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Digital Empowerment in Agricultural Supply Chains: Theoretical Logic, Challenges, and Pathways from a Logistics Cost Optimization Perspective

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Abstract: ***The rural revitalization strategy is advancing. Meanwhile, the digital economy is deeply integrated into agriculture. Under these dual drivers, efficient agricultural supply chains are vital for high-quality sector growth. However, high logistics costs and waste rates remain major bottlenecks in China. This study examines how digital technologies enable supply chain development through logistics cost optimization. It analyzes the theoretical logic, current challenges, and potential solutions. The goal is to provide a reference for policy and practice. Digital transformation faces several constraints. These include weak infrastructure, poor data coordination, and low digital literacy among stakeholders. To achieve cost reduction and efficiency gains, targeted measures are necessary. These involve strengthening infrastructure, building data ecosystems, and improving stakeholder capabilities. A supportive policy system is also required. Such actions will promote the integration of the digital economy with agriculture. Consequently, they will facilitate the digital transformation of supply chains and support rural revitalization.***

Keywords: Digitalization, Agricultural Supply Chain, Logistics Cost Optimization, Circulation Efficiency.

1. Introduction

In 2024, the General Office of the CPC Central Committee and the State Council issued the *Action Plan for Effectively Reducing Overall Societal Logistics Costs*. This highlights a critical priority. Labor and raw material costs are rising across the national economy. Consequently, reducing logistics costs is essential for improving overall economic efficiency [1]. Agriculture forms the foundation of this economy. Agricultural supply chains link production to consumption. Their efficiency directly impacts farm incomes and rural prosperity. Consumer demands are evolving. There is growing demand for freshness, quality, and safety traceability. However, a structural conflict persists. The country is characterized by small-scale production yet confronts a large-scale market. This contradiction remains unresolved. High logistics costs and waste rates continue to bottleneck industrial upgrading. The data illustrates this challenge. Logistics costs account for 30%–40% of total agricultural product costs in China. This is significantly higher than the 10%–15% average seen in developed economies [2]. Furthermore, the loss rate during circulation reaches 25%–30%. In contrast, developed nations maintain rates below 5% [3]. These high costs and losses squeeze profit margins along the entire supply chain. They also undermine the competitiveness of agricultural products. Nevertheless, the rapid growth of the digital economy offers new opportunities. It provides a pathway for transforming and upgrading these traditional supply chains. Digital technologies are evolving rapidly. These include big data, the Internet of Things (IoT), blockchain, and artificial intelligence (AI). They offer technical solutions to persistent problems. Such problems include high logistics costs, information asymmetry, and poor coordination.

In 2021, the State Council issued the *14th Five-Year Plan for Digital Economy Development*. The plan mandates accelerating the digital transformation of agriculture. It promotes the deep integration of technology across production, circulation, and consumption. Consequently, digitally empowering agricultural supply chains has become a national strategic priority. These technologies demonstrate clear value. Big data and AI are applied throughout the supply chain. Smart sensors collect data in farm fields. Temperature and humidity are regulated in warehouses. Transport routes are dynamically optimized. This digital shift is restructuring logistics operations. It creates tangible possibilities for cost optimization.

Preliminary progress has been made in digital empowerment. However, systematic theoretical analysis remains insufficient. Three key questions arise. First, what are the transmission channels through which digitization affects logistics costs? Second, what practical barriers exist? Third, how can effective solutions be designed for China's unique context? Current research focuses mainly on single technologies or specific links in the chain. It lacks a holistic analytical framework. This framework should integrate theoretical logic, practical constraints, and breakthrough pathways. Consequently, existing studies fail to fully reveal the link between digital empowerment and cost optimization. This paper addresses these gaps. It centers on logistics cost optimization. Its objectives are threefold: First, it elucidates the theoretical mechanisms involved. This study develops an analytical framework for the transmission pathway, comprising information transparency, process synergy, resource efficiency, and cost optimization. Second, it identifies practical constraints. These are analyzed across four dimensions: technology application, stakeholder capacity, coordination mechanisms, and infrastructure. Finally, it proposes actionable solutions. Measures are suggested at four levels: standard setting, stakeholder empowerment, benefit sharing, and infrastructure consolidation. This study aims to provide theoretical support. It offers guidance for the digital transformation of agricultural supply chains. It also supports the effective control of logistics costs.

