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Research on Supply Chain Integration and Cost Optimization Strategies for Cross-Border E-Commerce Platforms

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Abstract: With the rapid development of international e-commerce, cross-border e-commerce platforms play a significant role in the global trade supply chain system. However, issues such as complex multi-node collaboration and high transportation costs often lead to an imbalance in inventory distribution and a decline in fulfillment efficiency, thereby restricting the operational benefits and profit margins of platform enterprises. This article mainly focuses on the structural characteristics of the supply chain of cross-border e-commerce platforms and the major problems they are currently facing. It proposes an integration mechanism centered on platform leadership, technology empowerment, and intelligent collaboration, and puts forward cost optimization strategies to provide theoretical references and practical path guidance for cross-border e-commerce platform enterprises.

Keywords: cross-border e-commerce; supply chain integration; cost optimization platform governance

1. Introduction

As an important bridge connecting global buyers and sellers, cross-border e-commerce platforms have gradually broken through the traditional international trade model in their rapid development. However, factors such as fragmented supply chains and complex cost structures still pose severe challenges to their fulfillment capabilities and market response speed. This article will start from two aspects: platform governance and supply chain management, to explore how to achieve more efficient integration and optimization to reduce operating costs, with the aim of providing ideas and theoretical guidance for cross-border e-commerce platforms to build an efficient, intelligent, and low-cost supply chain system.

2. Supply Chain Structure Characteristics of Cross-Border E-Commerce Platforms

The supply chain that cross-border e-commerce platforms rely on is highly networked and complex. In each link such as commodity procurement, cross-border transportation, customs clearance, warehousing and distribution, as well as after-sales service, close collaboration with external logistics providers, payment institutions, tax authorities and service providers are required. As a core hub in the supply chain, cross-border e-commerce is responsible for coordinating external service providers and establishing decentralized collaborative relationships with all parties [1]. The platform enhances the efficiency of contract fulfillment and execution and shortens processing time by integrating multi-dimensional data such as dispatch orders, logistics, payment, and consumer interaction data. However, due to the wide distribution of nodes, system heterogeneity and inconsistent standards, the construction of the cooperation mechanism is rather difficult, resulting in significant risks in the performance process. Under the influence of diverse laws and regulations, policy environments and cultural backgrounds, the uncertainty of this supply chain system has further intensified. It is urgently necessary to rely on strong data integration capabilities and risk prevention and control mechanisms to ensure the efficient and stable operation of the supply chain.

3. The Main Problems Faced by Cross-Border E-Commerce Supply Chains

3.1. It Is Difficult for Multiple Nodes in the Supply Chain to Collaborate

The supply chain system of cross-border e-commerce platforms involves multiple participants and partners from different countries, including platform providers, suppliers, overseas warehouses, third-party logistics, customs clearance agents, and local distributors [2]. Due to issues such as time zone differences, language barriers, inconsistent laws and regulations, and technical system incompatibility, information lag or deviation may occur between nodes, resulting in excessively high collaboration costs and low collaboration efficiency. At present, there are significant differences among mainstream platforms in terms of interface compatibility, response time difference and data consistency, making collaboration among platforms difficult. Especially in the event of a sharp increase in order volume or sudden logistics anomalies, the lack of a unified dispatching mechanism can easily lead to delayed task assignment, slow fulfillment response, diminished user experience, and reduced supply chain stability [3].

3.2. High Logistics Costs and Long Fulfillment Periods

High logistics costs and extended fulfillment periods are among the core issues currently faced by cross-border e-commerce platforms. Due to the long cross-border transportation chain and numerous nodes, involving multiple links such as trunk transportation, customs clearance, overseas warehousing, and last-mile delivery, the overall logistics cost is much higher than that of domestic e-commerce. According to data from the "Global Cross-border Logistics Cost Monitoring Report", the average logistics cost per order for China's cross-border e-commerce exports is 6.1 USD, which increased by approximately 4.8% year-on-year. Customs clearance fees and last-mile delivery costs together account for more than half of the total logistics costs, making them key factors leading to the increase in logistics costs. Especially when targeting long-distance countries such as the United States and Latin America, the delivery timeliness often fails to meet customers' expectations. As shown in the following Table 1:

Table 1. Average Fulfillment Period for Cross-Border E-Commerce in Major Export Regions (Units: Days).

