Transitions:**

The refrigeration sector is the most carbon-intensive segment of agri-logistics. ESG-compliant logistics providers are aggressively transitioning from high-Global Warming Potential (GWP) hydrofluorocarbons (HFCs) to natural refrigerants like Ammonia (NH_3) and Carbon Dioxide (CO_2).

(a) Natural Refrigerant Adoption: Large-scale cold storages are utilizing low-charge ammonia systems which offer superior thermodynamic efficiency and zero ODP (Ozone Depletion Potential).

(b) Variable Frequency Drives (VFDs): The implementation of VFDs on compressors allows systems to adjust cooling output based on actual load, reducing energy waste during partial-fill periods.

(c) Thermal Energy Storage (TES): Using phase-change materials (PCMs) or ice-slurry systems allows facilities to "store" cold during off-peak energy hours, reducing the strain on the grid during peak demand.

(d) Waste Heat Recovery: Advanced facilities are capturing waste heat from refrigeration compressors to provide hot water for cleaning and sanitation in packhouses, creating a circular energy loop.

- **Carbon-Aware Logistics and Green Transport:**

Decarbonizing the "moving" part of the supply chain is essential for achieving scope 3 emission targets. Carbon-aware logistics involves the strategic selection of transport modes and routes based on their carbon intensity.

(a) Fleet Electrification: As noted in Section 5.6, the shift toward electric trucks and "Green Reefers" is accelerating. Electric refrigerated vans eliminate tailpipe emissions and noise pollution, making them ideal for nighttime urban deliveries.

(b) Multimodal Optimization: Shifting long-haul agricultural freight from road to rail (via Dedicated Freight Corridors) can reduce carbon emissions by up to 75% per tonne-km.

(c) Digital Decarbonization: AI-driven route optimization reduces "empty miles" and idling time at checkpoints. In 2026, many logistics platforms have integrated "Carbon Calculators" that provide exporters with a verified emissions certificate for every shipment, a requirement that is becoming mandatory for entry into EU markets under the Carbon Border Adjustment Mechanism (CBAM).

Logistics Technologies: Building a Sustainable and Smart Agri-Supply Chain

Figure 15: Sustainable and Smart Agri-Supply Chain

As agricultural value chains in India expand beyond traditional markets and producers increasingly engage with food processors, modern retail and e-commerce, logistics technology has become a critical enabler. Post-harvest losses remain substantial; an NCCD assessment estimated that India produced over 282 million tonnes of fruits and vegetables in 2023 but suffers losses equivalent to 3.5 % of agricultural GVA. Traditional cold-chain infrastructure is concentrated on single-commodity storages (mainly potatoes), leaving first-mile facilities such as pack-houses and pre-cooling rooms extremely sparse. The gap cannot be bridged by more of the same; it demands a new generation of technologies from construction and insulation materials to refrigerants, digital sensors and data platforms that improve efficiency, reduce environmental impact and offer real time visibility. This chapter critically examines these technologies, their evolution, and their role in a climate-constrained future.

8.1. Construction Technology and Insulation Materials

Cold-chain facilities were historically built using masonry and conventional insulation such as loose fill or sprayed foam. These methods are labour-intensive, leaky and energy-inefficient. Pre-engineered steel buildings (PEBs) are now replacing these practices. PEBs are fabricated off-site, shipped in “completely knocked down” form, and assembled on site with bolts; this reduces construction time and allows better thermal design. The shift also enables adoption of advanced materials:

Sandwich insulation panels: Rigid panels comprising polyurethane or polystyrene foam sandwiched between metal skins have largely replaced old insulation methods. They offer high thermal resistance, structural strength and rapid installation. The Cooling India survey notes that insulated panel technology has largely replaced conventional practice and is being used for both cold stores and process halls. The panels’ tight joints reduce air leakage, improving temperature stability and lowering energy consumption.

High-performance doors and docks: Modern cold stores use insulated doors and scientifically designed loading docks. These minimise temperature loss during loading and unloading and ensure worker safety. The adoption of mechanised dock systems is essential in large hubs handling perishable commodities.

Eco-friendly building materials and renewable energy integration: The cold-chain industry increasingly uses eco-friendly construction materials and designs facilities with solar roofs or other renewable power options. Integration of solar photovoltaic (PV) panels reduces dependence on grid electricity and lowers carbon emissions. The NCCD energy transition roadmap highlights that cold stores are integrating on-site solar and wind to reduce reliance on fossil fuels.

Blind spot to challenge: Investing in modern buildings alone does not guarantee efficiency. Many owners still operate old potato storages with outdated insulation and high energy intensity. Upgrading to PEBs and sandwich panels requires capital and skills that small operators lack. Policy makers must therefore combine soft loans, standardised designs, and quality control to prevent the proliferation of substandard structures that undermine energy savings.

In Maharashtra and the Nashik region, the increasing proliferation of mixed-commodity cold storage hubs, integrated pack-houses, and pre-cooling facilities demonstrates how advanced insulation and renewable integration can support horticultural value chains (such as grapes, pomegranate, and citrus). Nashik's expanding cold storage network enables growers to participate in high-value markets with improved produce quality and reduced spoilage.

8.2. Refrigerants and Cooling Agents: The Transition to Clean Cold

8.2.1. From CFCs to HFCs to Natural Refrigerants

Cold-chain equipment historically relied on chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs). These were phased out because of ozone depletion and later global warming potential (GWP). Hydrofluorocarbons (HFCs) became the default but are now being phased down under the Kigali Amendment. The NCCD energy transition report compares refrigerant use in 2015 with current trends: pack-houses and ripening chambers once used HCFC-R22, HFC-134a and R404A; current systems are adopting CO_2, ammonia (NH_3), hydro-fluoro-olefin (HFO) blends and propane (R-290). Bulk cold storages still predominantly use ammonia but are incorporating CO_2 and HFO blends; reefers are moving from R-134a/R-404A to R-452A, R-513A and low-GWP HFOs. These transitions reflect global regulations on GWP caps and a push towards natural refrigerants.