2. Literature Review

2.1 Research on Logistics Costs in Agricultural Supply Chains

Logistics costs refer to the total expenses incurred during circulation. These cover transport, storage, packaging, handling, processing, and information management. Early research focused on cost composition and accounting systems. Cooper and Kaplan (1988) pioneered the Activity-Based Costing (ABC) method. This provided a tool for precise cost measurement. Subsequently, many scholars applied ABC to calculate costs in storage and transportation [4]. Chinese scholar Wang classified these costs into six categories. These included transport, storage, and processing costs. He then built a comprehensive indicator system for cost accounting [5]. Later research shifted to identifying the causes of high costs. Some studies attribute high costs to the perishable nature of produce. Fresh goods require strict temperature and humidity controls. This inevitably increases investment [6]. Other scholars point to systemic issues. These include fragmented stakeholders, information asymmetry, and weak infrastructure. The mismatch between smallholders and large markets creates redundant links. This leads to inefficient resource allocation. Conversely, digital transformation improves supply chain efficiency [7]. Firm-level coordination is also considered essential. It serves as the foundation for cost reduction [8]. Regarding optimization strategies, scholars propose solutions across three dimensions: infrastructure, business models, and policy. For infrastructure, experts recommend building cold-chain facilities at production sites. They also suggest improving the overall circulation network [9]. Regarding business models, scholars advocate direct sales models such as farm-to-supermarket and farm-to-enterprise schemes, which reduce intermediate links [10]. For policy, scholars advocate increasing fiscal subsidies. They also recommend tax breaks for cold-chain logistics providers [11].

2.2 Research on Digital Empowerment in Agricultural Supply Chains

The rise of digital technologies has driven a digital shift in agricultural supply chain research. International studies began earlier, focusing on applying digital tools across supply chain stages. For example, Barrett et al. (2015) explored IoT use in fresh produce storage. They reduced spoilage rates via real-time temperature and humidity monitoring [12]. Moe (2018) examined blockchain's value in product traceability. It enabled transparent information sharing among supply chain stakeholders [13]. Domestic research centers on empowerment models and effects. Scholars have proposed multiple models-including e-commerce platform + farmer, smart logistics + agricultural supply chain, and digital finance + agricultural industry chain. For instance, Alibaba's Digital Agriculture initiative integrates origin and destination warehouses and proposes building a digital agricultural circulation system to upgrade e-commerce supply chains [14]. Regarding effects, digitization boosts supply chain transparency. It cuts transaction costs and improves circulation efficiency [15, 16]. It also enables product traceability, ensuring food safety and strengthening market competitiveness. Some scholars examine influencing factors. Weak rural digital infrastructure limits transformation. Low farmer digital literacy and missing stakeholder coordination mechanisms are key barriers [17]. During digital agriculture growth, data security and privacy concerns arise. High technology application costs also hinder adoption across supply chains [18].

2.3 Research on the Link Between Digital Empowerment and Logistics Cost Optimization

Research connecting digital empowerment and logistics cost reduction is still emerging. Current findings remain largely fragmented. Some studies analyze cost effects through single technologies. Big data analytics improves market demand forecasting. This reduces unnecessary transport and excess inventory. Consequently, storage and transport costs decrease [19]. Reducing total logistics costs is vital. It enhances industrial competitiveness and economic efficiency. The digital economy drives high-quality development. Specifically, it helps lower overall logistics costs [20]. Technology enables process re-engineering. Ecosystem collaboration breaks down logistical barriers. This achieves cost optimization [21]. A smaller body of work adopts a supply chain-wide perspective. It examines how digital procurement management optimizes costs [22].

Overall, existing research has yielded valuable insights. Studies on agricultural logistics costs and digital empowerment are accumulating. However, significant gaps remain: First, the theoretical logic lacks sufficient elaboration. A systematic analytical framework is missing. Second, analyses of practical barriers during digital transformation are incomplete. They fail to address the core needs of cost optimization. Third, proposed solutions lack specificity and feasibility. They do not effectively resolve the issue of high logistics costs. This paper addresses these gaps through in-depth investigation.

