Recent Innovations in Cold Chain Industry

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Introduction

A cold chain in the HVAC industry is a temperature-controlled supply chain mainly related with refrigerated production, storage and distribution facilities supported by equipment that can constantly maintain the required low-temperature range of perishable products during transportation time frame. However, it is far more complex than it sounds. For example, some pharmaceuticals require constant maintenance of an ultra-low temperature range from the time they are manufactured until they are used by the end-user customers. The requirement is so exact that if the temperature deviates slightly from this range, even for a short time, it could lose its potency and become unfit for use.

Cold supply chain technology mostly used for storing and transporting perishable products can be categorized into active refrigeration systems and passive cooling devices. Active systems include mains refrigerators and off-grid refrigerators. The mains refrigerator systems are mainly cooled by conventional vapor compression system compressors that are powered by the electric grid. Off-grid refrigerators include two main subsets:

1. Absorption refrigerators powered by the burning of liquid petroleum gas or kerosene like conventional fuels and solar-powered refrigerators, which use electric compressors that may be driven either from batteries that have stored the power generated by solar panels (solar battery-powered) or directly from the solar panels themselves (solar direct-driven).
2. Passive cooling devices have no active refrigeration mechanism. In these devices, the cooling is provided by coolant packs containing phase change material (traditionally plain water) frozen into solid form. In order to avoid freeze damage to products in conventional passive cooling devices, an extra step of 'conditioning' is required, taking coolant packs out of the freezer long enough so that they begin melting before placing them in the device.

The performance issues that emerged for these early off-grid technologies in field deployment inspired technology innovation. Meanwhile, traditional solar battery-powered refrigerators were also presenting challenges. The batteries often required regular maintenance and had a lifespan far shorter than the refrigerator and solar panels, shortened further by the absence of required maintenance. Solar energy proved susceptible to theft, either by outright removal of the panels or by rerouting of the electricity from the battery system, which compromised the performance of the

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refrigerator. This required innovations in design to ensure that the refrigerators would be able to maintain their cold temperatures even overnight and during cloudy weather. Hence, all countries need to be made aware of the latest technologies and understand the newly available features relative to existing technology so that they can demand the new and better products.

Cold chain logistics is the technology that allows safe transport of temperature-sensitive goods and products such as frozen food, photographic film, chemicals and pharmaceutical drugs along the supply chain. It impacts every stage of the supply chain from purchase to transportation, storage and last mile delivery. The transportation modes for the product supply include refrigerated trucks, railcars and cargo. The process further involves utilization of temperature-controlled warehouses for storage and cold-insulated transport vehicles for product distribution. Furthermore, the cold chain supply technology is essential for extending marketing, preventing over capacity, reducing transport bottlenecks during the peak period and maintaining product quality. In addition to providing quality and safe products, cold supply chain logistics largely contributes to the economy and workforce. Quality products can lead to higher demand and contribute to economic growth of the company and country both. Furthermore, it plays a vital role in reducing the wastage of perishable products and commodities, thus providing a boost to the rural economy of India. It also provides high growth to the food processing sector by modern warehouse management through the use of advanced heavy duty refrigeration systems that help to maintain proper temperature during transportation and storage of goods. The adoption of innovative IoT-based latest technology provides live data to operators, thus allowing unmatched visibility into every process and transaction within cold chain logistics. Factors such as an increase in the number of refrigerated warehouses and growth in the pharmaceutical sector are also expected to drive the growth of the cold chain logistics market. In addition, exponential growth in the processed food sector is anticipated to boost the market growth. On the contrary, radiofrequency identification technology (RFID) technology for cold chain applications and the adoption of software for cold chain logistics provide lucrative growth opportunities for the market players.

The global cold chain logistics market is segmented on the basis of end-use industry, business types and region. The cold storage market had been present in India even before independence. However, significant growth has come only after 1980s. Decade by decade, India has made progress in all aspects. Strength in the cold chain industry became more of a need. However, we missed getting the industry organized. It has been traditionally owned with pre-fixed mindsets. There are around 8,500 cold storages in India today, amongst which 75% are single commodity cold storages. There is no denying the fact that we have come a long way; yet, there is a long way to go. Indians are now prime contributors to global development. The Indian cold chain sector is expected to grow at 14% CAGR during 2021- 2023.