The India Cooling Action Plan (ICAP) articulates national targets: reduce refrigerant demand by 25–30 % and cooling demand by 20–25 % by 2037–38. Achieving these requires both improved efficiency and a shift to low-GWP refrigerants. The global "Move-to-15ºC" coalition and U.S. American Innovation and Manufacturing Act (AIM) are already enforcing GWP limits and promoting natural refrigerants. India's adoption of similar standards is lagging; policy makers should accelerate the phase-down of HFCs, provide incentives for low-charge ammonia and CO_2 systems, and ensure domestic manufacturers build capability. Failing to do so will lock in obsolete equipment for decades.

8.2.2. Climate Impact and the Imperative for Clean Cooling

Cooling is energy-intensive and has a substantial climate impact. The Clean Cold and the Global Goals report notes that refrigeration and air-conditioning cause about 10 % of global CO_2 emissions, with demand growing rapidly as urbanisation and middle-class consumption rise. Refrigerated vehicles also emit disproportionate amounts of nitrogen oxides and particulate matter. Without a shift to efficient and low-emission technologies, the cold-chain's share of global emissions could double to 13 % by 2030. Thus, the choice of refrigerants is not merely technical, it is central to meeting India's climate commitments.

Challenge for decision-makers: The widespread perception that "any refrigeration is better than none" overlooks the long-term climate liability of high-GWP refrigerants. Low-GWP alternatives often require higher capital cost and specialised maintenance. But the cost of inaction higher emissions, potential trade penalties and stranded assets when future regulations tighten is far greater. Policymakers must internalise these externalities through standards, fiscal incentives and training programmes.

8.2.3. Chemical Use, Food Safety and Environment

Agri-logistics involve several chemical interactions from fruit ripening agents to fumigants and insulation adhesives. Food safety authorities have cracked down on hazardous chemicals. The Food Safety and Standards Authority of India (FSSAI) has banned the use of calcium carbide and acetylene gas for ripening fruits and permits only ethylene gas at low concentrations in controlled chambers.

Although the specific FSSAI guidance note is inaccessible, official notices emphasise that ethylene is a natural plant hormone and that misuse of calcium carbide poses health risks. Traders must therefore invest in proper ripening chambers rather than resorting to banned chemicals. India still lacks uniform enforcement; the unorganised sector often uses harmful agents due to cost and ignorance. Strengthening inspections and farmer awareness is critical.

Insulation panels themselves use polyurethane foams and adhesives that may emit volatile organic compounds (VOCs). Transitioning to non-CFC blowing agents and low-VOC adhesives, as mandated by global and national standards, can reduce occupational hazards and environmental damage. However, many small contractors procure inferior materials to save costs, undermining energy efficiency and safety. Standards and certification for insulation materials under the National Horticulture Board and Indian Standards are vital.

8.3. Technologies for Energy Efficiency and Resilience

8.3.1. Energy-Efficient Equipment and Renewable Integration

Energy consumption is the largest contributor to cold-chain emissions. The NCCD report observes that old bulk storages (>10–15 years) are highly energy-intensive. Modern facilities are adopting high-efficiency refrigeration systems, variable-speed compressors, and automatic capacity control to minimise power use. Low-charge ammonia systems and CO_2 secondary loops, which use smaller refrigerant quantities and operate at lower pressures, are being introduced. Integration of renewable power sources especially rooftop solar and energy-efficient motors, LED lighting and power factor correction further reduce operating costs.

Despite these innovations, adoption is uneven. High upfront costs and lack of skilled technicians deter small and medium players. Government schemes such as the PM Kisan Sampada Yojana provide subsidies for cold-chain equipment but have primarily funded cold storages rather than energy-efficient technology. Soft loans, tax incentives and targeted training should explicitly link support to adoption of low-charge systems and renewable integration.

8.3.2. Resilience to Climate Variability

Climate change threatens cold-chain operations through extreme weather events, temperature spikes and power outages. The NCCD report emphasises the need for regionalised distribution centres, pre-cooling at farm gate, and mobile processing units to reduce reliance on long-haul transport. Renewable-powered micro cold rooms and pack-houses can provide resilience in regions with unstable grid supply. Improved insulation and passive cooling techniques (e.g., phase-change materials in panels) can maintain temperatures for several hours during power interruptions, protecting produce. Designing facilities to withstand floods and heatwaves must become standard practice.

8.4. Digital Sensors, Tracking and Control Technologies

8.4.1. IoT Sensors and Real-Time Monitoring

Fragmented supply chains and manual record-keeping have historically left logistics actors blind to the condition of perishable cargo. The NCCD energy transition report notes that IoT-enabled tracking systems can monitor temperature and humidity in real time during transportation, reducing spoilage. Start-ups like Tessol deploy plug-and-play thermal storage solutions for last-mile delivery. These systems use embedded sensors to transmit data on temperature, humidity and door openings, enabling predictive maintenance and dynamic rerouting. The report also highlights that advanced cold-chain operators use IoT sensors, RFID and automation to monitor temperature, track inventory and optimise operations in real time, which enhances efficiency and reduces spoilage. AI-driven analytics combine sensor data to predict equipment failures and adjust compressor loads.

Despite these advances, adoption remains limited. Many small logistics firms still rely on manual checks and paper records. Sensors cost only a few thousand rupees, but operators hesitate due to limited digital literacy and fear of data transparency. Government initiatives should therefore subsidise IoT kits for farmers' producer organisations (FPOs) and create training programmes. Without wide deployment, claims of digital transformation will remain superficial.

8.4.2. Unified Logistics Interface Platform and Data Integration

The National Logistics Policy (2022) emphasises technology adoption, standardisation and tracking across modes. Press Information Bureau notes that the policy aims to develop a technologically enabled, integrated and cost-efficient logistics ecosystem, highlighting the need for data-driven decision support mechanisms and better track-and-trace. A central element is the Unified Logistics Interface Platform (ULIP). As of March 2025, ULIP had surpassed 100 crore API transactions, integrating 43 systems from 11 ministries through 129 APIs, covering over 1,800 data fields. More than 1,300 companies had registered, and the platform was processing about one crore API transactions per week, providing automation, real-time cargo tracking and regulatory compliance. ULIP's multi-modal API ecosystem enables real-time tracking across road, rail, ocean and air, facilitating just-in-time inventory management and cost savings.

