

# Research on the Stability of Express Delivery Supply Chain Based on Risk Propagation Model ----- Case Studies of SF Express and JD Logistics

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**Abstract:** Against the backdrop of the rapid development of e-commerce, the stability of the express delivery supply chain, as a core component of the logistics system, has garnered increasing attention. Risk propagation is a critical factor affecting the stability of the express delivery supply chain. However, traditional research has largely been confined to qualitative descriptions of risks, lacking systematic quantitative analysis of risk propagation mechanisms. This study constructs a three-tier risk propagation model of "warehousing-transportation-distribution" based on complex network theory, analyzing the risk transmission characteristics of the express delivery supply chain from three dimensions: node risk propagation, path sensitivity, and system stability. Through a comparative analysis of SF Express (centralized network) and JD Logistics (distributed network), the following findings are revealed: (1) The risk amplification effect of centralized warehousing systems during peak order periods is 23% higher than the baseline value; (2) Crowdsourced delivery networks improve delivery flexibility while reducing terminal risks by 34%, but increase information leakage risks by 2.3 times. Based on the research results, optimization strategies such as dynamic path optimization algorithms and blockchain-based information isolation mechanisms are proposed, providing theoretical tools and practical references for risk prevention and control in the express delivery industry.

## 1. Introduction

The rapid expansion of e-commerce has positioned the express delivery supply chain as a critical element within modern economic frameworks. Over the past decade, China's express delivery sector has experienced exponential growth, consistently leading global parcel volumes for eight consecutive years [1]. As reported by the State Post Bureau, the industry handled 110.58 billion parcels in 2022, marking a substantial increase compared to previous decades [1]. However, this surge in demand has escalated network complexity by 19.7% annually, intensifying vulnerabilities such as warehouse congestion, transportation bottlenecks, and cybersecurity breaches, which exhibit cross-layer propagation dynamics [2].

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A notable instance occurred during the 2021 "Double Eleven" sales event, where a major logistics provider faced warehouse overloads in East China, resulting in a 15.2% nationwide delivery delay and economic losses exceeding ¥230 million [3]. Such incidents underscore the imperative for robust risk mitigation strategies during peak operational periods.

Historically, logistics optimization prioritized cost reduction in organizational activities [4]. However, advancements in smart technologies—such as AI, big data, and IoT integration—have transformed supply chains into drivers of industrial growth while introducing multifaceted risks, including delays, theft, natural disasters, and cyber threats [5, 6]. Under competitive pressures and policy-driven digitalization, companies like SF Express and JD Logistics have leveraged mergers and acquisitions to enhance market positioning [7]. Analyzing their risk management approaches offers valuable insights for academia and industry stakeholders aiming to fortify supply chain resilience [8].

This study constructs a quantitative risk propagation model grounded in complex network theory to dissect transmission mechanisms across "warehousing-transportation-distribution" tiers. By contrasting SF Express's centralized architecture with JD Logistics's decentralized framework, the research identifies structural disparities in risk diffusion. Theoretically, it introduces novel metrics—Node Vulnerability Index (NVI) and Path Sensitivity Coefficient (PSC)—to enrich supply chain risk analysis. Practically, the findings enable tailored risk mitigation frameworks, enhancing operational stability and adaptability.

## 2. Literature Review

Supply chain risks within express logistics have garnered significant scholarly attention. Defined as "the probability and impact of unforeseen macro/micro events disrupting supply chain operations" [9], such risks propagate through interconnected nodes, potentially cascading into systemic failures [10]. Methodologically, complex networks, system dynamics, and Monte Carlo simulations dominate risk analysis [11], yet existing models predominantly target manufacturing sectors, overlooking express-specific features like dynamic routing and crowdsourced delivery [12].

While prior studies elucidate general risk transmission patterns [13], gaps persist in contextualizing these frameworks to express logistics. For instance, Liu demonstrated that distributed warehousing reduces regional disruption risks by 30% [14] but neglected holistic network impacts [15]. Additionally, theoretical models often lack empirical validation, particularly regarding physical-informational network interdependencies [16] and real-time adaptability [17]. This study addresses these gaps by integrating structural nuances of express networks and proposing actionable optimization strategies.

## 3. Model Construction

### 3.1 Network Architecture and Complex Network Theory

The supply chain is modeled as a three-tier weighted directed network: warehousing (upstream), transportation (midstream), and delivery (downstream). SF Express's centralized system revolves around 12 national hubs, whereas JD Logistics employs 1,500+ distributed front warehouses [3]. Transportation weights derive from route utilization and capacity metrics, with SF relying on 98% self-operated nodes versus JD's hybrid model (54% crowdsourced) [5].

