Digital Transformation of Cross-Border Logistics Supply Chains and Collaborative Development of Ecosystem-Oriented Railway Logistics Parks

Huang Xiang
Sichuan Land-Sea Cloud Port Development Group Co., Ltd., Chengdu, Sichuan, China

Abstract: Digital transformation is revolutionizing cross-border logistics supply chains. Ecosystem-oriented railway logistics parks, serving as hubs for multimodal transport and industrial collaboration, play a crucial role in regional economic development. This paper develops a theoretical model that integrates digital assetization and intelligent empowerment in cross-border logistics. It proposes a blockchain-based mechanism for logistics data assetization and establishes a governance and collaborative innovation framework for the ecosystem. Empirical analysis of representative railway logistics parks demonstrates the positive effects of digital transformation on supply chain efficiency and risk management. This research enhances the theoretical framework for digital supply chains and offers innovative pathways and practical models for developing cross-border logistics in inland and peripheral areas.

Keywords: Cross-Border Logistics; Digital Assetization; Blockchain; Ecosystem-oriented Railway Logistics Park; Intelligent Supply Chain; Multimodal Transport

1. Introduction

As global economic integration accelerates, nations face unprecedented competition in supply chain management and logistics [1,2]. In this context, the efficiency and intelligence of cross-border logistics supply chains have become critical indicators of national strength [3,4]. Recent initiatives, such as China's "Belt and Road" and inland openness strategies, have invigorated the development of railway logistics parks, promoting deeper multimodal transport and regional industrial clustering [5,6]. However, traditional logistics parks predominantly rely on hardware upgrades, revealing significant deficiencies in digital transformation and intelligent management that hinder their adaptability to modern supply chain demands [7-9].

Emerging technologies, including digitalization, artificial intelligence (AI), and blockchain, are gradually realizing their potential in logistics supply chain management [10]. Digital assetization innovatively integrates information, data, logistics, and transactional processes. AI facilitates dynamic optimization, forecasting, and decision-making within supply chains, while blockchain enhances information security and transaction transparency [11]. The integration of these technologies lays a robust foundation for supply chain innovation and explores new avenues for developing ecosystem-oriented railway logistics parks. By establishing collaborative governance mechanisms among stakeholders across departments and enterprises, these parks promote resource sharing and risk management, resulting in a more efficient and flexible supply chain model.

This paper aims to investigate the digital transformation of cross-border logistics supply chains and the development of core capabilities, providing systematic theoretical guidance and practical insights for transforming and upgrading logistics parks in inland and marginal areas. A blockchain-based data assetization model is proposed, alongside an ecological governance framework informed by empirical case studies. Through a comprehensive analysis of innovative pathways and practical applications, this study seeks to guide the future development of China's cross-border logistics supply chains toward enhanced intelligence, safety, and efficiency.

2. Theoretical Basis and Research Framework

2.1 Digital Transformation and Intelligent Empowerment of Supply Chains

The digital transformation of cross-border logistics supply chains represents a crucial trend

in the global restructuring of supply chains, aimed at achieving process transparency, automation, and intelligent decision-making through the integrated application of information technology. This transformation encompasses the development of logistics information infrastructure and emphasizes the creation, circulation, and appreciation of digital assets, known as "digital assetization." Digital assetization involves converting logistics transactions, transport statuses, warehouse information, and supply chain financial data into tradable digital assets using standardized data models, quality control mechanisms, and structured processing. This process enhances the data resources of logistics supply chains and fosters innovations in supply chain finance.

Regarding intelligent empowerment, artificial intelligence technologies—including deep learning, reinforcement learning, and graph neural networks—are applied at critical stages of the supply chain. Key functions include:

Demand Forecasting: Accurate prediction of cross-border market demand through big data and machine learning to alleviate inventory pressure.

Intelligent Scheduling: Dynamic allocation of transport resources and path planning using optimization algorithms to improve transport efficiency.