3. Theoretical Logic of Digitally Enabled Agricultural Supply Chains

3.1 Internal Mechanisms for Logistics Cost Optimization

3.1.1 Reducing Information Asymmetry Costs via Information Synergy

Information asymmetry is a core driver of high logistics costs. In traditional models, information gaps create inefficiencies at every stage. At the production end, farmers lack access to market demand data. This leads to blind production and overstocking. Consequently, warehousing costs rise. Logistics providers lack real-time data on supply and transport status. This results in empty backhauls and inefficient routing. Transport costs increase accordingly. At the sales end, retailers cannot track shipment progress. This causes stockouts or overstocking. Circulation costs rise.

Digital technologies break down these information barriers. They enable real-time information sharing and synergy across the chain. First, big data integrates multiple data streams. It merges production, demand, and logistics capacity data. Through analysis and forecasting, it guides production based on demand. This reduces excess inventory and lowers storage costs. Second, the IoT enables real-time tracking. Sensors are installed on vehicles, in warehouses, and on packaging. They collect logistics data and sync it to collaborative platforms. Logistics firms adjust routes dynamically, cutting transport costs. Retailers track shipments in real time, minimizing stock risks. Third, blockchain builds a decentralized information system. It ensures data immutability and full traceability. This reduces verification and trust costs. Ultimately, it optimizes overall information-related logistics expenses.

3.1.2 Enhancing Logistics Resource Efficiency via Resource Allocation

Traditional agricultural supply chains suffer from fragmented and inefficient resource allocation. First, logistics facilities are scattered. Cold-chain storage is insufficient at production sites. Yet, there is surplus capacity at consumption centers. Different stakeholders cannot share facilities. This leads to low utilization rates. Second, transport capacity is mismatched. Production areas are often in remote regions. They lack adequate transport resources. In contrast, urban areas have abundant capacity. This spatial mismatch raises transport costs. Third, human resources are misallocated. There is a shortage of skilled professionals. These include cold-chain and smart logistics experts. This shortage constrains operational efficiency.

Digital technologies enable optimal resource allocation through matching and smart scheduling. A shared digital logistics platform can be built. It integrates idle facilities like warehouses and trucks. This allows cross-regional and cross-stakeholder sharing. AI further optimizes operations. It enables intelligent dispatch and route planning. This reduces transit times and fuel consumption. Regarding personnel, digital training platforms pool educational resources. They provide online courses for rural logistics workers. This indirectly lowers labor costs by improving productivity.

3.1.3 Streamlining Redundant Logistics Links via Process Re-engineering

Traditional agricultural supply chains involve lengthy and complex processes. Produce typically passes through multiple intermediaries. These include local collectors, regional wholesalers, and retailers. Each link adds logistics, storage, and transaction costs. Furthermore, repeated handling increases product damage. This pushes up overall logistics costs.

Digital technologies re-engineer these logistics flows. They streamline redundant links to cut costs. First, e-commerce platforms enable direct connections. They bypass traditional multi-tier distribution. Farmers and cooperatives link directly to consumers or retailers. This eliminates wholesale intermediaries. Consequently, multi-stage storage and transport costs are reduced. Second, automated warehousing and sorting systems transform operations. They handle intake, storage, picking, and dispatch. This automation reduces manual intervention. It lowers handling and labor costs. Additionally, automated sorting accelerates processing. It shortens storage turnover times. This reduces inventory holding costs. Third, integrated cold-chain systems optimize temperature-controlled flows. They ensure seamless connectivity from pre-cooling at origin to refrigerated transport and final storage. This eliminates breaks in the cold chain. It reduces spoilage costs for fresh produce. Ultimately, it enhances the overall efficiency of the logistics process.

3.2 Transmission Channels for Cost Optimization

The core problem lies in three areas. These are information asymmetry, process fragmentation, and resource misallocation. Digital technologies address these issues through data penetration. They build information transparency and process synergy. This enables the efficient use of resources at lower costs. This optimization is supported by key technologies. These include big data, the IoT, AI, and blockchain. The impact spans the entire chain. It covers production, storage, transport, and distribution. By solving core problems at each stage, a systemic cost reduction is achieved. The following sections detail the specifics of this digital empowerment. They explore three distinct dimensions.

