International Journal of Social Science and Economic Research

ISSN: 2455-8834

Volume:11, Issue:04 "April 2026"

To what extent do supply chain inefficiencies affect the quality, shelf life, and market competitiveness of agricultural produce in Punjab, and what role can cold storage and logistics infrastructure play in addressing these challenges?

Amrit Jolly

The Shri Ram School, Moulsari

DOI: 10.46609/IJSSER.2026.v11i04.019 URL: https://doi.org/10.46609/IJSSER.2026.v11i04.019

Received: 5 April 2026 / Accepted: 18 April 2026 / Published: 25 April 2026

1. Introduction

Punjab is the breadbasket of India -a land where every furrow tells the story of a farmer's resilience and the nation's sustenance. Agriculture is a major contributor to Punjab's economy, contributing 24% to its Gross State Domestic Output and while also employing 36 percent of the state's total workforce (Government of Punjab, 2023). It played a leading role in India's Green Revolution and recorded 5.7% agriculture-GDP growth between 1971 and 1986 and still to this day remains a major contributor to the national food supply and is central to food security in India(World Bank, 2006). However, due to major problems in its supply chain, the agricultural state ends up losing a lot of its fruits and vegetables post harvest. These supply chain inefficiencies are not just a problem for Punjab, they are a problem for the country as a whole as this ends up reducing the shelf life of the produce which hurts the domestic and the export markets. India loses 30–40% of fruits and vegetables post-harvest due to poor cold storage and logistics (ASSOCHAM, 2020) and out of the post-harvest produce, only 4% is handled through cold chains, compared to 70% in developed countries. These gaps in the supply chain reduce the overall produce quality, and make Indian goods less competitive in global markets(NCCD, 2021). The agenda Procedural burdens in their certification and bureaucratic inefficiencies further slow down the movement of organic goods through supply chains(Singh & Sidhu, 2021). There is also fragmentation among small and marginal farmers which makes coordination difficult, especially when cold chain or quality standards are involved. Though, nothing is unsolvable and there are solutions emerging to improve logistics and reduce the immense wastage. Some already in place as national policies like PM Kisan SAMPADA Yojana, Mega Food Parks, and Operation Greens are promoting cold chain development and infrastructure upgrades while, Investments in grading centres, ripening chambers, centralized cold storage, and reefer logistics are helping reduce losses and improve export readiness(FICCI, 2022).

ISSN: 2455-8834

Volume:11, Issue:04 "April 2026"

In addition to all of this private companies in both domestic and export-focused agriculture are building better supply chains, though reach remains limited. The same can be said for organic produce where government-backed initiatives like Agri Export Zones and Diversified Agriculture Support Projects aim to strengthen storage, logistics, and farmer- market connections. Modern retail requirements are also being met, such as traceability, consistent quality, and timely delivery which are pushing supply chains to become more organized and value focused (KPMG, 2022). Having said that, the question that still ponders in everyone's mind is that Is there enough Punjab-specific research on these issues. Most data and policies; which was mentioned, operate at the national level, while Punjab-specific supply chain gaps and their impact on market outcomes remain underexplored. One rare study surveyed 60 organic farmers across Punjab and directly analysed how storage, logistics, and certification barriers affected product shelf life, income, and scalability and it was noted down that better infrastructure and institutional support is needed to improve the overall outcome of the supply chain (Grewal & Brar, 2020). The ultimatum of all of this is the need of dual research as it will assess how inefficiencies reduce quality and farmer profits, and evaluate how improved infrastructure (like cold chains) can reverse those losses. The reason this problem regarding the agriculture-supply chain in Punjab has been chosen is to give light to the citizens of our country on the major wastage of produce happening in Punjab. Most people associate Punjab's agriculture with the farming of rice and wheat crops, but its much more than that. There is not enough data to solve this problem as no one has bothered to look into the amount of wastage that is happening.

Agriculture supply chain also suffers with poor handling, outdated storage, and fragmented supply systems which create delays and spoilage, restricting market reach, resulting in Farmers forced to sell produce quickly at low prices before it perishes, reducing income and discouraging investment in high-value crops. There is also an absence of pre- cooling and reefer transport which causes early-stage degradation in quality that cannot be reversed later. Perishable produce like fruits, vegetables, and dairy play a crucial role in India's agricultural economy due there everyday use in most households and there strong nutritional value (NCCD, 2021) India ranks as the second-largest producer of fruits and vegetables globally, with crops like bananas, mangoes, papayas, and okra which have strong domestic and export demand but are highly sensitive to delays, poor storage, and transport issues(FAO, 2022).

Similar can be said for perishables in the organic sector, as turmeric, jaggery, and pulses offer higher prices and lower input costs—but also face higher risks from pests, storage issues, and lower yields. Without efficient handling, perishables quickly lose quality and fetch lower prices, which deters farmers from growing them at scale. As mentioned before, there are many inefficiencies in Punjab's agriculture supply chain such as delayed payments, volatile pricing,

ISSN: 2455-8834

Volume:11, Issue:04 "April 2026"

and the absence of organized markets which discourage farmers and reduce predictability. There is also a lack of storage infrastructure, poor transport, and multi-layered distribution chains, leading to inconsistency, delays, and reduced farmer margins. In particular, organic farmers face marketing constraints, limited branding, and access to institutional buyers(Grewal & Brar, 2020)

2. Theoretical Framework Supply Chain Management (SCM) Theory

Supply Chain Management (SCM) theory delves into how firms coordinate the movement of goods, services, and information along the supply chain to ensure maximum efficiency and value generation (Mentzer et al., 2001). In agriculture, SCM encompasses purchasing inputs, production, post-harvest handling, transportation, storage, and distribution to end-markets.Inefficiencies like slowed-down transportation, dispersed networks, non-coordination, lack of information and poor infrastructure can result in high post-harvest losses and decline in product quality, thus diminishing the shelf life and marketability of farm produce (Christopher, 2016).In Punjab, these inefficiencies are especially significant given the state's position as an important producer of perishable items like vegetables, fruits, and dairy products. SCM theory therefore provides a foundation to find where the breakdowns happen and how systemic interventions like cold storage improve performance

Post-Harvest Loss Theory

Post-harvest loss (PHL) theory deals with the quality and quantity decline in farm produce from harvest time to the point of final consumption (FAO, 2011). This theory focuses on physical losses in quantity due to spoilage, damage, loss in quality (nutritional), and economic losses (reduced prices due to loss in quality).In line with the FAO (2011), PHL in India varies between 4% and 16% for different crops, with perishables bearing greater losses. Underdeveloped cold chain logistics particularly the absence of temperature- controlled storage and transportation are great drivers of PHL. Cold storage is crucial in the provision of shelf life extension, quality maintenance, and ensure competitiveness of produce in domestic and export markets. The theory thus justifies exploring the effects of such infrastructure on reducing supply chain inefficiencies

