Asian And Pacific Economic Review
ISSN: 1000-6052

REFRAMING INDIA'S COLD CHAIN CRISIS: FROM POST-HARVEST LOSSES TO SUSTAINABLE VALUE CHAIN TRANSFORMATION

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https://doi.org/10.5281/zenodo.19690199

Received: December, 2025
Revised & Accepted: 5th January, 2026
Published: 25th January, 2026

ABSTRACT

The farming sector has evolved much since the green revolution now productivity is no longer a challenge with India producing surplus agricultural produce despite which due do lack of proper post-harvest infrastructure the farm sector not reached its full potential. One major reason why our post-harvest management is lacking is because of the lack of adequate cold chain infrastructure leading to wastage of food produce and losses to the farmers and also this waste adds up to environmental damage in terms of greenhouse gas emissions. This paper aims to examine the gaps in the cold chain infrastructure from different perspectives structural, technical and legal policy related and their overall emphasis on the value chain infrastructure development. The study uses secondary data for the purpose and descriptive analysis. The study shows how the supply chain infrastructure in India is fragmented causing accessibility issues to small farmers due to cost burdens. The study suggests that to address the gaps in the infrastructure the focus should be on modernization of the existing technology and the usage of renewable sources of energy to lower the environmental impact. The paper concludes by providing a roadmap for cold chain infrastructure development that follows a holistic approach focusing on sustainability, food security, policy reforms and overall development of the rural economy.

Keywords: Cold Chain, Post-Harvest Losses, Sustainability, Agricultural Supply Chain, India, Food Security.

1. INTRODUCTION

India is one of the largest producers of horticultural crops in the world. Despite this achievement due to lack of proper cold chain infrastructure there is a huge of food wastage. Since the green revolution the focus of the policy makers has been scale of production to address the problem of famine the management of the produce post the harvest has not received the much-needed attention. (Chakraborty, 2020).

Perishable commodities throughout the distribution cycle need acceptable temperature conditions. India does not have adequate cold storage infrastructure and the existing one is obsolete. This leads to wastage of the perishable food crops estimated to be around 30-40% (Tiwari et al., 2022).

These losses in the farm produce not only have economic implications in terms of loss to the farmers but these leads to environmental degradation causing greenhouse gas emissions.

The development of cold chain infrastructure therefore is an essential pivot in the sustainable future of the farm sector.

2. LITERATURE REVIEW

Research widely points to inefficiencies in the cold chain as a fundamental weakness in India's agricultural supply network.

In the early phase the researchers pointed out at the lack of infrastructure and storage capacity leading to the wastage of food products (Maheshwar & Chanakwa, 2006). This was again reiterated in the researches done later that out of the perishable food produce only a miniscule portion had access to proper cold storage highlighting that the disparities were due to systemic failure (Aravindaraj et al., 2020).

In the recent times the research has focussed on how if we use energy technologies that are renewable for the modernization of the cold chain it will not only save the costs of operation but also reduce the environmental damage (Singha et al., 2025). Similarly, integrated cold chain systems have been identified as critical for improving food security and supply chain resilience there is a need to develop the cold chain infrastructure in an integrated manner to the address the food security and address the problem of fragmented supply chains (Shankarnarayan & Jahan, 2025).

The researches highlight that there is a gap in the awareness level of the farmers as to how modern cold chain technology will benefit them which has slowed down the adoption of new technology there is a need to establish awareness and coordination amongst the farmers and other key stakeholders at the policy level (Singh, 2019; Negi & Anand, 2018).

The current study tries to address the gap in the existing literature which fails to address the question that can a strong cold chain infrastructure be linked with sustainable development.

3. RESEARCH METHODOLOGY

The study uses descriptive analysis based on secondary data from sources like research articles, newspaper articles, reports and policy documents of the Government of India, publications by various national international institutes. We have analysed the challenges and key constraints in the cold chain infrastructure development, did a comparison of the traditional methods and the modern systems. The study uses a holistic approach looking at different perspectives and stakeholders to develop a better understanding of the issues involved.

4. STRUCTURAL CHALLENGES IN INDIA'S COLD CHAIN SYSTEM

4.1 INADEQUATE INFRASTRUCTURE AND SKEWED DISTRIBUTION

Around three- fourth of India's cold storage facility is utilised towards storing potatoes which has since a very long time been in high demand (Singha et al., 2025). Although it does ensure proper storage of potatoes but this comes at the cost of limited facility for a wider variety of food produce like dairy, meat products, fruits and vegetables. Depending upon the type each perishable food item demands a certain level of temperature and the storage facility fails to accommodate such diverse variety of commodities also there are regional disparities in the storage capacities wherein some facilities are not utilised at their full capacity and there is shortage in the other regions altogether especially for perishable items of higher value.

As a result of which the farmers engaged in growing crops other than potato have to suffer from high amount of losses selling their produce at very low prices. Therefore, we need to develop cold storage infrastructure that caters the diverse range of food products.

4.2 HIGH POST-HARVEST LOSSES

Approximately 40% of the perishable food produce is lost in the country due to lack of proper cold chain infrastructure throughout the distribution cycle especially transportation (Tiwari et al., 2022). A significant part of the farmers produce does not reach the consumer in a proper condition and this denies the farmers their true potential earning and not only that such losses also have serious consequences in terms of lack of proper food security and nutritional disparities.