Risk Monitoring and Management: Employing anomaly detection and causal analysis models to predict risks such as supply chain disruptions and delays, facilitating prompt responses from decision-makers.

Operational Optimization: Integrating real-time sensor data to enhance warehouse management, cargo tracking, and distribution strategies.

Moreover, blockchain technology underpins digital assetization by addressing challenges such as data silos, information fraud, and trust deficits in cross-border logistics. It ensures the authenticity and traceability of logistics data, promoting supply chain finance innovations through mechanisms like on-chain data financing, credit rating, and risk control, thereby significantly enhancing capital flow efficiency and security.

In summary, the digital transformation and intelligent empowerment of supply chains establish the digital infrastructure necessary for efficient collaboration and value co-creation in cross-border logistics.

2.2 Concept and Functions of Ecosystem-Oriented Railway Logistics Parks

Ecosystem-oriented railway logistics parks are spatial carriers and collaborative innovation platforms for the digital transformation of cross-border logistics supply chains. Their core characteristic lies in constructing a digital technology-driven industrial ecosystem around railway multimodal transport hubs, achieving deep integration of logistics, supply chain finance, information services, and related industries. Specific functions include:

Multimodal Transport Hub: Integrating railway, road, waterway, and air transport resources to provide efficient transport connections and seamless service, reducing cross-border logistics time and costs;

Industrial Cluster Platform: Attracting upstream and downstream supply chain enterprises, service providers, and financial institutions to foster collaborative innovation ecosystems and enhance overall supply chain competitiveness;

Digital Platform Construction: Implementing data sharing, business collaboration, and intelligent decision-making among multiple stakeholders through big data platforms, IoT, cloud computing, and blockchain technology;

Logistics Financial Services: Providing diverse supply chain financial products and services based on digital assetization, such as accounts receivable financing and warehouse receipt pledging, to solve financing challenges for small and medium-sized enterprises;

Ecological Governance System: Establishing a multi-stakeholder governance mechanism to ensure data security, promote standardization, and foster the sustainable development of the ecosystem.

The operational mechanism of ecosystem-oriented railway logistics parks emphasizes "openness," "sharing," and "collaboration," promoting efficient cooperation among enterprises within the park and with external partners through digital platforms and collaborative governance mechanisms. This creates a virtuous cycle of resource optimization and value co-creation, driving the digital transformation and upgrading of cross-border logistics supply chains.

2.3 Research Framework

His paper establishes a comprehensive research framework for the collaborative development of digital transformation within cross-border

logistics and ecosystem-oriented railway logistics parks, as detailed in Table 1. The framework is structured around five interrelated modules:

Digital Assetization: This module focuses on converting logistics-related data into tradable digital assets. It involves the implementation of standardized data models and quality control mechanisms that facilitate the creation, circulation, and appreciation of digital assets. By enhancing the data resources of logistics supply chains, this module lays the groundwork for innovative financial solutions within the supply chain.

Intelligent Supply Chain Empowerment: This module emphasizes the integration of cutting-edge artificial intelligence technologies, such as machine learning and predictive analytics, to enhance various stages of the supply chain. Key applications include demand forecasting, intelligent scheduling, risk monitoring, and operational optimization, all aimed at improving efficiency and responsiveness in cross-border logistics operations.

Ecosystem Governance Mechanisms: This module explores the establishment of collaborative governance structures among stakeholders, including logistics providers, regulatory bodies, and technology partners. It focuses on creating frameworks that promote resource sharing, risk management, and decision-making processes that are aligned with the interests of all parties involved, thereby fostering a cohesive ecosystem.

Multimodal Transport Coordination: This module addresses the integration of various transportation modes (e.g., rail, road, air, and sea) to ensure seamless logistics operations. It highlights the importance of optimizing transport routes, schedules, and resource allocation to enhance overall transport efficiency and reduce costs in cross-border logistics.

