Strategic Management Insights

Article

Research on Real-Time Data Monitoring and Feedback Mechanism in Supply Chain Management System

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Abstract: Amid the growing complexity of dynamic supply chains, the development of real-time data monitoring and intelligent feedback systems has become essential. This paper mainly focuses on three aspects: data visualization, artificial intelligence-assisted decision-making, and blockchain-based security assurance. It introduces a systematic approach to monitoring the supply chain, and explores the intelligent development of feedback system in detail by adopting reinforcement learning, Internet of Things, and distributed ledger. The integration of intelligent warehousing, logistics matching, risk early warning, and demand alignment underscores the critical need for a real-time monitoring and feedback system. This enables enhanced supply chain resilience and more informed decision-making.

Keywords: supply chain management; real-time data monitoring; intelligent feedback mechanism; artificial intelligence; Internet of Things

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1. Introduction

In current supply chain systems, real-time data monitoring and intelligent feedback systems play a vital role in improving operational efficiency and coping with unknown factors. The traditional supply chain is unable to cope with market changes due to lagging information. By leveraging artificial intelligence, the Internet of Things, and other advanced technologies, the supply chain can achieve data transparency, intelligent alerts, and automated adjustments for enhanced optimization. This paper focuses on the construction of real-time monitoring system and feedback system, discusses the application of the system in intelligent warehouse, transportation planning and crisis prediction, and promotes the intelligent process of supply chain management.

2. Real-Time Data Monitoring System for Supply Chain Management

2.1. Supply Chain Data Visualization and Intelligent Early Warning System

Through supply chain data visualization, complex information can be presented clearly using dynamic charts and interactive interfaces, which helps improve operational efficiency and decision-making clarity. Through real-time monitoring of key links such as inventory, transportation, and orders, enterprises can clearly grasp the operation status, reduce information delays, and accelerate feedback and decision response time. Based on data analysis and machine learning algorithms, the intelligent warning system can identify anomalies, such as a surge in orders, sharp fluctuations in inventory or transportation delays, and immediately issue alerts to help companies avoid risks and prevent supply chain disruptions in advance. Data acquisition is primarily carried out via Internet of Things (IoT) devices, such as sensors, cameras, and RFID tags, which send real-time data to a central hub to ensure accurate, timely, and comprehensive information. It can also combine historical and current data for comparative analysis [1]. This allows continuous optimization of procurement, storage, and transportation strategies to further enhance asset allocation efficiency. Figure 1 below illustrates the supply chain data visualization and intelligent early warning system:

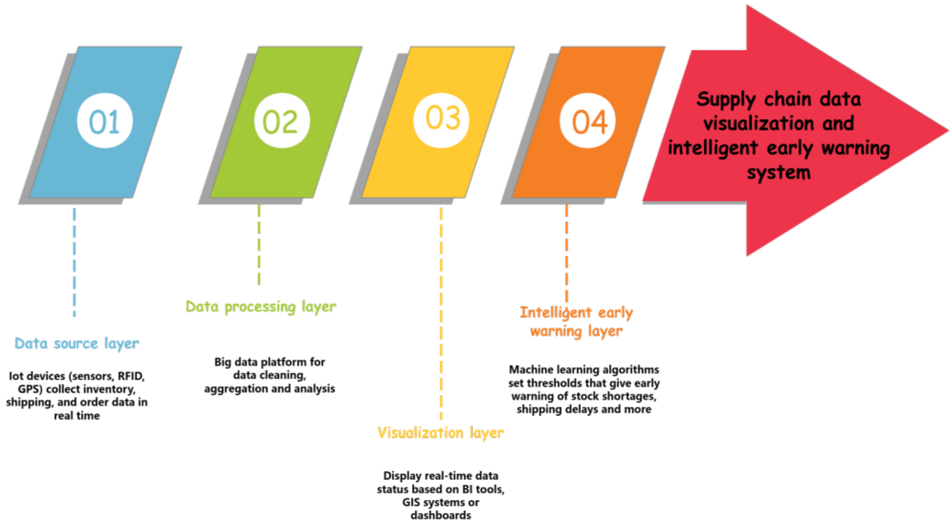

Figure 1. Supply Chain Data Visualization and Intelligent Early Warning System.

