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Digital-driven Logistics Supply Chain Transformation: Current Situation, Challenges and Countermeasures Research

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Abstract

With the rapid changes in digital technology, logistics supply chain management is in a critical period of transformation from the traditional model to intelligence and greening. The deep penetration of Industry 4.0 technologies, such as the Internet of Things, Artificial Intelligence and Big Data Analysis, provides new possibilities for improving logistics efficiency, reducing operating costs and achieving sustainable development goals. On the basis of sorting out the theoretical basis and realistic background of the digital transformation of the logistics supply chain, this article systematically analyzes the problems of ideological lag, outdated technical equipment, lack of professional talents, and other problems in the current management, aims to put forward optimization countermeasures from the dimensions of concept renewal, technology application, talent training, etc., in order to provide reference for the digital butterfly transformation of logistics enterprises and the strengthening of supply chain resilience.

Keywords

logistics supply chain, digital transformation, information collaboration, trust mechanism, intelligent logistics, sustainable development

1. Introduction

As a link between production and consumption, the logistics supply chain plays a crucial role in the modern economic system. In recent years, with the deep adjustment of the global trade pattern and the continuous prosperity of e-commerce, the logistics industry has ushered in unprecedented development opportunities, but it also faces multiple pressures such as efficiency improvement, cost control and environmental protection. Research indicates that digital supply chain services are experiencing significant growth due to increased demand for resilient and tech-driven networks, particularly following the disruptions caused by the COVID-19 pandemic [1]. Especially in the post-epidemic era, the resilience and transparency of the supply chain have become the core elements of enterprise competitiveness, and the traditional logistics management model is increasingly difficult to adapt to the rapidly changing market demand.

At the same time, the daily change of digital technology has injected a strong impetus into the transformation and upgrading of the logistics supply chain. The application of the Internet of Things, artificial intelligence, blockchain, big data analysis and other technologies is reshaping all aspects of logistics operation.

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As noted in recent scientometric analyses, there has been a significant surge in academic research on Logistics 4.0, with 77.36% of all studies in this field published between 2021 and 2023, reflecting growing interest in how digitalization and sustainability have become central to supply chain innovation [2]. From transportation path optimization and intelligent warehousing management, to accurate demand forecasting and digital capabilities, are gradually becoming a key component of the core competitiveness of logistics enterprises. It is predicted that the market scale of the digital supply chain will continue to expand rapidly, and increasing enterprise managers have turned their attention to digital capacity building.

Against this background, it is of great theoretical and practical significance to promote the high-quality development of the logistics industry and enhance the resilience and sustainability of the supply chain by deeply exploring the digital transformation path of the logistics supply chain, analyzing existing problems and putting forward systematic optimization countermeasures.

2. Background

2.1 Current Situation of Industry Development

At present, China's logistics industry is in a stage of rapid development and parallel transformation and upgrading. On the one hand, the scale of the logistics market continues to expand, the infrastructure continues to improve, and the level of information technology is steadily improving; on the other hand, the competition in the industry is getting hotter and hotter, and customers' requirements for service timeliness, quality and transparency are also rising. According to relevant data, the scientific and technological content of the logistics distribution system is improving, and the application pace of automatic sorting, intelligent warehousing, unmanned distribution and other technologies is accelerating. Recent research highlights that integrating automation with blockchain in warehouse operations can achieve a 78% reduction in processing time per order and a 94% decrease in error rates relative to manual operations, demonstrating the significant operational benefits of these technologies [3].

In terms of digital transformation, some leading enterprises have begun to explore cutting-edge applications such as artificial intelligence-assisted decision-making, digital twin simulation optimization, and blockchain cross-border traceability. However, from the perspective of the whole industry, digital transformation is still in the primary stage, and there is an obvious gap in the digital level of enterprises of different sizes and regions.

2.2 The “Roadblock” in Front of You

Although digital transformation has become the consensus of the industry, there are still many obstacles in the actual promotion process.