This digital spine is a game changer for agri-logistics. Real-time data on vehicle location, estimated arrival times and cargo conditions can synchronise harvesting, processing and market activities, reducing idle time and spoilage. It also democratizes access to logistics data, allowing small farmers to verify transporter credentials and choose cost-effective routes. However, integration of cold-chain sensors with ULIP remains nascent; bridging this gap will require open APIs and standard data formats for temperature and humidity data.

8.4.3. Blockchain, Traceability & EUDR Compliance in Agri-Supply Chains

Blockchain technology brings immutable, decentralised traceability across the agri-logistics ecosystem, creating an auditable and trustable digital record of every transaction, movement and condition update from farm level to final delivery. Unlike traditional systems that rely on fragmented records and manual verification, blockchain creates a unified chain of provenance where data cannot be altered once recorded, ensuring authenticity and visibility for every actor in the chain.

This transparency has multiple strategic benefits:

- **Real-time visibility across stakeholders:** Each step from harvest and pre-cooling to cold transport and market delivery is logged in real time, allowing operators, regulators and buyers to verify product history and handling conditions.
- **Food safety and rapid response:** In the event of spoilage or contamination, blockchain enables rapid pinpointing of affected batches reducing recall scope and protecting consumer health.
- **Efficiency gains via smart contracts:** Automated smart contracts embedded on the blockchain can govern logistics events (e.g., release of payment upon delivery confirmation) without intermediaries, thereby streamlining processes, lowering transaction costs, and shortening settlement times.
- **Trust and quality assurance:** For horticultural exports or premium domestic markets, blockchain backed documentation of origin, cold chain integrity and quality checks builds brand confidence among buyers at domestic and international endpoints.

Blockchain for EUDR Compliance and Global Market Access

With the introduction of the European Union Deforestation Regulation (EUDR), exporters to the European Union must now demonstrate that agricultural commodities are deforestation-free and legally produced. The regulation mandates geolocation data of production plots, traceability to the farm level, and proof that products are not linked to deforestation after the prescribed cut-off date.

Blockchain systems can significantly strengthen compliance with EUDR requirements by:

- **Providing immutable geotagged farm records:** Farm boundaries, land-use history and production data can be recorded and verified, creating a tamper-proof compliance trail.

- **Integrating satellite and IoT data:** Remote sensing and farm-level digital records can be linked to blockchain entries, strengthening verification of deforestation-free claims.
- **Ensuring due diligence transparency:** Exporters can securely share verified supply chain documentation with European buyers and regulators.
- **Reducing compliance risks:** Automated documentation reduces the probability of rejected consignments, shipment delays or reputational damage.

For export-oriented regions like Maharashtra, particularly Nashik, a major producer of grapes, pomegranate, banana and citrus blockchain pilots integrated with IoT sensors can certify:

- Cold-chain temperature integrity
- Variety-specific handling standards
- Farm geolocation and land-use compliance
- Chemical residue tracking and quality certifications

Such systems not only enhance export credibility but also position regional producer organizations, FPOs and exporters to meet emerging global sustainability standards. By aligning blockchain-enabled traceability with EUDR due diligence frameworks, Indian agri-value chains can transition from reactive compliance to proactive market differentiation, strengthening competitiveness in European and other premium markets.

In this way, blockchain moves beyond operational efficiency to become a strategic enabler of regulatory compliance, environmental accountability, and long-term trade resilience in agricultural supply chains.

8.4.4. Agri-Fintech & Digital Financial Tools including e-NWRs

Beyond physical tracking and traceability, digital financial technologies are reshaping how capital and risk flow across the agricultural supply chain. Agri-fintech platforms that integrate logistics data with credit and marketplace mechanisms are enabling new financing models that support investment, liquidity and risk management for farmers and logistics operators.

- **e-Negotiable Warehouse Receipts (e-NWRs) and Collateral Finance:** Digital warehouse receipts represent stored commodities as monetised and tradable digital assets, enabling farmers and FPOs to access working capital without liquidating physical stock. When combined with logistics traceability whether IoT sensor data or blockchain records these receipts carry verifiable proof of stock quality and location, making them acceptable collateral for banks and NBFCs. Companies such as StarAgri have developed real-time tracking systems and integrated backend finance platforms that leverage warehouse and collateral data to extend financing to storage operators and farmers, helping them scale operations while mitigating traditional information asymmetry.
- **Digital Marketplaces and Liquidity Platforms:** Platforms such as eNAM (National Agriculture Market) provide a digital marketplace where farmers and buyers transact seamlessly across geographies, enhancing price discovery and reducing dependence on intermediaries. While not a direct payment solution, eNAM's real-time digital exchange of bids and offers functions synergistically with agri-fintech tools, setting the stage for conditional financing tied to fulfilment of logistics milestones.
- **AI-Enabled Financial Services:** The convergence of AI analytics with financing accelerates dynamic risk assessment, crop-linked credit scoring and adaptive loan structuring, which can dramatically broaden access to credit for small holders and MSME logistics firms. Automated evaluation of logistics performance data (transit reliability, cold-chain integrity) allows lenders to offer better terms and reduce credit risk, strengthening the capital ecosystem for agri-supply chain participants.

For agricultural hubs in Maharashtra, where seasonal harvest peaks demand flexible liquidity for cold storage and transport services, these fintech innovations can unlock timely capital flows aligned with logistics realities, fuelling both operational scale and income stability.

8.4.5. Mobile Apps and Farmer-Centric Tools

Beyond enterprise platforms, mobile applications are emerging to support farmers. Apps like KrishiHub provide real-time advice on post-harvest management, market prices and weather conditions. With rising smartphone penetration, such apps can deliver location-specific alerts on storage conditions and integrate with sensor data to recommend cooling adjustments. Policy makers should encourage public-private partnerships to develop open-source tools that integrate with ULIP and local language interfaces, ensuring smallholder adoption.

8.4.6. AI-Driven "Agentic" Planning and Predictive Logistics

Artificial intelligence (AI) is emerging as a decision-making cornerstone in smart agri-logistics, enabling systems that do more than monitor they anticipate and optimise logistics flows. AI-driven planning tools integrate real-time data from sensors, weather forecasts, demand signals, port/market congestion and transport availability to orchestrate logistics decisions proactively.