2.2. AI-Driven Real-Time Decision Support System (DSS)

AI-driven DSS, which leverages data mining and the analytical capabilities of artificial intelligence to make real-time judgments, can help improve supply chain efficiency and responsiveness. AI-driven decision support systems use machine learning algorithms to deeply analyze various data types — such as supply and demand, inventory, and transportation — to identify business bottlenecks and propose effective solutions. Compared with the traditional way of relying on human experience to make decisions, AI-driven decision support systems have the capability to analyze vast amounts of data and make informed decisions in dynamic environments. It can continuously improve procurement and inventory strategies and transportation arrangements by using past data for training and model optimization to minimize resource waste and cost control. In addition, these systems can also incorporate external market trends, consumer behavior, weather conditions, legal regulations, and other environmental changes into their decision models to stay up-to-date, make forecasts more adaptive and apply reinforcement learning and self-optimizing algorithms to enhance DSS strategies through continuous feedback and practice to improve DSS strategies from constant feedback and practice [2].

2.3. Reliability Assurance of Blockchain in Supply Chain Data Monitoring

By utilizing the decentralization and immutable characteristics of blockchain technology, the true integrity and traceability of supply chain data can be effectively guaranteed. However, under traditional supply chain models, data is often concentrated at a single point, which increases the risk of tampering, loss, and inconsistency, which may cause data tampering, loss and information inconsistency. Blockchain technology utilizes distributed ledger systems to record all stages of data, covering every step from procurement and production to transportation, storage, and delivery, so that all transactions can be tracked and made public, greatly reducing the occurrence of falsification of data and data information inequality. Any operation must be validated through a consensus mechanism to ensure data accuracy and credibility among all parties, thereby avoiding management errors and cooperation failures caused by misinformation. At the same time, the use of smart contract technology can also be automated in order confirmation, payment settlement, logistics tracking, etc., reducing human intervention and improving operational efficiency. Similarly, Cryptographic techniques can ensure the confidentiality of data transmission and storage, preventing unauthorized access and reducing the risk of information theft [3]. In addition, the distributed storage structure enhances data availability and disaster resilience, improving the overall stability of the supply chain. It also provides a reliable information platform for collaboration among multiple participants, and ultimately promote the entire supply chain to intelligent and information development. Figure 2 below illustrates the trustworthiness of blockchain in supply chain data monitoring:

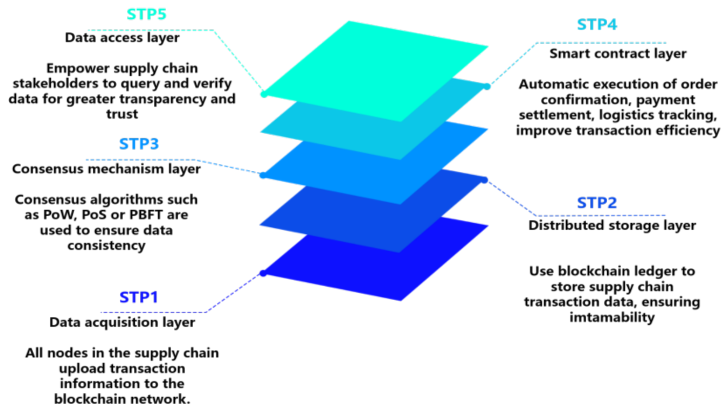

Figure 2. Reliability Assurance of Blockchain in Supply Chain Data Monitoring.

