Research Framework of Fresh Agricultural Products Logistics Network Optimization Based on Cold Chain

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Abstract: The paper comprehensively integrates multidisciplinary theoretical knowledge such as complexity network, game theory, ecology, system coordination optimization theory, using mathematical analysis and system model construction and other tools to carry out structural analysis and operation mechanism research on agricultural product cold chain logistics ecosystem. The paper explains the interrelationship between the micro-behaviors of the node members of the cold chain system and the evolution of the macro-structure of the system, reveals the complexity of the evolution of the cold chain logistics ecosystem, and studies the impact of the system coordination mechanism on the optimal decision of the system members. The agricultural product cold chain ecosystem network will be comprehensively coordinated and optimized, thereby ultimately improving the overall performance of the cold chain system.

1. Introduction

In recent years, with the adjustment of agricultural structure and the improvement of residents' consumption level, the output and circulation of fresh agricultural products have increased year by year, and the whole society has put forward higher requirements for the safety and quality of fresh agricultural products. Accelerating the development of cold chain logistics for agricultural products is of great significance for promoting farmers' continued income increase and ensuring consumer safety.

The significance of research on coordination and optimization of agricultural products cold chain logistics ecosystem is as follows: 1) Through the coordination of interests among the members of the cold chain system, the design of the system network structure, the selection and guidance of the operation mode of the cold chain system, the synergy effect between the members of the system is increased, the internal friction between the members of the system is reduced, the stability and adaptability of the cold chain system are improved, and the overall performance of the cold chain system of agricultural products is finally improved. 2) The large-scale circulation of agricultural products needs to speed up the development of cold chain logistics of cross regional fresh-keeping transportation. The cold chain system is affected by the interaction of time and space, low-temperature guarantee, supplier and demander. It is urgent to strengthen the coordination and optimization management of cold chain node enterprises. 3) The food safety risk of agricultural products is difficult to be eliminated by the mechanism of cold chain system itself, which must rely on external coordination and supervision mechanism[1]. 4) It can help the government to build the circulation management system of agricultural products, promote the stakeholders to improve the level of technology and management, enhance the market adaptability and competitiveness, reduce the postpartum loss and circulation loss of agricultural products, and promote the development of local economy.
2. Literature Review
There are few studies on the coordination and optimization of agricultural products cold chain system directly. Most of them use industrial products supply chain model to replace agricultural products supply chain model. Boehlje and Schrader (1988) believe that the focus of agricultural supply chain should not be the market, but the vertical coordination within the chain. The factors limiting the vertical coordination and coordination relationship of chain nodes are the key parts of the supply chain; the efficient integration of the supply chain is conducive to the control of product cost, quality and improvement of the overall performance. Zhao Xiaofei (2004) constructed a kind of agricultural products supply chain alliance model, based on which the benefit distribution scheme of each member in the supply chain was given. Osvald (2008) established the distribution model of fresh agricultural products supply chain under the condition of time constraint. Zhou Lingyun (2009) discussed the collaborative development stage of regional logistics system based on the niche theory of biological population in ecology, and established the collaborative evolution equation of regional logistics system, so as to provide decision support for industrial structure adjustment and collaborative development of regional logistics system[2]. Ma Shihua (2010) studied the collaborative model of risk sharing between two suppliers and a single manufacturer system based on penalties for overflow inventory under the premise of random output from suppliers. It is verified that there is a Nash equilibrium between supplier and manufacturer under the condition of overflow inventory penalty, and that the supply chain profit is not greater than the optimal value of the supply chain system. You Chen (2013) studied the mechanism of agricultural product supply chain self-organization, and built a cooperative model of agricultural product supply chain co-evolution; analyzed the self-organization process and dynamic factors of agricultural product supply chain co-evolution and the effect of random fluctuations forces on the evolution of supply chain. He Shengyu (2016) analyzed the network structure characteristics of agricultural product cold chain system based on ecological theory, constructed a system evolution model, and described the evolution process of agricultural product cold chain logistics system by using a compound Logistic development mechanism[3]. In addition, some literatures have made reference studies on food safety, node selection, optimal site selection, resource allocation and risk control management.

In summary, scholars have made some important and meticulous research results on the cold chain of agricultural products. However, most of the research perspectives focus on the technical application of a link in the cold chain logistics or the local optimization of the supply chain, and rarely involve the overall coordination research of the agricultural product cold chain logistics ecosystem, the recognition and research on the complexity of the agricultural product cold chain ecosystem being insufficient. Some studies and model building have too many assumptions. This simplified treatment is helpful for theoretical research, but it deviates too much from the objective complexity of the agricultural cold chain logistics system, which reduces the accuracy and adaptability of the research conclusions. In terms of research method selection, it is also necessary to further strengthen the integrated application of multi-disciplinary theories and multiple analytical tools to build a cognitive system that is more complex than cognitive objects, thereby forming the overall advantage of the research subject over the research object.