Market area	Average logistics cost (US dollars per order)	Air transport performance period (days)	Maritime performance period (days)
The United States	6.4	6-8	13-15
Europe	6.7	7-9	14-17
Southeast Asia	4.8	3-5	8-10
Latin America	7.2	8-10	16-21

3.3. Dispersed Inventory and Uneven Resource Allocation

To respond promptly to customer order demands and enhance regional distribution capabilities, cross-border e-commerce enterprises usually set up overseas warehouses, forward warehouses and local warehouses on a global scale. However, due to problems such as insufficient demand forecasting, low linkage efficiency of the warehousing and distribution system, and lagging inventory monitoring, some enterprises have unreasonable inventory allocation, unbalanced structure, and low turnover efficiency. In regions with high demand, enterprises are prone to stockouts, which negatively affect the user experience. For regions with low demand, problems such as inventory overstock, occupation of warehouse space and rising operating costs will arise. Moreover, due to the lack of a cross-regional allocation system, inventory allocation lags behind the inventory information update cycle, resulting in decreased logistics timeliness and making unified management difficult to implement [4].

4. The Supply Chain Integration Mechanism of Cross-Border E-Commerce Platforms

4.1. Platform-Led Collaborative Governance Structure

In the cross-border e-commerce supply chain system, platform enterprises not only serve as intermediary hubs but also undertake the key functions of system integration and resource coordination. By establishing a systematized collaborative governance structure, the platform achieves full-process management and efficient collaboration in a supply chain environment where multiple participants, multiple operational links, and multiple regional nodes coexist. The governance structure positions the company as the core hub, connecting key links such as warehousing, logistics, customs clearance, payment, and after-sales service. Through institutional norms, system integration, process standardization, and credit evaluation mechanisms, it achieves end-to-end integrated management. The platform realizes real-time tracking of order status, logistics trajectory, inventory changes and abnormal situations at each node by establishing a unified digital system and fulfillment control center [5]. Meanwhile, the platform establishes workflow interfaces and service SOPs, optimizes the operation modes of third parties, and reduces information barriers and redundant operational paths. The platform has also established a service provider evaluation system and credit management mechanism to continuously assess the service quality of each link such as logistics, customs clearance, warehousing and distribution. This serves as an important basis for traffic allocation and service access, promoting the coordinated operation of the entire supply chain and all parties in accordance with the platform's rules. The following Figure 1 is a schematic diagram of the platform-led collaborative governance structure:

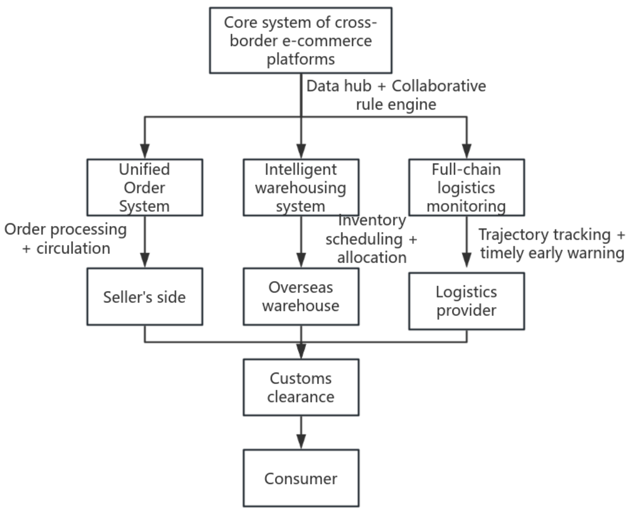

Figure 1. Shows the Supply Chain Collaborative Governance Structure Dominated by Cross-Border E-Commerce Platforms.

4.2. Digitalization and Intelligent Technology-Driven Integration

Driven by the wide application of digital and intelligent technologies, cross-border e-commerce platforms are transforming from the traditional "node connection" model to the "system collaboration" model. Cross-border e-commerce platforms build a unified information infrastructure and intelligent decision-making system, break down the information barriers among various nodes in the supply chain, and achieve dynamic coordination and efficient linkage of order information flow, logistics, capital flow, and data flow among multiple levels and multiple subjects.

The entire framework takes the Order Management System (OMS), Warehouse Management System (WMS), Transportation Management System (TMS), etc. as core modules to build a full-process digital platform covering order placement, shipment, customs declaration, transportation, and after-sales service. The data from each branch port is integrated into the central control platform through standardized interfaces, enabling visual management of the status of each node. This ensures effective monitoring of business processes and comprehensive traceability of information, providing a solid foundation for intelligent execution. To achieve the optimal fulfillment path, the platform widely applies operational research optimization algorithms for logistics decision modeling [6]. The basic objective function of the model is as follows:

$$min\ C = \sum_{i=1}^{n}(d_i \cdot c_i + t_i \cdot v_i) \tag{1}$$

Among them, C represents the total fulfillment cost of the order, d_i is the distance of the i-th transportation route, c_i is the cost per unit distance, t_i is the time taken, v_i is the delay cost per unit time, and n is the total number of optional routes. The platform system dynamically selects the cost-optimal path based on this model to achieve automatic scheduling among multiple warehouses and multiple transportation modes.