Resource-Based View (RBV) of Infrastructure

The RBV suggests that organizations achieve enduring competitive advantage through the acquisition and utilization of valuable, rare, inimitable, and non-substitutable (VRIN) resources (Barney, 1991). In agricultural value chains, cold storage and logistics capacity can be regarded as strategic assets that improve performance by minimizing wastage, increasing reliability, and providing market access. For the agricultural economy of Punjab, investments in sound logistics and cold chain infrastructure could make its produce stand out on freshness, shelf life, and consumer confidence, thus enhancing market competitiveness. RBV offers a conceptual

ISSN: 2455-8834

Volume:11, Issue:04 "April 2026"

framework for assessing the impact of such infrastructures as a strategic facilitator.

3. Literature Review

Inefficiencies in supply chains in Punjab's agriculture severely impact the quality, shelf life, and competitiveness of produce in the market. Sudan (2020) points out that fragmented market structures, poor infrastructure, and delayed information lead to post- harvest losses and lower farmer incomes. These inefficiencies take the form of delayed procurement, poor storage, and poor access to market insights, all of which combine to lower produce quality and reduce shelf life. The research highlights the necessity for strong Agricultural Market Information Systems (AMIS) and information technologies to increase transparency, competitiveness, and supply chain coordination in Punjab's agrarian economy.

Cold storage facilities are one of the most crucial factors in maintaining the quality and shelf life of perishable agricultural produce. Shahi (2024) describes that India wastes nearly 40% of production after harvesting food, with Punjab playing a major role because of poor cold storage and inefficient logistics. Cold storage keeps the temperature in check, preserving food from spoilage,damage and nutrient loss. In addition, refrigerated transportation and well-functioning distribution hubs minimize transit losses and stabilize prices in markets. The research highlights that cold chain logistics not only help in waste reduction but also enable farmers to escape uneven sales and adopt crop diversification.

Punjab enjoys a leading position in agriculture still its cold chain facilities are underdeveloped and lack balance in their distribution. (Pooja et al. 2025) study the dynamics of cold storage in India and uncover that Punjab is severely lacking in infrastructure in the high-value horticulture segments. The research identifies that the majority of the cold stores are potato-compatible, without humidity and temperature controls for fruits and vegetables. These constraints result in high post-harvest losses and lower competitiveness in home and overseas markets.

Government programs have grown to concentrate on reinforcing local cold chain infrastructure to overcome supply chain problems. The Ministry of Food Processing Industries (2025) sets forth the Pradhan Mantri Kisan SAMPADA Yojana (PMKSY), that supports value addition and integrated cold chain infrastructure from consumer to farm gate. Punjab alone has sanctioned more than 60 projects under PMKSY, increasing storage capacity and minimizing wastage (Boosting Food Processing & Storage Infrastructure in India) (PIBGOV,2025). These efforts aim at increasing farmer returns, price stabilization, and encouraging sustainable farming practices. Yet, the report observes that stand-alone cold storages are not being supported and recognizes the necessity for more integrated policy frameworks that bring together logistics and market access.

ISSN: 2455-8834

Volume:11, Issue:04 "April 2026"

4. Methodology

The study employs a qualitative method relying on secondary data to investigate the impact of supply chain issues on the quality, shelf life, and market competitiveness of farm produce in Punjab. It further investigates how improved cold storage and logistics can address these issues. This study analyzes prevailing literature from government reports, academic journals, and business magazines—referencing sources such as the Ministry of Agriculture, FAO, and online databases like JSTOR and ScienceDirect.Through content analysis, the study establishes typical problems in harvesting, transportation, storage, and distribution, particularly of perishable produce. It also uses principles from the Resource- Based View and Transaction Cost Economics to explore how infrastructure such as cold storage enhances efficiency and competitiveness.

5. Data Analysis & Discussion Supply chain efficiency vs. inefficiency

Efficiency in Punjab's agricultural supply chain is still a major driver of produce quality, market competitiveness, and farmer well-being. Despite Punjab's status as India's breadbasket, systemic inefficiencies still prevail, especially in the post-harvest handling and distribution of paddy, peas, vegetables and other agricultural products. Such inefficiencies are evident through delayed procurement, a lack of proper storage facilities, and disintegrated logistics, which together result in the degradation of shelf life and market value of agricultural produce.For example, when Punjab was expecting 185 lakh tonnes of paddy in the 2024–25 Kharif Marketing Season, the Food Corporation of India (FCI) yet had more than 121 lakh tonnes of rice from earlier years, leading to a jam in warehouse capacity and slowing down procurement (Rana, 2024). This slowdown compelled farmers to sell at less than the Minimum Support Price (MSP), frequently to middlemen, thus reducing their income and market competitiveness. Additionally, the gradual withdrawal of stock from mandis during which only 3–4 trucks were operational as against 10 in earlier years caused backlogs and additional loss of produce quality (Pandey, 2024).

The supply chain failures also have environmental implications. The reduced paddy harvest to wheat sowing window has heightened stubble burning, leading to high levels of air pollution in northern India (Pandey, 2024). Rice millers have also declined to process some hybrid paddy varieties with lower yields, adding to the inefficiencies in supply and resulting in distress sales by farmers.

In the vegetable supply chain, supply chain inefficiencies also impact marketing margins and producers' share. A research study of green peas in Punjab concluded that direct- to-consumer supply chains realized the maximum marketing efficiency (14.83) and producers' share (94%), as opposed to conventional chains that included several middlemen, with efficiencies ranging as low as 2.38 (Sidhu, Sidhu, & Singh, 2011). This indicates the value of streamlined, decentralized

ISSN: 2455-8834

Volume:11, Issue:04 "April 2026"

models in improving supply chain performance.

In order to meet these needs, specialists call for institutional reform such as diversified procurement infrastructure, public-private partnerships for market modernization, and digital platforms to improve traceability and coordination of logistics. Without these measures, Punjab's agricultural supply chains are likely to remain inefficient, jeopardizing the livelihoods of farmers and regional food security.

