

ASSESSING RISK IN COLD CHAIN LOGISTICS MANAGEMENT OF AGRICULTURAL PRODUCT

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INTRODUCTION

India is the second largest producer of fruits and vegetables, largest producer of milk and one of the leading producer of meat and fish. Owing to its diverse agro-climatic zones and resources, the production of these commodities not only extends in quantity, but also to a wide variety of them. Despite these merits, India is also one of the leading countries in terms of food loss, even though a sizeable share of the population are suffering from hunger and malnutrition. The farmers in India, even though they are producing the largest quantities of the forementioned agricultural and horticultural produce, their economic situation is not really presenting a happy picture. Compared to developed nations, the Indian agricultural scenario is very complex and so are the reasons leading to this situation. Among all, the important reasons in leading to the high quantities of food loss are poor post-harvest care, highly complex and inefficient supply chains, lack of storage and processing infrastructure.

Cold chain sector is set to play an important role in addressing these problems. Addressing the issue of perishability, Cold chain extends the shelf life and thus usability of the commodity in its best form. Depending on the nature, purpose and the stage where it is employed, the application of cold temperature is divided into Frozen ($<-18^{\circ}\text{C}$), Chilled (0°C to 10°C), Mild Chilled (10°C to 20°C) and Normal ($>20^{\circ}\text{C}$) storage. For most of the horticultural produce, cold chain needs to be handled at Chilled and Mild chilled zones, whereas for meat and fish the handling temperature lies between Chilled and Frozen zones

The advantages of employing Cold chain are increasing the availability of produce in lean season, increasing the affordability and accessibility by streamlining the supply chains, improving the quality of the produce, employment generation and improving the economic status of the stakeholders. Cold chain infrastructure in India is classified into Pack houses, Ripening chambers, Cold storages and Reefer transportation. The importance and need for Pack houses is understood by all the stakeholders after a little delay. At present there are only 250 fully equipped functional Pack houses as against the required number of 70,000. Of the total 812, most of the Ripening chambers are concentrated in the states of Maharashtra, Uttar Pradesh and Andhra Pradesh and being used for ripening of Mangoes. Cold stores in India are concentrated in the states of Uttar Pradesh, West Bengal, Gujarat, Punjab and Andhra Pradesh. Most of the cold storages created before the last decade are suitable for storing single commodity only. The total cold store capacity of the country is about

31.82 million metric tons. Reefer transportation is under severe shortage in India, with about 9000 vehicles in place of the required number of approximately 62,000. The estimated need for investment to bridge the gap in the infrastructure is about Rs. 89,000 Crores. The Government of India (GoI), understanding the importance of Cold chain, is extending the support in creation of the infrastructure by means of various agencies like Ministry of Food Processing Industries

(MoFPI), National Horticultural Board (NHB), Agricultural and Processed Food Export Development Authority (APEDA) and NABARD. GoI, recently made important policy changes to allow 100 % FDI and tax exemptions in Cold chain sector, in order to catalyze the growth of the sector. It is also important to consider the inclusion of cold chain sector and promotion of low cost technologies in the “Vision 2022 - Doubling the farmer’s income”, as it is one of the bridging element in mitigating the losses and streamlining the agricultural supply chains, which are hindering the farmer in realizing the true value of his produce.

The cold chain sector in India has not progressed at par with the global developments in the monitoring and control technologies. Even though new entrants in the sector are employing some of these modern technologies, most of the earlier generation cold storages are still dependent on the manual modes of monitoring assisted with conventional measuring systems. The upcoming trends that need to be fully embraced by Indian companies are RFID based systems for unit level measurement, WSN based systems for a local unit, and IoT based monitoring systems for covering the entire supply chain.

STATUS AND IMPORTANCE OF COLD CHAIN LOGISTICS

In a world of finite resources, in order to lead a sustainable life, it is important to produce better and consume intelligently. In India, one-third of horticultural produce especially fruits and vegetables are wasted every year. In today’s world though there is enough food for everyone but not everyone eats, owing to the inefficient supply chains and poor processing levels. Millions across the country suffer from malnutrition and die due to hunger. India, with a Global Hunger Index Score 28.5 in 2016, has 15.2% of undernourished population. In such a dire situation where food preservation must be given high priority, the estimated annual value of losses of agri produce is Rs. 92,651 crores. Of these perishable products like fruits and vegetables, meat, fish, and milk account for an estimated loss of Rs. 50,473 crores. Cold Chain sector holds a key solution to address the problems of food loss, directly by ^{oooo}the shelf life of the food and indirectly by increasing the reach of the food to markets and processing facilities.

