Intelligent Food Cold Chain System Design

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Abstract. This paper proposes a design scheme of intelligent food cold chain system. Firstly, the functional structure of the system is defined based on the requirement of different subjects participating in the system. Then the system is designed from the technical perspective by introducing intelligent logistics support technology. Different from the existing food cold chain system, the system proposed in this paper is relatively macro, not specific to food categories; and it focuses on the whole process of the cold chain, instead of only considering some parts.

1. Introduction
Food cold chain system is a special supply chain system. On the one hand, its object is fresh food which is easy to rot and deteriorate; on the other hand, the whole process of operations must be in a suitable low temperature environment.

Because of its importance, food cold chain has attracted many scholars' attention. Some researches focus on the cold chain logistics of a certain kind of food, such as the cold chain of fresh fruits and vegetables or meat logistics [1,2]; some scholars only focus on several links of the cold chain logistics of food, mainly studying the temperature control problems in these links [3,4]. This paper is dedicated to building a food cold chain system, focusing on the whole process of cold chain, not for specific food categories.

The effect and efficiency of food cold chain system cannot be separated from the support of technology. Building intelligent cold chain logistics system by integrating food cold chain logistics and new technologies such as internet of things and big data, is helpful to solve the pain points of enterprise development and break through the bottleneck of development. Constructing food cold chain information sharing platform and product traceability system are also conducive to the supervision and guidance of regulatory authorities, and helps to protect the rights and interests of consumers.

The second part of this paper carries out the system requirement analysis and functional structure design from the overall perspective, and analyses the requirement of each subject participating in the system which also means the overall functions of the system to achieve. The third part builds the intelligent food cold chain system based on M2M framework and the characteristics of food cold chain.

2. System Requirement Analysis and Functional Structure Design
The construction of intelligent food cold chain system needs the joint efforts of all subjects including the government, industry associations, relevant enterprises and consumers. It is impossible to succeed on either side alone. In this system, different subjects have different roles, so they have different service needs. From another point of view, these needs also constitute the responsibilities of different subjects. Therefore, it is necessary to carry out requirement analysis before building the system.
2.1. System Requirement Analysis

This section analyzes the functional requirements that the system needs to meet from the perspectives of government regulatory departments, industry associations, relevant enterprises and consumers.

**Government Regulators.** As a regulatory authority, the government participates in the system in order to promote the standardization of food cold chain. Its authority should be higher than that of all enterprises and consumers. In order to create a safe food environment, the intelligent food cold chain system must be able to carry out visual traceability throughout the whole process, ensuring that government supervision departments can query any enterprise and any batch of food information at any time in the whole process of food circulation. As a result, government can timely correct the existing problems in the circulation process, and change ex post control into ex-ante control. This will minimize unnecessary losses. In addition, the government regulators also need to feedback the results of each query to the system. This will generate benefit in two ways: on the one hand, it helps to keep records for regular analysis and summary; on the other hand, in the form of publicity and information transparency, the restraint and deterrent effect on relevant enterprises is stronger, which is conducive to promoting healthy competition and cooperation among enterprises.

**Industry Associations.** As the highest-level regulator, the government needs to pay attention to the situation of all kinds of enterprises in the whole chain, covering a wide range of areas, which means they cannot go deep enough in one specific industry. Industry associations make up for this shortcoming. Each industry association focus more on the relevant enterprises in their industry. Through this system, they can understand the operation status of enterprises in the industry and push the enterprises to implement the relevant national laws and regulations as well as the industry standards. The functional requirements of industry associations and government regulators are similar, which can query and feedback the query results to the system.

**Relevant Enterprises.** Relevant enterprises mainly include food raw material suppliers (including farmers), production and processing enterprises, wholesale and retail enterprises, cold chain logistics enterprises. As the main provider of information, they are an important part of the system. First of all, the intelligent food cold chain system must be able to collect, transmit and manage data in every part. Then they upload data in time, realizing information sharing within enterprises as well as between upstream and downstream of supply chain. In each key site, enterprises should set the temperature and humidity range in accordance with the relevant standards. When the parameters are close to the threshold, the related systems can send out early warning, and automatically control the relevant equipment for intelligent adjustment. Once the parameters exceed the self-processing ability of the system, the alarm mechanism will be triggered. Then the relevant staff will be notified to take action. The system should also pay attention to the links between enterprises to ensure that no information about food handover is omitted. What’s more, responsibilities can be quickly identified in case of problems.