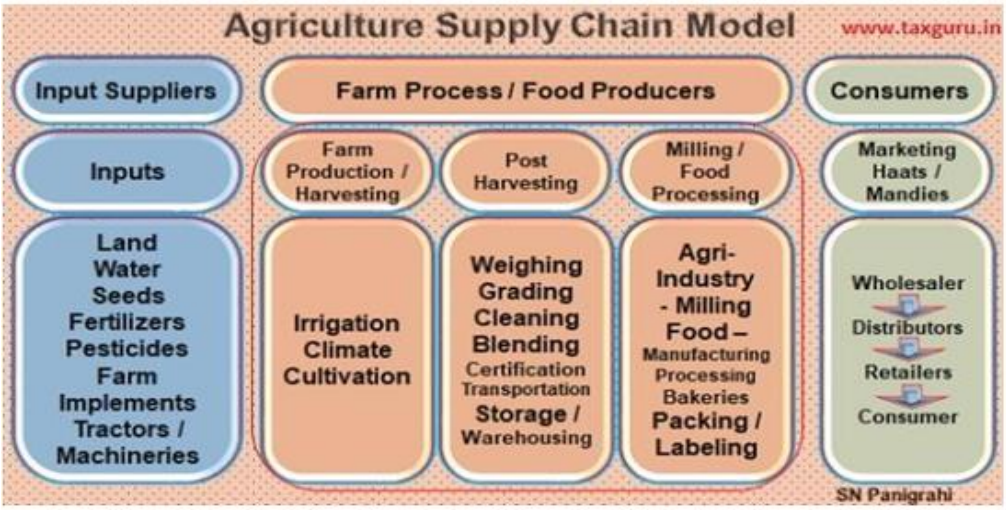


Image:https://taxguru.in/corporate-law/integrated-agriculture-supply-chain.html#google_vignette

Perishability and loss-to-market ratio

Punjab's agricultural sector faces huge post-harvest losses, particularly in perishable horticultural crops, due to fragmented supply chains, inadequate cold storage,poor infrastructure and inefficient transportation. A study by Sidhu, Mohapatra, and Singh (2024) revealed that tomatoes suffer the highest losses 17.71% at the farm level and 30.10% at the retail level while peas experience peak losses at the wholesale level (8.19%). These losses are exacerbated by disease infestation, bruising, and over-maturity, often resulting from delayed procurement and poor handling. In contrast, wheat, a non-perishable staple, shows significantly lower post-harvest losses of just 1.84% due to improved mechanization and storage practices (Grover & Singh, 2013). However, seasonal disruptions such as early heatwaves and floods have led to massive crop failures. For instance, Punjab incurred a ₹7,200 crore loss in wheat during the 2022 season due to premature heat stress that reduced yield by 5 quintals per hectare. Similarly, the 2023 floods submerged over 2.21 lakh hectares of paddy, threatening nearly 7% of the state's kharif rice area, though community nurseries helped mitigate losses worth ₹2,800 crore (Punjab

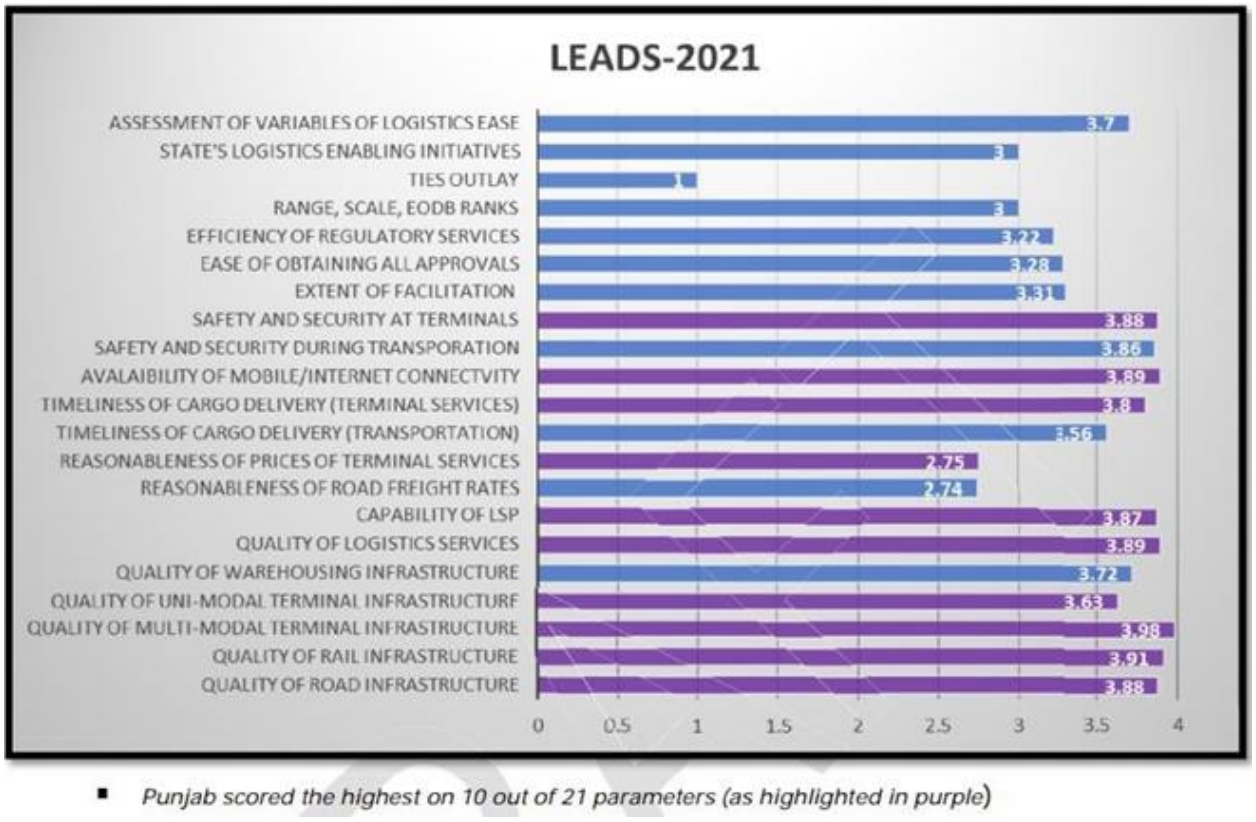
ISSN: 2455-8834

Volume:11, Issue:04 "April 2026"

Agricultural University, 2024). These regional and seasonal contrasts underscore the urgent need for crop-specific post-harvest infrastructure, especially for vegetables and fruits, which suffer losses ranging from 15% to 50% due to poor storage and market access (Kaur & Khurana, 2021)

Quality and shelf-life impact

In Punjab, logistics and supply chain inefficiencies have had a major effect on the shelf-life and quality of perishable commodities, especially in the food and agricultural industries. In spite of Punjab's robust agricultural economy and its position as the third-best performing state in logistics based on the LEADS Index 2021 (score of 3.51), ongoing challenges like lack of proper cold storage facilities, poor last-mile connectivity, and unbalanced road development still erode product integrity during transit (Government of Punjab, 2021). For example, the absence of refrigerated logistics and reefer trucks causes spoilage rates reaching 15% for fruits and vegetables along transportation, as emphasized in national logistics evaluations of perishable products (Igilar, 2023). Not only do these losses diminish the economic value of produce, but they also harm food safety and customer satisfaction.



