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Strategic Management Mechanisms and Implementation Pathways for Collaborative Development of Agricultural Product Distribution and Textile Packaging Enterprises in Digital Transformation

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ABSTRACT The digital transformation of agricultural supply chains requires efficient coordination among heterogeneous stakeholders and reliable information exchange across distributed logistics networks. As a key component linking agricultural production and downstream distribution, collaboration between agricultural product distribution and textile packaging enterprises has become increasingly dependent on intelligent communication and data-sharing infrastructures. This study systematically investigates the strategic management mechanisms and implementation pathways for collaborative development by integrating transaction cost economics, complex adaptive systems theory, and network effects theory. A four-dimensional management framework encompassing technological support, organizational coordination, benefit distribution, and risk prevention is established, in which entropy weight–TOPSIS is employed for strategic objective alignment, blockchain-based architectures enable trusted information sharing, Shapley value optimization supports dynamic benefit allocation, and Value-at-Risk (VaR) models facilitate quantitative risk control. The proposed framework further incorporates smart contracts and permission-controlled data interaction to improve collaboration efficiency while preserving data security. The resulting management architecture provides a quantitative and scalable solution for digital supply chain coordination and demonstrates practical value for intelligent logistics systems. Moreover, its distributed information-sharing mechanisms and network-oriented optimization strategies offer methodological references for communication-enabled industrial ecosystems, wireless sensing infrastructures, and electromagnetic information transmission environments requiring reliable multi-node coordination and secure data exchange.

INDEX TERMS digital transformation, blockchain-based information sharing, supply chain collaboration, wireless information transmission, strategic management

I. INTRODUCTION

A. RESEARCH BACKGROUND

At the policy level, a series of documents such as the Digital Rural Development Strategy Outline and the 14th Five-Year Plan for Digital Economy Development have been released in rapid succession. These explicitly call for "promoting the digitization of agricultural product distribution" and "deepening the integrated development of manufacturing and agriculture," creating a favorable policy environment for the coordinated growth of agricultural product distribution and textile packaging enterprises [1,2]. At the market level, rising consumer demand for "premium agricultural products + high-end packaging" has emerged alongside the rise of new distribution models like fresh food e-commerce and community group buying. These developments further compel both industries to break down boundaries and pursue collaborative innovation. Against this backdrop, establishing a scientific and efficient strategic management mechanism for collaborative development, anchored by digital technology, has become the critical pathways to overcome the developmental challenges facing both sectors [3-5].

Textile packaging has irreplaceable functional advantages such as breathability, moisture resistance, and reusability, which are widely applied in scenarios like long-distance transportation of root and stem agricultural products (potatoes, onions) and fresh fruits and vegetables. In 2023, the market scale of textile packaging for agricultural products reached 85 billion yuan with an annual growth rate of 10.2%, showing strong market vitality. Meanwhile, under the 'dual carbon' policy, the biodegradable and recyclable characteristics of textile packaging align with environmental protection requirements, making it a key development direction for green packaging. Additionally, textile packaging enterprises generally face pain points such as weak customized production capabilities and disconnection from the demand of distribution enterprises, which urgently require targeted collaborative mechanisms, while collaborative research on other material packaging has been relatively sufficient.

B. RESEARCH SIGNIFICANCE

1) Theoretical Significance

This study builds upon industrial chain collaboration theory and digital economy theory to construct an analytical framework for the collaborative development of agricultural product distribution and textile packaging enterprises. By embedding multiple quantitative models, it addresses the traditional research bias of "overemphasizing qualitative analysis while neglecting quantitative measurement." This enriches research outcomes at the intersection of industrial collaboration and digital transformation, providing theoretical references for subsequent studies in related fields [6].

2) Practical Significance

The strategic management mechanisms and practical pathways proposed in this paper can directly guide corporate collaborative practices. For agricultural product distribution enterprises, collaboration enables access to tailored packaging solutions, reducing distribution losses and enhancing brand value. For textile packaging enterprises, leveraging market demand data from agricultural distributors facilitates targeted innovation and increases product value-added. For the entire industrial chain, this approach promotes deep integration between agriculture and manufacturing, supporting rural industrial revitalization and digital economic development [7,8].

C. RESEARCH METHODS

Literature Review: Systematically synthesizing relevant literature on industrial chain collaboration and digital transformation to establish theoretical foundations.

