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AI-Driven Approaches to Energy Management in Agricultural Cold Chains

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Abstract – Organizations operating within the cold chain logistics sector are adopting a strategic approach towards using big data in order to effectively navigate the substantial potential and challenges presented by Artificial Intelligence (AI) and Internet of Things (IoT). When used in the broader context of cold chain logistics, IoT technology enhances the traditional information transmission network. In recent years, there has been a notable emergence of research focused on technological breakthroughs in the field of Internet of Things. As technology progresses to a certain threshold, the model of application will undergo maturation, leading to an expansion in range of requisitions and an augmentation in their capabilities. This paper examines the prevailing concerns pertaining to energy consumption across the agricultural supply chain and asserts the indispensability of using AI as a means to address these challenges. Furthermore, this paper examines several aspects of energy system planning and operation, specifically focusing on the potential use of AI in addressing energy challenges within the cold supply chain. In conclusion, this study undertakes more research on the problems and potential of the next generation of super cold chain. Its aim is to establish a standard for the good expansion of cold-chain logistics within the agricultural industry, with major interest in minimizing carbon emissions.

Keywords – Super Cold Chains, Cold Chain Logistics, Artificial Intelligence, Internet of Things, Cold Chain Infrastructure, Cold Chain Industry.

I. INTRODUCTION

The expansion of the cold chain is accompanied by growing apprehensions over its environmental implications and energy consumption. The current predicament confronting the cold chain industry pertains to the imperative task of mitigating excessive energy use while simultaneously ensuring the preservation of perishable agricultural commodities. The cold chain logistics is an inherent and inevitable trend in the progression of agricultural commodities preservation. It is distinguished by its attributes of minimal energy consumption, reduced emissions, and enhanced operational efficiency.

In order to establish connectivity between the communication main network and item terminals, various communication technologies such as infrared sensors, global positioning system, and radio frequency identification are employed, adhering to a specific protocol. This convergence of network technology, software technology and embedded technology defines the IoT technology as a pivotal intersection. The use of intelligent communication technology. The sensing layer, the network layer, composed primarily of metering devices that sense, consisting of software and hardware implementation, and the application layer, and the network stack, encompassing a user application software and distributed or centralized cloud computing platform, among other components, serves as the controlling element of the network.

The IoT communication protocol consists of two components, namely the transmission protocol and the access protocol. Access protocols, such as ZigBee, largely focus on enabling communication among devices inside the underlying sensing layer. The internet protocol or transport control protocol is a fundamental component of the internet infrastructure, facilitating the transport of data at the layer of application. The MQTT protocol is extensively used as a communication mechanism within the IoT domain. The MQTT protocol enables efficient and asynchronous communication between a remote and a device system via its "push" method. This technique, according to Kegenbekov and Saparova [1], alleviates the server from the burden of handling simultaneous data requests in real-time. Additionally, MQTT provides three distinct levels of quality of service. The architecture of the network of the protocol is shown in **Fig. 1**.

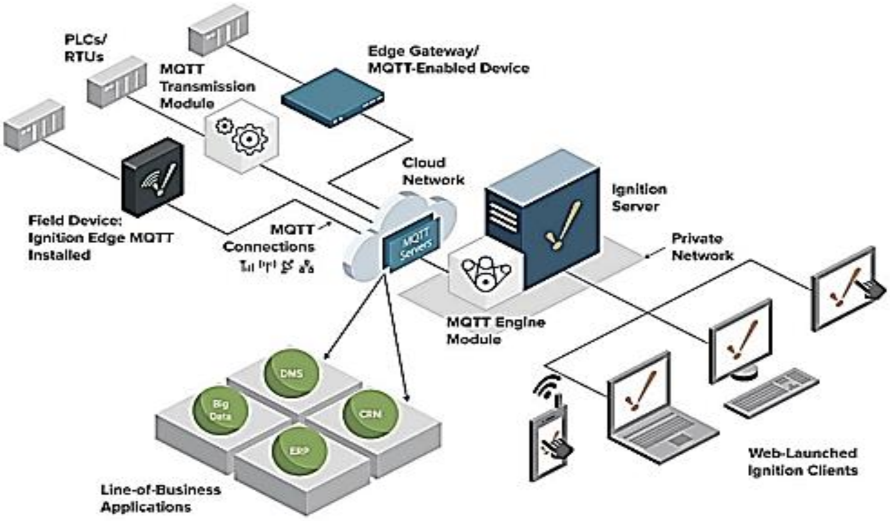

Fig 1. The MQTT Protocol's Hub-and-Spoke Network Architecture

This paper examines the prevailing concerns pertaining to energy consumption along the agricultural supply chain and asserts the indispensability of Artificial Intelligence in facilitating the identification and implementation of viable remedies. Furthermore, this paper examines several aspects of energy system planning and operation, specifically focusing on the potential use of AI to address energy challenges within the cold supply chain. In conclusion, this study undertakes more research on the challenges and potential of the next super cold chain, aiming to establish a standard for the better expansion of supply chain techniques within the agriculture industry, with keen interest in reducing carbon emissions. The sections of this articles have been organized as follows: Section II presents an overview of the cold chain logistics, ranging from its definition, characteristics, and composition. Section III focusses on energy consumption in the agricultural cold chains. Section IV is about the applications of AI in the Ultra Cold Chains, with major focus on the model of food cold chains management improvements, and AI in super cold chains. Section V presents general discussion of the research as well as challenges posed by AI in ultra-cold chains. Lastly, Section VI presents a conclusion to the research.

