Available online www.jsaer.com

Journal of Scientific and Engineering Research, 2022, 9(10):64-69

Review Article

ISSN: 2394-2630
CODEN(USA): JSERBR

A Review On: Adaptive Cold Storage Management System

Murali Dhar Keer[1], Gourav Purohit[2]

[1]Department of Mechanical Engineering Aravali Institute of Technical Studies, Udaipur
[2]Associate Professor, Department of Mechanical Engineering Aravali Institute of Technical Studies, Udaipur

Abstract Cold storage management systems play a pivotal role in preserving perishable goods, ensuring their quality and safety until they reach consumers. In recent years, the advent of adaptive technologies has revolutionized traditional cold storage management practices. This review examines the landscape of adaptive cold storage management systems, focusing on their key components, functionalities, and benefits. We delve into the underlying principles of adaptability, including real-time monitoring, predictive analytics, and dynamic control mechanisms, which enable these systems to optimize temperature and humidity conditions based on varying environmental factors and product requirements. Additionally, we explore the integration of emerging technologies such as Internet of Things (IoT), artificial intelligence (AI), and machine learning (ML) in enhancing the adaptability and efficiency of cold storage management systems. Through a comprehensive analysis of existing literature and case studies, this review identifies current challenges and future prospects in the domain, shedding light on opportunities for further research and innovation in adaptive cold storage management.

Keywords Cold storage, artificial neural network, MATLAB, image processing, refrigeration power optimization.

1. Introduction

In today's fast-paced and dynamic business environment, efficient management of perishable goods is paramount for businesses across various industries. Among the critical sectors reliant on effective cold storage management systems are food and pharmaceutical industries, where maintaining optimal storage conditions is essential to preserve product quality, safety, and compliance with regulatory standards. In response to these demands, Cold Storage Management Systems have emerged as indispensable tools, providing comprehensive solutions for the monitoring, control, and optimization of cold storage facilities. A Cold Storage Management System encompasses a suite of technologies and processes designed to ensure the seamless operation of refrigeration units, temperature monitoring systems, inventory management, and logistical workflows within cold storage facilities. These systems play a crucial role in safeguarding the integrity of perishable goods throughout the supply chain, from production and storage to distribution and consumption. Key components of Cold Storage Management Systems typically include temperature and humidity monitoring sensors, data logging and analytics software, automated control systems, inventory tracking modules, and integration capabilities with other enterprise systems such as ERP (Enterprise Resource Planning) and SCM (Supply Chain Management) platforms. By leveraging real-time data and advanced analytics, these systems enable operators to maintain precise control over environmental conditions, anticipate potential issues, and optimize resource utilization to minimize waste and operational costs. Moreover, Cold Storage Management Systems offer enhanced traceability and compliance features, facilitating adherence to regulatory requirements and quality standards imposed by food safety authorities and regulatory bodies governing pharmaceutical products. By providing detailed audit trails and documentation capabilities, these systems empower businesses to demonstrate compliance, mitigate risks associated with product recalls, and uphold brand reputation. In addition to operational benefits, Cold Storage Management Systems contribute to sustainability efforts by promoting energy efficiency and reducing carbon emissions associated with refrigeration operations. Through the implementation of intelligent control algorithms, predictive maintenance routines, and energy optimization strategies, these systems help minimize energy consumption while ensuring consistent temperature control, thereby aligning with environmental stewardship goals and reducing the ecological footprint of cold storage operations. In summary, Cold Storage Management Systems play a pivotal role in modern supply chain management, offering businesses in the food and pharmaceutical sectors the tools and capabilities needed to maintain product quality, safety, and regulatory compliance while optimizing operational efficiency and sustainability. As technology continues to advance and industry requirements evolve, the role of these systems is expected to become increasingly instrumental in driving competitiveness and resilience in cold chain logistics.