3. Research Frameworks
The coordination and optimization of agricultural product cold chain logistics ecosystem research can be carried out from the following aspects—the system network structure and optimization, the benefit coordination mechanism between system stakeholders, the system operation mechanism and its element integration optimization, and the prevention mechanism of “broken chain” risks of agricultural product cold chain logistics ecosystem.

3.1. Network structure and optimization of agricultural products cold chain logistics ecosystem
Cold chain logistics ecosystem of agricultural products refers to the mutually beneficial ecosystem formed by long-term evolution of the cooperative relationship among suppliers, producers,
transporters, logistics distribution centers and other system network members of agricultural products based on mutual trust, business cooperation, resource sharing and risk sharing. In the process of system operation, through the coordinated adaptation and cooperation between system subsystems or system elements, the system can effectively integrate and utilize the material, capital, information, technology and other resources of the system, so as to realize the co-evolution of the system. Between the member companies of the system and between the system and external environment variables, an association relationship based on a complex network is formed, and it has a complete social network attribute[4].

The cold chain logistics ecosystem of agricultural products is a three-dimensional network composed of multiple supply chains. The network structure includes horizontal infrastructure network, logistics organization network, logistics information network, and vertical logistics demand network, logistics function network, target customer network and so on. Using the computer simulation technology of complex network modeling or multi-agent modeling, this paper describes the dynamic characteristics of cold chain logistics system, analyzes the interaction mechanism between network members of cold chain logistics ecosystem and external factors of the system, and constructs the evolutionary model of agricultural products cold chain logistics ecosystem.

3.2. Interest coordination mechanism of members of cold chain logistics ecosystem
Reasonable profit distribution is an important guarantee for stable cooperative relationship among members of cold chain system and efficient operation of ecosystem. The cooperation among stakeholders promotes the orderly and stable development of cold chain system network of agricultural products. However, individual stakeholders pursue the maximization of individual interests, and the profitability is uneven. The location advantage, scale, technical level and information asymmetry in the cold chain system further enlarge the differences of benefit distribution among the members of each subject, and ultimately lead to the decrease of the overall operation efficiency, stability and adaptability of the system network. Therefore, based on the incentive principle, reasonable principle and efficiency principle of benefit distribution, the original benefit distribution pattern of agricultural product cold chain system is adjusted and optimized to ensure the efficiency and stability of cold chain system operation[5].

This paper discusses the behavior game of node members in cold chain logistics system based on different coordination mechanisms, studies the influence of coordination mechanism on the optimal decision-making of each subject in the system, and then constructs a coordination mechanism model based on multi-agent system to seek the overall utility optimization of cold chain logistics system.

Based on different types of contracts, such as cooperation mode, member's risk attitude preference, system network structure type, production capacity constraint, information asymmetry and so on, the influence of the construction and design of contract models such as quantity, price, quality, inventory, flexible procurement etc. on the local benefit optimization and overall performance optimization of the cold chain system was investigated. Furthermore, the adaptive selection algorithm of system coordination strategy is designed. The Shapley value algorithm is used to solve the problem of maximizing the overall revenue of the system and reasonably distributing the revenue under the premise of assuming that each agent of the system has the motivation of cooperative alliance.

3.3. Operation mechanism and elements' integration and optimization of cold chain logistics system
Combined with the internal mechanism of cold chain system network, this paper explores the system operation law and the choice of operation mode; uses logistic curve equation model to describe the evolution process of cold chain logistics ecosystem, explains the influence mechanism of system evolution, system network internal stability and external adaptability, and studies the influencing factors and evolution strategies to improve the ecological value of the ecosystem.

The cold chain logistics ecosystem of agricultural products includes five main activities: precooling, cold chain processing, cold chain storage, cold chain transportation and cold chain sales. With the rapid development and application of modern sensor technology, communication technology, radio
frequency identification technology, positioning technology and cloud computing processing technology, all aspects of the cold chain system can realize real-time monitoring and information sharing, and greatly reduce the logistics loss of the cold chain system[6].

With the help of government monitoring system, product traceability system, dynamic monitoring and early warning system, network order processing and network payment subsystem, the functions of monitoring, early warning, traceability, regulation and information sharing of agricultural products cold chain system are realized, and the operation efficiency of cold chain logistics is fully improved. In this process, resource integration and coordination optimization of system elements play a key role.

At present, the operation modes of agricultural products cold chain system mainly include wholesale market, logistics distribution center, large-scale supermarket, e-commerce platform and rural professional cooperatives. The formation and selection of models are closely related to the evolution of agricultural products cold chain logistics ecosystem in a certain stage. The evolution process of system network subject relationship follows three rules: changing the existing connection, establishing new connection and quitting the network. There are complex functions of mutualism, concurrence and neutral relationship between network agents. Under this effect, the cold chain system network adapts to the external environment of the system. Through the optimization of the main body of the system network, the optimization of the logistics information platform and the function optimization of the system network nodes, the withdrawal and increase of the network nodes are appropriately arranged, the network structure of the cold chain logistics ecosystem is improved, and the adaptability and stability of the system network are enhanced.