- **Optimised Route and Inventory Planning:** AI algorithms can analyse historical and live data to determine the most efficient storage and transport pathways, aligning cold-chain capacity with expected harvest volumes and downstream processing schedules. This reduces idle time, ensures temperature compliance, and maximises throughput.
- **Predictive Maintenance and Demand Forecasting:** By applying machine learning to IoT sensor feeds, logistics operators can predict equipment failures (e.g., compressor breakdowns, insulation breaches) before they occur reducing unplanned downtime and safeguarding perishable goods. Similarly, AI models that learn from seasonal consumption and market price trends support demand forecasting, informing allocation of cold-chain assets and labour planning.
- **Advanced Decision Support for Regional Clusters:** For integrated horticulture clusters such as Nashik, AI-driven systems can coordinate regional micro-cold rooms, pre-cooling units and multimodal movement, balancing storage usage with outbound market requirements. Agentic planning systems that self-adjust logistics actions based on predictive indicators foster resilience against weather volatility, holiday demand cycles and supply shocks.When layered with blockchain traceability and integrated logistics data from platforms like ULIP, these AI tools become decision engines capable of enhancing speed, reliability, and cost-effectiveness throughout the agri supply chain.

Global Logistics trends

The global logistics landscape for 2026 is defined by an accelerating push towards technological integration, heightened demands for supply chain resilience, and an undeniable imperative for sustainable practices. These macro trends are reshaping how goods move, are stored, and are prepared for market, presenting both transformative opportunities and significant challenges, particularly within dynamic emerging markets like India. A core driver of this evolution is the modernization of agri-food systems, where the integration of advanced cold chain technologies and autonomous transport is bridging the gap between farm-gate production and global consumer demand[115].

9.1. Global Logistics: A Paradigm Shift Towards Intelligence and Resilience

The contemporary global logistics environment is undergoing a profound transformation driven by several key forces. Foremost among these is the pervasive adoption of hyper-automation and AI-driven optimization. Artificial intelligence is no longer a nascent concept but a standard in predictive analytics for demand forecasting, dynamic route optimization, and autonomous warehouse operations. Robotics, including Automated Storage and Retrieval Systems (ASRS) and Autonomous Mobile Robots (AMRs), are increasingly common in advanced warehousing, while generative AI and cloud platforms enhance control tower functionalities, offering unprecedented visibility and decision-making capabilities. This technological thrust aims to "embrace complexity through automation," offsetting global labor shortages and improving overall efficiency[116].

Simultaneously, the industry is prioritizing supply chain resilience and agility above all else. Lessons learned from recent global disruptions have shifted focus from lean, cost-cutting models to robust, adaptable networks capable of dynamic rerouting and rapid response to unforeseen events. This involves diversifying sourcing strategies, investing in real-time visibility tools enabled by IoT and blockchain, and building redundant capacities. The goal is to move towards "resilient supply chains" that can mitigate risks and ensure business continuity[117].

Finally, sustainable operations and the green imperative have become non-negotiable. With increasing regulatory pressure and consumer demand, logistics providers are investing heavily in electrification of fleets, green warehousing solutions (e.g., solar-powered facilities), and optimized packaging to reduce waste and carbon footprint. This trend is pushing "sustainability moves toward measurable goals," integrating environmental, social, and governance (ESG) metrics directly into operational strategies.

9.2. India’s Logistics Transformation: Overcoming Manual Legacies

India's logistics sector, projected to reach nearly $800 billion by 2030, is actively engaging with these global trends, albeit with a unique set of opportunities and inherent challenges, particularly its enduring manual dependencies. The drive for digitization and efficiency is pronounced, yet significant infrastructural and procedural gaps persist[118].

9.2.1. Evolution of Storage Infrastructure: Beyond Bricks and Mortar

Globally, storage infrastructure is witnessing a revolution with the proliferation of smart warehouses equipped with IoT, AI-driven analytics, and robotics. . A significant 2025–2026 trend is the rapid growth of multi-commodity and multi-temperature cold storage facilities. Unlike traditional single-commodity sheds, these integrated systems utilize quick-switch evaporator technologies that allow operators to store frozen, chilled, and ambient products within the same facility by rapidly adjusting zone temperatures. This represents a transformation in storage efficiency and flexibility, allowing for the consolidation of diverse agri-food products and optimizing supply chain throughput. Technologies such as exosuits, wearable technology, voice-activated systems, and machine vision are enhancing productivity and safety, with some "dark warehouses" operating with minimal human intervention[119].

In India, the narrative for storage is bifurcated. While the data center storage market is experiencing exponential growth valued at USD 10.14 billion in 2024 and projected to reach USD 39.98 billion by 2033 (a CAGR of 16.47% from 2025-2033) driven by IT infrastructure expansion, hyperscale investments, and data localization mandates, the physical storage infrastructure, especially for agriculture, presents a mixed picture. Only an estimated 35% of

perishable foods currently benefit from proper cold chain facilities, leading to significant post-harvest losses. There is a growing trend towards strategically located micro-warehouses near consumption centers to enhance last-mile efficiency. However, traditional warehouses and agricultural godowns often rely heavily on manual inventory management, rudimentary stacking, and paper-based record-keeping. The lack of automation in these older facilities translates into higher labor costs, slower throughput, and increased damage rates, underscoring a substantial manual dependency that limits scalability and efficiency compared to global benchmarks[120].

9.2.2. Revitalizing Transportation: Electrification and Drone Logistics

Global transportation networks are becoming smarter, leveraging AI for route planning and adopting electric vehicles. A critical advancement in 2026 is the electrification of reefer trucks(refrigerated transport vehicles). These electric reefers eliminate the reliance on diesel-powered cooling units, significantly lowering the carbon footprint and operational costs of the agri-food cold chain.

In India, while the smart transportation market is forecasted to reach ₹1.9 lakh crore ($23.40 billion) by 2033, manual dependencies such as paper-based documentation and fragmented supply chains remain. However, the emergence of drone-based logistics solutions is providing a leapfrog technology for the "first-mile" challenge. Drones are proving especially relevant for high-value agricultural produce and remote farm-gate pickups. By enabling faster, more efficient connectivity from deep rural areas to primary collection centers, drone logistics bypass congested road networks and reduce the post-harvest losses caused by traditional manual handling and slow transit.