3. Intelligent Feedback Mechanism in Supply Chain Management

3.1. Adaptive Control of Reinforcement Learning in Supply Chain Feedback System

In supply chain feedback systems, reinforcement learning emphasizes adaptive self-adjustment to optimize operations in response to dynamic changes. This method can realize the flexible management of supply chain through continuous training and improvement, so as to adapt to market changes such as the impact of demand fluctuations, inventory fluctuations, logistics arrangements and so on. This model optimizes supply chain decisions by applying a state-action-reward framework, coupled with continuous trial, error, and correction. For example, in the area of inventory management, the RL model will automatically adjust the number of orders to avoid too much or too little, taking into account historical sales data, supply-demand schedules, and cost variations [4]. The data in Table 1 below analyzes the application of reinforcement learning in supply chain feedback system:

Table 1. Application of Reinforcement Learning in Supply Chain Feedback System.

Application scenario	Reinforcement learning	Feedback mechanism	Expected return
Inventory management	Forecast market demand, optimize inventory replenishment strategy	Adjust orders in real time based on inventory status and sales data	Reduce inventory costs and reduce out-of-stock rates
Logistics scheduling	Optimize delivery routes based on order density, weather and traffic conditions	Real-time transport feedback and dynamic route adjustment	Reduce transportation costs and improve on-time delivery
Production planning optimization	Adjust production schedule according to	Adjust production schedule with real-time data feedback	Improve production efficiency and

	market demand and capacity constraints		reduce raw material waste
Supply chain resilience optimization	Anticipate supply chain disruption risks and develop contingency strategies	Dynamic feedback of external environment changes, automatically adjust the supply chain strategy	Enhance supply chain stability and reduce risk impact

As shown in Table 1, intelligent inventory management, logistics, and production planning optimization enhance the adaptive control capabilities of reinforcement learning within the supply chain. This feedback mechanism can make real-time decision adjustment in each link of the supply chain, improve the efficiency of resource utilization and operation, and improve the flexibility of the supply chain.

3.2. Intelligent Perception and Feedback of IoT in Supply Chain Monitoring

The application of Internet of Things technologies — such as sensors, RFID, and GPS — enables intelligent data collection and real-time responses across all stages of the supply chain. This equipment can monitor information such as inventory, logistics status, and environmental temperature, With the help of cloud computing and big data analytics, the supply chain status becomes both visible and automated. For example, IoT sensors in the cold chain field can respond immediately when the temperature changes, and automatically regulate the freezing system or generate alarms once the warning interval is exceeded to avoid product spoilage [5]. Table 2 below illustrates the intelligent perception and feedback mechanisms of IoT in supply chain monitoring:

Table 2. Intelligent Perception and Feedback Mechanism of IoT in Supply Chain Monitoring.

Application link	Internet of things technology	Feedback mode	Optimization effect
Warehouse management	RFID, Sensor	Automatically identify inventory status and adjust replenishment strategies	Improve inventory management efficiency and reduce inventory errors
Transportation monitoring	GPS, temperature and humidity sensor	Monitor the transport environment and adjust transport conditions in real time	Ensure the quality of goods and improve the reliability of distribution
Production monitoring	Device condition monitoring sensor	Feedback equipment operation and predict maintenance needs	Reduce equipment failure rate and improve production continuity
Order tracking	IoT gateway + data management platform	Real-time update of order status, abnormal situation warning	Improve order visualization and optimize customer experience

Table 2 illustrates how IoT technology enables real-time tracking of supply chain status. By leveraging intelligent feedback, it optimizes key supply chain processes such as inventory management, transportation, and manufacturing, ultimately enhancing overall supply chain efficiency.

3.3. Implementation of Distributed Ledger in Supply Chain Data Security and Feedback Traceability

Supply chain data can be stored in a decentralized and immutable form through distributed ledger technology to improve data security and traceability. The distributed ledger based on blockchain can help realize the openness, transparency, authenticity and credibility of the supply chain transaction data, enhance data quality, and reduce the incidence of fraud and information asymmetry. By cryptographically storing transaction data on the blockchain network, copies of the data are identical across nodes to maintain their credibility. In addition, smart contracts can be used to automate supply chain transactions and improve feedback efficiency. Table 3 below summarizes the online application of DLT in supply chain data security and feedback traceability based on different utilization modes:

Table 3. Implementation of Distributed Ledger in Supply Chain Data Security and Feedback Traceability.