3.2.1 Data Collection and Information Transparency: Breaking Down Barriers

Information asymmetry is the root cause of hidden logistics costs. Upstream producers cannot predict market demand. This leads to overstocking and waste. Warehouses rely on outdated information. This results in excess inventory. Transport operators face supply-demand mismatches. This causes high empty backhaul rates. Essentially, these are all instances of resource waste caused by data disconnects. Digital technologies establish data collection systems. They convert fragmented node information into quantifiable assets. These assets can be shared across the supply chain. This creates a solid foundation for cost optimization.

The IoT allows for real-time data collection at the production stage. Sensors deployed in the fields-temperature and humidity sensors, soil detectors, GPS devices-capture core data including growth conditions, maturity cycles, and yield forecasts. This data is combined with weather and market demand figures. It establishes a direct information link between production and consumption. Blockchain technology facilitates information sharing at circulation stage. Its decentralized structure ensures data integrity. Every step is recorded on the chain. This covers harvesting, packaging, warehousing, transport, and distribution. Recorded data points include logistics nodes, vehicle details, temperature fluctuations, and handling logs. Authorized stakeholders can access this data. They track and monitor the logistics process in real time. Information transparency reduces dispute costs. It prevents delays caused by outdated information. It also minimizes scheduling errors. This transparency provides a solid basis for subsequent process optimization.

3.2.2 Process Synergy and Resource Integration: Cutting Logistics Costs

Building on data transparency, digital technologies reconstruct logistics flows. They integrate resources efficiently via collaborative platforms and smart decision-making systems. This is the core of the cost optimization pathway. It focuses on three nodes: storage, transport, and distribution. Technology enables optimal resource allocation at each stage.

1) Storage: Smart Scheduling and Dynamic Management

Produce is highly perishable. Inventory overstocking and poor climate control increase costs. Digital tools combine big data forecasting with smart warehousing. This enables dynamic resource scheduling and inventory management. First, algorithms predict market demand and circulation cycles. They analyze production yields, consumer demand, and historical transactions. This informs warehouse planning and inventory targets. It prevents blind stocking, thereby avoiding waste and holding costs. Second, smart systems link IoT devices with automation. Warehouse operations become unmanned. This boosts efficiency. It also reduces product damage and human error caused by manual handling.

2) Transportation: Smart Matching and Route Optimization

Transportation accounts for the largest share of logistics costs. Traditional models suffer from inefficiencies. These include empty backhauls and circuitous routing. This leads to high costs and low efficiency. Digital technologies address these issues. They use freight information matching platforms and intelligent route planning systems. This optimizes transport resources and processes. First, matching platforms connect shippers with carriers. They link cargo demands with vehicle availability in real time. Big data algorithms facilitate this matching. This reduces empty backhaul rates caused by information asymmetry. Companies integrate nationwide freight data through digital means. This significantly lowers transport costs. Furthermore, smart systems plan optimal routes. They consider real-time traffic, weather, and product shelf life. Artificial intelligence calculates the best paths. This shortens transit times. It also reduces spoilage caused by delays.

3) Distribution: End-Point Integration to Cut Last-Mile Costs

The “last mile” is the final distribution stage. It is also the most difficult area for cost control. End-point networks are scattered. Delivery frequencies are high. Customer demands are personalized. These factors lead to low efficiency and high costs. Digital technologies integrate scattered end-user resources. They innovate distribution models. This optimizes last-mile costs. First, integrated nodes are established. These include community group-buying pick-up points and rural e-commerce service stations. Scattered individual orders are consolidated for delivery. This reduces delivery frequency and travel distances. Second, big data enables user profiling. It predicts customer locations and preferred delivery times. This avoids the need for redelivery. Consequently, it saves on secondary delivery costs.

3.2.3 Optimizing Cost Structure and Enhancing Supply Chain Value

The essence of digital empowerment lies in two outcomes. First, it systematically optimizes the cost structure. Second, it enhances the overall value of the supply chain.

Digital technologies reduce labor and time costs. They achieve this by improving operational efficiency. They lower empty backhaul and inventory costs through better resource allocation. They also cut spoilage costs via stricter process controls. Consequently, the share of logistics costs in the total product value drops significantly.

