Exploration of the Application of Internet of Things Technology in Real-time Monitoring of Cold Chain Logistics

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Abstract: The Internet of Things technology provides a comprehensive solution for the real-time monitoring of cold chain logistics by integrating sensors, wireless communication, cloud computing, and big data analysis. Based on this, this paper deeply explores the overview and characteristics of the Internet of Things technology, the feasibility analysis of the Internet of Things technology in the cold chain logistics monitoring, the application analysis of the Internet of Things technology in the cold chain logistics real-time monitoring to better improve the management level and operational efficiency of the cold chain logistics, to provide consumers with safer and fresh products.

Keywords: Internet of Things technology; Cold chain logistics; Real-time monitoring

1. Introduction

With reform and innovation as the fundamental driving force, and with the fundamental purpose of meeting the people's ever-growing needs for a better life, it strives to improve the cold chain transport infrastructure, upgrade the level of technology and equipment, innovate the transport service model, improve the cold chain transport supervision system, and promote the smooth, efficient, intelligent, convenient, safe and standardized development of cold chain transport. To provide strong support for ensuring the safety of food circulation, reducing waste in food circulation, promoting consumption upgrading, cultivating new growth points, and building a new development pattern. In combination with the construction of the national cold chain logistics backbone channel network, relying on the advantageous production areas of agricultural products, important distribution centers and major sales areas of freight hubs, major ports, railway logistics bases, hub airports, coordinate the planning and layout of cold chain logistics infrastructure, and promote the special railway lines into logistics parks and ports. Improve the cold-chain transport service functions such as trunk and branch connection, regional distribution,

warehousing, and distribution, and enhance the cold-chain transport support and guarantee capacity [1]. Colleges and universities should follow the national policy documents and follow the path that suits the country's development, to better promote the cultivation of talents.

2. Overview and characteristics of Internet of Things technology

Based on Internet technology, the Internet of Things realizes the information transmission and interaction between things and things, things and people through the connection of various devices and the Internet, to promote the transformation of various industries in the direction of intelligence and automation [2]. According to the China Cold Chain Logistics Development Report (2024 edition), the total demand for cold chain logistics in 2023 is about 350 million tons, up 6.1 percent year on year [3]. In the face of the increasing demand for cold chain logistics, a comprehensive and multi-level logistics management system can be built by properly utilizing the advantages of Internet of Things technology [4].

The Internet of Things technology has the characteristics of real-time data processing, which can greatly improve the agility and flexibility of the Internet of Things system. IoT devices can obtain environmental data in real time, find problems, and respond in time. Most of the IoT systems are highly distributed network architectures, composed of a variety of devices and nodes, so they have strong flexibility and scalability. Users can add and remove devices at any time according to demand, to avoid affecting the overall system operation. In addition, most of the Internet of Things devices need to operate in a low-power environment, LoRa and NB-IoT (narrowband Internet of Things) and other communication protocols are designed for low-power Internet of Things devices, which can ensure the reliability of data transmission at the same time, extend the battery life of the equipment, and lay a solid foundation for the all-weather monitoring and management of cold chain logistics.

3. Feasibility analysis of Internet of Things technology in cold chain logistics monitoring

3.1. Economic feasibility

From a technical point of view, sensor technology needs to invest a certain amount of capital in the early development of enterprises, but as these technologies mature and are applied to the production process, the cost will gradually reduce. For example, with the development of Internet of Things technology, the price of RFID tags continues to decline, which will enable most factories can use the equipment to better save goods, reduce costs, and better meet the needs of consumers [5]. From the point of view of operating costs, the application of Internet of Things technology can detect changes in temperature and humidity in real time, so that enterprises can adjust transportation conditions and storage conditions in time, reduce the deterioration of products caused by temperature problems, that is, reduce the cost of decay. From the perspective of efficiency improvement, the Internet of Things technology can be optimized in production, distribution, warehousing, and sales [6]. For example, in the sales link, the Internet of Things technology can track the whole process of the product to provide consumers with safer products. In terms of social benefits, the Internet of Things technology can reduce energy consumption by optimizing transportation routes. For example, transportation personnel can optimize the entire transportation route through the Internet of Things technology to ensure transportation safety and reduce energy consumption.

3.2. Technical feasibility

Production personnel can realize real-time detection of cold chain products and environmental parameters through various sensors such as temperature sensors, humidity sensors, optical fiber sensors, etc., to better ensure the freshness of products [7]. For example, Sensirion SHT35 is a high-performance digital temperature and humidity sensor, because it not only has the characteristics of high precision, but also the characteristics of long-term stability, and is very suitable for use in cold chain logistics monitoring systems [8]. Production personnel can also use wireless communication, satellite communication, and other technologies to achieve remote data transmission and real-time sharing. For example, production personnel can realize the connection of NB-IoT external network through NB-IoT dual network gateway, to better ensure the transmission of equipment in low power consumption, so that cold chain personnel can timely know the product location, temperature, humidity and other information, provide intelligent scheduling solutions for logistics enterprises, improve logistics efficiency; Production personnel can also comprehensively process the data through cloud computing technology to make better decisions. For example, production personnel can predict the future market demand and transportation situation through the content of historical data, to provide a certain reference and reference for the planning of cold chain logistics.