**Consumers.** For consumers, the system needs to provide full visual traceability function, for example, which supplier the food raw materials come from, how to process, storage status, whether the whole process is strictly operated in accordance with the regulations, whether there has been a broken chain situation when the temperature exceeds the prescribed range, and so on.

In terms of inquiry methods and ways, we should try our best to be diversified, intuitive and convenient. The introduction of website inquiries, mobile phone applications, etc., can facilitate the vast number of consumers to inquire. Taking into account the low penetration rate of the network among the elderly, in order to meet the query needs of these consumers, video information inquiry terminals can be installed at various retail terminals and equipped with corresponding auxiliary personnel. In order to be more intuitive, the system should display the whole process in the form of video clips, and supplement the information of time, site, relevant enterprises, environmental temperature and humidity with subtitles. The system should also give consumers the right to feedback. Once the violation is found, the consumers can upload it to the information system, and the relevant enterprises will be punished after the verification by the government regulators. In order to avoid the phenomenon that consumers maliciously smear enterprises or enterprises retaliate against consumers, this kind of feedback mechanism of consumers had better adopt the form of real-name report and anonymous publicity.
2.2. Functional Structure of Intelligent Food Cold Chain System

Based on the functional requirements of government regulators, industry associations, related enterprises and consumers, we construct the functional structure of the intelligent logistics system of food cold chain as shown in Figure 1.

**Food Production and Processing Management System.** Real-time collection of relevant information of food production and processing enterprises, covering the relevant information of raw material supply, the transfer information between raw material suppliers (or farmers) and production and processing enterprises, and the processing information of production and processing enterprises. Once the collection is complete, the information needs to be uploaded to the Enterprise Information Collection and Monitoring System after collection.

**Food Storage Management System.** Real-time collection of food warehousing related information, including the transfer information from production and processing to warehouse, warehouse location, storage temperature and humidity information at different time nodes. Once the collection is complete, the information needs to be uploaded to the Enterprise Information Collection and Monitoring System after collection.

**Food Transportation Management System.** Real-time collection of food transportation and distribution related information, covering the transfer information from storage to transportation, GPS positioning in the transport process, transportation routes, temperature and humidity information at different time nodes. Once the collection is complete, the information needs to be uploaded to the Enterprise Information Collection and Monitoring System after collection.

**Food Sale Management System.** Real-time collection of the transfer information from food transportation and distribution to the point of sale, temperature and humidity information at the point of sale. Once the collection is complete, the information needs to be uploaded to the Enterprise Information Collection and Monitoring System after collection.

**Enterprise Information Collection and Monitoring System.** Each subsystem uploads the information to the system. The system analyzes temperature and humidity parameters. If it approaches the threshold, it will issue an early warning to the corresponding subsystem, and the latter automatically controls the relevant equipment to make adjustment. Once the parameters exceed the self-processing ability of the subsystems, the alarm mechanism of the monitoring system will be triggered, and the relevant staff will be informed. The system uploads the collected information, early warning and alarm information to the central database of the intelligent system. At the same time, it collects feedback information from the government and consumers.

**Supervisory and Feedback System.** Through this system, government regulators and industry associations can inquire any enterprise and any batch of food information at any time. And the inquiry results are uploaded to the central database through this system.

**Query and Feedback System.** Consumers can obtain information from the central database through this system to realize food information traceability. In case of food spoilage, the system can also be fed back to the central database for verification by the relevant units. Consumers can also report the violations of relevant enterprises by their real names, which can be uploaded to the central database and verified by the government regulatory department or industry association. If true, relevant enterprises will be punished and published in the system.
3. Construction of the intelligent food cold chain system

3.1. M2M System
M2M is a networked application and service with intelligent interaction of machine terminals as its core. [5] By embedding wireless communication module inside the machine and using wireless communication as access means, M2M provides comprehensive information solutions to meet the information needs of monitoring, command and dispatch.

From the common application forms, M2M is mainly based on two "end" connected applications: "terminal" devices and "cloud" applications, "end-to-end" M2M system solutions, that is, enterprise assets are connected by M2M devices or modules through wireless or wired communication to centralized management application platform. On the one hand, all kinds of state information of enterprise assets (machines, tools, consumables, etc.) are collected and transmitted to the management application platform; on the other hand, the management application platform can also issue operation instructions to control the corresponding machinery and equipment.