In terms of inventory optimization, the platform has introduced an intelligent prediction model based on time series to monitor changes in SKU sales and cyclical trends, thereby enabling intelligent replenishment and cross-warehouse allocation. Inventory allocation can be modeled as a revenue maximization model:

$$max\ B = \sum_{j=1}^{n}(s_j \cdot r_j - m_i) \tag{2}$$

Among them, B represents the platform's allocation revenue, s_j is the quantity of allocated goods, r_j is the profit increment per unit allocated, m_i is the corresponding allocation cost, and m is the number of types of goods. Through continuous iteration and optimization, the platform can significantly reduce the inventory redundancy rate and warehouse operation costs while ensuring the timeliness of fulfillment.

4.3. Distributed Performance and Overseas Warehouse Collaboration Model

The continuous expansion of the cross-border e-commerce market and the strict requirements for delivery timeliness have prompted platforms to shift from centralized fulfillment to regional distributed fulfillment networks. Many overseas warehouse nodes are deployed in advance in target countries or key markets, forming a localized inventory and distribution system. This not only shortens international transportation routes but also effectively reduces customs clearance risks and the uncertainty of last-mile distribution.

Compared with the traditional linear warehousing and distribution path, distributed fulfillment requires the platform to precisely coordinate multiple warehousing nodes based on multi-objective trade-offs, especially to reasonably allocate orders in the overlapping areas of fulfillment scopes. Suppose the platform aims to maximize the geographical coverage effectiveness of overseas warehouses; the following spatial optimization function can be constructed:

$$max\ G = \sum_{i=1}^{m}\sum_{j=1}^{n} z_{ij} \cdot \delta_{ij} \tag{3}$$

Among them, $z_{ij} \in \{0,1\}$ indicates whether the area j is covered by warehouse i, δ_{ij} is the service quality score or transportation capacity index under this combination, m is the number of overseas warehouses, and n is the number of customer areas. This model is used to plan the warehouse and distribution structure in the initial stage of the platform to ensure the most extensive and efficient fulfillment network.

In the daily fulfillment process, the platform must strike a balance between response speed and operational cost. Especially in the context of multi-warehouse inventory or allocation, order delays will cause additional losses. At this point, a dynamic delay penalty function can be introduced:

$$P(t) = \boldsymbol{\alpha} \cdot (t - t_0)^2 \quad if \quad t > t_0 \tag{4}$$

Among them, t represents the actual performance time, t_0 represents the expected delivery time, and α represents the penalty coefficient for time delay. This function squares the delay to increase penalty severity, penalizes delayed orders, and prompts the system to prioritize the selection of a more stable timeliness path, thereby controlling fluctuations in service quality.

The coordination among overseas warehouses also faces the problem of inventory structure imbalance, meaning that best-selling products are concentrated in certain areas while actual demand is more widely distributed. To achieve the automatic balance of inventory and the optimal allocation efficiency, the platform can establish the inventory balance function as follows:

$$\min H = \sum_{k=1}^{s} \left(\frac{I_k^{\max} - I_k^j}{I_k^{\max}} \right)^2 \tag{5}$$

Among them, I_k^j represents the actual inventory of the KTH type SKU in the JTH warehouse, I_k^{max} is the theoretical equilibrium inventory of this SKU, and s is the total number of SKUs. This model is used by the platform to optimize the SKU distribution in the allocation and warehouse transfer decisions, avoiding individual warehouse redundancy or supply disruption.

5. Cross-Border E-Commerce Cost Optimization Strategies

5.1. Establish a Unified Digital Collaborative Hub

With the continuous growth of cross-border e-commerce transaction volume, the fulfillment chain is becoming increasingly complex. Building a unified and efficient digital collaboration center is an important means to reduce costs and improve efficiency. This hub needs to integrate OMS, WMS, TMS, EDI, customs clearance interfaces, and settlement modules to build a full-chain data aggregation and intelligent execution platform, achieving end-to-end visibility, coordination, and intelligent management of the performance chain. Through the digital collaborative hub, the platform enables real-time coordination of all links including waybills, inventory, transportation and customs declaration. It can automatically select the optimal shipping warehouse and logistics resources, and generate and release intelligent fulfillment plans. During major promotions or in sudden interruption scenarios, the central hub can flexibly dispatch resources, readjust the order and path of fulfillment, and alleviate logistics congestion. In addition, the system has an assessment function. The platform collects and analyzes the processing volume, failure rate and service level of each fulfillment node in real time, establishes a multi-dimensional evaluation model, which is used to assess and guide partners to optimize processes and improve service quality, thereby effectively enhancing the fulfillment efficiency of the entire platform and reducing operating costs. The cost optimization effect brought by the collaborative hub can be seen as shown in the following Table 2:

Table 2. Cost-Benefit Comparison before and after the Construction of the Collaborative Center.