The first to bear the brunt is the backwardness of the management concept. Some enterprises still adhere to the traditional supply and marketing model. Logistics management is limited to the integration of internal functions and fails to truly establish the awareness of supply chain coordination. This conceptual lag has led to enterprises' insufficient understanding of the strategic value of digital transformation and a lack of systematic transformation planning.

The problem of obsoletion of technical equipment is also prominent. Many small and medium-sized logistics enterprises have a weak information foundation, low penetration rate of automated equipment, and limited data collection and processing capabilities. Even in some enterprises that have introduced information systems, the phenomenon of inter-system separation and data isolation is widespread, making it difficult to give full play to the overall effectiveness of digital technology. Studies on digital transformation risks in emerging markets reveal that risks are amplified by misalignment, ineffective management, volatile market conditions, and limited digital literacy, with DT solution adoption heightening cybersecurity vulnerabilities [4]. In addition, the lag in the construction of the logistics standard system also restricts the scale effect of technology application.

The shortage of professional talents has become a bottleneck in the transformation. The digital transformation of logistics requires composite talents who understand both logistics business and digital technology, and there is a disconnect between the current talent training system and industrial demand. According to industry data, by 2025, logistics-related job vacancies are projected to reach 437,000 in China

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alone, with the shortage of high-quality logistics talent becoming a critical bottleneck constraining the industry's digital and intelligent upgrading [5]. The slow updating of the knowledge structure of the original employees of the enterprise, the difficulty of recruiting emerging technical positions, and the insufficient supply of talents seriously restrict the in-depth promotion of digital transformation.

3. Theoretical Background

3.1 Core Technologies to Support Transformation: Logistics 4.0 and Digital Supply Chain

Logistics 4.0 is an extension of Industry 4.0 in the field of logistics, and it is also an important direction for the current logistics industry toward intelligent and digital transformation. Logistics 4.0 extends the Industry 4.0 vision into the logistics domain by applying technologies such as the Internet of Things (IoT), Cyber-Physical Systems (CPS), Artificial Intelligence (AI), blockchain, cloud computing, and big-data analytics to create smart, interconnected, and autonomous supply chains [1]. In the face of the common problems of low efficiency, slow response, transparent information and high labor costs in traditional logistics, digital technology represented by the Internet of Things, artificial intelligence, big data, blockchain and cloud computing has provided systematic solutions for the logistics supply chain from multiple levels, such as data perception, intelligent decision-making, trust construction and infrastructure, and promoted the transformation of the logistics industry from “manual drive” to “data-driven and intelligent drive”.

In actual operation, these technologies are no longer pilot applications, but deeply integrated into daily work:

3.2 Internet of Things Technology

Through RFID tags, sensors, GPS and other devices, you can sense the location of goods, warehouse environment, vehicle status and other information in real time. In the warehousing link, Internet of Things equipment can automatically monitor goods 24 hours a day, greatly reducing the manual inventory workload; in cold chain transportation, sensors can monitor temperature changes in real time, warn abnormal situations in time, and effectively ensure the safety of special goods such as fresh food and medicine.

3.2.1 Artificial Intelligence and Machine Learning

AI has become an important tool for logistics decision-making. In terms of path planning, the system can automatically recommend the best route in combination with real-time road conditions, cargo weight, distance, travel restriction policies, etc., which is more fuel-efficient and time-saving than manual planning; in terms of demand forecasting, it can more accurately predict market demand through historical sales, seasons, promotions, user behavior and other data, help enterprises prepare goods reasonably, and reduce the risk of backlog and out of stock; in terms of intelligent scheduling, AI can automatically assign tasks according to the order volume, personnel and vehicle situation, and improve the overall operation efficiency.

3.2.2 Blockchain Technology

Blockchain mainly solves the problems of trust and traceability in the supply chain. In cross-border logistics, blockchain-based electronic waybills can realize document non-tampering and multi-party real-time sharing, greatly shorten the audit and settlement time, and improve the efficiency of capital turnover. In food, agricultural products and other fields, blockchain can record the whole process from production to sales, realize the source can be checked and the place can be tracked, and improve regulatory transparency and consumer trust. Research demonstrates that blockchain integration in supply chains provides secure and immutable transaction records, delivering real-time transparency and resilience against tampering [6].