II. OVERVIEW OF COLD CHAIN LOGISTICS

Definition of Cold Chain Logistics

The phrase "cold chain logistics" is used to refer to the transportation of perishable commodities that need temperature control.

Properties of The Cold Chain Logistics

The key properties of cold chain strategies may be delineated as follows.

Transporation and storage products are perishable

The degradation rate of products is accelerated when they are kept or transported for a longer duration, compared to products that are not exposed to such conditions. When a product fails to fulfill the expectations of consumers, it results in significant financial losses for the firm due to diminished demand. Different goods have diverse temperature requirements for their transportation and storage. Certain items need refrigeration during processing, while others must be maintained at freezing temperatures.

Significant Investments in Cold Chains Infrastructure

In order to maintain the safety and quality of certain products throughout their manufacturing, shipping, and distribution processes, it is necessary to store them at low temperatures. This necessitates the use of cold storage facilities and entails a significant investment in refrigeration equipment to provide real-time temperature monitoring. Considerable resources are required for the regular maintenance of cold chain equipment and for providing training to staff on the proper use of refrigeration apparatus. In order to ensure the preservation of perishable items, it is essential to maintain a low atmospheric pressure throughout the various stages of distribution, shipping, processing, production, and procurement. Particularly, special attention should be given to the interfaces between each of these steps. Hence, the implementation of cold chain logistics necessitates greater capital investments and administrative expenses compared to traditional logistics.

High Cold Chain Logistics Levels and Requirements of Information Technology

Cold chain goods need a specific storage condition in order to minimize deterioration and optimize customer satisfaction and retention. Various technologies are used in the cold chain, including refrigeration technology, refrigerant selection, refrigeration system management, and vehicle refrigeration technology. These technologies are utilized at different phases of the cold chain, spanning from the procurement of raw materials through the transportation and delivery of the finished products. The actual monitoring of the supply chain is crucial for the effective management of the process and preservation of product freshness. The utilization of various logistics technologies such as RFID, GPS, GIS, and GPRS is essential for the successful execution of this operation.

Cold Chain Logistics Composition

Freezing

Refrigerants are used manually to lower the temperature. Pre-chilling of the process of reducing the temperature of perishable items to their desired level prior to their transportation in a refrigeration unit. This methodology has the potential to extend the freshness of fruits and vegetables and safeguard them from desiccation during transportation and storage. The processes of waste management and consumption contribute to ensuring that consumers are able to acquire locally cultivated, organic agricultural products.

Frozen Storage

Following the freezing operation, the subsequent phase involves the storage of the frozen materials. One of the key purposes of this system is to provide a controlled environment for the storage of processed items, therefore prolonging their shelf life and mitigating the potential for spoiling. Conversely, it serves the purpose of transporting initial-stage processed products to a distribution center or directly to the retailer for warehousing, so potentially minimizing the time lag between production and sales. This ensures that consumers may get goods even during periods of low demand.

Refrigerated Distribution and Transportation

The phrase "refrigerated transportation and distribution" encompasses the series of cold-chain procedures beginning with the procurement of raw materials and concluding with their ultimate distribution to customers. In our decision-making process, we consider both the distance and the nature of the commodities being carried. Both humidity and temperature play a crucial influence in deciding the ultimate quality of the finished product. Ensuring optimal vehicle performance and implementing actual monitoring of atmospheric pressure and humidity inside the car are crucial for effectively managing these factors throughout transportation and distribution processes. The quality of distribution products and refrigerated transportation, cold chain technology and cold chain technology and equipment can be influenced by various factors, including unloading, tear and wear during loading, and road conditions and the transformation between distinct transportation means. These factors, along with temperature and humidity, are the primary determinants of the overall effectiveness of the cold chain system.

III. ENERGY CONSUMPTION IN THE AGRICULTURAL COLD CHAIN

The demand for supply chain strategies has seen a significant surge due to the expansion of deep processing in the agriculture sector and the increase in average wages. One aspect to consider is the incorporation of transportation expenses associated with room temperature logistics when examining the energy optimization of live agricultural products and supply chain strategies. Nevertheless, it is important to consider the expenses associated with the power consumption of refrigeration equipment in transportation vehicles, as well as the financial implications of perishable agricultural items that are lost throughout the circulation process. The complete realization of the traditional cold chain for agricultural items is impeded by technical and environmental limitations.