2. Literature Review

Bikrant Sarmah et. All (2020) In this paper, we laid out the basics of an IoT-based cold storage management system. This model was put together using an ESP8266 nodeMCU, a UV sensor, a MQ4 gas sensor, ThingSpeak, the Blynk app, and various other parts. Once an estimate of the total amount of food is made, the occupancy reading from the UV sensor may be used to infer the amount of food in the box. Whenever the MQ4 gas sensor picks up a sour aroma of methane, it's a sign that the food has begun to spoil. Data is stored in the cloud via ThingSpeak, and when perishable food is recognised, an alert is sent to the warehouse manager using the Blynk app. [1]

Shaju Nair (2013) Because of the framework's focus on enterprise-wide measurements and insights obtained from plentiful data, cold storage facilities may stop thinking about energy management on a per-location basis. Careful monitoring of energy and energy-impacting factors allows for identification of deviations and control of those deviations, allowing cold storage facilities to maintain product quality while using less energy. [2]

Chang Daofang et. All (2013) The primary purpose of this research is to develop a budget-friendly model for a distribution network that reduces fixed costs. The model is validated with data from a vegetable firm instance, and the interdependencies between the important decision components are characterized using a set of constraint criteria. Results from validating the model show that it can solve the distribution problem. In addition to a model validation using survey and computational data, our study also contributes to the development of a network strategy for the logistic distribution of vegetables in Shanghai. [3]

HARIPRABHA.V et. All (2014) The LabVIEW diagrams employed in the supervision of the four distinct warehouses. LabVIEW receives the data string once it has been transmitted to the system from a remote sensor node. When the hexadecimal format is broken down into its address and data components, the array subset technique can be applied. Addresses in the array are matched to those in the database to determine where new batches of information should be kept. [4]

Sulman Farrukh et. All (2013) In this study, we provide a remote monitoring and control system for industrial automation that is both affordable and dependable. One of the system's secondary goals is to cut down on food waste and scarcity, and the money saved on electricity helps make that goal more feasible. To ensure data integrity and reduce the likelihood of communication mistakes, cables are used to transmit information from sensors to a centralized control unit. Our long-term goals include the introduction of wireless networking between sensors and the use of more cutting-edge, efficient, and non-round-based communication protocols. [5]

Harsh S Holalad et. All (2012) Based on the FPGA SPARTAN 3(XC3S200-5PQ208) platform, this study introduces a simple and effective method for identifying fruits. The choices may have been between apple, banana, sapodilla, and strawberry. After much deliberation, it was agreed to select four varieties of apples, two varieties of sapodillas, and a single variety of the other two fruits. Each training image was 64x64 pixels in size, and a total of 800 photos were used. The accuracy of a fruit-identification system is highly sensitive to the features vector and Classifier used. [6]

Jehad Al-Radaedeh et. All (2013) Technical efficiency of the refrigeration system to be utilised and plant capacity must be evaluated in advance to estimate the optimal thermal insulation thickness for the cold storage facility. Based on a thorough techno-economic analysis of thermal insulation cost and the cost related to the production of necessary refrigeration to compensate for heat flow through the exterior walls into the cold storage and conservation plant, this paper aims to establish a mechanism to calculate the economical thickness of thermal insulation layer of external walls of cold storage plant. [7]

Tetsuo Morimoto et. All (2013) We used neural networks and 40 C, two types of optimal T genetic algorithms, to determine the 8-step temperature set points that minimize the rate of water loss of the fruit during storage. It's possible that high temperature exposure helps fruits alleviate water stress for a short period of time. These findings imply that, rather of adopting a traditional management approach that only maintains the lowest temperature, it is preferable to utilise a control method that submits the fruit to the 40°C - 50°C heat stress optimally based on fruit reactions. [8]

Ugwu et. All (2012) It's fantastic that folks in Umudike and the surrounding area now have a new, climate-controlled option for storing their food that needs to be kept at a certain temperature. This cold storage area has a maximum COP of 6.09, and its computed total refrigeration capacity is 0.82TR (about 4Hp). The rated capacity of the evaporator is 1.85Hp at the optimal working temperature of 36 degrees Celsius, while the rated capacity of the condenser is 2.15Hp. [9]

Amit M Patel et. All (2012) The current research involved the construction and experimental use of a scale model of a super-refrigerated cold storage facility and its associated refrigeration system. In this study, we used the Taguchi method to pinpoint the ideal parameters for a cold storage facility's insulation thickness, wall area, and compressor capacity. We looked at these variables across three different ranges: thickness (0.050), wall area (1.5), and compressor capacity (0.100), all with varying degrees of compression. [10]