Empirical Analysis: This module involves the examination of real-world case studies and data-driven insights to validate the effectiveness of the proposed framework and its components. By analyzing practical applications and outcomes, this module aims to provide actionable recommendations for practitioners and policymakers in the field of logistics.

Through the detailed exploration of these modules, the framework aims to offer a robust theoretical foundation and practical guidance that can aid in the digital transformation of cross-border logistics. Additionally, it supports the collaborative development of railway logistics parks, ultimately contributing to improved efficiency, resilience, and sustainability in the logistics sector.

Table 1. Research Framework for Collaborative Development of Cross-Border Logistics Digital Transformation and Ecosystem-Oriented Railway Logistics Parks

Module	Main Content
Digital Assetization Model	Blockchain-driven data on-chain, smart contract management of asset transactions
Intelligent Supply Chain empowerment	AI scheduling, risk prediction, intelligent warehousing and transport management
Ecosystem Governance Mechanism	Multi-stakeholder collaborative governance, benefit-sharing mechanisms, open innovation platforms
Multimodal Transport Coordination	Coordination of rail, road, water, and air transport
Empirical Analysis and Path exploration	Data analysis of park case studies, verification of Transformation effects, and optimization recommendations

3. Data Assetization in Cross-Border Logistics and Intelligent Supply Chain Platform Construction

3.1 Blockchain-Based Logistics Data Assetization Model

In traditional cross-border logistics, the authenticity of data is difficult to guarantee due to information silos and fragmented data, which severely restricts the effective sharing and circulation of logistics information, ultimately limiting supply chain efficiency. Logistics transaction data, as a vital resource, lacks standardized asset management and circulation mechanisms, hindering the development of data-driven supply chain finance and value-added services. To overcome these bottlenecks, this paper proposes a blockchain-based logistics data assetization model, constructing an alliance chain framework that involves logistics enterprises, financial institutions, and regulatory bodies in building a trusted distributed data ledger, thereby ensuring secure data sharing and value realization.

The core processes of this model include:

1). Implementing a strict data quality verification mechanism to standardize and encrypt key data from cross-border logistics transactions before uploading it to the blockchain, ensuring data immutability and traceability;

2). Utilizing smart contract technology for automated registration, transaction settlement, and risk warning functionalities of logistics data assets, enhancing the automation and real-time capabilities of business processes;

3). Providing real and transparent credit foundations for supply chain finance through on-chain data assets, significantly improving financing efficiency and risk control;

4). Employing multi-layer encryption algorithms and permission management to ensure the information security of commercial secrets and personal privacy.

This model enhances the transparency and credibility of logistics data, facilitates multi-party collaborative data circulation, effectively reduces financing risks and credit costs, optimizes capital liquidity, and fosters innovative service models based on data, such as dynamic insurance and real-time financing.

3.2 Key Technologies for Intelligent Supply Chain Platforms

The construction of intelligent supply chain platforms relies on a unified data repository, aggregating heterogeneous data from multiple enterprises and systems to achieve cross-organizational information integration and management. The platform integrates advanced artificial intelligence algorithms, particularly machine learning and deep learning technologies, for scientific forecasting of cross-border logistics demands, intelligent planning of transport routes, and dynamic identification of potential risks. Through precise demand forecasting, the platform effectively reduces inventory backlog and shortage risks; intelligent path planning enhances transport efficiency and resource utilization; and the risk monitoring module analyzes real-time and historical data to alert potential supply chain interruptions, delays, or anomalies, supporting proactive decision-making and risk mitigation.

Moreover, IoT technology plays a critical role in the perception layer, enabling real-time collection and monitoring of key indicators such as vehicle status, cargo location, and environmental conditions, thus improving the visibility and traceability of the supply chain. Blockchain technology provides data security and transaction verification, ensuring the safety and integrity of multi-party data interactions. The intelligent supply chain platform also possesses high flexibility in scheduling, supporting dynamic coordination of multimodal transport systems, enabling rapid adjustment of transport plans based on real-time transport demands and resource status, thereby improving the operational efficiency and emergency response capabilities of the entire cross-border logistics network. This integrated platform not only enhances the intelligent management capabilities of the supply chain but also provides comprehensive technical support and implementation pathways for the digital transformation of cross-border logistics supply chains.