4.3 HIGH-COSTS

Vapor Compression Refrigerator (VCRS) based cold storage have huge installation and operational costs. They require continuous supply of power which is difficult in rural areas of the country and therefore usage of diesel generators is common. This further increases the costs as diesel-based energy is comparatively costlier (Tiwari et al., 2022). Also overdependence on diesel which is a non-renewable and polluting source of energy has led to increased emissions with negative consequences for the environment.

4.4 GAPS IN SUPPLY CHAIN

Cold chain facility is required at every stage of the distribution process absence of which reduces quality of the produce causing losses. Post the harvest there should be a pre cooling facility in the farm itself, post which there is a need of storage facility and while on the go during transportation temperature control is essential. Due to several gaps in the cold chain at all stage the perishable food items are exposed to varied levels of temperature causing spoilage and downgraded quality. Which is why farmers find it extremely difficult to reach distant markets where they can get a better price for their produce. (Negi & Anand, 2018).

5. USAGE OF ENERGY EFFICIENT TECHNOLOGY

Traditional cold storage systems as discussed earlier consume huge amount of power. Now there are better technology alternatives that have inbuilt energy management mechanism, proper insulation and efficient compressors these can replace traditional systems and reduce the energy consumption (Singha et al., 2025).

6. ENVIRONMENTAL IMPLICATIONS

There are two ways in which lack of adequate cold chain infrastructure affects the environment on the one hand traditional outdated technology consumes a lot of energy causing harmful green house gas emissions and, on the hand, huge amount of food gets decomposed causing environmental degradation.

7. POLICY AND INSTITUTIONAL FRAMEWORK

Government has time and again taken steps be it through subsidies or infrastructure schemes to address the constraints in the cold chain system despite which challenges continue due to lack of coordination amongst relevant institutions, lack of awareness and accessibility especially for small farmers.

8. STRATEGY FOR SUSTAINABLE COLD CHAIN DEVELOPMENT

As per the findings the following strategy is suggested:

8.1 DE CENTRALIZATION OF COLD STORAGE SYSTEMS

Centralised system of cold storage is more suitable for urban locals whereas in rural areas decentralised cold storage which are more localised are more apt as they provide timely pre cooling facility nearby the farms thus minimising losses post-harvest. Small village farmers with limited resources will especially find it beneficial. (World Bank, 2020).

8.2 INTEGRATION OF GREEN ENERGY

Instead of using traditional fuel-based energy for powering the cold chain system solar and other non-renewable sources of energy can be used this will reduce the operational costs as well. If we use solar energy combining it with the traditional modes that will lead to consistent supply of power at reasonable costs addressing main challenges of rural areas where power shortage is an issue. The adoption of such hybrid models will reduce the dependence on fossil fuel-based energy which is significant for sustainable development. (International Renewable Energy Agency, 2020; Food and Agriculture Organization, 2019)

8.3 INTEGRATION OF SUPPLY CHAIN

The cold chain system should be developed in an integrated manner ensuring no constraint at any level of the supply chain beginning with pre cooling decentralised units at the farm level to transportation with cooling facility to storage facility with temperature control. Thus, ensuring quality check at every level which will help farmers sell at distant markets with better profitable price options (Negi & Anand, 2018; Maheshwar & Chanakwa, 2006)

8.4 INSTITUTIONAL STRENGTHENING

Small farmers do not have the resources to invest in cold storage therefore a cooperative model is needed where costs and risk of losses can be shared which will improve their access to such facilities. These farmer producer organisations (FPOs) through the economies of scale have a stronger position in the market from a cost perspective and better bargaining position. (National Bank for Agriculture and Rural Development, 2020; NITI Aayog, 2018)

8.5 TECHNOLOGY ADOPTION AND INNOVATION

Innovations should focus on ecofriendly technology that is energy efficient, refrigerants should be customised to meet the needs of decentralised smaller units which will reduce the cost of installing and operating them. Research and development should be done in coordination by the research institutes with government and the industry stakeholders such innovation can be later scaled as per the local requirements. (International Renewable Energy Agency, 2020; The Energy and Resources Institute, 2018)

9. CONCLUSION

India's key goal of ensuring food security to all is still a distant dream if we do not address the supply chain constraints. The key to which is the development of a strong and sustainable cold chain infrastructure. Despite the progress in agricultural productivity our food wastage and losses continue causing farmers income to remain low and the small and marginal farmers are at the receiving end leading to social and economic disparities.

To address this issue, we need a decentralised approach to developing the cold chain infrastructure and to ensure accessibility we need better innovative cold storage systems that are energy efficient. There is a need to establish coordination amongst all the key stakeholders at the institutional and policy level.

There is need to transition from a fragmented supply chain to a well-integrated cold storage system that ensures quality at every level of the supply chain. Also, there is a need to integrate the vision of cold chain infrastructure development with the sustainable development goals of the nation. A well organised cold chain infrastructure can ensure profitable income to farmers address the social and economic inequalities, food security for all and environmental sustainability and for this a well-planned integrated approach is needed.

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