Prospects in Cold Supply Chain Industry

In an industry historically technologically underserved, the future of the cold supply chain is undoubtedly marked by innovations and industry collaboration. The ecosystem is ripe for change, eager to create new efficiencies, uphold safety demands and increase profitability. While this list of some technologies is by no means exhaustive, they have and will continue to drive the cold chain forward.

Increase in Refrigerated Warehouses

A warehouse is a large refrigerated area for storing temperature-sensitive products with ideal storage and transportation conditions. Owing to the fluctuating market demand for products, the need to store goods has increased the need for warehouses. Investment to create effective, efficient and reliable processes for end-to-end cold chain security is the weak link in the system. The introduction of refrigerated warehouses significantly satisfies the needs of manufacturers of these temperature-sensitive products. Owing to the increase in food processing industries in recent years, which require refrigerated transport in the retail market, the latter is estimated to grow exponentially in the coming years. Thus, an increase in refrigerated warehouses fuels the growth of the cold chain logistics market. Warehouse and distribution center automation encompasses a wide range of technologies – from mobile tablets and smartphones to software applications, (application programming interfaces) APIs and cloud databases. The goal of leveraging these technologies is to eliminate the repetitive, process-oriented tasks taking time away from warehouse employees and automating them to increase productivity and efficiency. Technology-driven automation in cold chain warehouses drives fulfillment and picking accuracy, and helps get food and beverage into the hands of consumers faster.

Growth in Pharmaceutical Sector

The pharmaceutical sector focuses mainly on product quality and sensitivity. Many factors such as shipment of temperature-controlled conveyors and demand for effective cold chain logistics services to maintain quality of goods for pharmaceutical market growth, etc., becoming more strategic and reliable. The international air transport association (IATA) had estimated approximately 6% rise in the cold chain logistics for pharmaceutical industries by the end of year 2021. Accordingly, logistics companies and airlines specializing in pharmaceutical transportation strengthened services that matched the increased demands. Hence, pharmaceutical products-demanded temperature controlled refrigerated transportation solutions across the entire distribution network drive worldwide growth.

Technological Innovations and Advancements

- Real-time tracking using GPS technology provides accurate temperature monitoring
- Active monitoring adjusts temperature if there is a fluctuation
- Passive monitoring provides a report at the end of the trip
- Bar code inventory tracking system – down to the item level
- RFID devices that can be embedded into pallets or individual items

Technology in the Trailer

- Properly insulated containers
- The right reefer unit for the job
- Proper use of bulkheads, chutes and venting
- Quality equipment: emissions-compliant trailers for optimum fuel- and cost-efficiency

Innovations in Cold Chain Industry

Cold supply chain is rising as one of the emerging industrial sectors that can really contribute to the massive growth of Indian economy. While the industry has been active for some time due to its niche category, it has not been able to get the attention it deserves. A lot has changed in the last couple of years. With an increasing number of cold chain companies now bridging the knowledge gap, the Indian cold chain industry is establishing an identity for itself and contributing a significant role in the Indian economy. The concept of cold chain has been re-defined from merely a method for cooling or agro-processing in the past, to one that integrates through procedures.

Emerging businesses are proving to be a life saver for traditional businesses that are still relying on refrigerated trucks for moving products from one place to another. The demand is further heightened by pharmaceutical logistics playing a key role in the cold chain space. While new entrants in the cold chain space are gaining an in-depth understanding of the industry, not just to survive but rather to thrive in the coming times, it is the old players that need to match the pace that the industry as a whole can grow. While the functioning of cold chain business has been enhanced in the present time, other innovations are expected in the coming times that can drive the cold chain industry in altogether new directions. As the space witnesses unprecedented growth, it is evident that embracing new technologies and innovations will be the way forward for the cold supply chain industry to thrive in the coming times, thereby contributing a larger role in the growth of Indian economy. A seamless supply chain is powered by the innovations described below.