Quantitative Analysis: Incorporating models such as Entropy Weight-TOPSIS, Shapley Value, and VaR to achieve quantitative design of the collaborative mechanism [9].

Case Study Analysis: Validating the feasibility of the mechanism and pathways through analysis of representative enterprise collaboration cases.

D. INNOVATION POINTS

First, innovative research perspective: Focusing on the highly interrelated yet understudied domains of agricultural product distribution and textile packaging, constructing a collaborative development system from a digital transformation viewpoint. Second, methodological innovation: Embedding multiple quantitative models into collaborative management mechanisms to achieve a breakthrough from "qualitative description" to "quantitative decision-making." Third, the innovation in the mechanism lies in constructing a four-dimensional collaborative mechanism integrating "strategy-information-benefit-risk," forming a closed-loop management system across the entire process [10,11].

II. THEORETICAL FOUNDATIONS AND LITERATURE REVIEW

A. CORE THEORETICAL FOUNDATIONS

The theory of industrial chain synergy was proposed by Michael Porter in his 1985 work Competitive Advantage. Its core premise is that maximizing overall industrial chain efficiency is achieved through resource sharing, division of labor, and complementary strengths across all chain segments. This theory emphasizes that entities within the industrial chain should break down boundary barriers to form a collaborative ecosystem characterized by "shared benefits and shared risks." Agricultural product distribution and textile packaging enterprises occupy pivotal positions within the agricultural and manufacturing value chains, respectively. These sectors share an inherent supply-demand relationship: the efficiency of agricultural distribution relies on textile packaging technology, while the market expansion of textile packaging depends on the demand traction from agricultural distribution. The theory of industrial chain synergy provides core theoretical guidance for the collaborative development of these two industries. The cooperative game theory formula is presented below [12-14].

$$\phi i = \sum S \subseteq N, i \in S n!(|S|-1)!(n-|S|)![v(S)-v(S\setminus\{i\})] \quad (1)$$

where N is the set of participants, S is a subset containing participant i, $|S|$ is the number of elements in subset S, n is the total number of participants, $v(S)$ is the cooperative benefit of subset S, and $v(S\setminus\{i\})$ is the benefit of the subset excluding participant i. This formula provides a scientific solution to the issue of benefit distribution in the collaborative development of agricultural product distribution and textile packaging enterprises [15].

B. LITERATURE REVIEW

Existing research has achieved certain results in areas such as agricultural product circulation digitization, textile packaging industry development, and industrial synergy. However, the following shortcomings remain: First, research perspectives are often narrow, focusing predominantly on the development of single industries with insufficient cross-industry collaborative studies. Second, research methods tend to be qualitative, lacking quantitative model support, resulting in limited operational feasibility of synergy mechanisms. Third, research content lags behind, with insufficient exploration of core issues in the collaborative development of these two industries under digital transformation, such as information sharing and benefit distribution. Building upon these gaps in existing research, this paper constructs a strategic management mechanism and practical pathway for the collaborative development of these two industries in the digital context, filling a relevant research void [16,17].

Existing research on packaging collaboration mainly focuses on plastics, pulp, and composite materials, while studies on textile packaging, which has unique functional and environmental advantages, are relatively scarce, forming a research gap that this paper aims to fill.

III. CURRENT DEVELOPMENT STATUS AND COLLABORATIVE SHORTCOMINGS OF AGRICULTURAL PRODUCT DISTRIBUTION AND TEXTILE PACKAGING ENTERPRISES

A. CURRENT DEVELOPMENT STATUS OF AGRICULTURAL PRODUCT DISTRIBUTION ENTERPRISES

1) Continuous Expansion of Industry Scale and Diversification of Distribution Models

In recent years, China's agricultural product distribution industry has demonstrated steady growth. According to National Bureau of Statistics data, the market scale reached 8.5 trillion yuan in 2023, representing a 6.2% year-on-year increase. Within this, the distribution scale of fresh agricultural products reached 3.2 trillion yuan, growing by 8.5% year-on-year. Distribution models have evolved from the traditional single-channel approach of "farmers → wholesale markets → supermarkets → consumers" to a diversified structure encompassing "wholesale markets + supermarkets + e-commerce + community group buying + direct sourcing from production areas" [18]. The details are as shown in Table 1.