3.2.3 New Ruler: Logistics Transformation Requirements under the Sustainable Development Goals

Under the background of the United Nations 2030 Agenda for Sustainable Development, green and low-carbon have become an important direction for the development of global logistics. The transportation industry is one of the main sources of global carbon emissions, among which the proportion of highway logistics is particularly prominent, and the pressure to reduce emissions is becoming increasingly obvious. Policies such

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as the EU's “Green Agreement” and China's “14th Five-Year Plan” Modern Logistics Development Plan have all put forward clear goals for the green transformation of the logistics industry, which means that logistics enterprises can no longer only pursue efficiency and cost, but must take into account environmental benefits in development and take the path of sustainable development. Recent studies emphasize the integration of Industry 4.0 technologies with circular economy strategies, highlighting how technologies such as blockchain and additive manufacturing enable sustainable and regenerative supply networks [2].

In this process, AI and digital technology play an irreplaceable role:

- In the transportation link, the AI dispatching system directly reduces fuel consumption and carbon emissions by optimizing the route, improving the loading rate, and reducing idling;
- In the warehousing link, the intelligent control system can automatically adjust lighting, air conditioning and other equipment according to the environment to achieve energy-saving operation;
- In terms of resource utilization, big data can help enterprises better plan the recycling of packaging, pallets, vehicles and other resources, and promote the development of logistics in a greener and more circular direction.

In general, the combination of digital technology with the concept of green development and circular economy is changing the model of “high consumption and high emission” of traditional logistics, making the supply chain more low-carbon and sustainable while improving efficiency, which is also the inevitable path for the high-quality development of the logistics industry in the future.

4. Literature Review

4.1 Research on Logistics Supply Chain Optimization Countermeasures

Under the dual background of digital transformation and global supply chain restructuring, the logistics supply chain has evolved from a traditional cost center into a strategic core of enterprise value creation and resilience building. Technologies such as the Internet of Things, big data analytics, artificial intelligence, blockchain and digital twins are now widely deployed in cargo tracking, warehousing automation, demand forecasting, route optimization and supply chain visualization, while the spread of electronic waybills has markedly improved both operational efficiency and environmental benefits. Looking ahead, the logistics supply chain will accelerate its evolution toward deep intelligence, green low-carbon operation, global synchronization and structural flexibility—unmanned transport, self-healing supply networks, and full-chain carbon-footprint transparency are becoming the new high ground of competition. However, existing research points to several persistent problems that technology by itself has not solved. A bibliometric analysis of the digital transformation of supply chains shows that integrating new technologies can help companies by automating repetitive tasks and improving decision-making, but many firms still fail to move from pilot projects to wider application because of legacy systems, resource scarcity, and poor organizational alignment [3]. Taken together, the first two problems, severe cross-organizational information silos and weak coordination, suggest a deeper two-part cause: fragmented information and a lack of trust.

Upstream and downstream data are still difficult to share, not only because of technical barriers, but also because many firms remain stuck in zero-sum thinking and are unwilling to expose their “bottom-drawer data.” That reluctance worsens demand distortion and the bullwhip effect. Other obstacles also matter. Uneven technological adoption leaves many SMEs at a basic digital stage, there is a serious shortage of compound talents who understand both logistics operations and digital technologies, and industry standards and data security mechanisms are still underdeveloped. These factors continue to block the reliable circulation of data and effective coordination across the wider supply chain. Put simply, the problem is a “hard-soft mismatch”: digital “pipes” are being built, but the relational “water”, trust and willingness to collaborate, is still not flowing through them. On this basis, this article proposes a set of optimization countermeasures centered on information collaboration and the rebuilding of trust.