According to data from the Ministry of Agriculture and Rural Affairs, digital transformation yields clear results. In traditional models, logistics costs account for 30%–40% of the total value. In digitally enabled chains, this figure falls to 15%–20%.

Cost optimization boosts market competitiveness. Agricultural products can be sold at more favorable prices. Shorter circulation times ensure better product quality. Ultimately, this drives the supply chain toward high efficiency and low consumption.

In summary, the optimization path follows a clear sequence. This optimization path is defined by data-driven process synergy. It transforms resource integration into cost optimization and value enhancement. Data serves as the core factor. Technology acts as the enabler. Process optimization is the key link. Cost reduction and value enhancement are the ultimate goals. Together, these elements drive the high-quality development of agricultural logistics.

4. Practical Challenges in Digitally Enabled Agricultural Supply Chains

In practice, digital empowerment faces multi-layered challenges. These exist at the technological, stakeholder, and ecological levels. They create significant barriers to cost optimization.

4.1 Lack of Technical Standards and Low Data Value

Supply chain stakeholders are highly fragmented. Smallholders and SMEs (small and medium-sized logistics enterprises) dominate the sector. Their capacity for digital investment is limited. Consequently, they adopt simple tools for single links only. They lack integrated digital systems. Data formats vary across links. Farming data cannot connect with warehouse or transport data. Furthermore, unified standards for digital logistics are missing. These include metrics for data collection, information protocols, and temperature thresholds. Without industry consensus, data cannot be shared across entities. Big data forecasting fails to function properly. Logistics resources remain mismatched. Empty backhaul rates stay high. The data fails to significantly optimize logistics costs.

4.2 Weak Digital Capabilities of SMEs and Last-Mile Adoption Barriers

The supply chain consists of many small players. The upstream comprises smallholders and family farms. The downstream includes numerous small retailers and regional logistics firms. These stakeholders generally lack digital awareness and technical skills. First, smallholders face multiple constraints. Their education levels and financial capacity are limited. They cannot afford IoT devices or maintenance costs. Even with government subsidies, technical hurdles remain. They struggle with equipment installation and data interpretation. This creates a data gap at the production stage. Consequently, logistics planning becomes difficult. Second, SMEs have limited capital. They cannot invest in smart warehouses or automated sorting systems. They rely on manual operations. As a result, warehouse damage rates are high. Transport efficiency remains low. Third, there is a shortage of talent. Professionals with both digital and agricultural expertise are scarce. This shortage further hinders technology adoption.

4.3 Lagging Rural Digital Infrastructure and Insufficient Logistics Support

The core scenarios for agricultural supply chains are located in rural areas. However, rural digital infrastructure faces significant gaps. First, network coverage is inadequate in remote areas. Signals are often unstable. This prevents IoT devices from transmitting data in real time. Smart route planning systems cannot access real-time traffic or weather data. Consequently, cost optimization in transport is compromised. Second, cold-chain infrastructure lacks digital integration. Most rural warehouses rely on manual temperature monitoring. They lack intelligent control systems. Refrigerated trucks have low digital equipment rates. Full-process temperature monitoring is impossible. As a result, product spoilage costs remain high. Third, supporting facilities are underdeveloped. Digital payment systems are not fully functional. Data security measures are weak. These shortcomings increase the operational risks and costs of digital logistics.

5. Breakthrough Pathways for Digitally Enabled Agricultural Supply Chains

To overcome these barriers, we must prioritize logistics cost optimization. We need a four-pronged approach. This involves standards, stakeholder empowerment, coordination mechanisms, and infrastructure. The goal is to build a feasible system. It must encourage participation and share benefits. This will drive down logistics costs.

5.1 Establishing Unified Data Standards and Integrated Platforms

Government departments should lead this initiative. They must collaborate with industry associations and key enterprises. Together, they can formulate a digital logistics standard system. This system defines data collection scopes, formats, and application standards. It enables seamless data sharing across all links. Next, a digital collaboration platform should be built. It can be hosted by a core enterprise or a third-party provider. This platform integrates data from production, storage, transport, and distribution. It develops three key modules: data sharing, smart decision-making, and cost accounting. Regional platforms can be constructed involving multiple stakeholders. Smallholders upload planting data via simple terminals. Logistics firms input their capacity information. Retailers synchronize order demands. The platform uses big data algorithms to generate optimal plans. It suggests the best storage options, transport routes, and delivery schedules. This matches resources efficiently. Consequently, it reduces empty backhaul rates and inventory costs.