Complex network theory facilitates structural analysis, where small-world and scale-free models capture local connectivity and global distribution traits [18].

### 3.2 Risk Propagation Dynamics

Time-series and stochastic processes enhance predictive accuracy. Node risk is quantified as:

$$R_i = \alpha D_i / C_i + \beta S_i \quad (1)$$

where  $D_i$ : historical disruptions,  $C_i$ : capacity,  $S_i$ : security score. Transportation-layer risk aggregates upstream contributions:

$$R_j^{trans} = \sum_{k=1}^m \omega_k R_k^{ware} \gamma \quad (2)$$

### 3.3 Data Integration

**Table 1** Data Collection Comparison: SF Express vs. JD Logistics

Data Type	SF Express	JD Logistics
Warehousing	12 hubs (coordinates/capacity)	Dynamic front-warehouse data
Transportation	Air route punctuality: 92.4%	Regional shuttle schedules
Delivery	Self-operated complaints: 0.17%	Crowdsourced response: 3.2 min

Parameters ( $\alpha=0.7, \beta=0.3$ ) are calibrated via industry benchmarks and sensitivity analysis [6][7]. Assumptions include node independence and short-term propagation invariance (<72h). As shown in Table 1, SF Express and JD Logistics differ in data collection methods, with SF Express using fixed hubs and high air route punctuality, while JD Logistics focuses on dynamic data and regional shuttle schedules."

### 3.4 Validation and Extensions

Centralized networks exhibit faster risk diffusion ( $v_c = \sum R_i K_i / n$ ) due to hub dependency, whereas distributed systems show slower spread ( $v_d = \sum R_i / n$ ). Model validation using 2021 "Double Eleven" data yielded  $\pm 8.3\%$  prediction accuracy [3, 5].

## 4. Case Analysis

### 4.1 SF Express: Hub Fire Scenario

A simulated fire at Guangzhou's hub disrupted 8 air routes within 24h, elevating North China delays to 19.7%. Dynamic rerouting reduced peak risks by 41.2%, shortening recovery to 58h.

### 4.2 JD Logistics: "618" Demand Surge

Crowdsourcing absorbed 63% of order spikes but increased data breaches from 3 to 12. Blockchain-based shunting boosted efficiency by 28% and curtailed leaks by 76%.

## 5. Comparative Analysis and Optimization

## 5.1 Structural Comparison

**Table 2** Structural Resilience Comparison: Centralized vs. Distributed Models

Metric	SF (Centralized)	JD (Distributed)
Risk Speed	2.4 nodes/h	1.7 nodes/h
Recovery Rate	83%	91%
Security Risk	0.32	0.68

As shown in Table 2, the structural resilience of SF Express (centralized model) and JD Logistics (distributed model) differs across several metrics. While SF Express has a higher risk speed at 2.4 nodes/h, JD Logistics achieves a higher recovery rate of 91%, compared to SF Express's 83%. Additionally, JD Logistics faces a higher security risk (0.68) compared to SF Express (0.32).

## 5.2 Optimization Strategies

Centralized: Digital twin monitoring; 5-15% cross-region buffer stocks.

Distributed: Homomorphic encryption; performance-based partner scoring.

## 5.3 Trade-offs

Centralized networks excel in efficiency but falter during hub failures. Distributed systems enhance resilience at the cost of complexity and security vulnerabilities.

## 5.4 Evaluation Framework

**Table 3** Performance and Efficiency Comparison: SF Express vs. JD Logistics

Category	Metric	Weight	SF	JD
Network Performance	Risk Speed	25%	2.4	1.7
Operational Efficiency	Delivery Time	30%	24h	31h

Hybrid models (centralized warehousing + distributed delivery) optimize peak-period performance. Table 3 highlights that SF Express excels in both risk speed (2.4 vs. 1.7) and delivery time (24h vs. 31h) compared to JD Logistics. Additionally, hybrid models, integrating centralized warehousing with distributed delivery, enhance performance during peak periods.

## 6. Conclusion

This study delineates the "upstream acceleration, downstream attenuation" risk pattern in express supply chains. While crowdsourcing enhances flexibility, it escalates cybersecurity threats. Future research should integrate spatiotemporal variables and extreme scenarios (e.g., pandemics, earthquakes). Machine learning could refine recovery protocols, and blockchain may further secure decentralized systems. Current limitations include exogenous factors (policy shifts, weather) and temporal-spatial dynamics.

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