Intelligent Control of Urban Fresh Agricultural Products Supply Chain using Big Data and Internet of Things

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Abstract

Aim to the problems among the supply chain of fresh agricultural products in China, such as difficult to sell and buy, frequent quality problems, and low logistics efficiency, this project focus on theses following key technologies: a top design for supply chain management and control of fresh agricultural products, Internet of Things (IoT) innovative design to supply chain management and control of fresh agricultural products, life cycle management of fresh agricultural products under big data environment, innovative service model of the urban supply chain of fresh agricultural products, cost control and revenue sharing for the urban supply chain of fresh agricultural products, and dynamic evolution and security control for the urban supply chain of fresh agricultural products.

Keywords. *City Public Service, Smart City, Supply Chain, Intelligent Management and Control, Fresh Agricultural Product*

I. INTRODUCTION

Up to March 2017, more than 500 cities (including 95% of vice-provincial cities and 83% of prefecture-level cities) in China have deterministically claimed to build a smart city in the government's plans. The development of intelligent cities constantly drives and innovates the chain of custody for food safety in cities. It is imperative to realize an intelligence-oriented leap of food safety supervision by virtue of massive data and intelligent means [1].

(1) To build a smart city, it is necessary first to solve the consumer node's food safety supervision to the agricultural and livestock bases. Various issues (outbreak of bovine spongiform encephalopathy and Avian influenza, illegal use of naphthalene red and melamine, and pesticide residue) are frequently reported, which indicates that China's food safety supervision system shows obvious drawbacks. The food safety supervision system is an important part of a smart city. The system is employed to reasonably supervise the food production, processing, and circulation process and effectively trace unqualified food. Thus, food safety accidents can be controlled and prevented, and food safety can be guaranteed to the maximum limit. The food safety supervision system has been extensively concerned by numerous scholars, and it is urgent to attain more effective research achievements [2].

(2) The intelligent control of the supply chain of fresh agricultural products (FAPs) is regarded as an important part of food safety supervision. With the development of social economy, improvement of human living standard, and acceleration of the pace of urban life, people increasingly concern their health and food quality; various natural FAPs that are less processed are increasingly popular; people show a higher demand for natural FAPs, more requirements on types, more care on the delivery rate and more attention on food safety. In the circulation process of FAPs, it is essential to use the least circulation links to deliver FAPs to consumers in the shortest time. The quality of the FAPs needs to stabilize or enhance the circulation process. It is possible to comprehensively lower the logistics cost by controlling and reducing the coefficient of losses. Therefore, it is urgent to construct an intelligent control system for the traceable, networked, and efficient supply chain of FAPs having a full chain, meeting high standards, and operating in new modes [3]. The system is powered by institutional innovation, supported by advanced technologies and management means, and guaranteed by normative and effective supervision.

(3) The emerging technologies, such as the internet of things (IoT), create a new means of intelligent control for the supply chain of FAPs. The radio frequency identification (RFID) technology and electronic product code (EPC) standard in the IoT can effectively collect, transmit and process real-time information on processing, storage, transportation, delivery, and sale in the supply chain of FAPs [4]; based on big data, it is feasible to predict the demand for FAPs accurately, balance the plan of the supply chain of FAPs and trace the quality of FAPs; the intelligent control cloud platform for the supply chain can break the information isolation between enterprises in the supply chain of FAPs, thus

effectively improving the overall efficiency of the supply chain [5]. The emerging industries with sustainable and scale development will surely occur in the supply chain of FAPs by virtue of some emerging information technologies such as big data, IoT, and cloud computing.

II. LITERATURE REVIEW

China is a major country in producing and consuming FAPs. Due to various reasons such as numerous producers of FAPs, the small size of participants, and the underdeveloped market in the perfect competition environment, many problems frequently appear during the supply of FAPs. These problems mainly appear as co-existence of difficult purchase and sale of FAPs, frequent appearance of quality problems, and low logistics efficiency. Under the guidance of the objectives of accelerating agricultural modernization and building a well-off society in an all-round way, how to guarantee the effective supply of FAPs has been an urgent issue to be solved that restricts China's agricultural development, improvement of people's living standard, and even social harmony and stability.

A. Supply Chain Control using IoT

IoT contributes to new changes in the supply chain of FAPs. It is urgent to build a traceability and management system for FAPs, expecting to guarantee safety in the whole circulation process from the producing areas to the consumer node.