ROLE OF TEMPERATURE IN COLD CHAIN:

Fresh foods continue to metabolize and consume their nutrients throughout their shelf life, from harvest or slaughter through packing, distribution, marketing and sale. Processes like respiration, enzymatic breakdown and microbial degradation break down the carbohydrates, proteins and other nutrients into simpler compounds. The degradation processes are highly dependent upon temperature and most of these processes double their rate for each increase of 10°C (known as the Q10 coefficient). In addition to physiological deterioration, foods are also subject to molds, rots or decays caused by microbes and wilting, shriveling caused by water loss. The rates of microbial growth and water loss increase with temperature increase.

Cooling provides the following benefits for perishable horticultural foods :

- Reduces respiration: lessens perishability and natural senescence
- Reduces transpiration: lessens water loss, less shriveling
- Reduces ethylene production: slows ripening
- Increases resistance to ethylene action
- Decreases activity of micro-organisms
- Reduces browning and loss of texture, flavor and nutrients.

LITERATURE REVIEW

In today's worldwide perishable sectors, cold chain (CC) management plays a crucial role. Although there are several definitions in the literature, it can be summarised as "the process of planning, implementing, and controlling the flow and storage of perishable commodities, related services, and information to maximise consumer value while ensuring low costs" (Singh et al., 2018, p. 532). From production to customer touchpoints, perishable items require a precise temperature-controlled environment across the supply chain (SC). This requirement, commonly abbreviated as "CC," is a post-production SC for perishable and temperature-sensitive goods that is designed to keep these products in a controlled environment (i.e., within an optimal temperature and humidity range) to ensure product safety, preserve value, and maximise commercial potential.

To put it another way, refrigerated transportation and storage are two critical parts of preventing product quality degradation. Non-perishable commodities that require controlled and low temperature settings (e.g. art objects) are typically not regarded as CC (Heap, 2006). As a result, CC management can be viewed as a

perishable goods-specific implementation of SC management (Bogataj et al., 2005), with special features and activities added to existing SCs (Kuo and Chen, 2010). Fresh agricultural products, frozen food, seafood, chemicals and pharmaceutical medications, as well as photographic film, are all included in the CC.

The goal of the cold-chain is to ensure the quality of refrigerated and frozen goods, with the primary goal of keeping food at a lower temperature during travel. In comparison to things delivered at ambient temperatures, refrigerated and frozen commodities require higher and more complicated transport methods and more rational organisation due to stringent time constraints. As a result, the cold-implementation chain's effect is determined by the amount of risk recorded in each connection. Hazard Analysis and Critical Control Points, or HACCP, are preventive principles that use qualitative analysis to detect potential dangers at each link.

Green logistics of fresh produce:

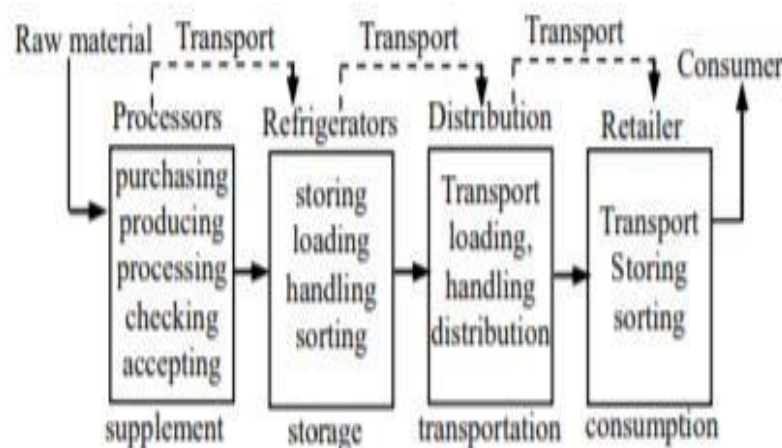
Transporting fresh fruit necessitates cold chain logistics that meet stringent specifications. Produce loss is caused by poor fresh-keeping management and technology, which generates waste in transit and makes it difficult to achieve the goal of sustainable development. Ingrao et al. employed life circle assessment, a tool that may be used to evaluate the potential environmental implications of a product, material, process, or activity, to address the environmental sustainability of food packaging technology. Perezmesa et al. looked at supply chain management strategies of significant retail distribution chains in Europe in the context of different sustainability concepts and methodologies. To identify and simulate critical barriers to sustainability in perishable food supply chains, Kumar et al. developed an integrated interpretative structural modeling–analytic network process decision framework. Gokarn & Kaipia et al. investigated the impact of supply, demand, price uncertainty, and information exchange on fresh produce supply chains in order to reduce waste and increase sustainability.