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4.2 Change the Mindset: Establishing a Trust-based Digital Collaboration Philosophy

For the digital transformation of the logistics supply chain to move forward, management first needs to change how it understands competition and cooperation. The main shift is from zero-sum competition to trust-based collaboration. At the strategic level, enterprises need to see that building digital capability cannot be separated from building relational capability. This means placing the logistics system within the broader corporate strategy, breaking internal departmental barriers, and setting up cross-functional digital coordination mechanisms. It also means developing a more open approach in which information sharing and joint planning with upstream and downstream partners are treated as strategic assets rather than risks.

In practice, firms can pursue resource sharing and complementary advantages through strategic alliances and industry platforms. Here, core enterprises in the supply chain have a larger role. They should not only push SMEs to upgrade digital tools, but also act as "trust anchors" by showing, through transparent governance and benefit-sharing, that collaboration can produce higher returns for the whole chain than isolated optimization within a single firm. Without that shift, the technical side of digitalization is unlikely to work as intended. Only when firms move from "single-point competition" to "trust-based chain collaboration" can they begin to build the conditions needed for real information synergy.

4.3 Graduated Implementation: Embedding Trust Mechanisms into Technology Deployment

Technology application drives digital transformation, but it works only when trust is built into the technical architecture from the start. Logistics enterprises need to adopt technology step by step, based on their own business characteristics and stage of development. At each stage, they also need to build a "trust layer" that allows data to become shared intelligence rather than isolated information.

At the foundation level, faster deployment of IoT sensing facilities can support digital mapping of goods, vehicles and warehousing resources. This does more than collect data. It creates a single source of objective information that authorized parties can use and verify, which is one basis for mutual trust.

At the operational level, the introduction of Transportation Management Systems (TMS) and Warehouse Management Systems (WMS) should go together with agreed data-sharing protocols and clear service-level transparency rules. Otherwise, partners may see process optimization as a way to shift costs rather than improve coordination.

At the advanced level, the use of artificial intelligence in demand forecasting, route optimization and intelligent scheduling faces a more direct trust problem. Enterprises are often unwilling to provide data to joint algorithms if they are concerned about leakage or misuse. In this case, privacy-preserving computation and federated learning may help because they support collaborative intelligence without exposing raw data. Blockchain can also be used in supply chain traceability and electronic document authentication, making transactions tamper-proof and auditable. The development of electronic waybills shows this clearly. A shared and verifiable data record can raise efficiency, reduce environmental costs, and increase confidence among supply chain actors at the same time. Research has shown that integrating blockchain and AI technologies can reduce data latency by 50% and improve demand forecasting accuracy by 30%, creating a self-governing data exchange ecosystem where authenticity is verifiable and decisions are data-driven [4]. Attention to digital twins and edge computing should also go beyond technical performance alone and assess whether these tools improve joint situational awareness and coordinated decision-making. That is where collaboration becomes real.

4.4 Strengthen the Foundation: Cultivating Talent for a Collaborative Digital Ecosystem

Talent is a basic condition for successful digital transformation, and the current shortage cannot be solved by enterprises alone. It requires coordination across multiple actors. Just as important, the goal is not only to build technical ability but also to develop the interpersonal and organizational skills needed to sustain trust across firms.

At the enterprise level, internal training mechanisms should help current employees update their digital knowledge and improve their abilities in supply chain relationship management, negotiation, and collaborative planning. Recruitment should also focus on people with data analytics and IT backgrounds who can

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communicate across functions, because this combination matters in day-to-day cooperation. Technical knowledge by itself is not enough.

At the educational level, universities and vocational colleges need to strengthen curricula that combine logistics and information technology. Modules on supply chain governance, trust mechanisms, and inter-organizational collaboration should also be included, along with practical training that matches the actual needs of a networked industry. This is especially important because many graduates may understand platform tools or data analysis, yet have less preparation for coordination across organizational boundaries.

At the government level, policy guidance and targeted financial support should encourage deeper industry-education integration and school-enterprise cooperation. The aim should be to cultivate "compound talents" who can connect hard digital systems with the softer collaborative relationships that keep those systems functioning across a supply chain. Recent policy initiatives, such as China's "Action Plan for Accelerating the Development of Digital and Intelligent Supply Chains," have explicitly identified strengthening digital and intelligent supply chain talent cultivation as a major task, calling for enhanced supply of innovative, application-oriented, and compound talent to bridge the gap between talent development and industrial demand [5].