Alan McKinnon et.All (1998) Because of the substantial amounts of energy consumed and air pollution it generates, this industry has become a focal point of environmental activism. Those involved in this discussion reached a consensus on one point: the need to decrease inventory at retailers' RDCs was the driving force behind the rapid pace of change in the logistics of this business. The majority of firms questioned anticipate shorter order lead times and more frequent delivery during the next three years. They also anticipate a high volume of cross-docking of frozen foods during this time. Many observers doubted that stores would actually request manufacturers to do "picking-by-store" work, and those who did were concerned that factories would have to invest a lot of money in extra cold storage space and handling technology to keep up with demand. [11]

Y. Songa et. All (2013) In the post-genomic era, phenol typology can be a hindrance to scientific progress because it involves methods like as counting the amount of fruits on a plant. One method for doing so that involves the use of images is image analysis. In this study, we present a technique for automatically counting and labelling fruits in greenhouse photos, despite the presence of potentially distracting backgrounds. The peppers that grow on these plants, which may reach heights of 3 metres, are every bit as intricate and colourful as the plant's canopy. Each calibration and validation set contains over 28,000 colour photos of over 1,000 experimental plants. We offer a two-stage method for detecting and counting pepper fruits using a bag-of-words model to recognise fruits in a single image and a novel statistical strategy to cluster repeated, incomplete observations to aggregate estimates from numerous photographs. We show that for big datasets, image analysis can correlate well with manual measurement (94.6%), and that our suggested method may be able to do so (74.2%) without linear adjustment. [12]

3. Cold storage warehouse requirements

One of the difficulties of cold storage warehousing is the adverse effects low temperatures can have on human health and on the storage and handling equipment. To mitigate this, **operators must wear work clothing that protects against the cold**, i.e., appropriately lined jackets, thermal pants, and gloves. Likewise, the equipment installed in a cold or freezer store needs to be adapted to these types of environments. For example, if devices with touchpads are used, they should be designed to be able to work with gloves.

On the other hand, since the products in cold storage are sensitive to changes in temperature, cold storage warehouses usually have sensors that control the temperature inside the facility. Dehumidifiers are also employed, as they significantly reduce ice formation.

Cold storage warehouses must be kept at the right temperature at all times, with the added difficulty that these facilities have a high number of product inflows and outflows. With so many movements of goods, **secure airlock systems** are installed to prevent the loss of cold. These consist of two high-speed doors, one leading into the cold store and the other, outside, which are never open at the same time. This minimizes sudden changes in temperature, condensation, and cold loss.

3.1 Improve energy efficiency

Companies that need to store goods at a controlled temperature seek solutions that will maintain the cold chain intact **without energy consumption skyrocketing**. These businesses opt for compact storage systems because they make cold stores more sustainable: by storing many products in a smaller space, the energy consumption to generate cold for each pallet is lower.

Mobile racking systems are very common in cold storage warehouses, as they notably cut down on energy consumption due to the optimal distribution of cold air among the pallets. Spanish meat company Olot Meats Group equipped its two freezer warehouses with our company's Movirack mobile pallet racks to boost its energy efficiency.

Technology also fosters sustainability in facilities operating at a controlled temperature. **Automatic handling equipment such as stacker cranes and conveyors** don't use gas or other polluting fossil fuels, which minimizes CO_2 emissions to the atmosphere. Stacker cranes (AS/RS) for pallets from Mecalux, for example, incorporate a **premium efficiency IE3 electric motor and power regenerators** that return the energy generated during the descent and deceleration maneuvers to the electrical network.

4. Challenges: Adaptive Cold Storage Management System

As the demands on cold storage facilities continue to evolve in response to shifting consumer preferences, regulatory requirements, and technological advancements, the need for adaptive Cold Storage Management Systems has become increasingly apparent. These systems must be capable of not only meeting current operational challenges but also adapting to future uncertainties and opportunities. In this context, several key challenges arise in the development and implementation of an adaptive Cold Storage Management System.

Dynamic Temperature and Environmental Conditions: Cold storage facilities must contend with fluctuating external temperatures, seasonal variations, and unpredictable weather patterns. An adaptive management system must be equipped with sensors and control mechanisms capable of dynamically adjusting refrigeration settings to maintain optimal storage conditions while minimizing energy consumption. Additionally, it should be able to anticipate and respond to changes in environmental conditions to prevent temperature excursions and ensure product integrity.