- *Punjab scored the highest on 10 out of 21 parameters (as highlighted in purple)*

Image: https://pbindustries.gov.in/static/assets/docs/draft_integrated_logistics_park_policy.pdf

ISSN: 2455-8834

Volume:11, Issue:04 "April 2026"

Additionally, the lack of combined digital tracking systems and disparate stakeholder coordination aggravates delays and mismanagement, further enhancing spoilage. Research indicates that regulating stable temperature and humidity across the supply chain can increase shelf-life by 25–40%, yet these methods are poorly utilized in Punjab's logistics environment (Singh & Corradini, 2022). Filling these loopholes by investing in cold chain facilities, real- time monitoring equipment, and efficient regulatory procedures is the key to upgrading product quality, minimizing wastage, and enhancing Punjab's agri-food exports competitiveness.

Market competitiveness and farmer welfare

Punjab's farm sector, though traditionally strong because of its productivity levels and role in national food security, is confronted with critical challenges to market competitiveness and farmer well-being through inefficiencies in supply chain and logistics capabilities. Even as it produces around 180 Lakh Metric Tonnes of paddy and wheat every year for the central pool, Punjab's farmers also tend to face delayed procurement as well as poor storage, compelling them to sell at rates below Minimum Support Price (MSP) and heighten dependence on middlemen (Punjab Development Commission, 2025). Gujarat and Maharashtra, however, have utilized diversified crops, better irrigation, and focused logistics investments to increase farmer incomes and minimize post-harvest losses (Modi & Manisha, 2025). Punjab's logistics score of 3.51 in the LEADS Index (2021) indicates moderate performance, but it is behind on cost-effective logistics and regulatory efficiency in comparison with leading states (Government of Punjab, 2021). Additionally, the Agriculture Infrastructure Fund (AIF) has delivered positive outcomes across states like a 28% decrease in post-harvest losses and 11 job opportunities per project but Punjab's take-up is held back by political barriers and glacial implementation (Press Information Bureau, 2025). These differences highlight the imperative for Punjab to implement region-specific reforms such as decentralized agri-infrastructure, digitised procurement mechanisms, and strengthened farmer producer organizations (FPOs) in order to align with national competitiveness and enhance farmer welfare in a sustainable manner.

Despite Punjab’s reputation as India’s agricultural powerhouse, the state has witnessed a troubling rise in farmer suicides over the past decade, largely driven by economic distress, rising input costs, and institutional debt. According to the *India Forum*, the annual average of farmer suicides in Punjab increased from approximately 70 per year (2000–2014) to over 263 per year post-2015, peaking at 323 in 2018 (Saini, Hussain, & Khatri, 2022). In 2020 alone, 257 suicides were reported among farmers and farm laborers in Punjab, accounting for 2.4% of India’s total farmer suicides that year (National Crime Records Bureau, as cited in Saini et al., 2022). A detailed study by the Journal of Global Health Reports, based on verbal autopsy surveys across five districts, recorded 2,473 suicides between 1980 and 2016, with 58.4% among agriculturalists and 40.7% among farm laborers (Taki et al., 2021). The study found a strong correlation between

ISSN: 2455-8834

Volume:11, Issue:04 "April 2026"

suicide frequency and rising debt levels, especially among small and marginal farmers. Notably, 51% of farmer suicides in Punjab were attributed to institutional indebtedness, followed by crop failure, illness, and family problems (Saini et al., 2022). These figures are likely underreported due to stigma and classification issues, with some estimates suggesting actual suicide rates may be five times higher than official data (Fleck, 2024). The persistence of these suicides underscores the urgent need for structural reforms in agricultural credit systems, mental health support, and crop insurance mechanisms to safeguard farmer welfare in Punjab.