3.2. Perception Layer Design
The function of the perception layer is "perception", which is to obtain environmental information through the sensor network. Perception layer is the key part of information acquisition. The technologies involved in this system include radio frequency identification technology (RFID), wireless multimedia sensor network technology (WMSN), global positioning system (GPS), and geographic information system (GIS), block chain technology.

Food raw material suppliers use RFID to encode raw materials, record raw material production date and suppliers (or farmers) information, and take pre-cooling measures. [6] In the raw material procurement process, the production and processing enterprises read the information in the RFID tags. In order to ensure the authenticity and reliability of information, block chain technology is used.

In the process of production, WMSN and RFID technology are used to record the progress of production and every step of operators. At the same time, the temperature and humidity of the surrounding environment are also detected and recorded. After product processing is completed,
processors' information, processing date, storage conditions and other contents are added to the RFID. The corresponding audio and video technology can provide more intuitive information for the public.

The storage time of products is a key information. Once confused, some products may expire. When design the system, managers set the basic information of product storage, including storage time, product quantity, storage location and so on, to automatic record. In addition, WMSN and RFID technology are used to record the temperature and humidity of storage environment at different time points in the form of data, audio and video.

In the whole process of food cold chain, the product discharging, loading and unloading is the most likely point to break the chain, so temperature and humidity monitoring is important. In addition, vehicle driving information should be obtained for path analysis and optimization.

In the aspect of temperature and humidity information acquisition, WMSN is used combined with RFID. The former identifies the target object and forms a wireless sensor network. The latter identifies the specific node information accurately and integrates the advantages of the two to better monitor temperature and humidity information.

In the aspect of vehicle driving information, GPS and GIS are used together. GPS can accurately report the specific position, running status and driving speed of vehicles at different time points. According to the longitude and latitude data of the vehicle location, GIS can mark the vehicle on the electronic map to realize real-time monitoring of the vehicle.

In the unloading process, the staff of the sales point should check whether the temperature, humidity and food temperature of the refrigerated transport car are up to the standard, and check whether the product information of the food is correct. When confirming that there is no mistake in starting the handover, the staff should record the temperature and time of handover, so as to make clear which party is responsible for the subsequent problems.

Finally, before putting food into the refrigerator of the point of sale, it is necessary to add QR code on the packaging, so as to facilitate consumers to inquire the product information.

3.3. Network Layer Design
The function of network layer is transmission, that is, information transmission through communication network. In the whole food cold chain, the nodes used to obtain information can be divided into fixed nodes and mobile nodes. Fixed nodes include processing workshops, storage refrigerators, etc. Mobile nodes are mainly refrigerated transport vehicles. Information needs to be transmitted between nodes and back-end servers, so when designing the network layer, we should combine wired network with wireless network. Fixed node should adopt wired network, which has fast and stable transmission speed; mobile node should adopt wireless network to solve the problem of inconvenient wiring of mobile node.

3.4. Application Layer Design
The function of application layer is processing and feedback. By calculating and processing the data collected by perception layer, the real-time control, accurate management and scientific decision-making of the physical world are realized. Through the analysis of the collected temperature and humidity parameters, if the threshold is approaching, the corresponding subsystem will receive an early warning, and then automatically controls the relevant equipment for intelligent adjustment. Once the parameters exceed the standard and exceed the self-processing ability of the subsystem, the alarm mechanism of the monitoring system is triggered, and the relevant staff are notified to take measures. According to the early warning and alarm information, government supervision feedback information, consumer feedback information, etc., the performance of the corresponding company is evaluated, and the next management focus is determined.
3.5. General design of intelligent food cold chain system

![Intelligent food cold chain system diagram]

4. Summary
With the vigorous development of economy and the rapid progress of science and technology, people's requirements for the quality of life are constantly improving. The increasingly prominent problem of food safety promotes the demand for both quantity and quality of food cold chain system. In order to improve the food cold chain, this paper introduces the related concepts and technologies of intelligent logistics to build a more advanced, efficient and reliable food cold chain system.

The main work of this paper is summarized as follows:
1. From the perspective of government regulator, industry associations, related enterprises and consumers, this paper analyzes the functional requirements of the system, and defines the overall functional objectives of the system and the responsibilities of each subject.
2. Based on the classical M2M system and combined with the specific characteristics of food cold chain, the framework of intelligent food cold chain system is given from the technical point of view.

Due to the lack of professional knowledge and practical experience, there are inevitably omissions in this paper. It is hoped that more managerial and technical personnel will join in the study of the intelligent food cold chain system in the future to promote the development of both theory and practice, so that academic research can benefit the public.

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