4.5 Improve the Ecosystem: Institutionalizing Trust Through Standards and Policy Coordination

Firm-level measures are not enough on their own. Trust also depends on the wider industry setting, so institutional arrangements need to support it in a more consistent way. One priority is to speed up unified data interface standards and information-sharing rules, so data barriers between enterprises and platforms can be reduced and information can move more smoothly across the supply chain. These standards are more than technical specifications. They set expectations in advance, make joint behavior easier to predict and verify, and address the "information island" problem more directly.

Another priority is stronger data security and privacy protection. Trusted computing, privacy-enhancing technologies, and clear data governance rules can reduce the perceived risk of sharing information. If firms believe their data will be misused or exposed, coordination is unlikely to improve much. Under these conditions, trust becomes less dependent on personal relationships and more anchored in stable institutional safeguards. Studies on digital transformation risks in logistics emphasize that cybersecurity vulnerabilities are amplified by expanded digital footprints, which points to the need for robust risk assessment and mitigation strategies [6].

Policy support also matters. Local governments can provide subsidies or tax incentives for SMEs adopting cloud-based collaboration tools, especially where cost is still the main obstacle to participation. At the same time, the successful experience of leading enterprises in building trusted data-sharing consortia can be formalized and promoted, so others have models they can realistically follow rather than general policy slogans. That makes replication more plausible.

Green and low-carbon indicators should also be included in supply chain performance evaluation systems. This would push enterprises to treat carbon footprint management and sustainable logistics network construction as part of cooperation, rather than as separate or optional goals. One might expect trust to depend mainly on efficiency and data transparency, but long-term cooperation increasingly depends on whether firms regard each other as credible partners in meeting sustainability commitments as well. In that sense, the future direction of the supply chain is built into the institutional framework used today, and that framework can reinforce trust.

Taken together, the four-part adjustment of "mindset shift toward trust—technology deployment with embedded trust—talent empowerment for collaboration—and ecosystem institutionalization of trust" helps the logistics supply chain move past narrow local efficiency gains.

5. Key Finding

The digital transformation of the logistics supply chain is an imperative pathway to adapt to the digital economy and enhance industry competitiveness. The integrated application of the Internet of Things, artificial

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intelligence, blockchain and other technologies is profoundly reshaping logistics operations, unlocking new possibilities for efficiency gains, cost optimization and sustainable development. However, problems such as outdated management mindsets, uneven technology adoption and a shortage of interdisciplinary talent remain formidable obstacles. Looking ahead, if these challenges are left unresolved at their relational root, a more disquieting future looms: information silos may solidify into permanent digital walls, zero-sum behaviors may accelerate into algorithmic distrust, and the very data that powers intelligent decision-making could become a new battleground of sovereignty disputes—leaving the supply chain technically hyper-connected yet trust-starved, visibly smart but structurally brittle.

To forestall such a future and move toward genuine global value creation, the core resolution lies in forging information synergy and technology-embedded trust relationships. Information synergy—the seamless, willing and trustworthy flow of data across organizational boundaries—must replace fragmented data hoarding and distorted demand transmission. At the same time, digital technologies must be deliberately architected as trust carriers, not mere efficiency instruments: privacy-preserving computation, federated learning, blockchain-based shared truth mechanisms, and joint digital twins should be deployed to enable collaboration without exposing sensitive raw data, so that coordination becomes predictable and verifiable. This “hard-soft fusion” turns technology from a potential source of vulnerability into relational glue that aligns interests and amplifies collective intelligence.