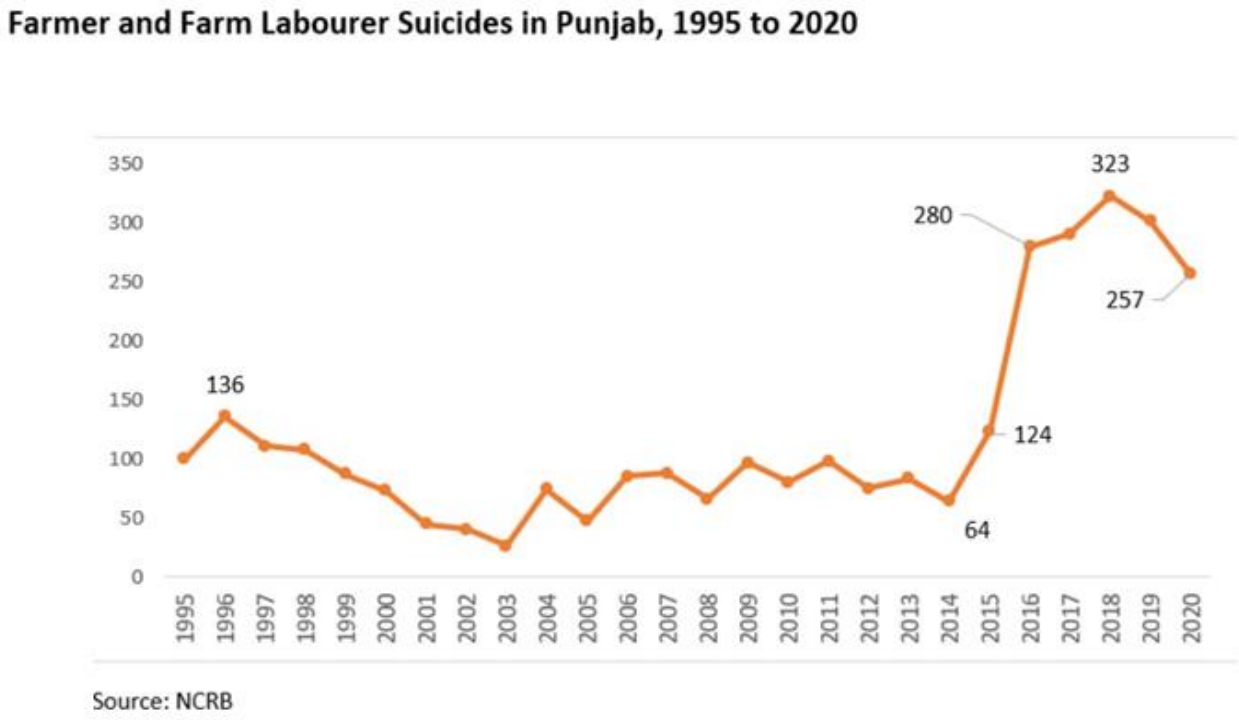


Image source:https://www.theindiaforum.in/article/spike-farmer-suicides-punjab

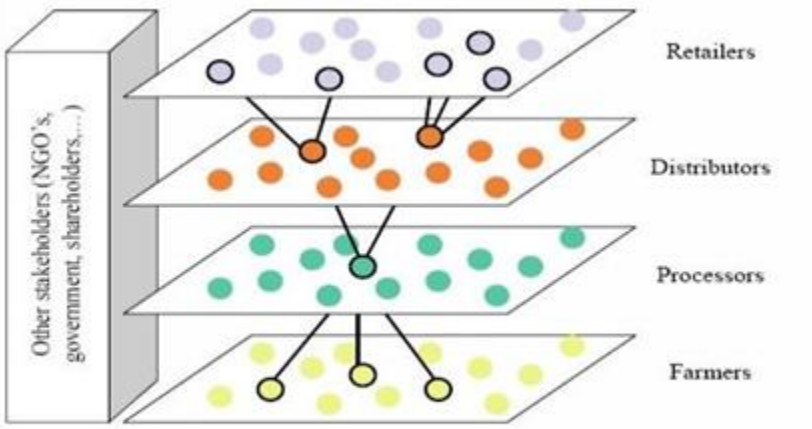
Supply Chain management

Supply Chain Management (SCM) in Punjab has witnessed considerable transformation in the last decade, riding the waves of agricultural supremacy and industrial diversification. Punjab's geographical position in northern India, combined with its comprehensive transportation infrastructure of more than 139,000 km of roads and 2,269 km of rail network—has made it a logistics hub for domestic as well as export trade (Government of Punjab, 2021). The agriculture sector of the state, which is a major contributor to India's central pool of food grains, is also dependent on effective supply chain functions. For example, the state of Punjab buys around 170–180 lakh metric tonnes of wheat and the same quantity of rice every year, requiring smooth logistics, storage, and payment networks (Punjab Development Commission, 2025).Supply

ISSN: 2455-8834

Volume:11, Issue:04 "April 2026"

chains in industrial sectors in Punjab have also registered significant improvements. The government witnessed a 6.92% growth in industrial Gross State Value Added (GSVA) in 2021–22, after contracting 2.11% in the pandemic year (Government of Punjab, 2022). This recovery was buttressed by policy measures like the Integrated Logistics & Logistics Park Policy, encouraging multimodal connectivity and warehousing facilities. (Government of Punjab, 2021).In addition, the Punjab Economic Survey points out that the services sector, connected to supply chain activities such as transport, telecommunication, and financial services, contributes close to half of the state's GSVA. The sector expanded at 8.12% during 2021–22, reflecting growth resilience and flexibility in logistics-oriented services after the pandemic (Government of Punjab, 2022). These trends reflect Punjab's shift towards a digitally integrated and technology-enabled supply chain platform necessary for maintaining its agricultural and industrial competitiveness.



Schematic diagram of a supply chain from the perspective of the processor (bold flows) within the total FSCN (based on Lazzarini et al. 2001)

Image:https://www.manage.gov.in/studymaterial/scm-e.pdf

Post Harvest loss

Post-harvest losses in Punjab, India, are a major threat to agricultural sustainability, food security, and farm livelihood. A recent study done by Sidhu, Mohapatra, and Singh (2024) identified and examined systematically the magnitude and reasons of post-harvest losses throughout the vegetable value chain in three prominent clusters in Punjab Nakodar, Malerkotla, and Baba Bakala Sahib. The research considered five important vegetables: tomato, pea, potato, okra, and cauliflower. Results indicated that losses were worst at the retailer level, with tomatoes having the highest loss rate of 30.10%, while farm-level losses amounted to 17.71% for the same crop. Losses at the wholesaler level were relatively low, reaching 8.19% for peas. The losses

ISSN: 2455-8834

Volume:11, Issue:04 "April 2026"

were caused by a myriad of reasons ranging from disease and insect infestation, bruising, over-maturity, to low adoption of post-harvesting practices.

The inefficiencies in the supply chain and logistics infrastructure like poor handling, insufficient cold storage, and delayed procurement augment these losses, especially during peak harvesting times. The study underlines the importance of intervention that is customized, like training farmers in post-harvest management, better storage and transport infrastructure, and efficient procurement procedures to reduce these losses and increase the overall efficiency of the Punjab's agricultural value chain(singh,2024).

Resource-Based view

The Resource-Based View (RBV) approach states that the source of sustainable competitive advantage lies in ownership and strategic utilization of valuable, rare, inimitable, and non-substitutable resources (Barney, 1991). From this perspective, Punjab's infrastructure presents a solid core of tangible and intangible resources supporting regional development and economic productivity. Punjab's road network, an infrastructural crowning jewel, stretched 92,109 kilometers in 2020 and 100% of its 12,096 settled villages were covered with roads—illustrating both coverage and inclusiveness (Government of Punjab, 2020). The state also reported more than 12.2 million registered vehicles, reflecting high mobility and logistical capability. With respect to energy infrastructure, Punjab possessed an installed capacity of electricity generated from hydro, thermal, and diesel sources, whose district-wise per capita consumption data indicated common access and use. Telecommunications further enhance Punjab's intangible infrastructure, with common mobile and fixed-line coverage among districts. These infrastructural assets are not only widespread but also fully integrated into the state's socio-economic life, hence making them quite immobile and hard to imitate. From an RBV view, Punjab infrastructure is a strategic resource that contributes to absorptive and adaptive capabilities that enable the state to adequately face economic change and development problems. Embedding these resources into governance and planning systems allows Punjab to take advantage of its infrastructural competencies for long-term regional competitiveness(World Bank, 2020)

6. Major challenges

The Punjab agricultural supply chain, while traditionally robust as a result of the Green Revolution, is hindered by several challenges to its efficiency and performance. One of the key reasons for supply chain inefficiency is the excessive dependence on conventional procurement systems, especially the mandi (APMC) model, which restricts market access and deterrers direct farm-to-market linkages. This model encourages inefficiencies, delays, and reliance on

ISSN: 2455-8834

Volume:11, Issue:04 "April 2026"

intermediaries, which often leads to poor price realization by farmers as well as wastage of perishable produce (Singh & Sidhu, 2020).