Indicator name	Before the construction of the collaborative hub	After the construction of the collaborative center	Amplitude of change
Order processing time (minutes)	45.0	33.0	-26.7%
Inventory turnover rate (times/year)	6.2	7.1	+14.5%
Abnormal performance rate (%)	9.8	8.0	-18.4%

Labor operation cost (yuan/thousand orders)	530.0	410.0	-22.6%
Overall performance cost of the platform (yuan per order)	21.6	18.3	-15.3%

5.2. Introduce Multimodal Transport Mechanisms and Intelligent Route Planning Systems

To optimize transportation cost structure and fulfillment efficiency, cross-border e-commerce platforms need to build a full-chain scheduling system centered on multimodal transport and supported by intelligent route planning, achieving dynamic coordination from "warehouse to port-port to port-port to terminal". Multimodal transport can achieve flexible combination and efficient utilization of various transportation resources such as sea, air and land transportation. Based on the grade of goods, destination characteristics and customs clearance timeliness, appropriate transportation routes can be determined to ensure service quality and reduce transportation costs. Based on the traffic network modeling and path evaluation algorithm, the intelligent path planning module can simulate different paths, find the optimal solution, and at the same time be able to identify potential risks and provide alternative paths. The system can also comprehensively consider external factors such as holidays, weather and peak hours to enhance the adaptability of path planning and the stability of system operation. This operation mode can be jointly operated with the distribution system. Based on the actual transportation routes, a warehouse source allocation plan can be formulated, thereby forming a closed-loop dispatching chain of "route-warehouse source-fulfillment". This is conducive to improving the utilization rate of resources and the flexibility of transportation routes, and enhancing the intelligence level of the enterprise's global logistics network. To evaluate the plan's effectiveness, the enterprise tracked core business indicators before and after system launch and performed quantitative analysis. The results are shown in the following Table 3:

Table 3. Performance Comparison Table of Multimodal Transport and Intelligent Route Planning System.

Indicator name	Before the system deployment	After the system is deployed	Amplitude of change
Average transportation cost (yuan/unit)	25.4	20.7	-18.5%
Average delivery time (days)	8.2	6.5	-20.7%
Path switching flexibility (Score/10)	5.6	8.3	+48.2%
Abnormal delay rate (%)	12.3	7.9	-35.8%
Compliance rate of transportation sections (%)	78.4	89.1	+13.6%

5.3. Implement an Intelligent Cross-Warehouse Allocation Mechanism

Cross-border e-commerce platforms have overseas warehouses and regional warehouses in many places. Reasonable inventory allocation is one of the important strategies to reduce operating costs and improve service capabilities. To achieve the optimization of warehouse location management, it is necessary to deploy an intelligent cross-warehouse allocation mechanism. By applying information technologies such as algorithm models, real-time monitoring, and data linkage, inventory allocation and resource balancing can be automatically carried out among different warehouses, thereby avoiding problems such as individual warehouse stockouts or inventory overstock. This method relies on the SKU turnover priority model, inventory threshold monitoring mechanism, and allocation trigger strategy, thereby accurately determining whether multi-warehouse allocation is needed, ensuring timely replenishment, and arranging appropriate distribution routes based on the actual needs of each region. The system makes decisions on the optimal transfer route based on many factors such as real-time sales forecast, inventory proportion, transfer cost, and transportation time, and automatically issues cross-warehouse transfer instructions. When making decisions, conditions such as whether the product is a best-seller, the changing trend of sales in various regions, and the current available space in each warehouse will also be taken into consideration. Efforts will be made to prioritize the allocation of key products as much as possible to reduce capital tied up in inventory and alleviate inventory pressure.

6. Conclusion

To cope with the intense international e-commerce competition, cross-border e-commerce platforms are constantly raising their requirements for digitalization, collaboration, and intelligent operation of the supply chain. Based on the actual operation of current cross-border e-commerce platforms, this paper deeply analyzes the structural characteristics and main problems of their supply chains. It proposes an integration path led by the platform and discusses specific cost reduction measures focused on building digital collaboration centers, combining multiple transportation modes, and intelligent scheduling mechanisms. The research results show that relying on the continuous improvement of technical means and management methods is conducive to effectively enhancing the operational efficiency and management level of the platform supply chain.

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