Enterprises must therefore carry out systematic planning from a strategic height, working simultaneously on mindset renewal, technology deployment with embedded trust, talent cultivation for cross-boundary collaboration, and ecosystem-wide institutional reinforcement. Building on the present foundation of information technology and operational efficiency, they must also focus on the long-term task of cultivating a collaborative trust ecosystem. Only by embedding trust into the digital fabric of the supply chain—making information the flowing blood and trust the animating soul—can managers truly shift from local optimization to holistic, resilient, and sustainable global value creation. In the unfolding era of scientific and technological revolution and industrial transformation, this is the way to build a modern logistics supply chain system that is not only agile, efficient and green, but also deeply collaborative and structurally empowered to absorb future shocks.

6. Discussion

6.1 Change Minds: Establish the Concept of Digital Supply Chain Collaboration

To promote the digital transformation of the logistics supply chain, the first task is the fundamental transformation of the management concept. Enterprises should recognize the importance of digital capacity building from a strategic height, and integrate the logistics system into the overall development strategy of the enterprise for overall planning. This means that enterprises need to break down departmental barriers and establish a cross-functional digital coordination mechanism; at the same time, they should establish an open and cooperative mentality and take the initiative to establish information sharing and business collaboration with upstream and downstream partners in the supply chain.

In practice, enterprises can achieve resource sharing and complementary advantages by establishing strategic alliances and participating in industry platforms. For the core enterprises in the supply chain, they should play a leading role in driving small and medium-sized enterprises to jointly improve the level of digitalization.

6.2 Lay Out Stalls and Steps: Accelerate the Integration and Application of Digital Technology

Technology application is the core of digital transformation. Logistics enterprises should promote technological upgrading in an orderly manner according to their own business characteristics and development stages.

At the basic level, managers should accelerate the deployment of Internet of Things perception facilities, realize the digital mapping of goods, vehicles and warehousing resources, and lay a good foundation for data collection and analysis.

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At the operational level, Transportation Management System (TMS) and warehousing management system (WMS) can be introduced to optimize the daily operation process.

In terms of advancing, managers can explore the in-depth application of artificial intelligence in demand prediction, path optimization, intelligent scheduling and other scenarios. For enterprises with conditions, the application of blockchain in supply chain traceability, electronic documents, etc. can also be further explored. Practice shows that the application of electronic waybills can not only improve operational efficiency, but also bring considerable environmental protection benefits. At the same time, managers should also pay attention to the application of emerging technologies such as digital twins and edge computing in logistics scenarios.

6.3 Strengthen Foundation: Build a Digital Talent Training System

Talents are the fundamental guarantee for the success of digital transformation. Solving the problem of talent shortage requires the joint efforts of many parties.

From the enterprise level, an internal training mechanism should be established and improved to help existing employees update their knowledge structure and improve their digital skills. At the same time, managers should actively introduce professionals with data analysis and information technology backgrounds to optimize the team's ability combination.

From the educational level, colleges and universities and vocational colleges and universities should strengthen the construction of a curriculum system integrating logistics and information technology, pay attention to the cultivation of practical ability, and make the cultivation of talents closer to the actual needs of the industry.

From the government level, through policy guidance and special financial support, managers can encourage the integration of industry and education and cooperation between schools and enterprises to jointly cultivate composite talents to adapt to the development of the industry.

7. Conclusion

The digital transformation of the logistics supply chain is the only way to adapt to the development of the digital economy and improve the competitiveness of the industry. The integrated application of the Internet of Things, artificial intelligence, blockchain and other technologies is profoundly changing the logistics operation mode, providing new possibilities for efficiency improvement, cost optimization and sustainable development. However, problems such as lagging management philosophy, uneven application of technology, and shortage of professional talents are still the main obstacles on the road to transformation.

To promote the digital transformation of the logistics supply chain, enterprises need to carry out systematic planning from a strategic height and work together in multiple dimensions such as concept renewal, technology application and talent cultivation. Managers should not only build on the present, consolidate the foundation of information technology, and improve operational efficiency. Managers should also focus on the long-term, lay out cutting-edge technologies, and cultivate competitive advantages. Only in this way can managers seize the opportunity in a new round of scientific and technological revolution and industrial transformation and build an agile, efficient and green modern logistics supply chain system.

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Conflicts of Interest

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