4. Collaborative Governance Mechanisms and Innovation Drivers in Ecosystem-Oriented Railway Logistics Parks

4.1 Multi-Stakeholder Collaborative Governance Framework

Ecosystem-oriented railway logistics parks represent a complex system interwoven with diverse interest groups, including railway operators, logistics service providers, upstream and downstream supply chain enterprises, financial institutions, government regulatory bodies, and technology service providers. To establish an effective multi-stakeholder collaborative governance framework, it is essential to adhere to principles of clear rights and responsibilities, shared benefits, and co-responsibility for risks, ensuring a balanced distribution of rights among all parties and sustainable development of the park. On this basis, a management committee for the shared platform is established as the core coordinating body responsible for data security management, operational norm formulation, and promoting innovation and development, forming unified governance guidance. By clarifying the responsibilities, obligations, and cooperation boundaries of each stakeholder, the transparency and execution of governance in the park are enhanced.

Additionally, the ecological governance framework emphasizes the innovative design of dynamic benefit distribution mechanisms, adjusting profit distribution based on the actual

contributions of each participant in data provision, risk sharing, and innovation investment, thereby encouraging active participation in collaborative innovation and resource sharing. Meanwhile, a unified standardization system encompassing data formats, communication protocols, service interfaces, and operational processes is constructed to address interoperability issues across enterprises and platforms, reducing collaboration costs. A continuous feedback mechanism collects operational data in real-time and implements multi-faceted assessments to dynamically optimize governance rules and service performance, promoting self-adjustment and healthy evolution of the park's ecosystem.

4.2 Collaborative Innovation Drive

Driven by digital technologies, ecosystem-oriented railway logistics parks significantly enhance information flow and resource integration by constructing an open and shared digital platform, breaking down barriers of traditional logistics systems, and promoting deep integration of multimodal transportation systems with upstream and downstream industrial chains. The platform facilitates seamless connections between transport scheduling, warehouse management, order processing, and supply chain finance, improving operational efficiency and service quality. Furthermore, the digital platform stimulates innovations in logistics service models, such as on-demand customized intelligent logistics, eco-friendly packaging solutions, and full-process visualization services, enhancing customer experience and market competitiveness.

From a supply chain finance perspective, the digital platform provides small and medium-sized enterprises with financing channels based on real transaction data, lowering financing thresholds and risk costs, and activating capital liquidity. Concurrently, the application of intelligent technologies such as blockchain, artificial intelligence, and IoT drives the intelligent upgrade of risk management, contract execution, and supply chain collaboration. The collaborative innovation driven by multi-stakeholder participation stimulates technological research and development as well as business model innovation, creating a multi-win industrial ecosystem encompassing logistics, finance, information, and manufacturing, thus supporting the efficient, green, and intelligent development of railway logistics parks within cross-border logistics supply chains.

5. Empirical Analysis and Future Outlook

5.1 Implementation Effects

Taking a specific inland railway logistics park as an example, this park undertakes cargo distribution tasks along the Belt and Road initiative. In traditional modes, issues such as information silos, slow capital flow, and unstable transport timelines have led to low overall operational efficiency. To address this, the park actively explored digital transformation pathways and built a digital asset management platform. On this platform, comprehensive collection and standardization of transaction data were performed, which were then managed through an alliance chain technology to ensure transparent and reliable processes via smart contracts. Practical applications have demonstrated significant results:

1). Supply chain financial institutions provided financing support based on verifiable blockchain data, reducing financing cycles by approximately 20% and financing costs by around 15%;

2). The introduction of artificial intelligence algorithms to optimize transport scheduling, coupled with IoT real-time monitoring, significantly improved transport timelines, achieving a 30% increase in on-time delivery rates;

3). The multimodal transport coordination system enabled seamless integration of railway and road transport, resulting in a roughly 10% decrease in overall logistics costs.