Insufficient modern storage and cold chain facilities is another key problem. Even though Punjab is a major producer of perishable crops such as fruits and vegetables, the state lacks cold storages severely, leading to post-harvest losses of around 15-25% for perishables (Planning Commission, 2012). Inefficient refrigerated transport, disintegrated cold chain systems, and scarce processing units make the situation worse, decreasing shelf life and competitiveness of the produce in the market (Narula & Nandwani, 2022).

Further, lack of digital integration and technological lag in supply chain operations, including a lack of real-time tracking, ineffective inventory management, and no data-driven forecasting, negatively affect logistics planning. Small and marginal farmers in particular are unaware of and lack access to such digital platforms, resulting in information asymmetry and missed market opportunities (Kaur & Dhaliwal, 2021).

Moreover, rare private sector investment and participation in logistics and agri- infrastructure deter scalability and innovation. Government programs tend to suffer from bureaucratic lag and implementation gaps, leading to a disconnection between policy intent and ground realities (Chand, 2021). Combined with poor rural roads and last-mile connectivity, all these dampen timely transport and distribution, especially during peak harvest periods or weather shocks

7. Emerging Cold Storage Facilities and Logistics Optimization in Punjab

Punjab's flourishing horticulture industry, covering 2.69 lakh hectares and yielding 51.48 lakh MT every year, has been propelling the establishment of around 550 cold storage units with a total capacity of 19 million MT. Out of these, 133 cold stores (.53 lakh MT) and 2,769 MT of ripening chambers came up under the National Horticulture Mission. State-of- the-art facilities now commonly include high-efficiency compressors, variable-speed drives, improved insulation materials, and on-site grading and sorting lines to reduce energy usage and spoilage.(Kumar,2015)

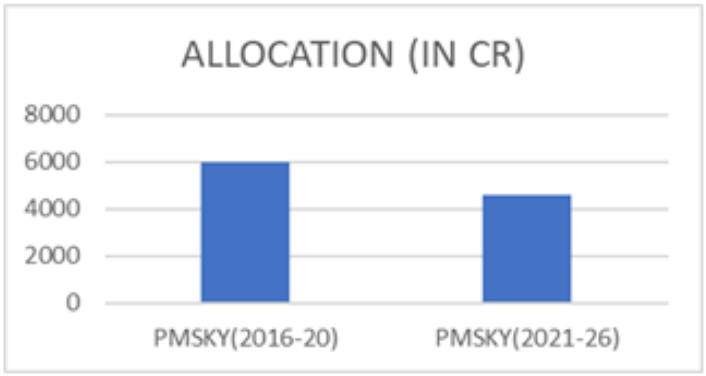
In order to simplify the transportation of perishable commodities, Punjab introduced its Integrated Logistics & Logistics Park Policy during 2021 with the objective to develop multi-modal logistics parks with temperature-controlled facilities at strategic production centers. The policy encourages developers with 100 percent refund of net SGST for ten years (up to 125 percent of fixed capital investment), exempting stamp duty on land transactions, and a ten-year waiver on electricity duty up to 100 percent of the capital investment. A minimum ground-level space of 3,000 sq ft is needed for qualifying cold chain and warehouse projects to provide scalable and standardized network reach throughout the state.(PIB,2021)

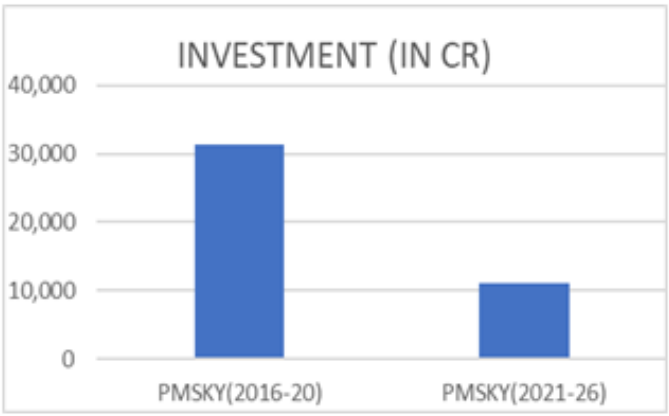
ISSN: 2455-8834

Volume:11, Issue:04 "April 2026"

At the national scale, the Pradhan Mantri Kisan SAMPADA Yojana (PMKSY) initiated in May 2017 with an initial investment of ₹6,000 crore is aimed at creating integrated cold chains and value-addition infrastructure. In 2016-2020, PMKSY utilized ₹31,400 crore worth of investments to manage 334 lakh MT of agro-produce, reaching 20 lakh farmers and providing approx 5.31 lakh direct and indirect employment opportunities. Its expansion from 2021–26, which has ₹4,600 crore provided and ₹11,095.93 crore mobilized, aims at another 28.5 lakh farmers and 5.44 lakh jobs, highlighting its lead role in stemming post-harvest losses across the country.(PIB,2021)

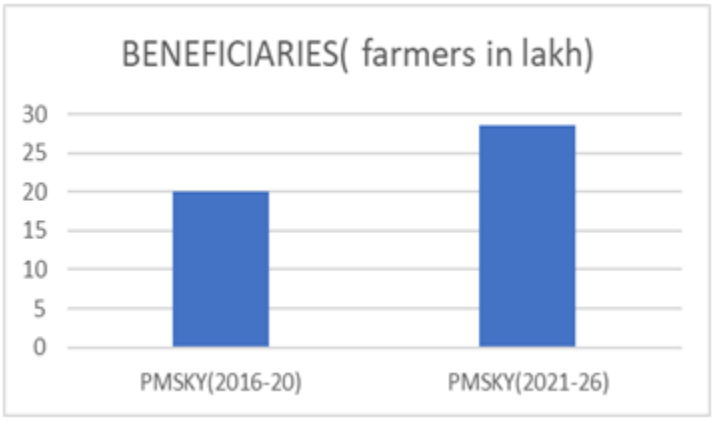
Along with PMKSY, the Mega Food Parks Scheme follows a cluster model where special purpose vehicles set up collection centers, primary and central processing facilities, and cold storage along with space for 25–30 food processing units. 24 mega food parks have been made operational in India as of May 2024, such as the International Mega Food Park in Fazilka and the Sukhjit Mega Food Park in Kapurthala, bringing to the forefront Punjab's significance in India's national cold chain network. Total 39 mega food parks and 298 integrated cold chain projects have been sanctioned countrywide, with 20 cold chain projects and three mega food parks in Punjab under these schemes.(PIB,2021)





ISSN: 2455-8834

Volume:11, Issue:04 "April 2026"



Looking forward, Punjab's cold chain growth focuses on digital tracking by IoT- enabled sensors to record temperature in real time, integration of solar and other renewable energy sources to reduce the cost of operations, public–private partnership with agri-startups for last-mile delivery, and skill development programs under PMKSY's human resources module to train rural youth as cold chain technicians. These technological changes hold out the promise of reducing spoilage even further, increasing farm revenues, and solidifying Punjab's position as a front-runner in India's cold storage infrastructure.