In September 2020, China put forth the proposition of attaining the objectives of "carbon peak" by two thousand and thirty and "carbon neutral" by 2060 [2]. This proposal aims to effectively address the adverse consequences of global climate change, expedite the attainment of environmentally sustainable and low-carbon economic growth, and enhance the establishment of an ecological civilization through a more scientifically informed approach. China has undertaken significant adjustments and strategic deployments in its approach to address global climate change, aiming to attain carbon neutrality. This shift is driven by the goals of promoting green and low-carbon growth, as well as advancing the development of ecological civilization in the contemporary era. As seen in **Fig. 2**, this first stage has significant importance in materializing the novel development paradigm.

The typical supply chain logistics method has several challenges, including high prices and inefficient transportation and distribution routes, which negatively impact the distribution of agricultural commodities. This study develops a supply cost optimization model for supply chain strategies, taking into consideration the weight limitation of the supply vehicle and time window constraint. The objective is to enhance the efficiency of the distribution process and minimize the associated costs. The agricultural sector in China has had steady growth in the production of its primary agricultural products. This can be attributed to the adjustment and upgrading of agricultural industry, which has effectively met the needs of the population. Furthermore, this growth has contributed to the advancement of the agricultural supply chain strategies sector. Simultaneously, it is imperative for the agriculture sector in my nation to actively develop a low-carbon economy in order to effectively accomplish the newly set ambitions and responsibilities of expediting the reform of promoting sustainable growth, ecological civilization, and establishing an aesthetically pleasing China. The supply chain strategies of agricultural items have a significant ecological impact, mostly attributed to their substantial energy consumption and carbon emissions. The integration least-carbon concept into the supply chain of agricultural goods has performance significance in addressing the resources of the contemporary era of progress.

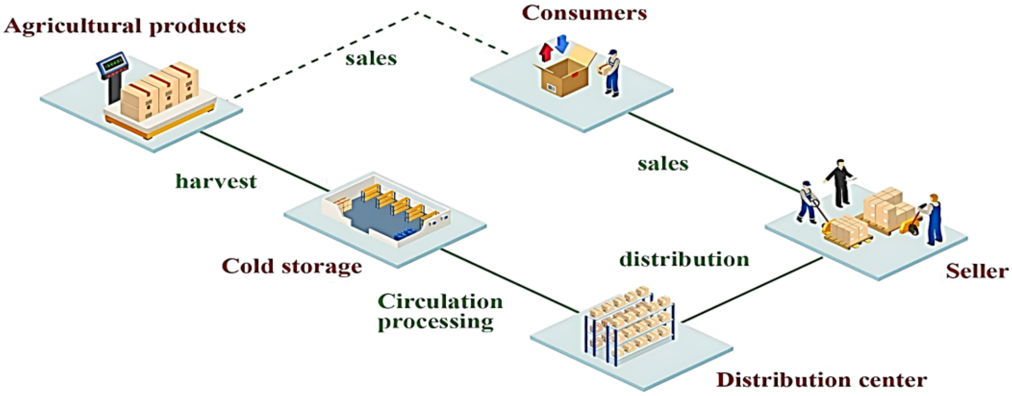

Fig 2. High-End Schematic of The Agricultural Supply Chain Logistics System

Chaitangjit and Ongkunaruk [3] provide a view of current status of energy concerns within the agricultural cold chain. According to research findings, it has been shown that the refrigeration system is responsible for around 80% of the energy consumption in the supply chain process. Furthermore, investigations have revealed that emission of carbon in cold chain transportation are approximately 30% larger compared to ambient strategies. Consequently, the investigation into energy usage should largely center on the refrigeration equipment responsible for sustaining a low temperature environment inside the cold chain. Contemporary refrigeration systems are confronted with many challenges, including outdated cooling techniques, excessive air circulation, and insufficient insulation. Several factors, including thermal insulation performance, ventilation systems, humidity, temperature and the inhaling heat of agricultural items, contribute to the overall effect of refrigeration. The numerical value provided by the user is 6. The inability to maintain a consistently low-atmospheric environment leads to elevated levels of product deterioration, energy dissipation, and carbon dioxide emissions.

Furthermore, the transportation activities associated with cold chain logistics use a substantial quantity of energy. The supply chain distribution process consumes a greater amount of energy due to inadequate architectural design and planning of the source and its corresponding distribution routes. Additionally, there has been a rapid increase in energy use due to the extended distances traveled and the practice of refrigerated trucks returning without any cargo. According to available statistics, it has been determined that carbon emissions from automobiles account for more than forty percent of global greenhouse gas emissions. The numerical value provided by the user is 7.

Lastly, it should be noted that a full cold chain energy management system has not been established at this time. The energy requirements of cold chain logistics are subject to variability, since they fluctuate at every phase within the supply chains, with different types of application equipment, during different hours of operation, and with varying control settings. The inadequate management of various components within the supply chain strategies has resulted in raising wasteful carbon emissions. Consequently, the need to identify strategies for reducing the resource requirements associated with the transportation of perishable agricultural commodities is of utmost importance.

