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Research on Supply Chain Collaborative Management and Resilience Enhancement Mechanism Driven by Digital Intelligence

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Abstract
With the increasing uncertainty in the global supply chain environment, traditional closed-loop logistics management models can no longer meet the practical needs of multi-agent collaboration. From the perspective of supply chain collaboration, and integrating theories of artificial intelligence and platform management, this paper deeply explores the impact mechanism of digital intelligence technologies on supply chain resilience. The study finds that current supply chain management faces structural limitations such as insufficient collaborative awareness, information silos, and low response efficiency. Artificial intelligence technology not only significantly enhances supply chain resilience but also exerts its mediating effect through two paths: "reshaping talent structure" and "improving innovation levels." Meanwhile, challenges in platform supply chains, such as high-dimensional decision-making and algorithmic opacity, need to be addressed through reinforcement learning, interpretable algorithms, and human-machine collaboration mechanisms. This paper proposes innovative strategies including building integrated collaboration, platform-based integration, and intelligent scheduling, aiming to provide theoretical basis and practical references for enterprises to achieve cost reduction, efficiency improvement, and high-quality development in supply chains.

Keywords: *Supply Chain Collaboration; Artificial Intelligence; Supply Chain Resilience; Platform Management; Model Innovation*

1. Introduction

Under the background of global economic restructuring and the accelerated penetration of digital technologies, corporate competition has shifted from individual contests to systemic confrontations within supply chain ecosystems. The report of the 20th National Congress of the Communist Party of China explicitly proposes to "focus on enhancing the resilience and security of industrial and supply chains." In 2025, the Ministry of Commerce and other departments also issued an action plan to accelerate the development of digital and intelligent supply chains. However, the structural defects of traditional logistics and business management models, such as information barriers, coordination failures, and response lags, have become increasingly prominent. How to use cutting-edge technologies like Artificial Intelligence (AI) to break corporate boundaries and achieve a leap from "passive response" to "proactive collaboration" has become a key issue to be solved.

2. Literature Review & Theoretical Basis

2.1 The Connotation and Evolution of Supply Chain Resilience

The concept of Supply Chain Resilience (SCR) originates from ecology, emphasizing the ability of a system to return to its original state after being disturbed. With the restructuring of global value chains, academia has extended its definition. Gölgeci & Kuivalainen (2020) pointed out that resilience includes not only "recoverability" but also emphasizes "resistance" and "adaptability." Zhang Shushan et al. (2023) further refined it as the ability of a supply chain to quickly recover and maintain basic functions when facing external shocks (such as natural disasters, geopolitical conflicts), and even achieve a higher level of operation through adaptation and adjustment. Existing research has shifted from a single focus on "efficiency first" to "equal emphasis on efficiency and resilience." Especially in the post-pandemic era, how to

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ensure the security of industrial chains has become a core issue.

Regarding the impact of digitalization on supply chains, existing literature mainly focuses on two dimensions: information effects and collaboration mechanisms. Qi Yudong and Xiao Xu (2020) believe that digital transformation breaks corporate boundaries through networked connections, significantly improving communication and collaboration levels between upstream and downstream. Tao Feng et al. (2023) empirically verified that the digital transformation of downstream enterprises in the supply chain can, by enhancing resilience, in turn promote the total factor productivity of upstream enterprises.

However, existing research mostly focuses on the macro concept of "digital transformation," while research on the specific technology of **Artificial Intelligence (AI)** is still in its infancy. Although Devi et al. (2024) and Xiao Jinghua et al. (2024) discussed the role of AI in improving efficiency in demand forecasting and inventory optimization, there is still a gap in research on how AI systematically shapes supply chain resilience through **micro-mechanisms** (such as talent structure, innovation capability). This paper attempts to make a theoretical supplement in this regard.

2.2 Algorithmic Management Challenges in Platform Supply Chains

With the rise of the platform economy, supply chain management has shown new characteristics of "high dimensionality and black-boxing" (Sun Libo et al., 2026). Traditional operations research methods face the "curse of dimensionality" when processing massive amounts of multimodal data. Existing literature has begun to pay attention to the application of algorithms in platform operations, such as the application of reinforcement learning in dynamic pricing (Luo et al., 2024), and the application of machine learning in logistics risk assessment (Shang et al., 2017). However, it also points out the human-machine trust crisis caused by the "algorithmic black box" (Caro et al., 2023). This review finds that how to balance the high accuracy and interpretability of algorithms, and how to solve execution deviations in human-machine collaboration, are frontier hotspots in current platform supply chain management research.

3. Mechanism Analysis of AI in Enhancing Supply Chain Resilience

Based on the empirical research framework of Cheng Xin et al. (2026), the enhancement of supply chain resilience by artificial intelligence is not a simple linear relationship, but a systemic transformation achieved through two mediating paths: "reshaping talent structure" and "improving innovation levels."

3.1 Path 1: Reshaping Talent Structure

The talent structure of traditional manufacturing presents a "pyramid shape," with a large number of repetitive operators at the bottom and a scarcity of top-level technical talents. The introduction of AI technology has triggered "skill-biased technological change":

- **Substitution and Complementarity Effects:** AI automation replaces low-skilled repetitive labor, while acting as an "intelligence augmentation tool" to complement high-skilled talents. For example, AI systems process massive amounts of data, while human experts are responsible for complex decisions.
- **Structural Upgrading Mechanism:** Empirical data shows that AI applications have significantly increased the proportion of technical personnel (such as data analysts, algorithm engineers) in enterprises. This optimized talent structure means that enterprises possess more core human resources with digital literacy. When the supply chain faces the risk of disruption, these high-quality talents can understand the system status faster, use intelligent tools for scenario analysis, and design recovery plans, thereby significantly enhancing the **response agility** of the supply chain.