Application field	Distributed ledger technology applications	Feedback mechanism	Security enhancement
Transaction record	Supply chain transaction data is linked to ensure that it cannot be tampered with	The ledger is automatically updated after the transaction is completed	Prevent data falsification and improve transaction transparency
Traceability management	Record the whole process of product production, transportation and delivery	Information is readily available to all parties in the supply chain	Traceability of responsibility to improve regulatory compliance
Smart contract execution	Automate order processing, payment and settlement	The order is automatically executed after the conditions are met	Reduce human intervention and improve execution efficiency
Data sharing	Decentralized storage of multi-party data reduces trust costs	Data updates are synchronized to all nodes in real time	Ensure data consistency and improve supply chain collaboration

As shown in Table 3, distributed ledger technology improves the confidentiality and traceability of supply chain data through a decentralized and tamper-proof data structure and the use of smart contracts. By ensuring the traceability of transaction information and transactions through feedback mechanisms, fraud and information asymmetry can be reduced, and trust and efficiency of supply chain management can be improved.

4. Collaborative Application of Real-Time Data Monitoring and Feedback in Supply Chain

4.1. Intelligent Storage Monitoring: Real-Time Inventory Tracking and Dynamic Replenishment

Intelligent warehouse storage control technology, through real-time data acquisition and intelligent analysis technology, can accurately grasp the inventory status, and real-time optimization of inventory replenishment decisions. The traditional inventory management technology has asymmetric information and lag, and the inventory prediction is also inaccurate. However, replenishing inventory according to intelligent algorithm can make the inventory quantity management more accurate and avoid the problem of inventory shortage or excess. Flexible adjustment of inventory generally adopts the model of controlling inventory quantity to adjust, so that the inventory quantity can be maintained at a reasonable level of safety inventory. If the (S, Q) type inventory policy is adopted, the replenishment quantity Q is determined as:

$$Q = \left(\frac{2DS}{H}\right)^{\frac{1}{2}} + \gamma \times \sigma_L \times \sqrt{L} \tag{1}$$

Among them, Q represents the optimal purchase quantity, D represents the total annual demand, S represents the amount to be paid for each purchase, H represents the cost of holding inventory per piece, and γ represents the safe reserve factor. At the same time, we also need to consider the demand fluctuations during the delivery period, and calculate the standard deviation σ_L. Finally, the result L is an improved traditional EOQ method, which can pay attention to both the cost of holding inventory and the cost of orders, and fully take into account the possibility of demand fluctuations, thus making our decision-making more flexible and targeted, and effectively reducing the potential risks caused by product demand changes, making the system more self-adjusting. This enables the system to better meet customer needs.

4.2. Logistics Scheduling Optimization: Intelligent Path Planning and Distribution Adjustment

The current logistics scheduling system must possess real-time sensing capabilities and the ability to optimize delivery routes of complex variables such as orders, real-time traffic and weather, while the path method based on static planning cannot meet the needs of efficient logistics distribution. The optimization problem of the target path with the lowest total transportation cost and time default cost can be described by the path planning model with time window, and the objective function is as follows:

$$min \sum_{i=1}^{N} \sum_{j=1}^{N} c_{ij} x_{ij} + \lambda \sum_{i=1}^{N} (T_i - E_i)^+ \quad (2)$$

In this model, c_{ij} represents the transportation cost from point i to point j, x_{ij} represents the decision variable of whether to take the route (i, j) (route selection, value 1; no choice, value 0), T_i is the journey time to reach customer i, E_i is the earliest time that customer i can accept the service, $(T_i - E_i)^+$is the cost beyond the service time. λ is the delay penalty factor.