IV. APPLICATION OF ARTIFICIAL INTELLIGENCE TO THE ULTRA COLD CHAIN

The Model Food Cold Chain Management Development

Significance of Blockchain and IoT Technology

The primary categories of meal cold chains are catering, sales, storage, shipping, packaging, processing, and pre-cooling. Temperature regulation and full-chain traceability are crucial components in maintaining meal safety and managing the COVID-19 spread inside cold chains. The influence of temperature on the longevity of food products and its significance in determination of the duration of SARS-CoV-2 persistence on exteriors of various products highlights the potential of precise temperature control to the viral transmissions and enhance the safety of food. In the case of a food-related incident, it is possible for authorities to trace the source and ultimate destination of a product by using data collected at each pivotal checkpoint across the supply chain. Due to its considerable importance, it is imperative that this data undergoes rigorous verification procedures prior to its use in making critical public health assessments on the safety of cold chain commodities. The utilization of these variables in the administration of the cold chain for perishable food items is shown in **Fig. 3**.

The aforementioned model outlines three critical aspects of a meal cold chain, including credible tracing, chain joining and information sensing. Effective cold chain management is contingent upon the robust use of information sensing. IoT technology enables the collection and integration of various data points, like manufacturing labels, humidity, and temperature, to establish an additional stratum inside the supply chain. The chain linking layer encompasses a range of operations performed by AI, including risk assessment, environmental alarms, information exchange and information management. The achievement of reliable tracing is facilitated with the application of blockchain technology situated at the highest tier of the architectural framework, wherein data derived from the preceding layers is employed as inputs.

Fig 3. Improvement Framework for The Food Cold Chain

Information Sensing

Based on the aforementioned cold chain enhancement paradigm, two fundamental data types are gathered: cold chain operational information and environmental information. The collection of geographical position, gas concentrations, humidity, and temperature data may be facilitated by the use of IoT sensors deployed within the surrounding environment. Supply chain information recording apps enable the actual collection of data including production labels, personnel identification numbers, operating protocols, and virus testing records.

In order to provide sufficient data capacity and privacy inside the suggested framework for enhancing the meal cold chain, a hybrid information storage solution is used. This approach combines off-chain and on-chain storage using the IPFS as described by Fujita [4]. Various forms of data, like as text, photographs, music, and video, may be saved on the Interplanetary File System (IPFS) and then organized into blocks by hashing. This enables the inclusion of such material inside a blockchain. The use of hash indexing proves to be a viable and reliable approach due to the limited storage capacity of individual blocks inside a blockchain. The use of an integrated hybrid data storage system ensures the protection of proprietary information for businesses engaged in the food cold chain industry. This system effectively stores and retrieves data in a manner that is both highly secure and easily traceable, hence facilitating efficient monitoring and tracking processes.

Chain Linking

A novel cold chain linking system, based on technology of blockchain, was designed to effectively monitor and record data collected at different stages along the transit process of perishable commodities. In the blockchain, every block is comprised of a hash index that stores data, and this index is modified whenever a new food item is included into the cold chain. The composition of each block consists of two components: the block content and the block header. The block header in a blockchain contains cryptographic hashes of the header of the initial block and the Merkle root of the block before it. On the other hand, the block content contains data that may be used by users for the purpose of product tracing. Whenever a block is created, the hash index is added to the existing parent chain. Hence, it is essential to consider the aspects of data management, data sharing, and data uploading into the blockchain.

Moreover, the inadequate maintenance of appropriate temperatures or the use of viral-contaminated practices during the operation of a cold chain for food might potentially increase the risk of corona virus transmission at different phases of the cold chain process. The implementation of environmental warnings and risk assessment measures is crucial in safeguarding consumers against possible health issues linked to cold chain commodities. Once a certain threshold is reached for a habitat parameter, such as humidity or temperature, it serves as an indication that the prevailing circumstances throughout the food cold chain deviate considerably from the optimal parameters. The term "environmental warning" refers to the communication of information on potential or existing threats to the environment. On the other hand, the process of risk assessment involves analyzing temperature and logistical data to quantify the potential risk to human health associated with cold chain goods. This assessment is based on the relationship between the duration of exposure to specific temperatures and the viability of viruses.

Credible Tracing
The suggested architecture for enhancing cold chains in the food industry aims to address the diverse requirements of customers and other stakeholders involved in the process. This architecture facilitates the execution of tracing inquiry smart contracts, which use a wide range of tracing information with varying degrees of precision. Customers, for instance, may seek information pertaining to the essential characteristics of a product, while those engaged in the supply chain may be granted access to more comprehensive details, including the identities and locations of all parties involved in the manufacturing and distribution processes of a certain food item. The departments responsible for health and food safety posses the largest level of authority and has the capability to access data across the whole supply chain. In the case of a corona virus contamination incident, the proposed tracking methodology would facilitate a prompt and efficient product recall process.