9.2.3. Packhouse Operations: From Farm Gate to Market Readiness

Internationally, modern packhouses are sophisticated facilities for cleaning, sorting, grading, pre-treating, packing, and cooling produce, essential for quality assurance and minimizing post-harvest losses. These operations are increasingly mechanized and automated, with advanced technologies ensuring product integrity and market readiness[121].

In India, the landscape of packhouse operations is characterized by a stark duality. On one hand, APEDA-recognized packhouses catering to exports incorporate modern sorting, grading, and pre-cooling lines to meet stringent international standards. On the other, the vast majority of domestic-focused packhouses and collection centres, particularly for smallholder farmers, are predominantly manual. These centres often serve merely as collection points, lacking proper infrastructure for sorting, grading, or even basic pre-cooling. This manual handling, coupled with inadequate facilities, contributes significantly to India's substantial post-harvest losses, estimated between 4.6% and 15.9% across various commodities. The absence of mechanized grading leads to inconsistent quality, while manual packing often results in bruising and reduced shelf life. While smart packaging technologies (e.g., QR codes, freshness sensors) are gaining traction among premium brands, their adoption is minimal in the broader market, reinforcing the reliance on manual checks and traditional, often ineffective, handling methods.

Identifying Opportunities for Structural and Operational Optimization

The Indian agri-logistics sector is currently navigating a period of intense structural transition. While production levels have historically been the primary focus, the system now faces the "production-centric legacy" challenge, where infrastructure and processes are not yet fully aligned with the requirements of a modern, value-chain-driven economy. This misalignment results in a staggering annual post-harvest loss of approximately ₹92,000 crore, with nearly 177 million tonnes of food wasted each year due to these systemic gaps.

Critical Infrastructure Shortfalls and Imbalances

A fundamental gap exists in the "first-mile" infrastructure. While India has a cold storage capacity of roughly 39.6 million metric tonnes, there remains a national shortfall of approximately 10 million tonnes. More pressing than the sheer volume is the geographical and functional imbalance: 60% of total capacity is concentrated in Uttar Pradesh and West Bengal, primarily serving the potato crop. This concentration leaves other regions and high-value perishables, such as fruits and vegetables, underserved. Furthermore, the industry faces a massive deficit in integrated pack-houses; only about 500 units are operational against a projected requirement of 125,000, leading to produce entering the supply chain with "field heat" that accelerates spoilage.

Fragmentation in Transportation and the "Mobile" Cold Chain

The transportation segment suffers from extreme fragmentation and a heavy over-reliance on road networks, which carry 97.4% of fruits and vegetables. The trucking sector is dominated by small-scale operators, 80% of whom own fewer than 10 vehicles; resulting in severe inefficiencies where trucks run empty for 30–40% of their total kilometers. The most critical "missing link" is the mobile cold chain. Only 4% of fresh produce moves through temperature-controlled transport in India, compared to 70% in developed markets like the UK. With only ~13,000 refrigerated vehicles currently in operation against a requirement of over 70,000, the integrity of the cold chain is frequently breached during transit.

Deficiencies in Quality, Hygiene, and Digital Visibility

Beyond physical assets, there is a significant gap in operational standards. Many traditional warehouses rely on manual inventory management and paper records, limiting scalability and increasing error rates. Hygiene remains an under-addressed issue; trucks are often not sanitized between loads, and a lack of pre-cooling facilities means produce is often transported in non-food-grade environments. Digitally, the sector is "visibility starved." Small operators rarely invest in the IIoT sensors or telematics necessary for real-time temperature monitoring, leading to information asymmetry and a lack of accountability for spoilage.

Operational Disruptions at Export Gateways: Evidence from Kandla and JNPT

Case Study 1: Kandla Port (Deendayal Port Authority) - The Wheat Export Ban

The interaction between policy restrictions and structural bottlenecks is most visible at India's western gateways. Congestion at ports acts as a "soft" trade restriction that increases the cost of doing business. A prominent example is the 2022 wheat export ban at Deendayal Port Authority (formerly Kandla Port). In May 2022, the Government of India's abrupt decision to halt wheat exports led to immediate operational disruption. Thousands of wheat-laden trucks were stranded outside the port, while vessels already berthed were asked to vacate without loading cargo. Approximately 400,000 tonnes of wheat were left stranded, and transporters incurred daily losses amounting to several crores due to demurrage and standing charges[28] [29]. The crisis exposed significant infrastructural constraints, as nearly 700 warehouses quickly reached full capacity, revealing the limited flexibility of port systems to respond to sudden regulatory changes.

Case Study 2: JNPT (Jawaharlal Nehru Port Authority) - Congestion and Dwell Times

Similarly, structural congestion at Jawaharlal Nehru Port Authority (JNPT), India's largest container port located in Navi Mumbai, operates as an indirect trade barrier. The port frequently experiences bottlenecks caused by capacity constraints, operational disruptions, and labor-related issues, resulting in missed vessel connections for exporters[30]. For horticultural producers in the Nashik region, congestion at JNPT is particularly damaging. Exporters of perishable commodities report slow container movement and heavy traffic at terminal facilities as major contributors to cargo spoilage and rising logistics costs. Elevated container dwell times where cargo remains in the yard significantly longer than at competing private ports extend the land-to-ship transit period and reduce the competitiveness of time-sensitive exports.

In effect, even in the absence of formal trade prohibitions, operational inefficiencies and infrastructural limitations at key ports function as de facto trade restrictions, compounding the economic impact of abrupt policy decisions.

The underlying inefficiencies at ports like JNPT and the logistics disruptions following export bans at Kandla underscore the need for integrated infrastructure planning. Addressing these bottlenecks is not merely a matter of building roads but of ensuring that policy frameworks and physical infrastructure are resilient enough to handle global trade volatility.

Opportunities: Building a Resilient and Integrated Value Chain

The systemic friction identified in the preceding gap analysis serves as the primary catalyst for modernization. By addressing these deficits, India has the opportunity to reduce its logistics costs from the current estimate of 14% of GDP to below 10% by 2030, as envisioned in the National Logistics Policy (NLP). This transition is not merely about building more warehouses, but about creating an integrated, multi-modal, and digitally-enabled ecosystem that connects the farm-gate directly to global value chains.