Several studies have attempted to lessen the likelihood of unforeseen incidents and fresh product losses by identifying and categorising risks. Nakandala et al. examined fresh food supply chain risk elements from both an internal and external perspective, then developed a hybrid risk assessment model to reduce the risk's negative impact. Rangel et al. classified supply chain risks as plan, source, make, delivery, and return, among other things, based on existing data. Using the Tropos Goal-Risk framework, Deng et al. offered risk management solutions for yoghurt supply chains to promote sustainability after exploring risk propagation mechanisms. Burek et al. investigated the influence of distribution centres on food distribution and sustainability using a combined life cycle inventory and regional life cycle impact assessment method. They also demonstrated the multi-facility state-level environmental implications of the United States' largest DC network. Using interpretive structural modelling, Prakash et al. presented a methodology for analysing risks and determining the most effective risk mitigation strategies.

Processes An examination of the cold chain:

Cold-chain operations can be divided into four areas based on the basic functions of logistics: supplement (producing, processing, purchasing, checking, and accepting), storage (storing, loading, handling, and sorting), transportation (transport, loading, handling, and distribution), and consumption (transport, storing, sorting) [2]. Figure 1 depicts the specific operation.

The cold chain's fundamental linkages are depicted in the diagram below.



A qualitative risk assessment of all cold-chain sectors :

1) Add to your supply: Producing, processing, purchasing, checking, and accepting are the four operations that make up this process, and the risks are primarily:

- A range of toxic additives are added to the manufacturing process to improve the appearance and prolong the preservation time of items in order to maximise revenues.
- Pollution of the environment at the source, as well as a lack of cold-chain facilities and equipment.
- The raw material acceptance management is lax due to a lack of scientific technical guidance and safe monitoring procedures.
- Existing safety standards and management technologies are unfinished, resulting in product safety being compromised.

2) A place to keep things

The hazards are primarily reflected in the following processes: storing, loading, handling, and sorting.

- a) Lack of appropriate monitoring and management tools as a result of a demand-supply mismatch.
- b) cross-infection between products due to improper storage of various characteristics. b) For the illogical stacking mode and location assigning pattern, damage, decay, pollution, and reversal of products.
- d) Dangerous working procedures and illogical temperature control. e) Theft and irresponsible work cause products to be lost or damaged.

3) Getting around: The following are the primary dangers involved with this process:

- a) Inadequate carrying arrangement: For long-distance transit, cold-chain products are easily contaminated by microorganisms and dangerous substances.
- b) Requirements for refrigeration and safety precautions are not met.
- c) Inadequate transportation equipment selection, resulting in safety concerns.
- d) Product loss and damage during the transporting process. storage supplement consumption of transportation unprocessed Transport Processors are in charge of purchasing, processing, and receiving orders. Refrigerators for storing and sorting loads Transport loading and distribution handling at the distribution centre Transport for Retailers Sorting storage Transportation Consumer Transport HACCP and the Cold-chain Risk Assessment.

4) Indulgence: The following are the key risks: a) Variable consumption needs and challenging sails management, which jeopardise product quality. b) Because customers' knowledge of certain cold-chain items is restricted, they are unable to properly safeguard themselves.

Fresh agricultural products, frozen food, seafood, chemicals and pharmaceutical medications, as well as photographic film, are all included in the CC (Allied Market Research, 2019). Fruits and vegetables, bakery and confectionary, dairy and frozen desserts, fish and shellfish, and medication and pharmaceuticals are the five primary end-use sectors in the CC market (Liu et al., 2020). Food cold chain (FCC) and pharmaceutical cold chain (PCC) are the two main CC fields included in this classification (Herjolfsson, 2019). Despite the fact that both areas have quite different packaging requirements (Brenner, 2015), FCC has had poorer product quality, packaging integrity, and punctuality than PCC due to better transportation schedules and automation for pharmaceutical products. Furthermore, unlike pharmaceutical items, food demand is prone to regular changes due to changing client tastes, preferences, and lifestyles (Aramyan et al., 2007). In the same way, the

FCC and the pharmaceutical CC have separate regulatory requirements for handling, sorting, and distributing connected products (RuizGarcia and Lunadei, 2010). Pharmaceutical SC interruptions, on the other hand, are restricted to departures from production plants, whereas food SC disruptions refer to lower overall performance (Brenner, 2015).