Agents have the capacity to get block numbers and traceability information via the process of scanning a product code, hence facilitating the establishment of a robust traceability system. The generation of hash values is derived from the traceability data that is linked to the scanned product code. The subsequent procedure involves verifying if the hash aligns with the social hash value kept on the blockchain. If there is a discrepancy between the two hash values, it is probable that the product data has undergone alterations during its transportation through the cold chain. Furthermore, the use of a smart contract may facilitate the monitoring of products' movement and determine liability in cases of COVID-19 contamination. This enables a prompt recall and efficient settlement of the matter.

AI in Super Cold Chains
Yadav, Singh, Gunasekaran, Raut, and Narkhede [5] have offered a variety of ways to address the aforementioned energy challenges in the supply chain of products of agriculture. Nevertheless, the variability in content, size, and shape of agricultural items necessitates the absence of a universally applicable solution to address the complexities of cold chain logistics. Cloud computing and machine learning are among the latest technological advancements that have facilitated the improvement of AI inside the cold supply chain. The use of data collection techniques inside the IoT facilitates the real-time monitoring of logistical objects and the acquisition of extensive quantities of data. The data processing and energy conservation capabilities of machine learning is unrivaled. Therefore, it is essential to carefully consider the potential of AI in reducing carbon emissions and improving energy efficiency within the supply chain. The monitoring operational and administration of artificial intelligence in the ultra-supply chain power of agricultural goods can be categorized into two primary aspects. 1 example is the intelligent consumption of energy management system, which effectively optimizes and coordinates energy use across the whole cold chain. The second objective is the optimization of local consumption of energy within the supply chain via the implementation of intelligent systems for monitoring, control, and analysis.

Establishing an Energy Management System
Due to their limited shelf life and high market demand, fresh agricultural products need enhanced coordination of supply chain strategies. The potential advantages of using AI in the ultra-cold chain lie in its capacity to provide a comprehensive solution for energy conservation. The establishment of a low-carbon agricultural super cold chain may be achieved by adopting a holistic approach that encompasses several stages, including harvesting, processing, shipping, storage, and sales.

Fig. 4 depicts the management of energy architecture of the smart supply chain. The information layer breadth of coverage includes the collection of information pertaining to the operating parameters of equipment and the conditions surrounding energy consumption. Nondestructive and computer vision systems are currently used in the supply chain process to effectively follow quality parameters like maturity and freshness. Subsequently, IoT technologies such as WSN and compressed technology sensing are used to effectively transfer the gathered data to the cloud. The optimization of refrigeration units to decrease energy consumption is achieved by the use of neural networks and other methodologies, aligning with the purpose of costs minimization and efficiency maximization. To fully gain intelligent power management and provide comprehensive traceability process, the assessed results and then converted into directives and sent the terminal via data center.

Big Data Analysis and Prediction of Energy Utilization
The assessment of temperature, humidity, and other variables throughout the cold chain is often conducted using a one-dimensional point detection method, which is deemed inefficient. Nevertheless, the wide range of sample point detection methods poses a significant challenge when evaluating the quality of meal in the supply chain process. The prospective advancements in food quality monitoring may include nondestructive monitoring, computer vision systems, and thermal imaging methodologies. Deep learning, which has the ability to learn features and generalize, may be used for analysis of

intricate food matrices and identification. Several crucial factors that have an important impact on the energy consumption and carbon emissions of the cold chain include the operational efficiency of refrigeration systems, prevailing climatic conditions, and the quality of the perishable goods being transported.

The use of deep learning in conjunction with a computer vision framework. The first step involves the acquisition of the image by a computer vision system, which is accompanied by the simultaneous uploading of other data pertaining to the vehicle's energy consumption, cargo, and surrounding environment. The neural network is provided with visual representations of fruits and vegetables, from which it collects and analyzes pertinent data to accurately discern variations in shape, color, and size. The dynamic and static loads of each link are determined by quantifying the power consumption of the supply chain using data mining, followed by the use of backcasting and forecasting techniques. In order to save costs and minimize energy consumption, it is optimal to integrate storage and distribution systems.