In this function, transportation cost c_{ij} and delay penalty cost $(T_i - E_i)^+$ are considered comprehensively, and the penalty factor λ is introduced to balance them. The system collects cargo and traffic data in real time and optimizes delivery routes and vehicle dispatch using machine learning algorithms, and optimize the transportation route of goods and vehicle scheduling results in real time by means of machine learning. In addition to meeting the shortest distance principle to determine the route, the route is also reasonably sorted according to the customer's service time to achieve the goal of on-time delivery.

4.3. Abnormal Early Warning Feedback: Supply Chain Risk Monitoring and Emergency Response

Based on the highly variable supply chain system, risk early warning can quickly monitor abnormal behaviors in the supply chain, analyze and model the system process through probabilistic inference, and predict the probability of abnormal events. The Bayesian decision approach is commonly used, and its risk evaluation function is as follows:

$$R_t = P(A|B) \cdot C(A) + P(\neg A|B) \cdot C(\neg A) \quad (3)$$

Where, R_t is the risk assessment value at time t, $P(A|B)$ the conditional probability that data B is observed when abnormal event A occurs, $P(\neg A|B)$ abnormal event A occurs, that is, the situation where B is observed. $C(A)$ and $C(\neg A)$ represent the costs associated with the occurrence of an abnormal event A and $\neg A$ non-abnormal event $\neg A$, respectively.

The core of the formula is based on the risk assessment formula combining expected loss and actual loss, and the risk measurement model is built with the possibility of subsequent occurrence, and updated in real time with the change of $P(A|B)$. Use real-time information such as supply disruptions, delays, and machine failures to determine the current level of risk and trigger an emergency backup plan. For high-risk situations that may arise, emergency protocols are activated to ensure real-time responsiveness and effective mitigation, emergency operations are started to ensure the real-time and action effect of alarm information, so as to strengthen the disaster tolerance and recovery ability of the supply chain to emergencies.

4.4. Accurate Supply Matching: Data-Driven Procurement and Supply and Demand Coordination

Accurate supply matching mainly relies on flexible procurement decisions made after data analysis to achieve dynamic coordination of supply and demand. When the traditional static purchasing mode is faced with the rapidly changing demand, the phenomenon of stock stagnation and stock shortage often occurs. The multi-cycle forecasting model can be used to determine the optimal purchase volume, which has certain practical significance in improving the scientific and flexible aspects of purchasing decision making, this is further described by the following multi-period forecasting model:

$$Q_t^* = \frac{\sum_{i=T}^{T} D_i}{T-t+1} + \theta\sqrt{\sum_{i=t}^{T} \sigma_i^2} \quad (4)$$

Among them, Q_t^* is the optimal purchase quantity for t, and D_i is the forecast demand for stage i. t is the number of time intervals in the planning stage, σ_i is the standard deviation of the demand in stage i, and θ is the safety factor.

The above equation comprehensively considers the total demand and cumulative volatility factors in the future, so that the purchase order plan can not only provide reasonable quantity, but also have the function of volatility alarm. The software will input indicators such as sales forecast, market trend, and previous orders into the model, and give real-time ordering suggestions based on the model prediction results, avoiding the inflexible, fixed-quantity ordering mode. In addition, by comparing the gap between the actual demand and the predicted value in real time, the software can also automatically optimize the model parameters to improve the prediction accuracy. Finally, the ordering strategy shifts from human subjective decisions to a data-driven approach, enabling adaptive supply coordination and effectively reducing operational costs.

5. Conclusion

With the increasing complexity of supply chain, building effective real-time information monitoring and intelligent response system has become the key. This research focuses on the use of data visualization, AI decision assistance, and blockchain to investigate how to run real-time monitoring systems, as well as research optimization methods using intelligent responsive systems that combine augmented learning and IoT technologies. Research shows that combining real-time monitoring with intelligent response systems can significantly enhance the responsiveness, operational efficiency, and risk resilience of the supply chain. This integration lays the foundation for building a truly smart and adaptive supply chain management system.

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