1. Policy-Driven Integration and Multi-Modal Synergy

The PM GatiShakti National Master Plan provides a revolutionary opportunity to rectify the connectivity gaps identified earlier. By integrating 16 central ministries into a single GIS platform, the government is now able to synchronize infrastructure planning.

- **Multi-Modal Logistics Parks (MMLPs):** The development of 35 MMLPs under the Bharatmala Pariyojana offers a significant opportunity for private developers to create "Grade A" warehousing. These parks are designed to serve as hubs for cargo aggregation, shifting the burden away from congested road networks and toward more efficient rail and water transport.
- **Direct Financing via AIF:** The ₹1 lakh crore Agriculture Infrastructure Fund (AIF) is a powerful lever for modernization. It provides debt financing at subsidized rates, specifically targeting the first-mile infrastructure gap. This empowers Farmer Producer Organizations (FPOs) to invest in primary processing and sorting units, effectively reducing the 5–6 intermediaries currently inflating costs.

2. The Expansion of the "Clean Cold" Chain

The severe undercapacity in refrigerated transport represents one of the most significant investment opportunities in the Indian logistics landscape.

- **Fleet Scalability:** As the India Co
- oling Action Plan projects the refrigerated vehicle fleet to grow to 300,000 units by 2037, there is a massive window for manufacturers and third-party logistics (3PL) providers to introduce specialized reefer vans and ventilated trucks.

- **Green Refrigeration and Sustainability:** Moving away from ozone-depleting substances toward low-GWP refrigerants (such as Ammonia or CO_2 systems) is a dual opportunity for environmental compliance and operational efficiency. The adoption of Pre-engineered Buildings (PEBs) and energy-efficient insulation can significantly reduce the high operating costs that currently plague older, potato-centric storage units.
- **Export-Oriented Infrastructure:** With agri-exports surging to $52 billion in FY 2024-25, there is a critical need for specialized cold storage units at major ports and airports to handle high-value perishables, ensuring that Indian produce meets the stringent phytosanitary standards of global markets.

3. Digital Transformation and Data-Driven Orchestration

Digitalization offers the only viable path to overcoming the fragmentation that currently hampers the trucking and warehousing sectors.

- **Unified Logistics Interface Platform (ULIP):** ULIP provides an unprecedented opportunity for end-to-end data integration. By linking warehousing data, transport telematics, and customs documentation, ULIP enables real-time visibility, reducing the "information gaps" that lead to delays and spoilage.
- **IIoT and AI-Driven Logistics:** The decreasing cost of sensors allows for the widespread deployment of IIoT devices to monitor temperature and humidity in real-time. When combined with AI-driven Warehouse Management Systems (WMS), logistics providers can utilize predictive analytics to optimize routes and manage inventory more dynamically, directly addressing the 30–40% empty-running inefficiency in trucks.
- **Blockchain and Traceability:** Blockchain technology offers a robust solution for food safety and trade finance. By creating immutable records of a product's journey and storage conditions, blockchain can digitize Electronic Negotiable Warehouse Receipts (e-NWRs), making it easier for smallholders to access credit while guaranteeing quality for institutional buyers.

4. Leapfrogging via Electrification and Drone Logistics

India is uniquely positioned to "leapfrog" traditional infrastructure hurdles through emerging technologies that bypass ground-level congestion.

- **Electrification (PM E-DRIVE):** The government's push for electric heavy trucks (targeting 5,600 units) aligns with the need for cleaner, more cost-effective medium-haul transport. Electric trucks are particularly well-suited for predictable routes between farm-gate aggregation centers and urban mandis.
- **Drone First-Mile Connectivity:** In remote or hilly regions like the North-East, drone-based logistics are emerging as a vital tool for the first-mile evacuation of high-value produce (e.g., organic spices or exotic fruits). Drones bypass poor road connectivity, drastically reducing transit times and ensuring that perishables reach processing centers while still fresh.

5. Transitioning to a Global Quality Regime

Finally, there is a opportunity to professionalize the sector through enhanced compliance. The transition from unorganized, manual operations to APEDA-recognized, automated pack-houses allows Indian exporters to move up the value chain. By adopting global standards like HACCP and investing in automated sorting/grading, the industry can reduce manual handling damage and ensure consistent quality, which is essential for capturing premium market segments in the EU, USA, and Australia.

Conclusion and Strategic Outlook

The transformation of Indian agri-logistics is anchored in the shift from a fragmented, production-led model to a synchronized, technology-driven value chain. By leveraging policy frameworks like PM GatiShakti and the Agriculture Infrastructure Fund, and by adopting "leapfrog" technologies like IIoT and electric transport, the sector can effectively bridge its current gaps. This evolution will not only reduce the massive post-harvest losses currently experienced but will also establish India as a reliable and competitive partner in the global agricultural trade.