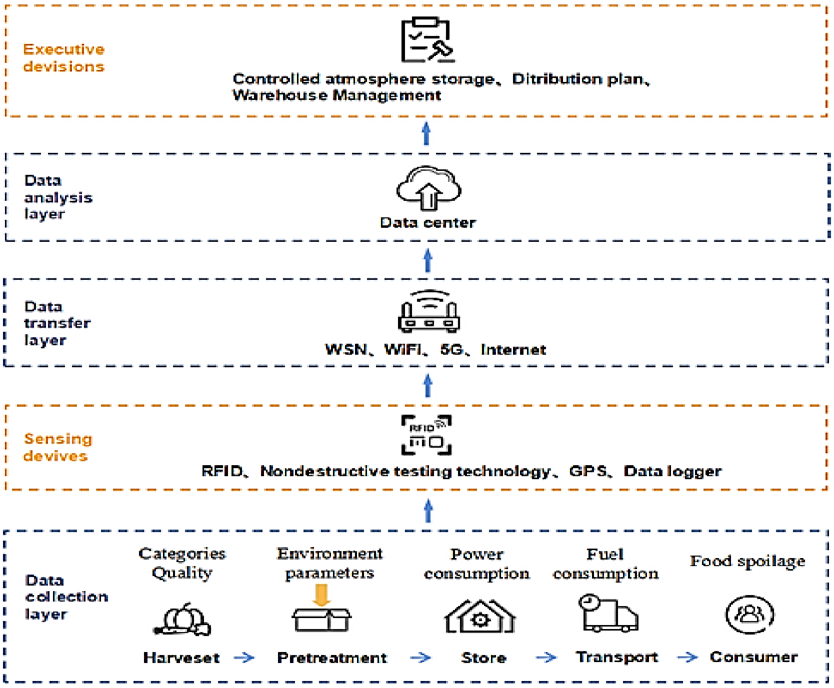

Fig 4. Cold Chain Architecture for Smart Energy Management

The use of AI and the IoT facilitates the identification of both external and internal quality attributes o agricultural goods, such as the absence or presence of hardness, soluble solids, diseases, and other relevant characteristics. This technological integration empowers farmers to optimize their harvests and produce higher quality food items. Simultaneously, it has the capability to precisely assess the real-time overall energy consumption rate of the supply chain, hence enabling better informed and perhaps completely automated decisions at every phase of the cold chain in food production. The achievement of precise identification of all operational parameters is facilitated by the use of a strategy that relies on optimum control algorithms, in combination with advanced technologies such as time-delayed neural networks and image recognition. Ultimately, the integrated refrigeration system's capacity modification enables the attainment of constant supply cooling for end equipment, optimization of airflow organization, and reduction in refrigeration energy consumption.

Big Data

The potential uses of big data technologies surpass those of traditional data management systems in terms of breadth and scope. The extent of data correlation is included by structured information with a certain range. The ability to store huge quantities of unstructured and structured data, analyze it in real-time, and iteratively improve algorithm models using real-time data are all indicative of this emerging trend. **Fig. 5** illustrates a conventional architectural framework for big data technologies.

Big Data Processing

The primary driving energy behind the improvement of huge data technology is the aspiration to get significant value from vast amounts of data. One of the primary challenges faced by big data systems is the efficient processing of large quantities of information within a small period of time. The use of big data real-time processing technologies becomes imperative during periods of peak system usage, whereby there exists a substantial influx of online data processing requests, perhaps numbering in the hundreds of thousands or even millions per second. The processing of large data encompasses three essential types: comprehensive processing for image data, on-time processing of digital data, and static data batch processing.

The process of accumulating static data refers to the constant collection of corporate data resources, resulting in the storing of data in a fixed format on storage media. The correctness of the data is commendable; nevertheless, the value density is suboptimal because of the substantial capacity of static data, which may vary from terabytes to petabytes. In addition, the processing of static data exhibits a prolonged duration, while the absence of user-system interaction functions further limits the system's capabilities. The use of batch processing of static data may be advantageous in several domains, such as behavior analysis within cost and efficiency, social networks, and product recommendations in e-commerce evaluation with social service sectors.

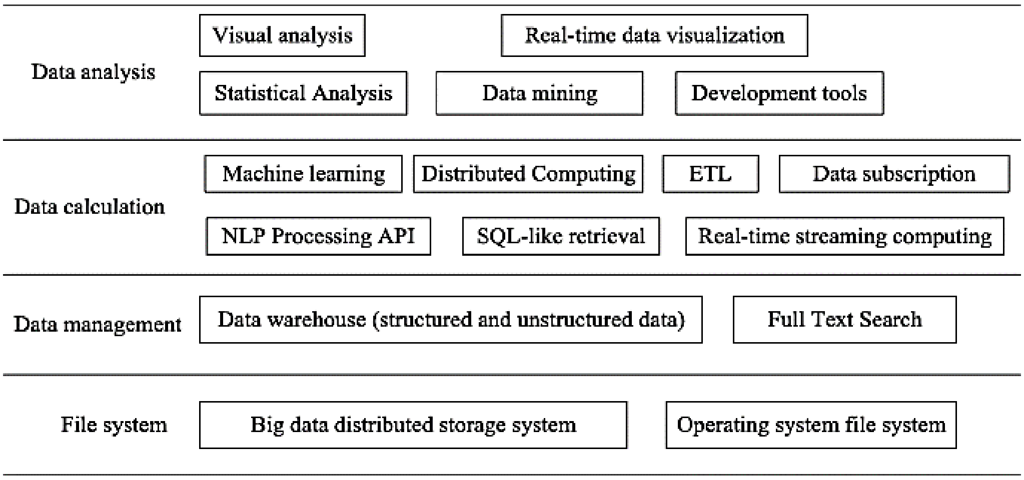

Fig 5. The Architecture of Big Data

The computer architecture known as MapReduce, which was created and popularized by Google, is very important to the efficient processing of static information in batch operations. The system has exceptional proficiency in parallelizing and expanding the processing capabilities of huge volumes of data. The application programming interface (API) is characterized by its simplicity and user-friendly nature. By using cost-effective X86 servers, it is possible to build a scalable big data framework that is both user-friendly and equipped with strong input/output capabilities. The process of decomposition, which is launched by the Map function, is afterwards followed by the combination of results, initiated by the Reduce function, in the MapReduce framework. The system has the capability to partition large datasets into smaller segments and distribute them over many servers for concurrent processing. After undergoing processing, they are then aggregated. The present data processing methodology exhibits a high degree of scalability and availability, hence leading to a substantial enhancement in processing velocity.

