

Cold Chain Supply Chain Management: The Invisible Backbone of Modern Commerce

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Due to rapid industrialization, innovation, globalisation, and the growing e-commerce activity in a quality-conscious world, consumers expect timely delivery of goods and services, which is only possible through efficient Logistics and Supply chain Management.

The logistics industry is one of the world's largest economic sectors, supporting manufacturing, retail, e-commerce, healthcare, and international trade. The global logistics industry, valued at USD 11.23 trillion in 2025, is expected to grow to USD 24.36 trillion by 2035 at a CAGR of 8.05%. Asia-Pacific leads the market with a 44.6% share, while road transportation remains the dominant logistics mode, accounting for nearly 39% of global freight movement.

India's logistics industry, valued at approximately USD 243.8 billion in 2025, is projected to reach USD 429 billion by 2034, growing at a CAGR of 6.48%. The sector contributes around 13–14% to India's GDP, with road transport accounting for nearly 70% of freight movement. The Third-Party Logistics (3PL) segment holds the largest market share, at approximately 48%, while North India accounts for around 30% of the country's logistics activity.

The rapid expansion in this sector is mainly driven by e-commerce growth, including Warehousing, Last-mile delivery, Express logistics, Cold chain logistics, and reverse logistics. The improvement in Delivery efficiency is due to AI-driven logistics, which has reduced transportation costs by 10-20%. Sustainable logistics is becoming a critical component of achieving net-zero supply chains and ESG goals.

More than 20% of perishable products worldwide require temperature-controlled logistics during storage and transportation. Time-sensitive deliveries, including fresh fruits and vegetables, life-saving vaccines, dairy products, seafood, and temperature-sensitive pharmaceuticals, lie in the Cold Chain Supply Chain Management- an essential system that ensures products remain within prescribed temperature ranges from production to consumption. The global cold chain logistics market was valued at approximately USD 350–400 billion in 2024 and is projected to exceed USD 800 billion by 2032, growing at a CAGR of around 10–15%. The pharmaceutical cold chain segment is one of the fastest-growing sectors, driven by rising demand for vaccines, biologics, and temperature-sensitive medicines.

India's cold chain industry has a storage capacity of approximately 40 million metric tonnes, supported by more than 8,000 cold storage facilities and 12,000–15,000 reefer vehicles. With agriculture contributing nearly 18% to India's GDP and over 30% of agricultural output comprising perishable products, an efficient cold chain network plays a critical role in reducing post-harvest losses, ensuring food security, and supporting the country's agricultural and pharmaceutical sectors.

Why Cold Chains Matter

According to the Food and Agriculture Organisation (FAO):

- Approximately 1.3 billion tonnes of food are lost or wasted globally each year.
- Nearly 14% of food is lost between harvest and retail due to inadequate storage, transportation, and handling.
- In developing countries, poor cold chain infrastructure contributes significantly to post-harvest losses.

India is the world's largest producer of milk and the second-largest producer of fruits and vegetables. Post-harvest losses in fruits and vegetables are estimated at 15–25%, primarily due to inadequate cold storage and transportation facilities. Annual losses in perishables are estimated to exceed ₹90,000 crore.

As per Sector-wise Utilization,

Potatoes account for nearly 65–70% of India's cold storage utilization. Fruits and vegetables utilize less than 20% of total cold storage capacity.

Pharmaceuticals and dairy are emerging high-growth segments. The global pharmaceutical cold chain market is expected to grow at over 12% CAGR through 2030. In the Pharmaceutical Cold Chain Data, around 25% of vaccines are degraded before reaching end users due to temperature-control failures. Nearly 50% of vaccines globally are wasted because of logistics, storage, and temperature-related issues. The temperature requirements for different product categories are different.