3.1.1 Country and regional performance:

There are 85 countries represented in the 1,189 articles, with 22.3 percent of them publishing only one paper. As demonstrated in Figure 2, the United States is in the forefront of FCC research, with China following closely after. The CC infrastructure in the United States is well developed, with around 90% of CC transportation facilities available for perishable goods (Pan et al., 2017). In addition, the business is benefiting from an increase in online grocery sales, which encourages CC advances in the United States (Diego, 2018). China and India are the most productive countries in Asia. Because of these two countries' rapid population increase, FCC is a vital topic for meeting present food demand while also saving food for the future. . India, for example, is Asia's second most productive country. However, this isn't always represented in the quantity of articles published. China, on the other hand, has around 3.5 times the number of publications as India. This could be due to the fact that the Indian CC sector is still in its infancy and the CC potential is mostly unexplored (Bharti and Mittal, 2018). Of this aspect, the recent expansion in refrigerated infrastructure and distribution systems is encouraging, but a fully refrigerated SC is still in its infancy (Dharni and Sharma, 2015; Mercier et al., 2017). Furthermore, China's CC is primed for extraordinary growth, thanks to the increasing prevalence of connected gadgets. In addition, the Chinese market has showed significant potential as a result of rising demand for perishable food items through online channels. Many worldwide CC companies are forming partnerships and alliances with China's local service providers (Market Research Report, 2018).

Surprisingly, African scholarship (with the exception of South Africa) makes a very small contribution. This is remarkable given that numerous African countries are experiencing severe food shortages (Trading Economics, 2019). Food waste is a big issue in African countries due to a lack of adequate and efficient CC infrastructure.

IMPORTANCE OF COLD CHAIN

There can be various causes of food losses. World Food Logistics Organization (WFLO) project measured postharvest losses for 26 perishable crops in 4 countries, and documented losses from 30 - 80% due to poor quality packages, poor temperature management, and delays in marketing.

Major benefits of a well-connected cold chain are:

- **Availability:** India has a wide range of climate and physio-geographical conditions which restrict the availability of fruits and vegetables all over the year. An efficient cold chain ensures delivery of produce throughout the year. Agriculture is a seasonal activity which results in surplus production in peak season whereas a lacuna in offseason. Perishable foods, like fruits, vegetables, meat, poultry and dairy, require an uninterrupted cold chain. Moderating parameters like temperature, humidity, and atmospheric composition, along with utilizing proper handling procedures, cold chain can significantly increase the product life of fresh foods for days, weeks or even months. These services allow fresh products to hold their value longer, increasing their transportability and providing opportunities that expand their market reach.
- **Affordability:** Vegetable and fruits production in the country has increased over the years but still the prices are not normal across the country. Normalizing price of the crops throughout the year and locations is possible through the holistic development of integrated cold-chain. It holds the key to reducing post-harvest losses, ensuring uninterrupted supply and thereby minimizing food inflation.
- **Quality:** Cold chain maintains the quality of perishable foods by slowing down the respiration rate, reducing transpiration, lowering microbial activity etc.

CURRENT STATUS OF COLD CHAIN IN INDIA

Over the years India has seen a gradual increase in production of perishable products like fruits, vegetables, meat and poultry products etc. It ranks first in dairy production, second in fruits and vegetables and 6th in chicken and meat production in the world. Unfortunately, cold-chain infrastructure development has not met this demand, which resulted in absence of mechanisms, for safe handling and storage, transportation of perishable products to markets. A resultant demand supply gap has emerged across these agricultural commodities, frequently contributing to widespread price fluctuations and inflation. This shortage of farm-to-market logistics, also contributed to high food losses in case of perishable foods, further adding to inflationary pressures. According to ICAR study on post-harvest losses of major agricultural and horticultural crops as well as livestock products, the losses in selected fruits and vegetables were found to be in the range of 5.8% -

18.0%, losses in inland and marine fisheries were estimated to be 5.23% and 10.52%, respectively. On board losses were not recorded in case of marine fisheries.