Major agricultural product distribution enterprises are accelerating the deployment of digital channels. For instance, CR Vanguard has established a digital procurement platform for agricultural products, directly connecting with over 2,000 agricultural production bases nationwide to reduce order response times to just 2 hours. Hema Fresh adopts a "direct sourcing from origin + forward warehousing" model, shortening the circulation time for fresh agricultural products to under 12 hours and lowering wastage rates to below 10%. Pinduoduo connects over 100,000 farmers nationwide with hundreds of millions of consumers through its "Agricultural Land Cloud Group Buying" model, enabling precise matching between agricultural production and sales [19-21].

B. CURRENT DEVELOPMENT STATUS OF TEXTILE PACKAGING ENTERPRISES

1) Massive Industry Scale with Gradually Optimized Structure

China is a major producer of textile packaging, boasting a vast industry scale and numerous enterprises. In 2023, the market size of China's textile packaging industry reached 380 billion yuan, representing a year-on-year increase of 5.8%. Among these, textile packaging products used for agricultural product packaging reached 85 billion yuan, growing by 10.2% year-on-year. With the tightening of environmental policies and the upgrading of market demand, the textile packaging industry is accelerating its transformation and upgrading, and the industry structure is gradually optimizing [22,23]. The details are as shown in Table 2.

Leading textile packaging enterprises are accelerating their expansion into the agricultural product packaging market. For instance, Zhejiang Yongli Warp Knitting has developed specialized fresh-keeping textile packaging materials for agricultural products, achieving annual sales exceeding 2 billion yuan. Jiangsu Hengli Group has pioneered biodegradable textile packaging for agricultural products, securing a leading domestic market share. The industry is gradually forming a development pattern characterized by "large enterprises leading the way, supported by small and medium-sized enterprises" [24].

2) Product Structure Upgrades and Enhanced Innovation Capabilities

Driven by both environmental policies and market demands, textile packaging enterprises are progressively shifting their product structure from traditional standard packaging toward eco-friendly, functional, and customized packaging solutions. In environmental sustainability, companies are adopting biodegradable polyester, recycled fibers, and other eco-friendly materials to develop sustainable packaging products. Functionally, tailored to the characteristics of agricultural product distribution, they have introduced specialized textile packaging solutions including freshness-preserving, waterproof, breathable, and antimicrobial variants [25,26].

IV. ESTABLISHING STRATEGIC MANAGEMENT MECHANISMS FOR COLLABORATIVE DEVELOPMENT IN DIGITAL TRANSFORMATION

A. STRATEGIC SYNERGY MECHANISM: AN ENTROPY-WEIGHTED TOPSIS-BASED GOAL ALIGNMENT MODEL

1) Construction of Strategic Goal Indicator System

Integrating characteristics of both industries, a strategic goal indicator system was established across financial, market, technological, and social responsibility dimensions. This system comprises 12 secondary indicators, forming a collaborative goal evaluation matrix. The specific indicator system is detailed in the Table 3 below:

2) Entropy Weight-TOPSIS Model Calculation Process

Step 1: Indicator Standardization. Due to differing dimensions and attributes among indicators, standardization con-

TABLE 1. Key Indicators of China's Agricultural Product Distribution Industry, 2019-2023

Year	Total Circulation Market Scale (Trillion CNY)	Fresh Circulation Scale (Trillion CNY)	Number of Agricultural Product Wholesale Markets	E-commerce Transaction Scale (Trillion CNY)	E-commerce Proportion (%)
2019	6.8	2.3	4300	0.7	10.3
2020	7.2	2.5	4350	0.9	12.5
2021	7.6	2.8	4400	1.0	13.2
2022	8.0	3.0	4450	1.1	13.8
2023	8.5	3.2	4500	1.2	14.1

TABLE 2. Key Indicators for China's Textile Packaging Industry, 2019-2023

Year	Total Industry Scale (Billion CNY)	Agricultural Product Packaging Scale (Billion CNY)	Proportion of Environmentally Friendly Products (%)	Industry CR10 (%)	R&D Investment Proportion (%)
2019	3000	620	28	15	2.3
2020	3200	680	33	18	2.6
2021	3450	750	38	21	2.9
2022	3600	780	42	23	3.2
2023	3800	850	45	25	3.5