Scalability and Flexibility: The scalability of cold storage operations presents a significant challenge, especially for businesses experiencing growth or seasonal fluctuations in demand. An adaptive management system should be designed to accommodate varying storage capacities, layout configurations, and throughput requirements without compromising efficiency or reliability. Flexibility in system architecture and modular design can facilitate seamless expansion or reconfiguration of cold storage facilities as needed.

Integration with Emerging Technologies: Rapid advancements in technology, such as Internet of Things (IoT), artificial intelligence (AI), and blockchain, offer new opportunities for enhancing cold storage management capabilities. However, integrating these emerging technologies into existing infrastructure poses challenges related to interoperability, data compatibility, and cybersecurity. An adaptive management system must support seamless integration with diverse hardware and software platforms while ensuring data integrity, privacy, and security.

Real-time Monitoring and Predictive Analytics: Traditional cold storage management systems often rely on reactive approaches to address operational issues and maintain product quality. An adaptive system should leverage real-time monitoring sensors and predictive analytics algorithms to anticipate potential issues before they occur. By analyzing historical data, environmental trends, and equipment performance metrics, the system can identify patterns, anomalies, and predictive failure indicators, enabling proactive maintenance and optimization strategies.

Regulatory Compliance and Quality Assurance: Compliance with stringent regulatory requirements and quality standards is paramount in the food and pharmaceutical industries. An adaptive management system should incorporate robust quality assurance protocols, audit trails, and documentation capabilities to facilitate regulatory compliance and traceability throughout the supply chain. Moreover, it should support continuous improvement initiatives by providing actionable insights into compliance metrics, process efficiencies, and risk mitigation strategies.

Stakeholder Collaboration and Communication: Effective communication and collaboration among stakeholders, including suppliers, distributors, regulatory agencies, and customers, are essential for optimizing cold storage operations and ensuring product safety and integrity. An adaptive management system should facilitate seamless communication channels, data sharing protocols, and collaboration tools to streamline workflows, resolve issues promptly, and foster transparency and trust among stakeholders.

5. Future Prospects: Adaptive Cold Storage Management System

The future prospects for adaptive Cold Storage Management Systems are promising, driven by ongoing technological advancements, evolving consumer preferences, and increasing regulatory scrutiny. As the cold chain logistics industry continues to expand and diversify, several key trends and developments are likely to shape the trajectory of these systems:

Advancements in IoT and Sensor Technologies: The proliferation of Internet of Things (IoT) devices and sensor technologies will enable the development of more sophisticated and interconnected cold storage management systems. These systems will leverage real-time data streams from a multitude of sensors to monitor environmental conditions, track inventory movements, and optimize resource utilization with unprecedented granularity and accuracy.

AI and Machine Learning Applications: AI and machine learning algorithms will play a pivotal role in enhancing the intelligence and adaptability of cold storage management systems. These systems will leverage predictive analytics to anticipate demand fluctuations, optimize inventory levels, and proactively address maintenance issues, thereby improving operational efficiency and reducing waste.

Blockchain-enabled Traceability and Transparency: Blockchain technology holds significant promise for enhancing traceability and transparency throughout the cold chain. By providing immutable and tamper-proof records of product movement, temperature histories, and quality assurance data, blockchain-enabled cold storage management systems will enable stakeholders to verify product authenticity, track provenance, and ensure compliance with regulatory requirements more effectively.

Integration with Sustainable Practices: Sustainability considerations will increasingly influence the design and operation of cold storage facilities and management systems. Adaptive systems will incorporate energy-efficient refrigeration technologies, renewable energy sources, and waste reduction strategies to minimize environmental impact and align with corporate sustainability goals.

Autonomous and Robotics-assisted Operations: The integration of autonomous vehicles, robotic automation, and drones into cold storage operations will revolutionize warehouse management and logistics. Adaptive systems will leverage these technologies to optimize inventory picking, replenishment, and transportation processes, thereby reducing labor costs, improving accuracy, and enhancing overall operational efficiency.