The European Union (E.U.) requires that all imported food be traceable: establishing a traceability system centered on beef products to enhance traceability information with the most advanced technology [6]. The United States requires that livestock wear the ear tag since birth to record the whole process's information from their birth to slaughter. Doing so is committed to realizing the traceability management of the whole supply chain of livestock products [7]. A relatively perfect traceability system of food has been constructed in Japan: a beef traceability system is built [8], and the Positive List System for Agricultural Chemical Residues in Foods provides a high reference standard for the limit of pesticides and feed additive residues in food [9]. Other countries also actively promote the food traceability system. For example, the livestock tracing system in Britain [10] and the livestock identification and traceability system in Australia [11] have been widely applied in the research into the traceability of various products such as livestock and fruits and vegetables [12].

The food traceability system in China has been built since the early 21st century. For example, it is stipulated in the Rules for Traceability of Exported Aquatic Products that it shall timely recall unqualified products; Methods for Livestock Identification and Culture Archives Management stipulates that all livestock shall wear ear tags for identification [13]. It is stipulated in the Food Safety Law of the People's Republic of China that the nation encourages producers and managers to collect information on food production and management with modern information technology to perfect the food traceability system [14]. In terms of the pilot project construction of the traceability system, the Shanghai information inquiry platform for edible agricultural products achieves the systematic management of the production process, information examination, and barcode recognition by using information technology and barcode technology [15]. The General Administration of Quality Supervision, Inspection, and Quarantine of the People's Republic of China has launched the barcode project, and some products hold their unique identity numbers [16].

B. Supply Chain Control under the Big Data Environment

The supply chain of FAPs driven by data can effectively improve the supply chain's operation efficiency, explore new profit sources in the whole supply chain, and strengthen the competitiveness of the supply chain [17].

In recent years, people have progressively proposed some prediction models for the supply chain demand based on artificial intelligence [18], such as the neural network model [19], particle swarm optimization [20], and support vector machine [21]. On this basis, some scholars put forward the multivariate prediction model [22]. Liu explored the prediction on the supply chain demand under the background of applying big data [23]; Wu theoretically investigated the supply chain demand management based on big data [24]. The models accurately analyze the correlation between the prediction result and the influencing factors, improving the overall prediction effect.

Wen constructed a cost control model for the purchase management system in enterprise resource planning using big data mining technology [25]. Cheng et al. proposed a framework for enterprise inventory management containing different modules (such as cloud accounting and big data analysis) [26]. Huang put forward several measures for reducing enterprise purchasing costs by using big data [27]. Roberto thought that the cost of searching and localizing a position and the structure of distribution networks would directly influence the delivery cost and efficiency [28]; Dubelar et al. suggested that the target costing should be paid more attention to [29]. Ma et al. explored the application modes of big data technology in cost control of the e-commerce supply chain [30].

At present, scholars in the world have progressively researched the control of the supply chain under the background of big data-based applications, such as the competitive intelligence, value creation of a supply chain, service innovation, active cooperation, financing, profit coordination,

risk management and performance management of a supply chain.

C. Supply Chain Control under the Cloud Platform

Xu et al. constructed a service cloud platform for the supply chain of agricultural machinery parts based on big data. By collecting and managing the information on the whole process concerning production, circulation, and after-sales service of agricultural machinery parts, the real-time management in the full life cycle and traceability of product quality of agricultural machinery parts are realized [31-32]. Tan et al. investigated the apparel supply chain's cooperative management system based on the cloud platform. They established a technical architecture of the Humen intelligent cloud storage platform [33-34]. Li and Xing reconstructed a beer supply chain's business with the powerful function of the Zhongding Logistics Park cloud platform, thus improving efficiency [35-36]. We explored the evolutionary game of information of a Supply-Hub supply chain based on the cloud platform [37-38]; Pan surveyed cooperation technology of multiple supply chains based on the cloud platform [39]; Zhang explored the modeling of a dynamic supply chain based on the cloud platform [40].

D. Research review

According to existing general knowledge, the following problems are urgent to be solved in controlling the supply chain of FAPs.

(1) Absence of top-level design: Two levels are contained: the general operation mode of a supply chain and the supply chain's structure and operation command system in the mode.

(2) Lacking integrated management: Various links in the supply chain of FAPs are incoherent, and effective value-added activities and profit-sharing system have not been formed.

(3) Absence of adaptability: An adaptive supply chain can learn from the environment and utilize the changing environment, which is significant for constructing and managing an advanced supply chain.

(4) Absence of compatibility: The information of various systems cannot be shared, and no unified application system and national database are built, so it is hard to be compatible.