3.2 Path 2: Improving Innovation Levels

The advanced form of supply chain resilience is "transition resilience," which involves upgrading through innovation during crises. As a general-purpose technology, AI is deeply integrated into the entire process of R&D and management:

- **Leap in R&D Efficiency:** Generative AI and machine learning accelerate the discovery of new materials, product design, and process optimization, significantly reducing trial-and-error costs.
- **Innovation Translated into Resilience:** A high level of innovation capability enables enterprises to have richer technical reserves and product portfolios. When facing raw material supply cuts or drastic demand changes, enterprises can quickly activate alternative plans or launch new products. This "technology conversion capability" constitutes the **deep-seated resistance** of the supply chain.
- **Empirical Support:** Studies show that AI indirectly enhances the recovery speed and stability of the supply chain after being impacted by increasing the number of invention patent applications (a proxy variable for innovation level).

4. Algorithmic Empowerment and Technical Challenges from a Platform Perspective

In the high-dimensional and complex scenarios of platform supply chains, traditional management methods fail, and advanced algorithmic empowerment must be relied upon. Combining the research of Sun Libo et al. (2026), we will analyze in depth from the following three dimensions:

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4.1 Addressing High-Dimensional Decision-Making: From Operations Research Optimization to Learning-Driven

Platform supply chains involve millions of SKUs, massive orders, and real-time logistics status, leading to an exponential explosion of the decision space (curse of dimensionality).

- **Reinforcement Learning (RL):** Addressing dynamic scheduling problems, RL can generate optimal strategies at the millisecond level through the continuous interaction (state-action-reward) between the agent and the environment.
- **Case Deepening: Lenovo Group** uses deep reinforcement learning to solve intelligent manufacturing scheduling problems. Facing complex constraints of 43 production lines and 550 models, the RL system shortened the scheduling response time from 6 hours to 30 minutes, and the order backlog decreased by 20%.
- **Transfer Learning:** Addressing the problem of data sparsity (cold start) for new products or niche categories, transfer learning uses knowledge from the source domain (such as click data, similar categories) to assist in the prediction of the target domain (such as purchase data), significantly improving the accuracy of demand forecasting.

4.2 Cracking the Algorithmic Black Box: Structured Representation and Interpretability

Although deep learning models have high accuracy, they lack transparency, making it difficult for managers to trust them (black-boxing).

- **Decision Trees and Market Segmentation Trees (MST):** Transform complex non-linear decisions into "if-then" rules. For example, the MST algorithm proposed by Aouad et al. (2023) can intuitively display segmentation rules based on user characteristics, ensuring prediction accuracy while allowing managers to clearly know "why this product is recommended to this user."
- **Low-Rank Matrix Approximation:** In high-dimensional data (such as user-item rating matrices), potential factors (such as seasonality, regional preferences) are extracted through dimensionality reduction techniques, transforming abstract algorithmic logic into visualized business insights, enhancing the **interpretability** of decisions.

4.3 Bridging the Human-Machine Gap: Deviation Calibration and Interaction Design

The deviation between algorithmic recommendations and manual execution (human-machine collaboration deviation) is a pain point in platform management.

- **Deviation Prediction and Calibration:** Use machine learning to predict high-risk scenarios where front-line personnel (such as warehouse packers) may deviate from algorithmic recommendations, and intervene in advance.
- **Case Deepening: Cainiao Network** found that packers often deviate from the optimal box type recommendation due to habit. By using a random forest model to predict the probability of deviation and dynamically adjusting the safety buffer, the packing deviation rate was reduced from 29.5% to 23.8%.
- **Real-time Feedback and Embodied Intelligence:** Learn preferences from human historical behavior through Inverse Reinforcement Learning (Inverse RL) to design more human-centric paths; or use real-time performance feedback systems (such as Zara's pricing system) to enhance human-machine trust and reduce execution resistance through visual interfaces.

5. Innovative Strategies for Supply Chain Management Models

Combining the above analysis, this paper proposes the following innovative strategies:

1. **Build an Integrated Collaborative Logistics Management Model:** Relying on Joint Managed Inventory (JMI) and Collaborative Planning, Forecasting, and Replenishment (CPFR), promote upstream and downstream to shift from independent decision-making to linked decision-making. Clarify the benefit distribution and risk-sharing mechanism through contract design, and evolve the collaborative relationship from a loose connection to a close community.
2. **Promote Platform-based Logistics Network Integration:** Build a digital collaborative platform and reduce the access cost of heterogeneous systems through standardized API interfaces. The platform should carry functions such as capacity matching and collaborative path planning, support joint distribution and milk-run collection, and systematically reduce the empty load rate.
3. **Develop Intelligent Dynamic Scheduling Management:** Deploy IoT devices to build a real-time visibility layer, and use machine learning to drive the dynamic optimization of path planning and warehouse sorting. Introduce digital twin technology to conduct simulation deduction in virtual space, realizing the transformation from post-event remediation to pre-event intervention.
4. **Explore Green and Sustainable Operations:** Embed carbon emission intensity into scheduling algorithms and seek the Pareto optimum of timeliness and emissions in path planning. Promote standardized recyclable packaging, layout reverse logistics networks, and respond to the national "Dual Carbon" strategy.

6. Conclusion

The innovation of supply chain management is a systemic project of technology-driven and organizational change. Artificial intelligence not only directly enhances supply chain

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resilience by reshaping talent structure and improving innovation levels but also solves the high-dimensional decision-making and human-machine collaboration problems of platform supply chains through technical means such as reinforcement learning and interpretable algorithms. In the future, enterprises should pay attention to the matching of "technology-talent-process," transform algorithmic advantages into management efficiency, and build a resilient and competitive supply chain ecosystem.

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