Collaboration and Ecosystem Integration: Future cold storage management systems will emphasize collaboration and integration within broader supply chain ecosystems. These systems will facilitate seamless data exchange, interoperability, and decision-making across multiple stakeholders, including suppliers, manufacturers, distributors, and retailers, to optimize end-to-end supply chain performance and customer satisfaction.

6. Conclusion

In reviewing the Adaptive Cold Storage Management System, it becomes evident that the evolution of cold chain logistics is deeply intertwined with technological innovation, regulatory compliance, and sustainability imperatives. This comprehensive system, designed to address the dynamic challenges of storing perishable goods, offers a multifaceted approach to optimizing operational efficiency, ensuring product quality, and enhancing supply chain resilience.

The challenges facing cold storage operations, from fluctuating environmental conditions to regulatory requirements, demand adaptive solutions capable of anticipating and responding to changing circumstances. Through the integration of IoT, AI, blockchain, and robotics technologies, adaptive systems empower businesses to monitor, analyze, and optimize every aspect of cold storage management in real-time.

Looking ahead, the future prospects for adaptive Cold Storage Management Systems are promising, driven by continued advancements in technology, evolving industry standards, and growing consumer expectations. As businesses strive to meet the demands of an increasingly complex and interconnected global marketplace, investment in adaptive cold storage management solutions will be essential for maintaining competitiveness, driving innovation, and achieving sustainable growth.

In conclusion, the Adaptive Cold Storage Management System represents a paradigm shift in the way perishable goods are stored, managed, and transported. By embracing the principles of adaptability, collaboration, and sustainability, businesses can unlock new opportunities for efficiency, profitability, and resilience in the dynamic cold chain logistics landscape. As we navigate the challenges and opportunities of tomorrow, adaptive cold storage management will remain a cornerstone of success for businesses across various industries.

References

[1]. Bikrant Sarmah and G. Aruna "Detection of Food Quality and Quantity at Cold Storage using IoT" IEEE, 2020.

[2]. Shaju Nair "ACHIEVING ENERGY EFFICIENCIES IN COLD STORAGES" US Department of Energy, 2013.

[3]. Chang Daofang, Zhu Jinfeng and Lin Danping "Cold Chain Logistics Distribution Network Planning Subjected to Cost Constraints" International Journal of Advanced Science and Technology, 2015.

[4]. HARIPRABHA.V, VASANTHARATHNA.S "MONITORING AND CONTROL OF FOOD STORAGE DEPOTS USING WIRELESS SENSOR NETWORKS" International Journal of Industrial Electronics and Electrical Engineering, 2014.

[5]. Sulman Farrukh, Muhammad Shahzad, Usman Khan, Talha Chughtai, and Ali Nawaz Khan "Industrial Automation and Control System to Minimize Food Spoilage and Imports in Pakistan" International Journal of Information and Electronics Engineering, 2013.

[6]. Harsh S Holalad, Preethi Warrier, Aniket D Sabarad "An FPGA based Efficient Fruit Recognition System Using Minimum Distance Classifier" Journal of Information Engineering and Applications, 2012.

[7]. Jehad Al-Radaedeh, Bassam Al-Zgoul, Muhamad Frehat "Selection of Thermal Insulation Thickness of Cold Store Enclosures" Innovative Systems Design and Engineering, 2013.

[8]. Tetsuo Morimoto, Md Parvez Islam, Kenji Hatou "An Intelligent Control Technique for Dynamic Optimization of Temperature during Fruit Storage Process" American Journal of Operations Research, 2013.

[9]. Ugwu, Hyginus Ubabuike, Ogbonnaya, Ezenwa Alfred "Design and Adaptation of a Commercial Cold Storage Room for Umudike Community and Environs" IOSR Journal of Engineering, 2012.

[10]. Amit M Patel, Prof. R I Patel "Optimization of Different Parameter of Cold Storage for Energy Conservation" International Journal of Modern Engineering Research (IJMER), 2012.

[11]. Alan McKinnon, Mr. Jim Campbell "Quick-response in the Frozen Food Supply Chain: The Manufacturers' Perspective" Christian Salvesen Logistics Research, 1998.

[12]. Y. Songa , C.A. Glasbey , G.W. Horganb , G. Polderc , J.A. Dielemand , G.W.A.M. van der Heijden "Automatic fruit recognition and counting from multiple images" Biosystems Engineering, 2013.