Phase Change Technology (PCM)

While much has been changing from adopting technologies like phase change materials (PCMs) to further strengthen the cold chain storage, there is a lot that still needs to be changed, especially a perspective towards the industry. Businesses like grocery and quick commerce too are aiding in the growth of the sector and many are leveraging technology like PCM, which is proving to be helpful for the cold chain industry. Besides large-scale enterprises and retailers, small vendors too are getting encouraged to use the technology in order to increase their sales and gain customers' trust. Solutions based on PCM or thermal batteries use customized chemicals with specific freezing and melting points (ranging from +18°C for use in chocolates to -25°C for use in ice creams). In comparison to the previously used glycols, these materials are designed to be non-toxic and non-flammable and, therefore, are suitable to be packed alongside food products. The proliferation of dark stores is also emerging as one of the sustainable options for cold storages. The use of PCM would replace previous options like the use of gel packs and dry ice. These solutions offer very accurate temperature control, thereby proving to be more effective control over temperature deviations. Further, by making it more efficient, different temperatures can be maintained in the same box by using different PCM packs or cartridges depending upon the product or location to be delivered at longer geographical distance. This further reduces the reliance on dedicated assets like reefer trucks, which come with limited advantages and higher cost. From an economic perspective, the capital expenditure and operational expenditure also gets reduced by up to 50% compared to a refrigerated truck. Also, the cost gets limited as one pays for what one uses and not the whole vehicle. These solutions suit models of e-commerce vendors very well and give them an edge over the traditional cold chain players while ensuring a cost-effective delivery to the customer every time. It also boosts the confidence of retailers as well as small businessmen who are constantly looking out for cost-effective solutions that can help them store products in a better and easy manner. These solutions are virtually maintenance-free and since the bag or box in which they are placed does not contain any moving parts, the chances of a product getting damaged become almost nil, as shown in *Figure 1*.

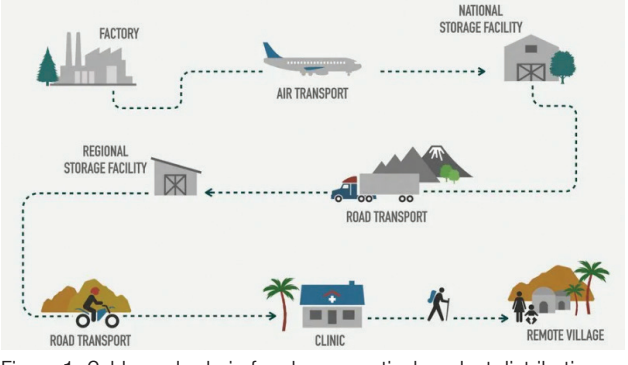

Figure 1: Cold supply chain for pharmaceutical product distribution

Robotics Technology

Along with software innovation for warehouse automation, robotics technology will continue to drive the cold chain in 2022 and beyond. In fact, the robotics market is expected to grow at a compound annual growth rate of 10% till 2028. Robots can prove to be incredibly helpful in managing inventory from the warehouse to the shipping zone, improving the efficiency, speed, reliability and accuracy of moving products.

Collaborative mobile robots are the future of supply chain automation as they offer greater flexibility and scalability as compared to traditional warehouse automation, increasing order picking efficiency and improving accuracy by guiding associates through tasks. By optimizing picking routes in real-time, collaborative mobile robots reduce unnecessary walking and improve warehouse productivity. Much like on-demand warehousing makes it possible to secure additional warehouse space as needed without infrastructure investment, companies (as shown in *Figure 2*) can rent collaborative mobile robots to increase capacity during peaks, returning them when demand returns to normal.

Figure 2: Use of collaborative mobile robot system

Product Monitoring

An important aspect to the cold supply chain is understanding what products need to be monitored, the conditions that they should be maintained at and the processes that will be required to remedy violations if they occur. This is how you will be able to then identify what kind of solution is needed in order to satisfy requirements.

