Scholar Publishing Group
International Journal of Social Sciences and Economic Management
https://doi.org/ 10.38007/IJSSEM.2026.070106
ISSN 2789-715X Vol. 7, Issue 1: 51-59

Research on the Application of Artificial Intelligence in Supply Chain Risk Early Warning

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Keywords: Artificial intelligence, Supply chain risk warning, Supply chain finance, Machine learning, Blockchain

Abstract: The uncertainty of the global economic environment and the complexity of supply chain networks have brought unprecedented risk management pressure to enterprises. Artificial intelligence leverages its capabilities in large-scale data processing, pattern recognition and prediction to provide new methods and tools for supply chain risk early warning. This paper analyzes its role in the digitalization of supply chain finance, intelligent risk control, and multi-source data integration, and studies the value of artificial intelligence in enhancing supply chain transparency, strengthening risk identification, and optimizing the efficiency of capital flow and logistics. At the same time, it points out that artificial intelligence still has deficiencies in responding to systemic risks, ensuring data security, and the interpretability of models. Research shows that integrating artificial intelligence with technologies such as blockchain and the Internet of Things can promote the development of supply chain risk management towards intelligence and systematization. However, in the future, continuous improvement is needed in data standardization, technical governance and policy coordination to establish an efficient and reliable supply chain risk early warning system, providing theoretical and practical basis for enterprises to achieve scientific, intelligent and sustainable risk management.

1. Introduction

The supply chain plays a crucial role in connecting production, circulation and consumption in the modern economic system. Its operation will affect the business performance of enterprises and the stability level of the entire economy. As global industries become increasingly interconnected and the degree of digitalization continues to rise, the types of risks faced by supply chains are also constantly increasing. Slow information transmission, high pressure on capital flow, unstable policy environment and the impact of unexpected events make traditional risk management methods difficult to adapt to the new situation. The management approach that relies on experience and manual judgment is not timely enough in response and is also difficult to make accurate early warnings and scientific decisions. Enterprises need more efficient and intelligent technological means to ensure the security and stability of the supply chain.

The development of artificial intelligence has brought new possibilities to supply chain risk management. By learning historical data and analyzing real-time information, artificial intelligence

can identify hidden risk signals and predict possible changing trends. It can identify potential threats before problems arise, thereby helping enterprises take measures in advance. Artificial intelligence can play a role in multiple links of the supply chain. In supply chain finance, it can conduct a more precise assessment of an enterprise's credit and reduce the risk of default. In logistics and warehouse management, it can plan transportation routes and inventory allocation based on real-time data, improving efficiency and reducing costs. In the procurement and production processes, it can predict changes in market demand and help enterprises formulate reasonable production plans. Through these approaches, enterprises gradually shift from experience-based management methods to data-driven intelligent management models, enhancing overall operational efficiency while also strengthening their ability to cope with complex environments.

Although the application of artificial intelligence in supply chain risk early warning has broad prospects, there are still some problems. Data privacy protection is an important issue that must be addressed. The reliability and transparency of the algorithm model are related to whether enterprises are willing to trust the judgment of artificial intelligence. The lack of unified standards among different systems can also affect the integration and analysis of information. To enable artificial intelligence to play a greater role in supply chain management, improvements need to be made in aspects such as data management, model validation, and system collaboration. A risk monitoring system that is intelligent, traceable and capable of real-time response can be established by integrating the perception capabilities of the Internet of Things, the security features of blockchain and the analytical advantages of big data. By integrating technological innovation with management improvement, artificial intelligence can enhance the risk identification ability and management efficiency of the supply chain, helping enterprises achieve stable, efficient and sustainable development.