References

[1]https://www.pib.gov.in/PressReleasePage.aspx?PRID=2195125
[2]https://m.economictimes.com/news/economy/indias-logistics-cost-estimated-at-7-97-of-gdp-in-2023-24-says-dpiit-report/articleshow/124118364.cms
[3]https://www.pib.gov.in/PressReleasePage.aspx?PRID=2195125
[4]https://www.pib.gov.in/PressReleasePage.aspx?PRID=2195125
[5]https://www.pib.gov.in/PressReleasePage.aspx?PRID=2195125
[6]https://gjia.georgetown.edu/2024/02/16/significance-and-implications-of-national-logistics-policy-of-india/
[7]https://sarkaripariksha.com/static-gk/pm-unveils-national-logistics-policy/
[8]https://www.pib.gov.in/PressReleasePage.aspx?PRID=2195125
[9] https://www.pib.gov.in/PressReleasePage.aspx?PRID=2195125
[10] https://gjia.georgetown.edu/2024/02/16/significance-and-implications-of-national-logistics-policy-of-india/
[11] https://www.pib.gov.in/PressReleaseIframePage.aspx?PRID=1993425
[12] https://www.pib.gov.in/PressReleasePage.aspx?PRID=2195125
[13] https://nationaleconomicforum.org/nef_articles/addressing-post-harvest-losses-in-india-a-silent-crisis-in-agriculture/
[14] https://www.pib.gov.in/PressReleasePage.aspx?PRID=2195125
[15] https://www.pib.gov.in/PressReleasePage.aspx?PRID=2195125
[16]https://www.pib.gov.in/PressReleasePage.aspx?PRID=2195125
[17]https://apeda.gov.in/
[18]https://timesofindia.indiatimes.com/city/nashik/maharashtra-achieves-highest-agro-food-exports-in-financial-year-202425/articleshow/121683135.cms
[19]https://agriwelfare.gov.in/sites/default/files/Nasik.pdf
[20]https://bankofmaharashtra.bank.in/writereaddata/documentlibrary/74de861a-a869-47a0-b1f7-456f32e976ee.pdf
[21]https://www.mofpi.gov.in/sites/default/files/KnowledgeCentre/State%20Profile/Maharashtra.pdf
[22]https://www.scribd.com/document/724192250/Nashik-MSS?utm
[23]https://indiandistricts.in/statistics/maharashtra/nashik/agriculture/
[24]https://indiandistricts.in/statistics/maharashtra/nashik/agriculture/
[25]https://niti.gov.in/sites/default/files/2025-10/Trade_Watch_Report_Q4_FY25_V4.pdf
[26]https://apeda.gov.in/Maharashtra
[27]https://www.msamb.com/Schemes/NationalAgricultureMarket
[28]https://www.tribuneindia.com/news/nation/wheat-export-ban-transporters-stranded-with-loaded-wheat-outside-gujarat-port-facing-rs-3-crore-daily-losses-395661/
[29]https://www.newsclick.in/gujarat-4000-wheat-laden-trucks-stranded-kandla-port-centre-bans-export
[30]https://container-news.com/nhava-sheva-port-temporarily-averts-transport-strike-that-threatened-rising-cargo-flows/
[31]Expenditure Budget 2026-27
[32]Bharat VISTAAR launch
[33]Agri Stack Digital Infrastructure by the States and the Central Government
[34]Figure 4: (Data Source: [pib.gov.in])
[35]https://www.pib.gov.in/PressReleasePage.aspx?PRID=2195125
[36]https://www.pib.gov.in/PressReleasePage.aspx?PRID=2195125
[37]https://www.linkedin.com/posts/fibre2fashion_indias-logistics-cost-797-of-gdp-in-2023-activity-7400728605082853376-Ksal
[38]https://www.pib.gov.in/PressReleasePage.aspx?PRID=2195125
[39]https://master-dpiit.digifootprint.gov.in/static/uploads/2025/09/7d467e0f4aee2362e4bf90b84b7a5332.pdf
[40]https://www.nsws.gov.in/portal/scheme/pmgatishakti
[41]https://www.pib.gov.in
[42]Figure 5: (Data Source: [pib.gov.in], [agriinfra.dac.gov.in])

[43]*https://www.pib.gov.in/PressNoteDetails.aspx?NoteId=154999&ModuleId=3*
[44]*https://agriinfra.dac.gov.in/Documents/Publication/06_AIF%20Bulletin_Sep%202024.pdf*
[45]*https://www.dpiit.gov.in/static/uploads/2025/07/f65999eeeca38c3ab5d15b50a60a1a6e.pdf*
[46]*https://www.pib.gov.in/PressReleseDetailm.aspx?PRID=2167224*
[47]*https://agritech.tnau.ac.in/pdf/Maha%20Agri-AI%20Policy%202025%E2%80%932029_English_250619_104818.pdf*
[48]*https://www.icfa.org.in/assets/img/souvenirs/ALW.pdf*
[49]*https://www.ibef.org/blogs/from-farms-to-fridges-how-cold-chain-infrastructure-is-transforming-india-s-agriculture*
[50]*https://indiainfrastructure.com/wp-content/uploads/2020/03/brochure-agri-logistics-in-india-march2020.pdf*
[51]*https://ncdex.com/downloads/Research/casestudies-conceptpaper/Agricultural%20Warehousing%20in%20India,%202022-%20A%20report%20by%20IIMB.pdf*
[52]*https://en.wikipedia.org/wiki/Dedicated_freight_corridors_in_India*
[53]*https://en.wikipedia.org/wiki/Roads_in_India*
[54] *agri-logistics in india - https://indiainfrastructure.com/wp-content/uploads/2020/03/brochure-agri-logistics-in-india-march2020.pdf*
[55]*Evolving landscape of warehousing and logistics in India - https://www.grantthornton.in/globalassets/1.-member-firms/india/assets/pdfs/evolving_landscape_of_warehousing_and_logistics_in_india.pdf*
[56]*Connectivity, capacity upgrades lift small ports - https://m.economictimes.com/industry/transportation/shipping-/-transport/connectivity-capacity-upgrades-lift-small-ports/articleshow/125140987.cms*
[57] *[morth.nic.in]*
[58] *https://pmgsy.dord.gov.in/*
[59] *[ibef.org]*
[60]*[pib.gov.in]*
[61]*[itln.in]*
[62]*[marineinsight.com]*
[63]*[ibef.org]*
[64]*[sagarmala.gov.in]*
[65]*[ibef.org]*
[66]*[isec.ac.in]*
[67]*[isec.ac.in]*
[68]*NITI Aayog / RMI – Fast Tracking Freight in India, 2021*
[69]*FreightReportNationalLevel.pdf*
[70]*MoEF&CC Study on Cold-Chain-Sector-Report.pdf*
[71]*https://www.pib.gov.in/PressReleasePage_ Ministry of Road Transport & Highways*
[72]*Ministry of Coal_PressReleasePage*
[73]*Lost in transit: Opportunities to remove public data roadblocks in Indian trucking - International Council on Clean Transportation*
[74]*FreightReportNationalLevel.pdf*
[75]*National Logistics Policy: Leaping India into the Future*
[76]*FreightReportNationalLevel.pdf*
[77]*India_Industry-Assessment_Fleet-Landscape.pdf*
[78]*https://www.pib.gov.in/PressReleasePage.aspx?PRID=2223331&reg=3&lang=1*
[79]*Evolution of Refrigerated Transport from Reefers to Chillkart | Rinac*
[80]*Lost in transit: Opportunities to remove public data roadblocks in Indian trucking - International Council on Clean Transportation*
[81]*AIS 140 GPS Tracker: Why It's Mandatory in India*
[82]*AIS 140 GPS Tracker: Why It's Mandatory in India*
[83]*Lost in transit: Opportunities to remove public data roadblocks in Indian trucking - International Council on Clean Transportation*
[84]*National Logistics Policy 2025 a timely move to strengthen export competitiveness | The Business Standard*
[85]*All India Cold-Chain Capacity Assessment (Status & Gaps) Released_2015*
[86]*addressing-post-harvest-losses-in-india-a-silent-crisis-in-agriculture*
[87]*National Logistics Policy: Leaping India into the Future*
[88]*FSSAI_foSTaCSAFE STORAGE, DISTRIBUTION & TRANSPORTATION OF FOOD PRODUCTS*
[89]*https://sustainablecooling.org/wp-content/uploads/2023/03/20710-India-Report-ST2.pdf*
[90]*All India Cold-Chain Capacity Assessment (Status & Gaps) Released*