One aspect of the cold chain sector is the transport of pharmaceutical products, which must remain within a temperature range – most commonly, 2°C to 8°C. Temperature is only one aspect; as pharmaceutical products are more sensitive to other environmental conditions, they can be highly fragile and often have some degree of time sensitivity. Due to the nature of perishable goods, they can be easily susceptible to damage. Hence, pharmaceutical products require temperature monitoring along with additional near-real time data on location tracking and tamper detection in order to be safely transported.

Packaging Innovation

The process of cold chain packaging is vital in maintaining a consistent product temperature. Even a slight temperature variation can render a perishable product unsafe for consumption. From a consumer standpoint, 31% of urban households now use an online grocery pick-up or delivery service in response to social distancing protocols. The past year has also seen new demand for prescription drugs and pharmaceutical products to be dispersed to a wider-ranging population, requiring innovation in cold chain packaging. As we think about trends driving the cold chain in 2022, it is worth keeping tabs on how perishable products are prepared for transport.

Blockchain

A blockchain is a permanent ledger of transactions that can improve transparency, reliability and efficiency in supply chains. While the concept of blockchain for the supply chain is still in development, it holds promise for all industries. In the pharmaceutical industry, for instance, where an estimated one million deaths each year are attributed to counterfeit medications, and 30% of pharmaceuticals sold in developing markets are counterfeit, blockchain could potentially reduce this risk. Likewise, the automotive industry could use blockchain to track parts and identify counterfeits. Lab simulations show that blockchain could handle more than seven billion unique serial numbers and 1,500 transactions per second.

Big Data

Supported by the real time tracking technologies mentioned earlier, big data and artificial intelligence are also transforming the supply chain. In fact, it is not the

tracking devices themselves that make the alerts possible, but tracking devices paired with cloud-based visibility and analytics platforms. With the use of IoT devices, companies can share supply chain information without the need for human interaction, and by leveraging big data, artificial intelligence technologies transform raw data into actionable insights that aid decision-making. A variety of supply chain innovations (such as collaborative mobile robots and drones) and even legacy functions like fleet optimization leverage AI for smarter decision making. These innovations certainly are not the only technologies shaking up the supply chain, but they are some of the most promising. Companies will not stop innovating anytime soon, so even more innovative and new technologies in supply chain are on the horizon for the industry.

Internet of Things (IoT)

Until recently, cold storage managers and operators had to be physically present inside a cold storage facility to monitor a product. Today, IoT has an important role in the cold chain system, creating the ability to monitor devices and provide live data about product temperature and location. The cold chain also requires a high level of maintenance – from warehouse refrigeration systems to frozen distribution centers. IoT presents an opportunity for a higher level of analysis and decision making, effectively boosting efficiency as shown in *Figure 3*.

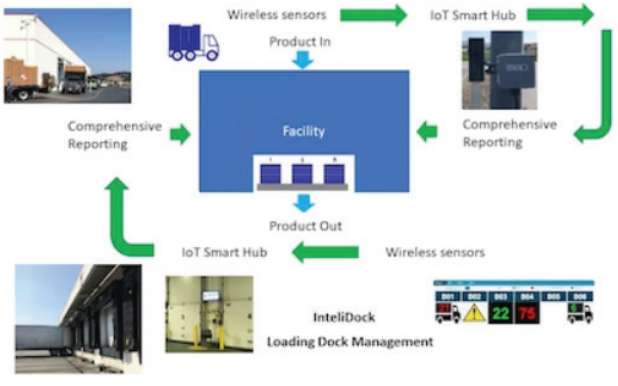

Figure 3: Use of IoT in logistics

Cold Chain Data Loggers

Consistent visibility is a key factor in maintaining well-managed cold supply chain procedures. The easiest way to gain clarity on the status of a temperature-sensitive shipment is by utilizing a near-real time asset tracking device. Cold chain data loggers are primarily used for these kinds of consignments as they are able to track the temperature of precious goods such as pharmaceutical medicines at regular intervals and accurately record and transmit data via the cloud. The information collected can reveal any challenges experienced throughout the cold chain process being monitored, which can then be used to learn and adapt these procedures to achieve a better outcome in the future. Near real-time cold chain data loggers allow stakeholders to take proactive action when violations of conditions occur. This enables violations of set conditions of perishable goods to potentially be rectified, saving products from being damaged and going to waste.