3.4. Research on the risk of "chain scission" in cold chain logistics system

From the perspective of logistics operation, on the basis of micro subject behavior analysis, the key factors and risk sources of agricultural products cold chain loss are identified, and the action mechanism of main risk factors of agricultural products cold chain and the transmission and influence mechanism of "chain scission" risks are analyzed. The paper studies the mechanism and transmission mode of risk transmission among nodes in the circulation process of agricultural products, constructs logistics risk transfer model (FAPSC) to analyze and calculate the risk loss caused by several kinds of disruption risks on the overall supply chain network.

Cold chain system is faced with various uncertain risks, such as supply and demand risk, operation risk and cooperation risk. Due to the difference of risk preference, node members may choose different decision-making behaviors and schemes. Based on the fuzzy credibility theory, this paper constructs a cold chain logistics system planning model, and studies the influence of the risk preference of the cold chain subject on the individual decision-making and overall performance of the system members[7].

The relationships among the unexpected risk events, the ability to resist interruption risk, the overall network structure of cold chain system, and the risk adaptability and self-healing ability of each node member in the cold chain system of agricultural products are explored. The paper analyzes the relationship between the cost and benefit of emergency measures for cold chain system interruption risk and the risk sharing mechanism of network node members; studies the problem of improving the network elasticity of cold chain system under the prevention mechanism of system network interruption risk, and the emergency coordination decision-making mechanism among network members of cold chain system when typical interruption risk occurs.

4. Countermeasures and suggestions

4.1. Construction of closed agricultural products cold chain logistics supply chain system

Compared with open supply chain, closed supply chain has stronger controllability and coordination, higher channel efficiency and stronger anti risk ability. The construction of closed supply chain can effectively control the whole process of quality and safety from the supply of raw materials to consumption of agricultural products, eliminate the uncertainty of products and supply, solve the information sharing problem of various actors in the whole supply chain, eliminate the lemon effect
caused by information asymmetry, establish some effective mechanism to realize the vertical integration control of the whole supply chain and improve the channel efficiency.

4.2. Promote the formation of ecosystem value-added synergy
We should use modern logistics information technology to implement business process reengineering, reasonably allocate element resources and optimize the distribution pattern of interests, strengthen the competition and cooperation among the main bodies of cold chain logistics ecosystem, create a fair and effective competition environment by means of interest driving, contract incentive and policy guidance, and promote the synergy effect of the overall value-added of agricultural products cold chain logistics ecosystem Formation.

4.3. Strengthen the resource integration and function optimization of agricultural products cold chain ecosystem elements
Based on the overall perspective of cold chain logistics system, we should coordinate the function optimization of system elements, implement collaborative strategy to balance various operation behaviors of the system, seek the balance between rationalization of each link, and finally achieve the overall optimization of the system. To strengthen the cooperation between logistics enterprises, which can break the division, integrate the scattered logistics resources, and realize the optimal allocation of logistics resources. Promote the coordinated development of regional logistics in the market environment, supporting policies, regulatory systems, talent strategy, government management, resource integration and other aspects.

4.4. Strengthen the risk prevention mechanism of "chain scission" in agricultural products cold chain logistics ecosystem
The stakeholders of agricultural products cold chain logistics ecosystem should use a variety of tools to identify and analyze the risk of cold chain supply chain, establish early warning and emergency response mechanism of cold chain system, strengthen the cooperation trust and information sharing among enterprises to make the cold chain system operation effectively link up, pay attention to the precooling management of agricultural products origin, strengthen the supervision and coordination management to dynamically control and reduce the uncertainty and risk possibility in the operation process.

5. Conclusion
The cold chain ecosystem of agricultural products is a complex adaptive system composed of multi-agent, physical network and virtual network. Only based on the micro behavior of the main body and the macro shape of the system, can we accurately grasp the evolution law and trend of the cold chain logistics system. The dynamic, multi-stage and multi parameter evolution characteristics of agricultural products cold chain system should be analyzed by using self-organization evolution theory, system dynamic transmission mechanism, synergy mechanism, system dissipative structure formation mechanism, system organization emergence mechanism and other research methods and theories, so as to reveal the evolution law of cold chain logistics ecosystem. The complexity of cold chain logistics ecosystem can be explained and revealed by using multi-disciplinary theories and analysis tools, such as ecosystem theory, complex network theory, game theory, mathematical analysis, network model construction, logistic equation, coordination and optimization theory. On this basis, the research methods and coping strategies of coordination and optimization of complex systems are further expanded.

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