[91]*Cold-Chain-Sector-Report.pdf*
[92]*Building Resilient Infrastructure for Storage of Food Grains*
[93]*Building Resilient Infrastructure for Storage of Food Grains*
[94]*Figure 8: (Source- Department of Agriculture and Farmers Welfare)*
[95]*How Cold Chain Infrastructure Transforms Agriculture*
[96]*Evolution of Refrigerated Transport from Reefers to Chillkart | Rinac*
[97]*https://ozonecell.nic.in/wp-content/uploads/2021/09/Cold-Chain-Sector-Report.pdf*
[98]*How Cold Chain Infrastructure Transforms Agriculture*
[99]*e-Truck Incentive Scheme Under PM Modi's Green Mobility Vision*
[100]*First-Ever e-Truck Incentive Scheme Under PM Modi's Green Mobility Vision*
[101]*States can lead the charge for e-trucks - International Council on Clean Transportation*
[102]*India's First Fleet of Hydrogen-Powered Heavy Duty Trucks Trials Flagged off*
[103] *How Cold Chain Infrastructure Transforms Agriculture*
[104]*https://assets.kpmg.com/content/dam/kpmgsites/in/pdf/2022/10/The-logistics-and-warehousing-market-in-India.pdf.coredownload.inline.pdf*
[105]*https://www.reliablelogistics.ca/emerging-trends-in-logistics-for-2025/*
[106]*https://www.mordorintelligence.com/industry-reports/india-data-center-storage-market*
[107]*https://dmi.gov.in/Documents/Final_GrAM_Guidelines_final_03012019.pdf*
[108]*https://www.pib.gov.in/newsite/PrintRelease.aspx?relid=86691*
[109]*https://www.newindianexpress.com/opinion/2022/Feb/25/aggregation-in-agriculture-is-still-a-challenge-2423774.html*
[110]*https://ddnews.gov.in/en/india-strengthens-food-security-with-record-harvest-and-enhanced-storage-infrastructure/*
[111]*https://ddnews.gov.in/en/india-strengthens-food-security-with-record-harvest-and-enhanced-storage-infrastructure/*
[112]*https://aradhnaaggarwal.com/op-ed/pack-houses-an-opportunity-to-promote-trade-in-fruits-and-vegetables-and-beyond/*
[113]*https://www.ibef.org/exports/agriculture-and-food-industry-india*
[114]*https://www.pib.gov.in/PressReleasePage.aspx?PRID=2099814*
[115]*https://www.cleo.com/blog/logistics-management-trends*
[116]*https://www.reliablelogistics.ca/emerging-trends-in-logistics-for-2025/*
[117]*https://triplettransport.com/whats-next-for-logistics-5-industry-trends-shaping-2026/*
[118]*https://assets.kpmg.com/content/dam/kpmgsites/in/pdf/2022/10/The-logistics-and-warehousing-market-in-India.pdf.coredownload.inline.pdf*
[119]*https://www.peaktech.com/blog/supply-chain-warehouse-trends-technologies/*
[120]*https://www.mordorintelligence.com/industry-reports/india-data-center-storage-market*
[121]*http://avrdc.org/download/publications/from_the_field/postharvest/Packhouse-manual-english.pdf*

Acknowledgement

ASSOCHAM Team

Sumita Chakravarty,
Regional Director, ASSOCHAM
Sumita.Chakravarty@assocham.com

Anita NaiK
Jt Director, ASSOCHAM
anita.naik@assocham.com

Synergy Technofin Pvt. Ltd. Team

Mamta Shah
Assistant Manager
shah.m@synergytechnofin.com

Anjali Thapliyal
Assistant Manager
Thapliyal.a@synergytechnofin.com

Bhawana Masiwal
Associate- Consulting
masiwal.b@synergytechnofin.com

Kinjal Kumari
Sr. Graphic Designer
kumari.k@synergytechnofin.com

About ASSOCHAM

The Associated Chambers of Commerce & Industry of India (ASSOCHAM) is the country's apex national chamber since 1920. It advocates actionable policy suggestions to strengthen the Indian economy by leveraging its extensive membership reach of over 450,000 companies, comprising of large corporates and SMEs. With over 70 Sector and State Councils, ASSOCHAM effectively represents diverse segments of Indian industry and focusses on aligning industry priorities with the nation's growth aspirations.

ASSOCHAM Corporate Office
4th Floor, YMCA Cultural Centre and Library Building
01, Jai Singh Road, New Delhi – 110001

Regional Office
315, Sprint Co Works
3rd floor, the Centrium Phoenix Market City Mall,
Kamani, LBS Marg, Kurla West, Mumbai 400070
Website: www.assocham.org

About Synergy Technofin

Synergy Technofin is a leading agribusiness consulting firm in India, offering end-to-end advisory and implementation solutions. With 16+ years of experience, we specialize in agri value chain analysis, market mapping, farmer engagement, business assessment, and India entry strategies. We support large corporations, agri-startups, and multilateral organizations in navigating the complex agribusiness landscape. Our deep sector understanding enables us to deliver customized, viable, and impactful solutions. Our transformational approach drives innovation, growth, and business effectiveness across all aspects of agribusiness.

With a nationwide presence and a representative office in Africa, our expert team delivers high-quality, tailored services backed by strong technical and implementation expertise.

Office Address: 231, 1st Floor, Greater Kailash I, New Delhi 110048
Phone: 011 4166 9393
Website: www.synergytechnofin.com

Disclaimer