Additionally, the established ecological governance mechanisms fostered information resource sharing among enterprises within the park and promoted collaborative research and development of intelligent warehousing and green packaging technologies, gradually forming a mutually beneficial and risk-sharing cooperation model that greatly enhances the park's overall competitiveness.

5.2 Conclusions and Future Outlook

Real-world case studies indicate that the implementation of digital asset management platforms and relevant information technologies effectively addresses information silos and slow

capital flows in traditional logistics parks, while also providing stakeholders with more precise decision support and scheduling tools. The park has significantly improved logistics efficiency and reduced operational costs through the deep integration of technology and management practices, facilitating efficient connections in multimodal transport.

As digital and intelligent technologies continue to mature and proliferate, logistics parks are expected to achieve greater breakthroughs in information sharing, supply chain finance, and intelligent scheduling. Information collaboration within and across enterprises will further strengthen, advancing logistics operations from localized optimization to overall cohesion. Concurrently, the widespread application of next-generation technologies may give rise to innovative business models such as intelligent warehousing, green packaging, and complete process traceability, thus providing deeper transformative momentum for the logistics industry. The continually improving ecological governance mechanisms will also provide solid support for constructing an open, transparent, and win-win logistics ecosystem among enterprises, guiding the digital transformation of logistics in China and the wider region.

This paper innovatively constructs a blockchain-based model for cross-border logistics data assetization, designs a multi-stakeholder collaborative governance framework for ecosystem-oriented railway logistics parks, and develops an intelligent supply chain platform, validating the positive impact of digital transformation on logistics efficiency and supply chain finance. Empirical evidence shows that digital assetization and collaborative ecosystem mechanisms are effective pathways for promoting high-quality development of cross-border logistics in inland and peripheral regions. Future research will further deepen intelligent algorithm optimization, flexible scheduling for multimodal transport, and cross-regional ecological collaboration mechanisms, facilitating the digital transformation of cross-border logistics supply chains into a new phase and providing more directive support for relevant policy formulation and industrial practices.

References

[1] Xiao, H., Wei, J., Fu, Q., et al. Research on the Cultivation of Logistics Management Professionals for the Construction of the New Western Land-Sea Corridor. Logistics Technology, 2025, 48(11), 159-162.

[2] Li, J., & Wang, J. Application of Digital Twin Technology in Logistics Management: A Meta-Analysis Perspective. Logistics Research, 2025, (03), 47-53.

[3] Feng, Z. Research on the Integrated Development of Third-Party Logistics and Supply Chains. Business Economics Research, 2025, (11), 103-105.

[4] Sui, L. Applications and Challenges of IoT Technology in Cold Chain Logistics Management. China Storage and Transportation, 2025, (06), 140-141.

[5] Chen, J. Research on the Digital Transformation and Intelligent Upgrade of Logistics Management Resource Libraries. China Shipping Weekly, 2025, (20), 90-92.

[6] Christopher, M. Logistics & Supply Chain Management (5th ed.). Pearson UK, 2016: 45-78.

[7] Ivanov, D., et al. Viability of intertwined supply networks: extending the supply chain resilience angles. International Journal of Production Research, 2020, 58(13): 4138-4163.

[8] Bektaş, T. The impact of carbon pricing on maritime routing and speed optimization. Transportation Research Part D, 2021, (95): 102851.

[9] Guo, X. AI-driven dynamic routing for last-mile delivery with crowdsourced vehicles. European Journal of Operational Research, 2023, 306(2): 789-805.

[10] Rogers, H. Blockchain adoption in pharmaceutical supply chains: Drivers and barriers. International Journal of Production Economics, 2022, 246: 108414.

[11] Zhou, L., Wang, S. Drone-based emergency medical supply chain for pandemic response. Transportation Science, 2023, 57(1): 116-135.