5.2 Tiered Empowerment for SMEs: Lowering Digital Adoption Barriers

Digital empowerment strategies must be tiered and categorized. They should match the capacity gaps of different stakeholders. This resolves the challenge of technology implementation. For smallholders and family farms, a combined model is adopted. Government subsidies are paired with platform concessions. Low-cost, easy-to-use digital tools are promoted. For example, a production-site information reporting system is built. It links with e-commerce platforms. Public welfare digital skills training is also provided. For SMEs, core firms are encouraged to open digital system interfaces. They provide ready-made digital solutions. This lowers initial investment costs. University-industry partnerships train targeted digital talent for agricultural logistics. This offers technical support to enterprises.

5.3 Multi-Stakeholder Coordination and Benefit-Sharing Mechanisms: Boosting Participation Incentives

A coordination mechanism is needed. It is led by core enterprises, involves multiple stakeholders, and shares benefits. This breaks down trust barriers and fixes imbalanced benefit distribution among parties. First, governments or industry associations take the lead. They establish a digital supply chain coordination alliance. The alliance clarifies rights and obligations of all stakeholders. It sets clear boundaries for data sharing. Blockchain technology enables data traceability and privacy protection. This removes small and medium-sized stakeholders' concerns. Second, a fair benefit distribution mechanism is designed to quantify digitalization-included logistics cost savings and allocate them to stakeholders based on specific metrics. This ensures tangible returns for smallholders and SMEs. This coordination model boosts stakeholder motivation. It incentivizes logistics firms to improve services. It achieves a win-win outcome for all parties.

5.4 Strengthening Rural Digital Infrastructure: Consolidating the Digital Foundation

Increase investment in rural digital infrastructure. Prioritize network coverage and signal enhancement projects in remote areas. Ensure full 4G/5G coverage across major agricultural production zones and logistics nodes. This guarantees real-time data transmission. Second, drive digital upgrades for rural cold-chain logistics infrastructure. Government earmarked subsidies support smart temperature/humidity control systems in warehouses. They also fund GPS tracking and real-time monitoring devices for refrigerated trucks. This enables end-to-end digital management of the cold chain. Third, improve supporting digital facilities. Promote digital payment adoption in agricultural transactions. Establish a rural data security framework. This reduces operational risks and costs for digital logistics. In summary, barriers persist along the path of digital empowerment for cost optimization. Multidimensional measures are required to resolve these challenges. These cover technical standards, stakeholder capacity, coordination mechanisms, and infrastructure development.

6. Conclusion

In the digital era, optimizing logistics costs in agricultural supply chains is critical. This optimization addresses the Three Rural Issues (agriculture, rural areas, and farmers) and contributes to rural revitalization. Theoretically, data serves as the core driver. It addresses persistent problems in traditional agricultural supply chains. These problems include information asymmetry, process fragmentation, and resource misallocation. Theoretically, data serves as the core driver. This study constructs a coherent pathway wherein information transparency enables process synergy, which in turn drives resource efficiency and culminates in cost optimization. This framework creates the potential for logistics cost reduction. It also enhances overall supply chain value. These include information asymmetry, process fragmentation, and resource misallocation in traditional chains. This creates potential for cost optimization and supply chain value enhancement. However, a gap persists between theoretical feasibility and real-world implementation. Digitally enabled supply chains face multiple barriers. These include fragmented technology adoption, weak capacity of SMEs and smallholders, imbalanced coordination mechanisms, and lagging infrastructure. Consequently, cost optimization gains remain limited. This constrains the high-quality development of agricultural supply chains. Ultimately, bridging stakeholders and geographic divides enables digital technologies to serve all supply chain participants, facilitating shared cost reduction and benefit distribution. This requires multi-stakeholder coordination, benefit-sharing systems, and stronger rural digital infrastructure. Collectively, these measures drive end-to-end digital penetration, transforming supply chains toward high efficiency and low loss, while improving circulation efficiency and farmer incomes.