Big Data Analysis

Big data analysis is utilized to undertake thorough examinations of information in order to identify valuable connections, trends, and patterns, with the aim of constructing decision-making models and offering prediction assistance approaches and ways. The ways of analyzing big data involves the use of suitable statistical analytic methods and tools. These techniques and tools are employed in conducting cause analysis, status quo analysis, and quantitative prediction analysis of the acquired data. Prior to engaging in data analysis activities, it is necessary to create clearly stated objectives and assumptions. These assumptions should be subjected to rigorous testing using various analytical techniques such as comparison, grouping, crossing, and regression analysis. Subsequently, the obtained findings should be carefully interpreted, leading to the formulation of conclusions based on the data.

V. DISCUSSION AND CHALLENGES

The majority of scholarly research on Technologies 4.0, with a particular focus on IoT and Blockchain, consists of applications, case studies, technological advancements, proofs of concept, and literature reviews. The following examples illustrate the application of Blockchain and IoT technologies in the agri-food segment during the last three years, showcasing various use cases and proofs of concept. In order to ascertain the safety of food for consumption, George, Harsh, Ray, and Babu [6] prose a prototype that gathers information from several holders in the entire food supply chains and then employs the Food Quality Index (FQI) technique.

In their study, Liang, Cao, Fan, Zhu, and Dai [7] use a practical implementation inside the cow supply chain, whereby they leverage SMS, texts, and a concise one-minute video to provide comprehensive information on the provenance of beef. Kumar and Kumar Singh [8] conducted a study to evaluate the effectiveness, flexibility, responsiveness, agri-food supply chains transparency, and food quality. Hafez and Attia [9] analyzed three specific real-life situations involving the supply chains of chicken meat, lemons, and oranges. Furthermore, Bumblauskas, Mann, Dugan, and Rittmer [10] conducted a study to explore the possible use of technology of blockchain in monitoring the eggs journey from the farm to the end consumers in significant markets. The study aimed to engagement and collect traceability information across different stages of the cold chain.

To protect the integrity of the vast volumes of immutable agricultural data, Hang, Ullah, and Kim [11] devised a system tailored to cater to the requirements of fish farmers. The use of a smart contract based on HyperLedger Fabric technology facilitates the automation of many processes within fish farming operations, therefore mitigating the occurrence of human errors and minimizing the potential for manipulation. In order to enhance the security of agricultural sample data inside the IoT network, Ren, Wan, and Gan [12] propose the use of a Double Blockchain (Ethereum) approach that relies on IPFS storage. In their study, Dey and Shekhawat [13] use statistical analysis to investigate the advantages of blockchain in sustainable e-agriculture context, as well as the possible uses and challenges associated with its implementation.

In this study, Nasiri, Ukko, Saunila, and Rantala [14] examine the many uses of technology inside supply chains, while also shedding light on the benefits and limitations associated with its implementation. By establishing connections among all stakeholders involved in the supply chain, including those in the upstream and downstream sectors, the IoT has the potential to gather significant and important information pertaining to their particular businesses. The increasing popularity of computers in recent years may be attributed to advancements in hardware, networks, and AI technology.

Fan and Gao [15] conducted an exploratory study to examine the modern cold chain system and its security concerns, focusing on the utilization of advanced IT such as the IoT and Blockchain. In a similar vein, Donthu, Kumar, Mukherjee, Pandey, and Lim [16] performed a bibliometric assessment to investigate the progress and evolution of literature evaluation on the IoT within the domain of supply chain management and logistics. The study conducted by Shafique, Rashid, Bajwa, Kazmi, Khurshid, and Tahir [17] examined and assessed many concepts like energy consumption behavior, IoT capabilities, green practices, and supply chain integration. The use of artificial intelligence in the better cold chain surpasses that of traditional cold chain logistics owing to its notable advantages such as reduced energy consumption, enhanced product quality, and heightened operational efficiency. AI plays a crucial role as a technical facilitator in the integrated design of energy consumption for agricultural cold chain systems, as well as in the coordination of control mechanisms across several nodes within the cold chain network. The system effectively incorporates the communication and display of cold chain information, as well as intelligent modification and automation.