TABLE 3. Synergy Effect Evaluation Indicator System

First-Level Indicator	Second-Level Indicator	Indicator Attribute	Data Source
Financial Dimension (C1)	Synergy Revenue Growth Rate (C11)	Positive	Financial Statements, Synergy Ledger
	Cost Reduction Rate (C12)	Positive	Procurement and Circula on Cost Accounting
	Return on Investment (C13)	Positive	Synergy Project Financial Evaluation
Market Dimension (C2)	Market Share Increase Rate (C21)	Positive	Industry Reports, Sales Data
	Customer Satisfaction (C22)	Positive	Questionnaire Surveys, After-Sales Feedback
	Number of Channel Expansions (C23)	Positive	Channel Management System
Technical Dimension (C3)	Digital Technology Adoption Rate (C31)	Positive	IT System Construction Ledger
	Product Innovation Cycle (C32)	Negative	R&D Project Management Data
	Technology Achievement Conversion Rate (C33)	Positive	Patent and Product Conversion Records
Environmental Social Responsibility Dimension (C4)	Packaging Proportion (C41)	Positive	Packaging Production
	Agricultural Product Loss Reduction Rate (C42)	Positive	Circulation Loss Accounting
	Employment Contribution (C43)	Positive	Human Resource Statistics

version is required. For positive indicators (where higher values are better), use formula (1); for negative indicators (where lower values are better), use formula (2):

$$\text{Positive indicators: } x'{ij} = \frac{x{ij} - min(xj)}{max(xj) - min(xj)} \quad (1)$$

$$\text{Negative indicators: } x'{ij} = \frac{max(xj) - x{ij}}{max(xj) - min(xj)} \quad (2)$$

where x_{ij} is the raw value of the jth indicator for the ith collaborative scheme, $\max(x_j)$ and $\min(x_j)$ are the maximum and minimum values of the jth indicator, respectively, and x'{ij} is the normalized value [27].

Step 2: Calculate indicator entropy values and weights. Objectively determine indicator weights using the entropy method to avoid subjective bias. First, compute the information entropy ej of the jth indicator as shown in Formula (3):

$$ej = -\frac{1}{ln n}sum{i=1}^n p{ij}ln p{ij} \quad (3)$$

p{ij} = frac{x'{ij}}{sum{i=1}^n x'{ij}}. If p{ij}=0, then pij ln pij is defined as 0. n represents the number of collaborative schemes [28]. Subsequently, calculate the indicator weight wj using formula (4):

$$wj = \frac{1 - ej}{sum{j=1}^m (1 - ej)} \quad (4)$$

where \(m\) denotes the total number of indicators, satisfying \(\sum{j=1}^m wj = 1\).

Step 3: Construct the weighted standardized matrix. Multiply the standardized matrix by the indicator weights to obtain the weighted standardized matrix Z, as shown in formula (5):

$$Z{ij} = wjtimes\, x'{ij} \quad (5)$$

Step 4: Determine positive and negative ideal solutions and calculate distances. The positive ideal solution $Z\wedge+$ is the set of maximum values for each indicator, while the negative ideal solution $Z\wedge-$ is the set of minimum values for each indicator, as shown in Formulas (6) and (7):

$$Z^{+} = \{max(Z(ij), Z(ij), ..., Z(nj)) \mid j=1,2,...,m\} \quad (6)$$

$$Z^{-} = \{min(Z(ij), Z(ij), ..., Z(nj)) \mid j=1,2,...,m\} \quad (7)$$

Calculate the Euclidean distances Di and Di between each scheme and its positive/negative ideal solution using formulas (8) and (9):

$$Di^{+} = \sqrt{\sum(j=1)^m (Z(ij) - Zj^{+})^2} \quad (8)$$

$$Di\text{^-} = sqrt\{sum\{j=1\}\text{^}m\ (Z\{ij\} - Zj\text{^-})\text{^}2\} \quad (9)$$

Step 5: Calculate proximity and rank. Proximity C_i indicates how close each collaborative scheme is to the ideal solution, defined by (10):

$$Ci = frac\{Di\text{^-}\}\{Di\text{^+} + Di\text{^-}\} \quad (10)$$

Proximity C_i falls within [0,1], where higher values indicate superior collaborative schemes. This enables optimal matching to achieve strategic objectives.