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References

[1] CAI, J. (2025). Promoting logistics entities to grow stronger, better and larger: Moving towards high-quality development of modern logistics. *Logistics Technology and Application, 30*(11), 34–35.

[2] XIANGXIANG, X. (2020). How high is China's circulation cost? Circulation cost of vegetable agricultural products accounts for 50%–60% of the selling price. *Toutiao*. Retrieved from https://www.toutiao.com/article/681203885709826510 2/?wid=1765443938109

[3] WANG, L. (2022). Accelerating the smooth flow of the "first mile" of agricultural product circulation. Retrieved from https://www.cnfia.cn/archives/26884

[4] COOPER, R., & KAPLAN, R. S. (1988). How cost accounting distorts product costs. *Strategic Finance, 69*(10), 20.

[5] WANG, X., & MAO, Z. (2014). Research on cost budget management system of agricultural product logistics enterprises in China. *Journal of Heilongjiang Bayi Agricultural University, 26*(6), 142–144, 148.

[6] YU, J. (2019). Research on logistics cost system of agricultural product supply chain under e-commerce environment. *Price Monthly*, (4), 54–58.

[7] ZHANG, S., & GAO, T. (2026). Research on the impact of digital transformation on enterprise supply chain efficiency: Evidence from textual analysis of annual reports of China's A-share listed companies. *Logistics Research*, (5), 43–51.

[8] WANG, X., & DUAN, Y. (2024). Mechanisms and paths of new quality productivity driving the reduction of total social logistics costs. *China Business and Market, 38*(7), 15–24.

[9] LI, C., WANG, E., & YUAN, J. (2017). Research on optimization of fresh agricultural product logistics distribution path under IoT environment. *Commercial Research*, (4), 1–9.

[10] YANG, B. (2016). Research on optimization strategies of fresh agricultural product logistics cost: Based on the perspective of "farm-to-supermarket" docking. *Journal of Commercial Economics*, (9), 72–73.

[11] DING, J. (2024). Research on reducing social logistics costs. *China Business and Market, 38*(7), 3–14.

[12] SAHOO, J., & BARRETT, K. (2021). Internet of things (IoT) application model for smart farming. In *Proceedings of SoutheastCon 2021*(1–2). IEEE.

[13] MOE, K. S., & THWE, M. (2019). Investigation of blockchain-based identity system for privacy-preserving university identity management system. *International Journal of Trend in Scientific Research and Development, 3*(6), 336–341.

[14] ZHANG, X., & SUN, X. (2024). Research on models, dilemmas and transformation and upgrading of agricultural product e-commerce supply chain. *Logistics Technology, 43*(10), 115–126.

[15] ZHAO, X., LI, M., & TAN, Y. (2025). Theoretical logic and practical approaches of digital transformation of agricultural product supply chain. *Academic Journal of Zhongzhou*, (6), 42–51.

[16] RAN, W., & ZHAO, J. (2026). Research on the driving mechanism of digital-intelligent integration on supply chain information sharing under information asymmetry. *Supply Chain Management, 7*(5), 62–75.

[17] HUANG, Z. (2022). Construction and development challenges of digital villages in China. *Agricultural Products Market*, (23), 49–51.

[18] ZHONG, W., LUO, B., & XIE, L. (2021). International experience and enlightenment of digital agriculture development. *Reform*, (5), 64–75.

[19] ZHANG, Q., & LI, X. (2019). Cost structure, control approaches and optimization strategies of central kitchen cold chain logistics. *Taiwan Agricultural Exploration*, (3), 67–71.

[20] ZHAO, L., & ZHOU, Y. (2025). Impact effect and transmission mechanism of digital economy on social logistics cost: Empirical evidence based on Chinese

provincial panel data. *Journal of Commercial Economics*, (18), 70–74.
[21] LI, Y., & LI, Y. (2026). Research on cost control strategies of logistics enterprises under digital transformation. *Logistics Sci-Tech, 49*(9), 93–94, 103.
[22] REN, C. (2025). Mechanism of digital procurement management on supply chain cost optimization. *Financial Supervision*, (11), 99–104.