a) Pack houses & Ripening Chambers

- Pack-houses and refrigerated transport are important to initiate the vital link of logistics chain from villages to city or distribution hubs (in case of fresh produce).
- As per the NCCD (2015) report, at present the country has about 250 fully equipped functional pack-houses, whereas to fulfil current consumption of urban clusters, India needs about 70,000 pack-houses, each equipped with a pre-cooler and dispatch room for onwards transport links.
- Backward integration in a cold chain has been completely neglected until recent past when the focus has been shifted from building just cold stores to holistic development of integrated cold chain.
- A small concentration of packhouses in Maharashtra has brought global momentum to India's grape sector. Maharashtra is also a leading state in terms of number of packhouses for Mango and Pomegranate, followed by Andhra Pradesh.
- In Uttaranchal customised packhouses have been created to cater to the need of exporting Litchi.

b). Cold Storages: • The Task Force on Cold-chain Projects (TFCP-2014) reported that 31.82 million metric tons of cold stores have been created in the country, out of these, a total of 10.58 million tons in cold storage size were created in the last decade, through Central Government Assistance.

- Top 5 states in terms of total installed capacity are
 - Uttar Pradesh (13.6 million MT)
 - West Bengal (5.9 million MT)
 - Gujarat (2.3 million MT) □ Punjab (2.0 million MT)
 - Andhra Pradesh (1.6 million MT)

In UP and West Bengal, majority of cold stores are single purpose storages which are utilized to store potatoes and in case of AP, they are used for storing chilies.

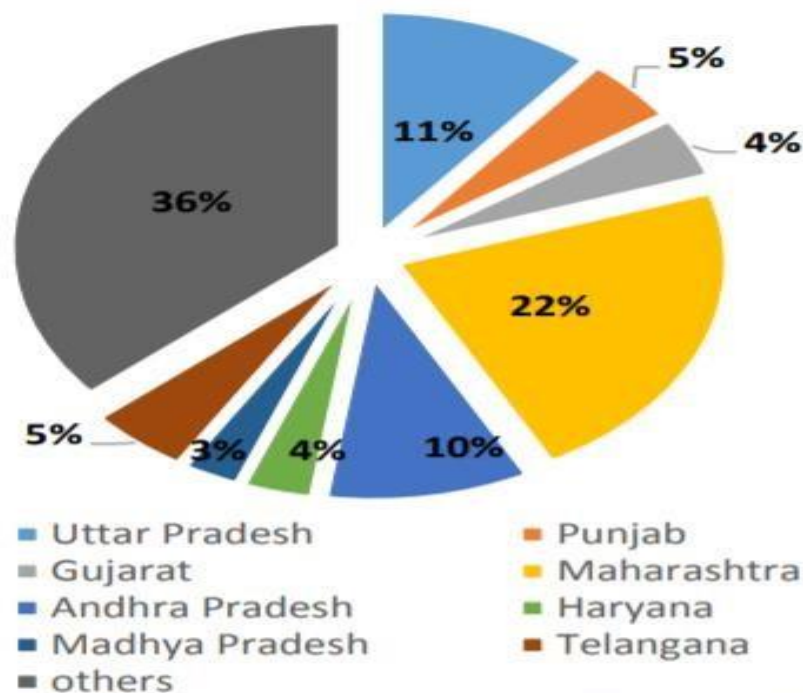
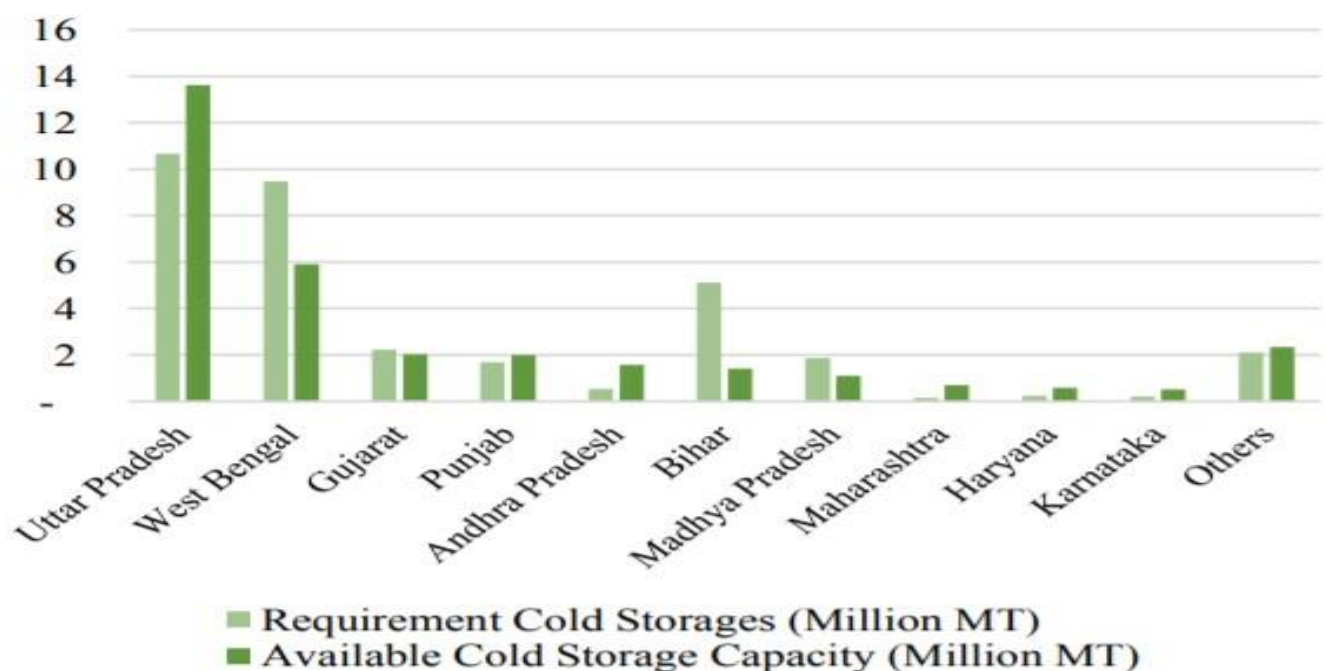