2. Review of relevant literature

In present - day supply - chain management, artificial intelligence has arisen as a vital asset for enhancing early risk detection and boosting operational results. Nilaish and Tiwari pointed out that methods such as linear optimization, mixed - integer optimization, fuzzy logic models, and heuristic or hybrid means allow AI to mitigate both internal and external supply chain troubles while enhancing process visibility. It has effectiveness in fields such as digital supply chain finance and quality control [1]. With an emphasis on small and medium - sized businesses, Tiwari indicated that AI secures organizational risk management, facilitates the restructuring of supply chain workflows, and heightens operational flexibility. Reengineering capabilities are key for adaptability and enable complex decision - making according to scenarios[2]. Jackson and associated researchers proved that generative AI promotes decision - making in supply chain and operations management via learning, perception, forecasting, interaction, and adaptive functions. Thereby, it better the accuracy of forecasting, inventory planning, supply chain structuring, and risk mitigation, and furnishes managers with practical frameworks for operations analysis and process optimization[3]. Jahin, with an in - depth review and bibliometric methods, found that AI and machine learning substantially increase the precision and responsiveness of risk forecasting in supply chains. Incorporating explainable AI, real - time datasets, and blockchain refines the transparency and traceability of decisions, with research leadership centered in China and the United States [4]. Within the scope of supply chain finance, Huang and research partners put forward a credit risk early - warning framework joining financial and non - financial metrics. They improved the indicators through principal component and grey relational analysis and used convolutional neural networks for predictive evaluation, with empirical evidence validating high precision and practical application in credit risk detection [5]. With regard to construction and logistics operations, a

proactive scheduling framework built upon production principles and four - dimensional building information modeling was put forward. By setting the exit process mode and combining on - site and exit operations, this framework can rapidly detect potential delays and visualize them in the BIM environment, giving clear time and location guidelines to construction teams and suppliers. This might augment the capability to adjust plans and lower the probability of delays [6]. Owolabi created an interdisciplinary framework which combines the financial systemic risk model with supply chain network analysis, and it pinpoints key suppliers via systemic importance scores. The research demonstrates that supply chain vulnerabilities present irregular attributes, and the overall network performance is consistent, yet core nodes are highly reactive to targeted shocks. A number of simulations have indicated that risks spread in a sequential - cascading fashion within the network [7]. Broadly speaking, existing research implies that artificial intelligence can considerably raise the prediction accuracy and response efficiency of supply - chain risk early warning. In the meantime, it can strengthen the flexibility and tenacity of the supply chain via data integration, model optimization, and cross - disciplinary techniques, presenting vital references for both theoretical research and business ventures[8]. At the same time[9], it can improve the supply - chain's flexibility and adaptability via integrating data, optimizing models, and using interdisciplinary means, presenting essential references for both theoretical research and business undertakings[10]. At the same time, it can better the flexibility and adaptability of the supply chain via data integration[11], model optimization, and interdisciplinary steps, presenting essential references for both theoretical studies and business undertakings[12].

3. Mechanism Analysis of Artificial Intelligence in Supply Chain Risk Early Warning

3.1 The basic mechanism of Artificial Intelligence in the Early Warning of Supply Chain Finance risks

Artificial intelligence can manage complicated data and detect risk patterns. It can identify potential troubles in data from different sources and structures[13], offering real - time early warning support to enterprises and so strengthening the security and stability of supply chain finance. Traditional supply chain finance is likely to face risks in complex circumstances[14], mainly demonstrated as slow - moving information dissemination, trouble in confirming the data's authenticity, scanty oversight, and a weak - linked trust system[15]. Artificial intelligence can effectively modify these problems for the better. AI can effectively sort out these problems.

Supply chain finance involves multi-party collaboration and multi-node operation. Information constantly flows among different participants. Complex data sources and lagging information updates often reduce the accuracy of risk identification. Artificial intelligence employs algorithms such as deep learning and semantic network models to consolidate and examine information across the entire supply chain, monitor the movement of goods, funds, and data in real time, and quickly identify irregular patterns. Deep learning models can comprehensively analyze contracts, transaction records, credit information and changes in the external environment, helping financial institutions and enterprises identify potential risks in advance and formulate response strategies. Artificial intelligence plays a prominent role in building trust mechanisms. By integrating blockchain and intelligent algorithms, the system can automatically verify and protect data security, achieving transparent and traceable management of the transaction process.

3.2 Construction of a Risk Early Warning Framework Integrating Artificial Intelligence and Multiple Technologies

Fintech firms create specialized platforms for the real - time collection of transaction, contract,

logistics, and credit data, enabling enterprises to comprehensively monitor risks on the asset and capital fronts. Internet of Things (IoT) sensing devices can exactly understand the logistics and warehousing state. Distributed ledgers warrant the authenticity and reliability of transaction records. Artificial intelligence algorithms are capable of identifying possible risks and abnormal behaviors, enabling enterprises to clearly comprehend the operation status of each link. Figure 1 exhibits the joint function of artificial intelligence in business process management, data validity, and risk prevention and control, showing the comprehensive worth of technology in supply chain finance risk management. Figure 1 shows the joint role of artificial intelligence in business process management, data reliability, and risk prevention and control, manifesting the comprehensive value of technology in supply chain finance risk management.