Temperature Requirements	
Product Category	Temperature Range
Fresh Fruits & Vegetables	0°C to 15°C
Dairy Products	2°C to 8°C
Frozen Foods	-18°C or below
Vaccines	2°C to 8°C
Biologics & Specialistic Drugs	-20°C to -80°C

Key Components in Cold Chain are:

- Cold Storage Facilities - Temperature-controlled warehouses maintain product quality before distribution. Modern facilities are equipped with automated refrigeration systems, humidity controls, and energy-efficient technologies.
- Refrigerated Transportation- Specialized vehicles, containers, and reefer trucks transport products while maintaining required temperature ranges. These vehicles are equipped with monitoring devices to prevent temperature fluctuations.
- Monitoring and Tracking Systems -Internet of Things (IoT) sensors, RFID technology, and GPS tracking systems provide real-time visibility into product conditions during transit.
- Packaging Solutions -Advanced insulated packaging materials, phase-change materials, and temperature-controlled containers help preserve product quality during transportation and storage.
- Distribution and Last-Mile Delivery The final stage of delivery is often the most challenging. Efficient route planning and real-time tracking are crucial for maintaining product integrity.

Impact of Technology on Cold Chain Performance

The use of IoT monitoring, AI, and Predictive Analytics helps with real-time monitoring and forecasting, which has tremendously reduced temperature excursions, improved shipment

visibility, optimized routes, reduced inventory holding costs, reduced product waste, and reduced stockouts.

Organizations using AI-enabled forecasting have reported:

- 20–30% reduction in inventory holding costs
- 15–25% reduction in product wastage
- 10–20% improvement in demand forecasting accuracy
- 15–30% reduction in stockouts

IoT-Based Monitoring

- Up to 40% reduction in temperature excursions
- 25–35% improvement in shipment visibility
- Real-time alerts for deviations in temperature and humidity

Route Optimization

AI-powered route optimization can:

- Reduce fuel consumption by 10–15%
- Reduce transportation costs by 15–20%
- Lower carbon emissions by 10–25%

Challenges in Cold Chain

Despite technological advancements, cold chain operations face several challenges:

- **Infrastructure Gaps**-Developing economies often struggle with inadequate cold storage facilities and transportation networks.
- **High Operational Costs** Energy consumption, refrigeration equipment, specialised vehicles, and maintenance significantly increase logistics costs.
- **Temperature Excursions** - Power outages, equipment failures, and improper handling can lead to product spoilage and wastage.

- Regulatory Compliance- Cold chain operators must comply with stringent food safety and pharmaceutical regulations, requiring robust monitoring and documentation systems.
- Sustainability Concerns -Traditional refrigeration systems contribute to greenhouse gas emissions and high energy consumption, creating environmental challenges.

Sustainability in Cold Chain

AI-enabled cold chains are becoming a key contributor to SDG 2 (Zero Hunger), SDG 9 (Industry, Innovation and Infrastructure), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action).

Sustainability has become a strategic priority for cold chain operators. Green cold chains focus on

- Energy-efficient refrigeration systems
- Renewable energy integration
- Route optimisation to reduce fuel consumption
- Eco-friendly packaging materials
- Reduction of food loss and waste

These initiatives not only lower environmental impact but also contribute to operational cost savings and improved brand reputation.

The Future of Cold Chain Supply Chains

The future of cold chain management lies in intelligent, connected, and sustainable ecosystems. AI-driven forecasting, autonomous logistics, smart warehouses, predictive maintenance, and carbon-neutral transportation networks will redefine how temperature-sensitive products move across the globe.

As industries continue to expand and consumer expectations rise, organizations that invest in resilient and technology-enabled cold chain systems will gain a significant competitive advantage.

Conclusion

Cold Chain Supply Chain Management is no longer merely a logistics function; it is a strategic enabler of food security, public health, and global trade. By integrating advanced technologies, sustainable practices, and robust infrastructure, organizations can create resilient cold chains

capable of delivering quality, safety, and value in an increasingly complex business environment. Cold chain management makes the process more effective and efficient, as

- A temperature increase of just 2–3°C can significantly reduce the shelf life of many fresh products.
- Nearly 70% of pharmaceutical products require temperature-controlled transportation at some stage.
- Effective cold chain management can reduce food waste by up to 40%.
- Every ₹1 invested in cold chain infrastructure can generate multiple times that value through reduced spoilage and improved market access.
- AI-enabled cold chains are becoming a key contributor to SDG 2 (Zero Hunger), SDG 9 (Industry, Innovation and Infrastructure), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action).

The cold chain may operate behind the scenes, but its impact is felt every day—in our homes, hospitals, and throughout the global economy.