Figure 3: State-Wise Distribution of Ripening Chambers created under various government schemes ¹¹



RESEARCH METHODOLOGY

A questionnaire-based survey was conducted so as to address concerns linked to Indian industries' and stakeholders' cold chain practises. The questionnaire was created using existing research and prior surveys as a guide. Practicing managers and academics in the field of perishable supply chain management were also

contacted during the questionnaire's creation. The farmer's survey in the questionnaire is aimed at gathering farmer practises and awareness in managing farm produce (MMP and FV) within the context of cold chain management.

Content validity and construct validity are the two basic forms of validity examined on the questionnaire. The adequacy with which a certain domain of content is sampled (Nunally, 1978) and that the instrument item comprises items that cover all facets of the variables being measured is known as content validity. The content validity of a piece of content cannot be determined statistically. Its determination is arbitrary and subjective. It is primarily determined by a claim to proprietary content and the manner in which it is presented (Nunally, 1978). The content validity of the instrument produced in this study may be seen in the selection of measurement items, which was based on both an extensive literature analysis and pre-testing appraisal by academicians and practicing managers.

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
	Between Groups	1.003	4	.251	1.059	.377
	Within Groups	73.880	312	.237		
	Total	74.883	316			
	Between Groups	5.936	4	1.484	2.713	.030
	Within Groups	170.638	312	.547		
	Total	176.574	316			
	Between Groups	1.816	4	.454	1.081	.366
	Within Groups	131.017	312	.420		
	Total	132.833	316			
Annual Income	Between Groups	1.263	4	.316	.359	.838
	Within Groups	274.289	312	.879		
	Total	275.552	316			
	Between Groups	.867	4	.217	.862	.487

Factors affecting the returns of farmers other than yield.	Within Groups	78.521	312	.252		
	Total	79.388	316			
Cleanliness & hygiene\ Pre-cooling	Between Groups	60.040	4	15.010	8.592	<.001
	Within Groups	545.058	312	1.747		
	Total	605.098	316			
	Between Groups	32.921	4	8.230	5.128	<.001
	Within Groups	500.764	312	1.605		
	Total	533.685	316			

POTENTIAL RISKS IN COLD CHAIN MANAGEMENT

The life of a Cold Chain is not easy. It must deal with all of the regular issues that stymie most supply chains, as well as its particular set of issues, all without losing its cool. However, the majority of the factors that can jeopardise your cold chain can be grouped into ten basic categories. Let's look at what they are and how you may deal with them.