III. RESEARCH PROPOSALS

A. Research objectives

The following problems exist in the supply of FAPs in China: it is hard to purchase and sell FAPs; the product quality problem frequently appears, and the logistics efficiency is low. To solve the problems, breakthroughs should be made in some key technologies, including top-level design and IoT innovative design for control of the supply chain of FAPs, the life-cycle management of FAPs using big data, innovative service model, cost control, and revenue sharing as well as dynamic evolution and safety control of the supply chain of urban FAPs. On this basis, intelligent control could platform for the supply chain of urban FAPs is developed. Also, the typical application examples for intelligent control of the supply chain of urban FAPs are constructed. The study aims to construct an intelligent control system for the traceable, networked, and efficient supply chain of FAPs having a full chain, meeting high standards, and operating in new modes, thus further promoting China's agricultural development, improving people's living standard and maintaining social harmony and stability.

B. Research contents

The supply chain of FAPs refers to a functional network chain covering multiple subjects from the production link of FAPs to the consumer nodes, which takes FAPs as the object and an enterprise (organization) as the core. The supply chain of FAPs belongs to an integrated structure mode, which contains the suppliers, producers (production organizations), liquidity providers, and consumers of agricultural products. It is not only a logistics chain, information chain, and capital chain connecting supply, production, sales, and consumption but also a value-added chain. The study intensively explores the intelligent control technology for the supply chain of urban FAPs using big data and IoT, which includes eight research contents.

(1) Top-level design for the control of the supply chain of FAPs: From the perspective of top-level design, it is essential to analyze the control principle, and general objective of the supply chain of FAPs and also design the control architecture of the supply chain of FAPs from four dimensions, i.e., overall structural system, business architecture, application architecture, and data architecture. According to the achievements of architecture design, analysis is performed based on function and supporting systems. The detailed top-level design is carried out from five aspects, i.e., application platform design, database design, integrated design, standard system design, and safety system design.

(2) IoT innovative design aiming at the control of the supply chain of FAPs: The status of the control of the supply chain of FAPs is analyzed by summarizing the related theories of the supply chain management and information sharing; on this basis, the IoT innovative design scheme for the control of the supply chain of FAPs is proposed, and the IoT information-sharing model is constructed according to the design framework of IoT; the data collection layer, sharing layer and application layer in the IoT system for the control of the supply chain of FAPs are analyzed. Moreover, the information flow model for the supply chain is established by utilizing Markov theory to numerically analyze the

performance of the IoT for the control of the supply chain of FAPs.

(3) The life-cycle management of FAPs using big data: A big data-based predictive analytic model in a combination of qualitative and quantitative methods for accurately predicting the demand for FAPs is designed; by comprehensively considering the relationships among the order quantity, production capacity, scheduling, inventory, and cost, a big data-based analysis model is designed to balance the plan of the supply chain of FAPs; a collaborative information platform for cold chain logistics of FAPs is built, and the infrastructures, various links, nodes and functions of logistics are effectively utilized based on big data to improve the logistics efficiency and performance of FAPs.

(4) The innovative service model of the supply chain of urban FAPs: Considering the main characteristics (perishable and fragile) of FAPs, the innovative service architecture of the supply chain of urban FAPs is established from the perspective of top-level design. To solve the great problems (such as lengthy and complex circulation links and high logistics cost) facing the supply chain of FAPs, an innovative service mode facing participants (including producers, liquidity providers, and consumers) is designed and proposed. In addition, an innovative service system for the supply chain of FAPs is constructed to maximize the total benefit of the supply chain.

(5) Cost control and revenue sharing of the supply chain of urban FAPs: Aiming at the outstanding problems such as a high damage ratio and high logistics cost in the supply chain of FAPs, the strategic alliance mechanism enabling cooperation, coordination, and win-win among various subjects in the supply chain of urban FAPs is explored from the perspective of top-level design; by utilizing reasonable constraint mechanisms such as internal contracts and legal contracts, the cost control mode of the supply chain of urban FAPs is established to globally reduce the total cost of the supply chain; the revenue sharing mode of the supply chain is built to realize the equal and rationale benefit distribution of various participants in the supply chain.

(6) Dynamic evolution and safety control of the supply chain of urban FAPs: Utilizing multidisciplinary knowledge including economics, management, and game theories of the supply chain, the motivation, and path of the dynamic evolution of the logistics supply chain of urban FAPs are investigated. Based on the evolutionary game theory, the pattern optimization technology for the logistics supply chain of urban FAPs is explored. On this basis, the safety control mechanisms and methods (e.g., quality management and risk management) for the supply chain of urban FAPs are surveyed.