The use of artificial intelligence with the better cold chain has a multitude of potential advantages, although it also encounters substantial challenges that must be addressed. The cold chain is increasingly acquiring data pertaining to operating parameters and energy use. In order to effectively tackle this issue, it is essential to use artificial intelligence systems that possess enhanced processing capabilities. In order to maximize cold chain management solutions without compromising the quality or efficiency of the supply chain, AI is required to pursue optimum solutions across several goals, including but not limited to efficiency of agricultural, energy consumption, and quality of goods. The integration of artificial intelligence and cloud computing, with low-power sensors, information detection technology and other outcoming technologies, is believed to significantly enhance the practical implementation of the IoT.

There is a forthcoming development in the field of cold chain systems for agricultural commodities that promises enhanced intelligence, energy efficiency, and visual aesthetics. The future of cold chains is expected to transition from manual administration to intelligent management, including the monitoring of a diverse range of parameters concurrently, as opposed to only monitoring a single parameter. The optimization of cold chain energy use not only enhances efficiency but also ensures that all phases of agricultural commodities distribution, spanning from production to consumption, take place within a controlled environment that is crucial for maintaining their quality.

The degradation of products is influenced by several factors such as temperature, humidity, and light. Consequently, cold chain logistics for commodities need strict adherence to certain temperature, humidity, and lighting requirements throughout the distribution process. Nevertheless, the objective of reducing product loss may be achieved by implementing a temperature, humidity, and light sensor inside the cold chain truck by the logistics firm. This sensor would transmit data to a distant service center, where it can be analyzed in conjunction with previous data. Furthermore, the terminal of the distribution vehicle establishes a connection with the server of the strategies enterprise through the telephone communication system in order to facilitate the transmission and reception of information data.

This enables the strategies enterprise or the personnel responsible for management of fleet to conveniently access GPS and other pertinent actual data, like the vehicle's current direction of travel and the duration of its journey. The availability of data pertaining to factors such as driver braking times, unloading conditions, product loading and driver acceleration times confers significant advantages upon carriers and shippers. This data enables them to actively monitor the progress of a shipment in real-time, ascertain the parties accountable for any issues that may arise, and ensure the secure release of the cold chain vehicle. This document provides guidelines aimed at reducing the wastage of produced items.

In the contemporary era of big data, companies operating within the logistics business are relieved of the burden of assuring the effectiveness and precision of their information analysis processes. The use of huge data technology enables managers to effectively address any challenges that may occur. By using efficient and expedient responses derived from data analysis approaches, the system showcases the advantageous outcomes of precise data in the realm of supply chain strategies. The aspect of timeliness is of significant importance within the context of supply chain strategies. The expenses and uncertainties associated with logistics enterprises are anticipated to increase to a certain extent due to the more specialized nature of the goods involved and their susceptibility to significant seasonal fluctuations.

Through the examination of available data, the use of big data technologies has the potential to assist logistics enterprises in optimizing their reactions to both internal and external challenges, as well as enhancing their marketing tactics. Furthermore, logistics enterprises have the capability to determine the progress of deliveries in on-time and make necessary operational adjustments accordingly. In order to optimize operational efficiency and cost-effectiveness, organizations may achieve a reduction in breakdown occurrences, streamline distribution routes, and achieve financial savings by collecting data tailored to their individual needs. This data may include information on transportation routes, management practices, maintenance charges, and other relevant factors.

VI. CONCLUSION

The faster growth of supply chain strategies has been enabled by the improvement of technologies, namely in response to the current surge in the use of cloud computing, big data, and IoT. The advent of the Internet of Things has led to the widespread use of the term "Big Data" within the supply chain strategies industry, generating significant interest in its possible applications. The collection and analysis of big data have the potential to provide advancements in supply chain strategies operations, energy efficiency, and resource allocation. This trend aligns with the emergence of the green ecological economy. In this research, we will delineate the characteristics linked with the application of AI in order to effectively tackle the issue of excessive power consumption within the agricultural supply chain. (i) artificial intelligence employs a sustainable and multi-scale technique to tackle the geographical, supply-demand, and temporal disparities in supply chain energy usage. (ii), the integration of artificial intelligence-based technology in the better supply chain has the potential to facilitate the reverse prediction of forthcoming trends and patterns across different stages of the cold chain, while also reducing total energy consumption. The adoption of an intelligent supply chain management system enables the achievement of intelligent energy management within the better supply chain, facilitated by the use of AI.

CRediT Author Statement

The authors confirm contribution to the paper as follows:
Conceptualization: Ting Li and Wan Fang; **Methodology:** Ting Li and Wan Fang; **Software:** Ting Li; **Data Curation:** Wan Fang; **Writing-Original Draft Preparation:** Ting Li; **Validation:** Ting Li and Wan Fang; **Writing- Reviewing and Editing:** Ting Li and Wan Fang; All authors reviewed the results and approved the final version of the manuscript.

Data Availability

The datasets generated during the current study are available from the corresponding author upon reasonable request.

Conflicts of Interests

The authors declare that they have no conflicts of interest regarding the publication of this paper.

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Competing Interests

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