When dealing with perishable goods, the possibility of a cold chain breach occurring is always present. Therefore, anticipating every possible risk, understanding the risks, and being armed with simple yet effective solutions will ensure more effective cold chain management. For example, there may be a scenario where a shipment of vaccines that is being tracked indicates that the temperature has fluctuated and therefore, exceeded the recommended temperature. The use of a near-real time cold chain data logger allows instant alerts to be sent when violations occur. This effectively enables the opportunity for corrective action to be taken to ensure the consignment remains compliant. If this same shipment had utilized a passive cold chain data logger instead, stakeholders may not have been able to understand violations that had occurred before the shipment reached its final destination. Therefore, always remaining prepared for these breaches to occur is imperative in maintaining effective cold chain management processes.

If there is ever a hurdle within the cold chain management process that can easily be avoided, it may likely occur due to a lack of communication. Not having the ability to readily and easily share information with stakeholders throughout the cold chain can lead to a lack of visibility. However, communication can be simplified through the use of near real-time cold chain data loggers**.**

Artificial Intelligence and Machine Learning

Machine learning (ML) and artificial intelligence (AI) technologies provide holistic visibility into the cold chain process by processing large volumes of real-time data. This data then drives improved decision-making. Challenges like inventory management, quality and safety, pricing and cost inefficiency can all be addressed while optimizations in predictive analytics, error reduction, fraud prevention and warehouse management can be realized. For example, traditional metrics – such as incident rate in a warehouse – only track issues after they have occurred. Predictive analytics from AI and ML can track safety using data, preventing dangerous incidents altogether. The supply chain use cases for AI and ML are numerous and will only continue as we address pandemic-related challenges.

E-commerce Platforms

After the onset of the pandemic, many grocery shoppers pivoted to digital shopping habits, opting to have groceries and pharmaceuticals delivered directly to their doorsteps. As retailers continue meeting increased digital shopping demand, the cold chain plays a crucial role in fulfillment. Beyond pandemic buying behavior, consumer e-commerce platforms will continue impacting the cold chain industry and force necessary upgrades for order fulfillment.

On-boarding Solutions

In some parts of the world, there is a drastic labor shortage impacting businesses in every sector. From a supply chain perspective, there is a lot of visibility into ongoing driver shortages, but there is less emphasis on the labor challenges felt at other points of the logistics and transportation supply chain process. Warehouse workers, inventory controllers, transport administrators and logistics managers are all crucial to a seamless cold chain. With today's labor shortages, businesses need to on-board new staff quickly and effectively. Solutions that support an expedited on-boarding process make sure employees are equipped to hit the ground running and keep the cold chain moving. Additionally, a proper on-boarding experience supported by technology increases the likelihood that 69% of employees stick with the business for three years.

Training and Professional Development Solutions

On the flip side of on-boarding, businesses in the cold chain need to invest in ongoing training and professional development solutions to retain their staff. The pandemic ushered in a widespread trend of a significant number of workers leaving their jobs. This is happening for a few different reasons, including lack of flexibility, instances of discrimination, not feeling valued, insufficient benefits and a lack of support for well being. As cold chain organizations work to attract top talent, innovative technologies that help maintain a steady workforce will always be necessary.

Payments Automation

By and large, a majority of supply chain payments and invoices are made on paper, which can be inefficient, error and fraud-prone. Automated, modernized and contactless payment solutions emerged with new importance during the pandemic as they allow users to get paid quickly while maintaining social distance. These technologies enable safe and efficient transactions and provide visibility into the payments process, which the industry needs to maximize revenue. In the cold chain ecosystem, efficiency is the priority. With solutions emerging that closely mirror consumer payment experiences, drivers and warehouse workers will benefit from time and money saved.