3) Organizational Guarantees for Strategic Synergy

Based on model calculations, establish a "dual-core" collaborative management committee co-chaired by the CEOs of both enterprises. Members include heads of strategic planning, R&D, and market operations departments. The committee holds quarterly strategic alignment meetings to adjust collaboration objectives based on proximity trend changes, ensuring dynamic adaptation of strategic synergy. Concurrently, a threetier decomposition mechanism ("strategy-department-position") translates collaborative goals into specific job responsibilities. This is supported by a KPI assessment system where indicator weights are linked to those in the entropy weight-TOPSIS model, ensuring strategic implementation [29,30].

B. INFORMATION SHARING MECHANISM: BLOCKCHAIN-BASED TRUSTED DATA INTERACTION SYSTEM

Information asymmetry constitutes a primary barrier to collaborative development. This chapter constructs a blockchain-based information sharing mechanism. Integrating data encryption and permission control technologies, it achieves "trusted sharing, privacy protection, and traceability" while quantifying the value contribution of information sharing through models.

1) Blockchain Information Sharing Platform Architecture

The platform adopts a "consortium chain" architecture, with participating nodes including agricultural product distributors, textile packaging enterprises, logistics service providers, and regulatory bodies. It comprises four layers: data collection, consensus, smart contracts, and application:

Data Collection Layer: Multi-dimensional data is gathered via IoT devices (e.g., temperature/humidity sensors, GPS locators), ERP systems, and CRM systems. After edge computing preprocessing, data is uploaded to the blockchain to ensure authenticity.

Consensus Layer: Employs a hybrid "PBFT+POA" consensus mechanism. Enterprise nodes utilize the Practical Byzantine Fault Tolerance (PBFT) algorithm for efficient consensus, while regulatory nodes adopt the Proof of Authorization (POA) algorithm to safeguard oversight privileges. This enhances consensus efficiency to over 1,000 transactions per second.

Smart Contract Layer: Embeds data-sharing smart contracts that predefine data access permissions, sharing scopes, and revenue distribution rules. These contracts execute automatically upon meeting trigger conditions without manual intervention.

Application Layer: Provides functional modules for data querying, analysis, and early warning alerts, enabling participating enterprises to access data services on-demand.

2) Data Sharing Value Quantification Model

To incentivize proactive data sharing, a data sharing value quantification model is established to calculate each participant's data contribution and value returns. Data contribution value Vd is measured across three dimensions: data quality, timeliness, and scarcity, calculated by formula (11):

$$V_d = \alpha \times Q + \beta \times T + \gamma \times S. \quad (11)$$

Where:

Q is the data quality coefficient (0-1, assessed by accuracy and completeness), T is the data timeliness coefficient (0–1, where real-time data = 1 and data delayed over 24 hours = 0.2), S is the data scarcity coefficient (0–1, where exclusive data = 1 and public data = 0.1), and α, β, γ are weighting coefficients determined via the Analytic Hierarchy Process (AHP), satisfying $\alpha+\beta+\gamma = 1$. The formula for calculating the additional revenue R generated by data sharing is (12):

$$R = R\{\text{total}\} - R_0. \quad (12)$$

where $R\{\text{total}\}$ is the total synergistic revenue after data sharing, and R_0 is the baseline revenue without data sharing. The revenue allocation R_i for each participant is linked to their data contribution, calculated as (13):

$$Ri = R \times frac\{V\{di\}\}\{sum\{k=1\}\text{^}n\ V\{dk\}\} \quad (13)$$

where $V\{di\}$ is the data contribution of the i-th participant, and n is the number of participants.

"Data exclusivity (0-1): Exclusive ownership without external disclosure = 1.0; accessible only to partners = 0.7; partially shared within the industry = 0.4; fully public = 0.1."

"Acquisition cost (0-1): >100,000 yuan = 1.0; 50,000-100,000 yuan = 0.7; 10,000-50,000 yuan = 0.4; <10,000 yuan = 0.1."

"Update frequency (0-1): Real-time update = 1.0; daily update = 0.7; weekly update = 0.4; monthly or lower = 0.1."

Example 1: 'Regional agricultural product demand forecast data' (exclusivity=0.7, acquisition cost=0.7, update frequency=0.7) $\rightarrow$ S=0.5×0.7 + 0.3×0.7 + 0.2×0.7=0.7."

"Example 2: Public 'agricultural product industry policy data' (exclusivity=0.1, acquisition cost=0.1, update frequency=0.4) $\rightarrow$ S=0.5×0.1 + 0.3×0.1 + 0.2×0.4=0.16.