A glimpse of cold supply chain

image :https://www.mofpi.gov.in//Schemes/cold- chain/project-components-0

ISSN: 2455-8834

Volume:11, Issue:04 "April 2026"

8. Dehaat model- a revolutionary model for punjab

DeHaat's end-to-end solution is a revolutionary model for Punjab agricultural supply chain management by having seamlessly integrated digital marketplace access, localized aggregation, and strong cold chain infrastructure. Farmers through DeHaat's app can buy inputs, get advisory services, and more importantly, directly sell their produce to bulk buyers like FMCG companies, exporters, and retailers. This digital consolidation is supplemented by a micro-entrepreneur network that runs DeHaat Centers, which act as last-mile connectivity centers, enabling quality evaluation and initial logistics coordination. To combat post-harvest inefficiencies, DeHaat has tactically allied with existing cold storage facilities in the proximity of production clusters and opened its own hubs where appropriate. The use of refrigerated transport vehicles (RTCs), coupled with a centralized logistics management system, provides temperature-controlled movement of perishables. Moreover, pre-cooling facilities in packhouses located at strategic aggregation points facilitate prompt post-harvest treatment, and IoT sensors in RTCs and cold rooms help monitor temperature and humidity in real-time and comply with quality standards (DeHaat, 2023).

This combined cold chain network has given rise to measurable enhancements in produce quality, shelf life, and overall competitiveness. By facilitating fast pre-cooling and hassle-free temperature-controlled logistics, DeHaat has registered a 15–20% drop in post- harvest losses for perishables (Business Standard, 2022). The longer shelf life of produce such as now and tomatoes has enabled farmers to deliver distant markets without any quality loss, and standardized handling procedures have guaranteed the same product condition upon delivery. Market access has also grown immensely, with farmers linking to high-end customers like Big Basket and Reliance Fresh, tending to receive prices 10–25% better than received at local mandis for good quality produce. The ability to store produce temporarily has empowered farmers to avoid distress sales during local glutes, and the app’s transparent pricing and transaction features have fostered greater trust.

Overall, DeHaat's model illustrates how combining digital aggregation, market linkages, and affordable, technology-facilitated cold chain infrastructure can readily resolve fundamental inefficiencies in Punjab's farm supply chain. By lessening losses, maintaining quality, and improving market connectivity, such solutions not only increase farmer incomes but also increase the competitiveness of Punjab's farm produce. Scaling up this model again—while taking care of challenges with power availability, cost of operation, and enabling collaboration between agritech companies, government agencies, and infrastructure providers—is the key to a holistic overhaul of the region's agricultural landscape.

ISSN: 2455-8834

Volume:11, Issue:04 "April 2026"

9. Future Direction

Punjab is aggressively repositioning itself as a logistics and agribusiness hub through a multi-pronged strategy. The state has undertaken end-to-end need-gap studies across agricultural and processed-food value chains, along with upgradation of APMC and non- APMC mandis with improved last-mile connectivity—including all-weather roads and rail connectivity—to bring down bulk logistics costs (Sikka & Associate, 2025).With its Integrated Logistics & Logistics Park Policy (2023), Punjab provides substantial fiscal and non-fiscal incentives—such as reimbursement of SGST, employment subsidy, and exemption from change-of-use and development charges—to attract investment in multi-modal logistics parks (MMLPs), transport hubs, specialized warehouses, and commercial cargo fleets (Hindustan Times, 2022; TeamLease RegTech, 2023).

The state of punjab is also enhancing its infrastructure with strategic industrial and rail freight corridors: corridors such as Amritsar–Kolkata and intra-state routes (e.g., Chandigarh–Amritsar, Patiala–Bathinda) are being developed concurrently with the Eastern Dedicated Freight Corridor's electrified railway network which will connect Sahibnewal, Khanna, Sirhind, and other nodes offloading freight from road and reducing congestion (Invest Punjab, 2025).Storage and transport infrastructure is growing too: integrated cold storage, mechanized warehouses, reefer vans, and mobile pre-cooling units are being subsidized—providing up to 35% for storage infrastructure and 50% for processing and value addition—to enable a seamless cold chain from farm gate to fork (Invest Punjab, 2024)

Punjab is also in the lead nationally in implementing the Agriculture Infrastructure Fund (AIF), having utilized ₹10,050 crore (original ₹4,713 crore, extended to ₹7,050 crore) to create cold rooms, warehouses, and solar-supported processing facilities, leading the country in sanctioned projects as of June 2024 (Department of Horticulture, 2025)One key innovation step includes supply chain modernization through route-optimization studies—with technical assistance from the World Food Programme—and development of GIS-enabled procurement and storage apps to minimize Public Distribution System transportation costs (Punjab News Express, 2023)Further digital and technological integration is underway through IoT-enabled sensor systems and real-time monitoring in cold chains, keeping pace with national trends— already promising to reduce perishable losses by 76% for now transport from Punjab to Bengaluru (NCCD, 2015 study).

10. Conclusion

Punjab's agriculture supply chain, while historically strong, is now bogged down by major inefficiencies in post-harvest handling, storage,poor infrastructure, and transport. As one of the top fruit and vegetable producers in the country, the state wastes almost a third of its horticultural

ISSN: 2455-8834

Volume:11, Issue:04 "April 2026"

produce every year due to ineffective logistics and lack of proper cold storage facilities. Apart from lowering farmers' revenues, such losses also lower the competitiveness of Punjab produce both domestically and internationally.

Infrastructural facilities for cold storage in Punjab are greatly under-developed and inequitably distributed. The state possesses 550 cold storage units with a cumulative capacity of 19 million MT, out of which just 133 units (0.45 million MT) have modern, multi- temperature facilities. The majority of the current units are potato-compatible and do not have the temperature and humidity control requisite for maintaining high-value perishables such as fruits and vegetables. Infrastructural deficit is the primary factor in post-harvest losses and low shelf life.