Cyber Security

Of the many lessons we could take from the last few years, the need to strengthen cyber security ranks high. The supply chain depends upon networks of digital systems, which are embedded in nearly every aspect of the supply chain process. Technologies that mitigate risk will be increasingly prominent in the industry, impacting how we think about these systems, employ them and monitor them for anomalies. As we live, work and operate in an increasingly digital world, we can expect to see an increase in resources dedicated to security.

Challenges in Cold Chain Industry

For the past nearly two years due to the pandemic, innovation has proven vital in any business sector, particularly in industries that keep the supply chain moving. This is because the supply chain industry has complex and unique challenges driven by an ongoing pandemic, but also compounded by an influx of holiday demands and a shortage of workers, equipment and capacity. For the cold food and beverage supply chain –one with a critical need for speed, efficiency and safety – these challenges must be addressed as quickly as possible. That is where technology comes in. It would be easy to feel discouraged during a challenging time in the industry. However, as we work together to solve today's pressing issues, we can and should feel encouraged about the ongoing innovation taking place. Supply chains for all industries have become incredibly complex, but for food and beverage manufacturers, supply chain management is more difficult than ever before. Transportation issues, market changes, consumer behavior, backlash from the pandemic, environmental problems, geo-political factors and many other disruptions have complicated the supply chain. When analyzing the supply chain of food manufacturers, critical areas need to be addressed.

The entire supply chain that a food manufacturer needs to manage is actually the coordination of multiple chains that roll up into the supply chain. The three major components of the master chain are distribution, manufacturing and procurement (supply) with each of these areas having smaller supply chains that need to be managed. The second consideration is that every supply chain has two components that need to operate in unison and be totally synchronized: the physical (inventory and products) and the digital (data and information). The physical supply chain consists of the actual inventory or products at all levels; finished goods, work in process and raw materials. The digital supply chain consists of the data and information that has to flow in unison with the movement of inventory. If these are not synchronized at all times, the shipment of inventory will stop, resulting in customer service delays, manufacturing disruptions, and most of all, lost profits.

Safety and efficiency are keys when it comes to the reefer and cold chain industries. Now, drivers and fleet managers can gain increased insights into every moment of the trip, encompassing the entire transportation experience from fuel efficiency and asset utilization to temperature monitoring and vehicle maintenance.

The third component that complicates all levels of operations today is the expanding value chain of this industry. There are more ways for consumers to get the products they need and desire. Online shopping, same-day delivery, subscriber services, club stores, specialty and convenience stores and even vending machines have expanded to where today one can buy almost anything anywhere. Food manufacturers have never had to deal with so many moving parts and so many value streams. Today's supply chains have more product touch points and more channels, which means there are more places where things can go wrong and disrupt plans.

In today's business environment, there is heightened pressure on employees not just to be experts on one thing, but everything. With their focus being pulled into multiple directions, employees are unable to master their skills in one just area. This allows all employees to stick to their core competencies and get expert insight on streamlining business processes.

Significant investment is needed in continuous education to prepare existing and future workforce to thrive in an age of robotics and automation. It is important not only to prepare for the widespread shifts, but to create prosperous societies going forward.

Despite the appetite for automation, our survey found a significant gap in the education and training needed to ensure the skills necessary for work in the increasingly connected and automated workplaces of the future. 80% of the respondents believe robotics and automation will shape the future of employment in the next 10 years, while only one in four education institutions currently use this innovative technology as a part of their teaching programs.

Conclusion

The supply cold chain is a complex, multi-faceted process encompassing everything from warehouse fulfillment to logistics. With many companies continuing to work towards supply cold chain optimization, the industry is ripe for innovation. As new technologies emerge that hold promise for streamlining fulfillment processes to speeding logistics, the traditional supply chain is rapidly transforming into a more advanced, more functional process driven by digital technology, artificial intelligence and other innovations.