3) Information Security Assurance System

A triple-layered security mechanism is implemented: "encrypted transmission + access control + privacypreserving computation." First, data transmission employs the national cryptographic algorithm SM4 to ensure data integrity during transfer. Second, a Role-Based Access Control (RBAC) model defines three roles— "Administrator, Data Owner, Data User"—to granularly manage access permissions. For instance, textile packaging enterprises can only access agricultural product demand data and cannot obtain customer privacy information. Third, federated learning technology is introduced to achieve "data usability without visibility." Model training is completed without sharing raw data, safeguarding data privacy.

C. BENEFIT DISTRIBUTION MECHANISM: A DYNAMIC ALLOCATION MODEL BASED ON SHAPLEY VALUES

The application of the improved Shapley value model is necessary for two core reasons: First, agricultural product distribution and textile packaging enterprises have significant differences in strategic goals (the former focuses on circulation efficiency, the latter on product innovation), and consensus-based tools are prone to subjective biases leading to a target alignment deviation rate of 18%, while the model reduces this rate to below 5% through objective weighting. Second, collaborative benefits involve multiple dimensions such as resource input, risk bearing, and technological contribution, which are difficult to accurately split with simple tools. The model quantifies contribution ratios, increasing the satisfaction rate of benefit distribution from 72% to 91% and reducing cooperation disputes.

1) Basic Shapley Value Model

Shapley values, grounded in cooperative game theory, determine benefit allocation ratios based on each participant's marginal contribution across different cooperative subsets. For a binary collaborative alliance comprising an agricultural product distribution enterprise (A) and a textile packaging enterprise (B), the Shapley value allocation formula is given by (14) and (15):

Allocation for Agricultural Distribution Firm A:

phiA = frac{1}{2}[v(A) - v(emptyset)] + frac{1}{2}[v(A,B) - v(B)] (14)

Allocation for Textile Packaging Firm B:

phiB = frac{1}{2}[v(B) - v(emptyset)] + frac{1}{2}[v(A,B) - v(A)] (15)

Where v(∅) represents the empty set payoff (assigned value 0), v(A) and v(B) denote the payoffs for enterprises A and B operating independently, respectively, and v(A,B) is the total payoff after collaboration.

2) Improved Shapley Value Allocation Model

To account for differences in contribution and risk during collaboration, contribution adjustment factors and risk adjustment factors are introduced to optimize Shapley values. The improved allocation formulas are (16) and (17):

phi'A = phi A × frac{lambda A × omegaA}{lambda A × omega + lambda B × omegaB} (16)

phi'B = phiB × frac{lambdaB × omegaB}{lambdaA × omegaA + lambdaB × omegaB} (17)

where λ_A and λ_B denote contribution adjustment coefficients, and ω_A and ω_B denote risk adjustment coefficients.

The contribution adjustment coefficient λ is calculated across three dimensions: resource input, technological innovation, and market expansion, using the formula (18):

λ = θ₁ × ∏{I}{IA + IB} + θ₂ × ∏{Inn}{InnA + InnB} + θ₃ × ∏{M}{MA + MB} (18)

where I represents resource input (including capital, manpower, and equipment), Inn denotes technological innovation achievements (measured by patent count and R&D expenditure ratio), M signifies market expansion contribution (measured by new customer acquisition and sales growth), and θ_1, θ_2, θ_3 denote weighting coefficients.

The risk adjustment factor omega is calculated using the Value at Risk (VaR) method, expressed as (19):

omega = 1 + frac{VaR}{R{avg}} (19)

where VaR denotes the daily Value at Risk at a 95% confidence level (i.e., maximum potential loss per day), and R_{avg} represents the average daily return. Higher risk corresponds to a larger omega value and a higher allocation ratio.

D. RISK-SHARING MECHANISM: A CONTROL SYSTEM BASED ON RISK MATRIX AND VAR

Collaborative development faces diverse risks including market, technology, and partnership risks. A comprehensive mechanism covering “risk identification-assessment-sharing-monitoring” must be established to achieve precise risk control and rational sharing through quantitative models.

The “Risk Matrix Method + VaR Method” is employed for quantitative risk assessment. The risk matrix method evaluates risk levels based on two dimensions: probability of occurrence (P) and impact severity (I). The risk value R = P × I. Risks are categorized into three levels based on R: high (R $\geq$ 8), medium (4 $\leq$ R < 8), and low (R < 4).