Transportation congestion and procurement backlogs add to supply chain inefficiencies. For instance, in the 2024–25 Kharif season, warehouse blockage and sluggish withdrawal of inventory resulted in distress selling and lower price realization for farmers. Poor last-mile connectivity and lack of refrigerated logistics translate into spoilage rates of 15% or more during transportation, compromising product quality and food safety.

Theoretical models like Supply Chain Management (SCM), Post-Harvest Loss (PHL) theory, and the Resource-Based View (RBV) point towards the strategic role of infrastructure in agricultural value chains. SCM theory accentuates coordination and efficiency, while PHL theory addresses loss reduction and economic waste. RBV places cold storage and logistics as valuable, rare, and inimitable capabilities that can give Punjab a competitive advantage if effectively leveraged.

Empirical evidence presents sharp differences in post-harvest loss between crops. Tomatoes incur maximum losses of 17.71% at the farm and 30.10% at retail level, while wheat, being non-perishable, incurs just 1.84% loss because it is more mechanized and stored. Seasonal disruptions such as heatwaves and floods add to these losses further, which highlights the requirement for crop-specific infrastructure and climate-resilient logistics.

Even after government programs such as PMKSY and Mega Food Parks, the implementation in Punjab has been gradual and patchy. While more than ₹3,116 crore have been sanctioned under the Agriculture Infrastructure Fund, bureaucratic tardiness and absence of integrated planning have confined the impact. Independent cold storages are not sufficiently supported, and coordination between market access and logistics is weak.

Digital integration and technological upgradation are becoming imperative solutions.

IoT sensors for real-time temperature monitoring, GIS-based procurement apps, and route optimization research are being piloted to lower spoilage and enhance efficiency. These

ISSN: 2455-8834

Volume:11, Issue:04 "April 2026"

technologies, backed by public-private partnerships and skill development initiatives, have the potential to transform Punjab's supply chain ecosystem.

Farmer well-being is an ongoing priority. Supply chain inefficiencies coupled with increasing input costs and institutional debt have resulted in alarming increases in farmer suicides in Punjab. The average annual suicide rate between the years 2015-2020 more than tripled, with economic stress and crop loss being key drivers. The concerns need to be addressed systematically through reforms in credit systems, mental health care, and crop insurance.

The future of Punjab is on a good path with aggressive policy initiatives to relocate the state on the logistics and agribusiness map. The Integrated Logistics & Logistics Park Policy provides financial incentives for cold chain growth, while strategic freight corridors and multimodal connectivity are being upgraded to make bulk logistics cheaper. All these, if well executed, can greatly boost the agricultural competitiveness and sustainability of Punjab.

In summary, Punjab's supply chain issues are complex but resolvable. Focus investments in cold storage, digital logistics, and institutional change along with stakeholder coordination can minimize post-harvest loss, enhance product quality and shelf life, and raise farmer incomes. With continued dedication and strategic implementation, Punjab can reassert its leadership of India's agri-economy and become a model for integrated, efficient, and equitable supply chain growth.

Bibliography

- Sudan, F. K. (2020). Addressing market inefficiencies through agricultural market information systems and digital technologies in Punjab. International Journal of Applied Business and Management Sciences, 1(2), 211–227
- Pooja, S. A., Moghana, L. S., Mahendran, K., Soundararajan, R. P., & Amuthaselvi, G. (2025). Cold storage warehouse dynamics in India: Growth trends, regional disparities and infrastructure gaps (2014–2023). *Plant Science Today*, 11(sp4)
- Ministry of Food Processing Industries. (2025, February 10). Boosting food processing & storage infrastructure in India. *Press Information Bureau*.
- Dinkle, & Sukhmani. (2024). *Vegetable value chains in Punjab: A review*.International Journal of Creative Research Thoughts
- Pandey, A. (2024, November 26). Crop burning: Inside Punjab’s broken paddy supply chain fuelled by politics and mismanagement. *The Economic Times*

ISSN: 2455-8834

Volume:11, Issue:04 "April 2026"

- Rana, K. (2024, November 20). Broken supply chains and rising pollution: Punjab farmers face a double whammy. *Logistics Insider*
- Sidhu, R. S., Sidhu, M. S., & Singh, J. M. (2011). Marketing efficiency of green peas under different supply chains in Punjab. *Agricultural Economics Research Review*, 24(2), 267–274
- Cooling India. (2024, July 22). *Advances in cold storages for the agriculture sector in India*.
- Agricultural and Processed Food Products Export Development Authority (APEDA). (n.d.). *Cold storages in Punjab*.
- Ken Research. (2021, October). *India agricultural cold storage industry outlook 2025*
- Barney, J. B. (1991). Firm resources and sustained competitive advantage. *Journal of Management*, 17(1), 99–120
- Government of Punjab. (2020). *Infrastructure Statistics of Punjab 2020*. Economic Adviser to Government Punjab
- Sidhu, J. K., Mohapatra, L., & Singh, D. (2024). Characterization of post-harvest losses along the supply chain of vegetables in Punjab. *Bhartiya Krishi Anusandhan Patrika*, 39(1), 74–80
- Punjab Development Commission. (2025). *Food Procurement and Supply Chain Oversight*.
- Government of Punjab. (2022). *Punjab Economic Survey 2021–22*. Department of Planning
- Taki, F., Witte, M., Jaijee, I. S., Jessel, S., Mauer, E., Lurie, J., & Kaur, G. (2021).
- Suicide in rural Punjab, India: Implications for ensuring farmer rights. *Journal of Global Health Reports*, 5, e2021037
- Fleck, A. (2024, May 15). Over 112,000 suicides in India's farming industry in 10 years. *Statista*
- Directorate of Marketing and Inspection. (2023). *State-wise distribution of cold storages in the country*

ISSN: 2455-8834

Volume:11, Issue:04 "April 2026"

- ASSOCHAM. (2019). Reducing post-harvest losses to strengthen India's food security.
- FICCI. (2020). *Post-harvest losses in India – Opportunities for strengthening the supply chain*
- Chand, R. (2021). *Transforming Indian Agriculture: Growth, Inclusiveness and Sustainability*.
- Kaur, H., & Dhaliwal, N. S. (2021). Challenges in Indian Agricultural Supply Chain: A Case Study of Punjab. *Journal of Supply Chain Management Systems*, 10(1), 23–31
- Singh, S., & Sidhu, R. S. (2020). Agricultural Marketing and Farmer Distress in Punjab: The Need for Reforms. *Economic and Political Weekly*
- Food and Agriculture Organization. (2011). Global food losses and food waste – Extent, causes and prevention. FAO