(7) Development of the intelligent control cloud platform for the supply chain of urban FAPs: By comprehensively considering new ideas (such as resource virtualization, servitization of business, and pluggability of services) in the context of using cloud computing, the architecture of the intelligent control cloud platform for the supply chain of urban FAPs based on platform and plug-in is constructed; by defining and partitioning the main functions, task queue and standard process of cloud, network and user ends, the virtual intelligent control cloud platform for the supply chain of urban FAPs based on cloud, network and user ends are built, and the supporting engine kits and management toolsets of cloud, network, and user ends are developed; a dynamic management platform for service plug-in containing plug-in memory, version management, open API and automatic upgrade and downgrade is built. The dynamic management toolkit of service plug-in containing plug-in development templates, plug-in release tools, and additional support tools for plug-in development is designed and realized, thus achieving dynamic management (including editing, installation, launching, shutdown, update, and uninstallation) of service plug-in.

(8) Typical application examples for the intelligent control of the supply chain of urban FAPs: By taking FAPs (such as fruits and vegetables) as an example, the typical application example for intelligent control of the supply chain of urban FAPs is established. By supporting multi-user, high-capacity, high-concurrency, and high-availability service applications online, the standard service of integrated general contract and professional subcontract for the supply of FAPs is realized. It provides technical and platform supports for the demonstration of the one-step supply service of FAPs.

C. Key scientific problems

(1) Top-level design for the control of the supply chain of FAPs: From the perspective of the intelligent supply chain, the top-level design method for the control of the supply chain of FAPs is investigated to explore some key technologies macroscopically (e.g., innovative service model, cost control and revenue sharing, dynamic evolution, and safety control) for the supply chain. Therefore, it is possible to select good cost control measures more effectively and optimize resource allocation to realize the informationized management, intelligent decision-making, and convenient service of the supply chain of FAPs.

(2) The innovative service model of the supply chain of FAPs: The supply chain of FAPs is a supply chain network system consisting of upstream and downstream enterprises ranging from the field to the consumer node, which involves producers, dealers, purchasing and processing enterprises, distributors, retailers, logistics distribution business and consumers. To reduce the logistics cost and enhance the quality, safety, and logistics service level

of FAPs, it is urgent to explore the innovative service model of the supply chain of FAPs and form a complementary strategic alliance between giants. Furthermore, an interesting community is fostered to participate in the market competition, rapidly respond to customer demand, and satisfy customers' diversified demand.

(3) Cost control and revenue sharing of the supply chain of urban FAPs: The cost management in the supply chain environment manages the cost across enterprises. The meaning of cost is extended to the whole supply chain, and transaction (relationship) cost between enterprises is particularly concerned. In view of this, it is urgent to explore the cost control and revenue sharing mechanism and method for the supply chain of urban FAPs and correctly determine the cost and revenue of node enterprises in the supply chain. It is expected to provide more valuable, true, and accurate cost information for the management and decision of the supply chain, provide necessary bases for cooperation between enterprises in the supply chain in the development of new products, inventory optimization, and revenue distribution and provide a basis for optimizing the whole supply chain.

(4) Dynamic evolution and safety control of the supply chain of urban FAPs. At present, the market environment is changing and becomes increasingly competitive, and the market demand is characterized by diversified and personalized customer demand and constantly improving consumption level. In the context, it is urgent to explore the dynamic evolution and safety control mechanism and method for the supply chain of urban FAPs so that various participants in the supply chain can share information and cooperatively operate in logistics, information flow, and capital flow to reach a flexible and stable supply-demand relationship.

(5) Development of the intelligent control cloud platform of the supply chain of urban FAPs: Equal attention should be paid to the institution, mode, technology and service innovations, and overall consideration, the unification of industrial clusters, supply chain coordination, and market service is supposed to be connected. Moreover, the big data, cloud, and network and user ends are fused to build an intelligent control cloud platform for the supply chain of urban FAPs. It is expected to promote vertical and horizontal connections and cooperative governance and realize the whole industry chain's joint fusion.

IV. CONCLUSIONS

The study persists to a combination of a breakthrough in key technologies, value-added development, and system integration, combining theory with practice and fully considering the urgent demand for the intelligent control of the supply chain of FAPs in China. By doing so, it expects to solve problems pertaining to the intelligent control of the supply chain of urban FAPs in the context of using big data and IoT.

(1) In terms of the general design, the research status of the intelligent control problems of the supply chain of FAPs in the world is fully explored. The experience of the project group in the previous research is summarized. The related advanced technologies are traced and developed, and a certain lead is applied during design to keep up with the international level when completing the design. In this way, the achievements are not only advanced but also can satisfy the demand for the intelligent control of the supply chain of FAPs.

(2) In the process of making breakthroughs in key technologies, the advanced technologies and research achievements in other countries concerning the intelligent control of the supply chain of FAPs should be kept a close eye on. It is also essential to enable research achievements to be at the advanced world level by comprehensively utilizing some systematic planning methods and technologies, including computer, artificial intelligence, programming and optimization, and modeling simulation technologies.

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