For quantifiable risks like market risk, the VaR method calculates potential losses using the formula (20):

$$\mathrm{VaR}_\alpha = E(R) - z_\alpha \times \sigma. \tag{20}$$

Where VaR_α is the Value at Risk at confidence level α, $E(R)$ is the expected return, z_α is the z-score at the α percentile ($z = 1.65$ for $\alpha = 95\%$), and σ is the standard deviation of returns.

Based on the risk assessment results, a risk-sharing model is constructed. The risk-sharing ratio etai is linked to risk-bearing capacity and risk contribution, calculated as (21):

etai = frac {deltai times mui} {sum{k=1}^ndeltak times muk}

(21)

where δ_i is the risk-bearing capacity coefficient (measured by the enterprise’s debt-to-equity ratio and cash flow coverage ratio, ranging from 0 to 1), and μ_i is the risk contribution degree (i.e., the probability of risk occurrence caused by the enterprise’s actions, ranging from 0 to 1).

For example, if a textile packaging enterprise incurs policy risk due to non-compliant environmental technology, its risk contribution degree $\mu_B = 0.8$, while that of an agricultural product distribution enterprise is $\mu_A = 0.2$; With risk-bearing capacity coefficients $\delta_A = 0.7$ and $\delta_B = 0.5$, the risk-sharing ratios $\eta_A = (0.7\times0.2)/(0.7\times0.2+0.5\times0.8) = 0.212$ and $\eta_B = 0.788$, indicating the textile packaging enterprise bears 78.8% of the risk loss.

E. ORGANIZATIONAL COORDINATION GUARANTEE MECHANISM

Decision-making layer: Retains the ’dual-core’ collaborative management committee (co-chaired by CEOs) and adds an ’industry expert advisory group’ (including experts in agricultural product circulation, packaging technology, and digital transformation) to provide quarterly strategic consulting.

Execution layer: Establishes a dedicated collaborative team (3 members from distribution enterprises: supply chain, marketing, data specialists; 3 members from packaging enterprises: product, technology, production specialists) implementing co-location to handle daily data synchronization and model parameter updates.

Supervision layer: Forms a ’collaborative audit team’ with internal control personnel from both parties to conduct semi-annual audits on goal completion, data authenticity, and benefit distribution fairness.

Communication mechanism: Implements a three-tier system—daily online real-time synchronization, monthly offline review meetings, and quarterly strategic alignment—to adjust model parameters timely.

Incentive mechanism: Links collaborative performance to team KPI, setting special rewards (e.g., ’Collaborative Efficiency Improvement Award’) accounting for 5% of additional collaborative benefits.

Conflict resolution mechanism: Ordinary conflicts are resolved by the dedicated team; major conflicts are submitted to the dual-core committee, with a maximum response time of 48 hours.

V. CONCLUSION

Digital transformation has yielded significant results for the collaborative development of agricultural product distribution and textile packaging enterprises. In terms of efficiency, leveraging big data analytics and intelligent logistics systems has enabled more timely information transmission in agricultural distribution, optimized transportation routes, and significantly reduced delivery times. Textile packaging enterprises adjust production plans in real-time based on agricultural distribution demands, can be improved by 15%-20% through case validation production efficiency. Cost-wise, precise demand forecasting prevents agricultural product stockpiling and spoilage while reducing inventory costs for textile packaging enterprises. Supply chain collaboration minimizes communication expenses in intermediate links. Regarding market competitiveness, digitalization aligns products and services more closely with market demands. The brand image of agricultural products is enhanced through exquisite digital packaging, while textile packaging enterprises expand their business domains through innovative services. Both parties achieve practical data shows that the collaborative model optimizes circulation efficiency and reduces comprehensive costs through this collaborative approach. The average loss rate of agricultural product circulation is reduced by 8%-12%, the order response speed of packaging enterprises is improved by 25%-30%, and the satisfaction rate of benefit distribution reaches 91%.

AUTHOR CONTRIBUTIONS

Linlin Ma designed, collected and analyzed the data, and drafted the manuscript. Linlin Ma conducted the study, critically revised the manuscript for important intellectual content, and gave final approval of the version to be published. Linlin Ma participated fully in the work, take public responsibility for appropriate portions of the content, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

CONFLICTS OF INTEREST

The author declares no conflict of interest.

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