Political upheaval, labour shortages, wars, geological catastrophes, and pandemic fears are just a few of the factors that may influence changes in transportation patterns and/or logistical methods. There's little your manufacturing or logistics teams can do if seemingly unrelated occurrences halfway around the world have an impact on a package out for delivery. This is due to the supply chain's inherent unpredictability. It's even worse for logistics that must be kept at a specific temperature. As a result, your best bet is to reduce the danger. When

handling high-value cargo, shippers are advised to prepare for the worst and do their best, ensuring that sufficient care and contingency are in place to reduce unexpected risks.

The difficulty is that supply chain risk management is expensive, especially in the case of a cold chain. Nonetheless, it is an essential expenditure to avoid avoidable loss, particularly when considering the strategic relevance of cold chains in improving, if not saving, lives. So, how can you control your supply chain costs while reducing cold chain management risk?

Understanding the 10 things that can go wrong despite cold chain risk control is the first step. What you can do to recognise and manage these risks before your cargo suffers the consequences.

CHALLENGES IN INDIAN COLD CHAIN INFRASTRUCTURE

Operational Challenges:

- **High lifecycle cost:** High real estate prices with an increase of more than 280% in last decade adds up significantly to the total cost, as for building a cold storage with 1 million cubic feet of space which requires an acre of land. Interstate barriers, intercity and state taxes, and bad roads etc. are other factors contributing to the rise in project and operational costs. In the country like the USA, the similar scale of installation cost less than half of the investment required in India
- **Quality cold warehouse infrastructure:** Nearly 75% of the cold storage infrastructure created in the past is suitable only to store single commodity, rendering them of no use for utilizing for the multi temperature and multi commodity storage.
- **Standards and protocols in construction and operation of facility:** Technical standards followed in India are mostly unsuitable for Indian conditions, which results in poor performance of a standard refrigerated system
- **Uneven distribution of cold storage:** Storage facility throughout the supply chain is another major challenge. Majority of cold storage facilities are located at the point of production, creating a lack of efficient supply chain to the downstream operations/ markets
- **Low awareness:** Cold chain industry consists of multiple players, of which are 85% of unorganized players who are unable to invest much in the technology required to build high quality cold storages along with reefer trucks. 36% of the total players are small players with capacity less than 1000MT and their lower margins further limit their ability to maintain quality standards and invest in growth.

- **Generic schemes on pan India basis:** Approximately, 4000 projects are funded through various schemes in India constituting a total investment of INR 3022.5 crores. These schemes are basically volume driven nearly based on parallel parameters throughout the country. Lack of focus can be seen on technologies, capacity variance and customization of policies depending on geographical area requirements.

Availability and supply of electricity through-out the country: India currently faces about 9% of peak power deficit, which enforces the use of fuel based operations leading to a marked increase in operating costs. The majority of electricity deficiency and unavailability could be found in the major agrarian states of the country, having a significant percentage of cold storages.

- **Supplier Risk in Your Cold Chain –**

Bad quality or spoilt raw materials to begin with —

Damaged items are packaged before they are checked for quality or spoilage, notably in the food and fresh produce industry.

Dodgy relationships with suppliers —

This could result in less-than-ideal product handling. Even if you had perfect SLAs in place, you'd have a hard time determining if they were followed, let alone enforcing them.

Bad packaging practices –

To avoid temperature excursions at the earliest stage of the transport chain, the packing process at the origin of the shipment must be completed in a temperature-controlled environment. It's easier to avoid temperature excursions if you start with the correct packaging and shipment conditioning.

- **Distribution/Delivery Risk in Cold Chain –**

Transport and storage are two separate actions that make up the distribution process. While the storage part of cold chain management is normally well-understood, temperature control in logistics and transportation is less so. It's ironic, because transportation in the cold chain logistics industry is really just a mobile kind of storage - but with a lot more variables to cope with.

There are numerous things that could go wrong, beginning with:

Packaging Failure – This is especially true when packaging isn't done properly or when it is destroyed during transportation or handling.

Hardware failure – Breakdowns in active cold chain cooling solutions, such as refrigeration equipment malfunctioning due to faults, insufficient maintenance, or simply losing power.

Truck or Modal Breakdown – Whether on a vehicle, plane, or ship, a vehicle or modal breakdown in the cold chain can result in more than simply a delayed shipment; it can even result in a shipment being destroyed.