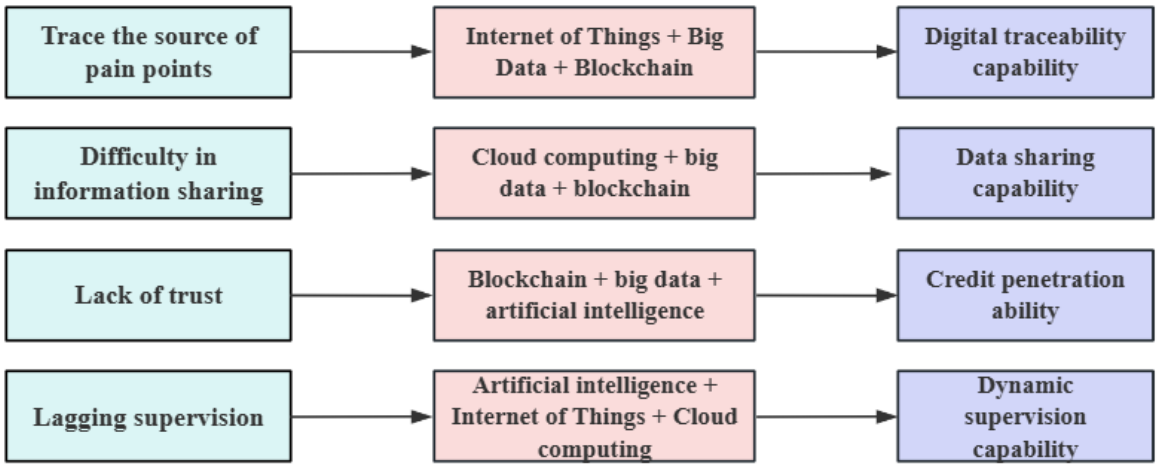

Figure 1 shows the multi-dimensional collaborative mechanism of artificial intelligence in the early warning of supply chain financial risks

From the capital angle, AI unites historical transaction and business data of enterprises with external credit information via intelligent credit assessment models. By applying smart contracts and automatic reconciliation mechanisms, it attains real - time transparency and closed - loop management of creditor - debtor relationships, heightening the accuracy and efficiency of financial decision - making. The adoption of artificial intelligence has enhanced the performance of supply - chain finance regarding information dissemination, network structure, and operational efficiency. The overall supply chain system has demonstrated higher stability and resilience in its daily operation. Figure 2 visually reflects the dynamic monitoring and decision-making optimization mechanism achieved by artificial intelligence under the collaborative empowerment of both assets and funds.

Artificial intelligence has played a significant role in reducing the existing risks of traditional supply chain finance, but it still has limitations when facing external economic fluctuations, industrial policy adjustments and unexpected events. Economic cycle changes and policy environment uncertainties can have an impact on the stability of supply chains, and the ability of technological means to respond to such systemic risks is limited. As artificial intelligence and big data systems accelerate the speed of information dissemination, risks may spread rapidly among nodes and form a chain reaction, which puts forward higher requirements for the resilience of supply chain finance. To maintain the effectiveness of risk early warning in complex environments, it is necessary to establish a multi-layer risk mitigation system composed of technical governance, data standards and policy regulation, so that artificial intelligence can maintain stable risk management functions in supply chain finance for a long time.