4. Application analysis of Internet of Things technology in real-time monitoring of cold chain logistics

4.1. Procurement link

Procurement personnel in the traditional procurement of goods will invest a lot of time and resources in the market research, which will not only waste a certain amount of energy, but also may cause a certain waste of resources, increasing the procurement cost [9]. In this context, the introduction of Internet of Things technology has brought certain changes to the procurement process. For example: In the process of purchasing fresh agricultural products, the procurement staff can detect and record the temperature, humidity and other key indicators of agricultural products in real time through the Internet of Things equipment, upload it to the central management system for in-depth analysis, and generate an RFID electronic tag (electronic product code, product information) for each product. This makes the purchaser only need to quickly scan the electronic tag through the reader, and they can instantly obtain the detailed information of the item, which greatly improves the procurement efficiency. Cold chain logistics requires strict monitoring of environmental parameters such as temperature and humidity during transportation to ensure that the quality of fruit is not affected. In this case, the procurement staff can use the LSTM-AD (Long Short Term Memory network anomaly Detection), which can predict the temperature in the future 30 minutes, in addition to the 3σ criterion, which means that the deviation of > 2 °C for less than 5 minutes will trigger an alert. In this way, not only do purchasers not need to constantly monitor the changes of environmental parameters during transportation, but they can also timely understand the temperature changes, to take corresponding measures to ensure the safety and quality of purchased agricultural products [10]. The application of Internet of Things technology in the procurement process not only simplifies the traditional procurement process, reduces the cost of labor and time, but also improves the accuracy and efficiency of procurement decisions through intelligent means, laying a solid foundation for the stable operation and continuous optimization of the supply chain [11].

4.2. Production link

Cold chain logistics plays a key role in ensuring product quality and safety in the production of sensitive products

such as food and medicine [12]. Enterprises can better understand the temperature change in the production environment by arranging the humidity sensor network within the production range. Once the temperature or humidity is detected to deviate from the preset safety threshold, the sensor will immediately launch an alarm, so that the production management personnel can quickly come to the environment to adjust the environmental parameters, so that the production temperature is maintained at the best temperature [13]. To avoid product problems caused by environmental problems. The Internet of Things technology can also remotely monitor and evaluate key production equipment, such as packaging equipment and freezing equipment, to develop scientific and reasonable plans for the maintenance of equipment, to better extend the service life of equipment, and reduce operating costs. In addition, the Internet of Things technology will be affixed to each commodity "RFID tag," which is mainly the raw materials into the warehouse to the finished product out of the warehouse for each step of recording, once the product quality problems, only need to use big data technology that can find the production batch problems, or processing problems or equipment problems. It can be seen that the application of the Internet of Things in the cold chain food production can not only shorten the processing cycle of the product, but also optimize the production steps, to better improve the quality of the product.

4.3. Warehouse management

Warehousing can be better managed through the use of Internet of Things technology [14]. Enterprise personnel can use the Internet of Things technology to collect data such as humidity and equipment operating status in the storage environment in real time, and build a transportation node topology diagram, taking the shelves in the storage, transportation equipment, product storage location, etc., as nodes, and the correlation between devices and product flow path as sides to form a dynamic knowledge graph. Among them, the enterprise personnel can conduct in-depth analysis of the contents of the topology diagram through the GNN model, to better detect the abnormal situation of regional temperature and the fault situation caused by the equipment, as well as the abnormal nodes and their influence scope, and synchronize the content to the enterprise personnel, so that they can quickly formulate the corresponding strategy. Each commodity will be tagged with an RFID tag when it is stored in the warehouse to transmit the location change and environmental data of the product in real time, to provide certain support for warehouse managers to better understand the inventory. Through the deep integration of the Internet of Things technology with the automatic control system, it not only realizes the whole process automation from warehousing, storage, and sorting to warehousing, but also improves the efficiency and accuracy of warehousing operations, reduces the burden of labor, and reduces the cost of operation.

4.4. Transportation management

Cold chain logistics enterprises can learn in real time which road is more congested and which road has certain emergencies through the navigation content of AutoNavi or HERE Map API, to re-plan the path, find the cold chain post station with charging pile as a passing point, and ensure that transport vehicles can quickly adjust the route when encountering road conditions changes. And can timely supplement the electricity required by the cold chain equipment and the production environment electricity required by the goods. For example, the use of this technology in the transportation of fruits not only reduces the mileage by 12%, but also reduces the fuel consumption of cold storage by 8%, to better achieve the reduction of transportation efficiency and transportation costs. In the cold chain logistics, transport link can also be through the genetic algorithm (GA), that is, to minimize energy consumption cost () as the fitness function. The Pareto optimal solution balances aging and refrigerated

power consumption, to real-time collection of vehicle location, cargo temperature, humidity, and environmental data, both to ensure the freshness of goods, but also can effectively control the operating costs [15]. For example, in the process of transporting drugs, transportation personnel can see the consumption of electricity in real time, to find a road suitable for their own, better supply of electricity, and transport products. The combination of these two ways can not only better plan the line, but also better ensure the temperature and humidity of transportation, to shorten the transportation time, reduce logistics costs, and better optimize the entire transportation management process.

5. Conclusion

The application of Internet of Things technology in real-time monitoring of cold chain logistics marks an important step in the transformation of the cold chain logistics industry to intelligence and information. With the continuous progress of Internet of Things technology and the continuous development of application scenarios, the cold chain logistics industry will usher in a broader space for development. Therefore, the training of talents in colleges and universities should be constantly changed according to the needs of the market, to better promote the all-around development of students. This study, from the procurement link, production link, storage management, and transportation management carried out to better provide a certain reference for the relevant researchers and scholars.

Disclosure statement

The authors declare no conflict of interest.

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