Equipment shortages – This is a particularly tough problem to solve. While you may have spent a lot of money on cutting-edge equipment to safeguard the integrity of your cold chain, any failure in the field will almost surely spell disaster if you don't have the skills or replacement parts on hand to fix it.

Supply chains are also being pushed to rethink their transportation modalities due to cost and environmental issues, and despite the dangers and stakes, cold chains can't afford to ignore these concerns.

There aren't many temperature-controlled storage spaces in ports or airports around the world. Even if they're present, they may work at set temperatures that aren't suitable for your shipment, presuming they're well-maintained and operational.

Even as the quality and availability of refrigerated transport for long-haul modes of transport such as reefers, refrigerated trucks, reefer containers, and temperature controlled ports and airports improves, the cold chain is still challenged when it comes to maintaining temperatures over longer supply routes due to a variety of factors such as packaging failure, processes, hardware failure, or the mode of transport itself.

RECOMMENDATIONS

The nature and the dynamics of the agricultural and food supply chains in the country, even for the same commodity/product, are very complex and there is no single point solution to this. In addition to this, the problems and challenges hindering the development of the cold chain sector are interdependent on diverse aspects. The need for creation of integrated solutions is the need of the hour to address the problems like colossal food wastage despite high production, increasing competition in agriexports from other countries marring the growth of forex and importantly, improvement of local supply chains to benefit the stakeholders from farmers to consumers.

Infrastructure creation and management: Infrastructure creation in the cold sector has been identified as an important factor for growth by various actors and receiving a fair amount of support from the government. As pointed from the earlier studies there is still a long gap in bridging the actual requirements and further to that there is an increased need for optimizing the infrastructure type addressing the specific shortages at different stages of the supply chain.

A holistic approach to addressing all the stages of the supply chain needs to be considered.

Commodity/ Cluster specific infrastructure plans: Identification of key commodity producing clusters and designing of infrastructure to create an integrated model should be taken up. The developed primary infrastructure should be extended to accommodate other suitable commodities in the region by creating sub-infrastructure by creating smaller cold rooms/ IQF plants. This leads to the creation of a network in the region and extends the usage of the infrastructure.

Utilization of railway network: India has a well-connected railway network, with a fair share of it, covered under stable power grid. This can be used for increasing the connectivity of the reefer transportation. The key intentions required to make this actionable are:

Development of more perishable cargo centers in the key localities

- b. Making available enough reefer containers with grid connectivity and
- c. Relative importance in clearing the trains carrying perishable cargo

• Development of common infrastructure for multi-commodity storage: In order to give unrestricted access to small farmers, development of smaller common multicommodity storages should be taken up by pooling two or three nearby villages.

TECHNOLOGY DEVELOPMENT

Technologically, the Indian cold chain infrastructure is still lagging behind to catch up with latest global developments. Even though recent companies are instrumental in adopting the latest technologies, the fragmented supply chain with the lack of prior data about produce is hindering in realizing the advantage of cold chain completely. On technology front the following aspects are to be taken up:

- Promotion of research and development of low cost technologies to address the problems of local supply chains.

Development of commodity specific packaging and temperature models representing the local supply chains

- India has a still long way to go in adapting efficient monitoring and tracking tools. Developing monitoring and tracking models with technologies like WSN and IoT, representing the local conditions is to be taken up.
- Low cost and small capacity reefer trucks with technology like PCM's are to be developed to connect the difficult areas.

CONCLUSION

Cold-chain logistics is a type of logistics and a complex cryogenic system made up of several connections in which the total activities of sourcing, processing, distribution, retail, and consumption are all carried out at a lower temperature.

Cold chain extends the shelf life and thus usability of the commodity in its best form. Depending on the nature, purpose and the stage where it is employed, the application of cold temperature is divided into Frozen ($<-18^{\circ}\text{C}$), Chilled (0°C to 10°C), Mild Chilled (10°C to 20°C) and Normal ($>20^{\circ}\text{C}$) storage. In cold-chain safety management, HACCP combines qualitative and quantitative analysis methods to identify risks and assess the weight of each risk, thereby determining critical control points and establishing internal relationships between hazards and risks from three perspectives: biological, chemical, and physical. The advantages of employing Cold chain are increasing the availability of produce in lean season, increasing the affordability and accessibility by streamlining the supply chains, improving the quality of the produce, employment generation and improving the economic status of the stakeholders.