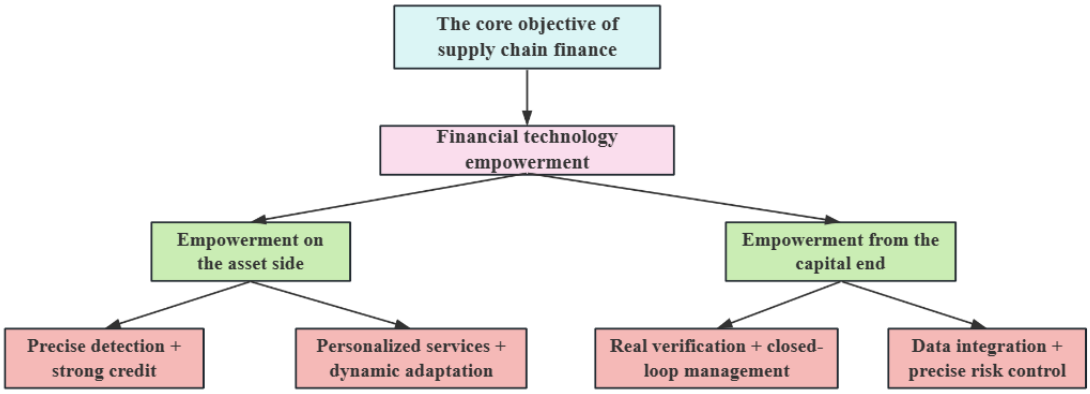

Figure 2 shows a dual-end collaborative monitoring mechanism for supply chain assets and funds based on artificial intelligence

3.3 Key Challenges of Artificial Intelligence in the Implementation of Risk Early Warning

In the supply chain finance system, the application of artificial intelligence technology has transformed the traditional way of risk identification. Financial institutions use multi-source data and intelligent algorithms to establish risk monitoring systems, enabling real-time assessment of the credit status and financial health of enterprises in the supply chain. Small and medium-sized enterprises no longer rely solely on the endorsement of core enterprises, and their financing capabilities can be quantified through real transaction data and business operations. The overall transparency and information availability of the supply chain have been enhanced. When artificial intelligence models handle transaction networks, capital flows, and logistics links, their ability to identify anomalies and risks has been strengthened, enabling financial institutions to detect potential credit defaults or capital fluctuations at an early stage.

Financial institutions use artificial intelligence systems to analyze contract texts, business reports, public opinion information and transaction data. Potential risk signals can be quickly captured from a large amount of information. When the system identifies financial abnormalities, credit fluctuations and pressure on supply chain nodes of enterprises, it generates actionable risk indicators. Automated analysis and machine learning algorithms are constantly optimizing models to adapt to changes in supply chain structure. However, financial institutions still face data security and model stability issues during the usage process.

4. Application Paths and Practical Exploration of Artificial Intelligence in Supply Chain Risk Early Warning

4.1 Construction and Implementation Effects of Intelligent Risk Control Mechanism

For supply chain finance, banks and financial organizations employ AI tools to build a risk oversight framework that amasses and inspects large - scale transactional records, corporate financial metrics, and market intelligence, facilitating continuous appraisal of firms' creditworthiness and financial standing. SMEs can disclose their borrowing capacity based on actual operational data instead of relying on support from vital corporations. The plainness and availability of information in the supply chain are substantially upgraded. In analyzing transaction networks, capital flows, and logistics links, artificial intelligence models can recognize potential irregularities and risk incidents. This enables financial institutions to detect the probability of credit defaults, capital variations, or supply - chain disruptions at an early phase and increases their ability

to prevent risks. Financial institutions use artificial intelligence for in - depth analysis of contracts, business reports, transaction data, and market opinions.

Financial institutions ought to set up a comprehensive data encryption and permission management system to guarantee the integrity and confidentiality of sensitive information during collection, transmission, and analysis. Algorithm design and model training ought to possess interpretable functions to guarantee that the analysis results are verifiable and traceable. Given the appearance of automated business and new transaction models, regulatory authorities and enterprise management ought to update their systems to address the legal and compliance issues stemming from intelligent decision - making. Via technical analysis, dynamic early - alert, and institutional governance, the supply chain finance system can maintain stability in complex market scenarios and in the face of external shocks. The operation gives enterprises comprehensive risk visualization, early - warning response, and decision optimization support.

4.2 Innovation in Research Tools and Methods

In the research on supply chain risk early warning, researchers use artificial intelligence to establish digital supply chain simulation models, applying intelligent algorithms to enterprise behavior and multi-level logistics and capital flow networks. In this way, the model can comprehensively assess the impact of different strategies on supply chain stability and the vulnerability of each node in a virtual environment. Simulation tools offer discrete event, system dynamics, and agent modeling capabilities and support programming interfaces. Researchers can develop and debug algorithms to handle risks, while training and optimizing models with simulacy-generated data to reproduce the actual operation process in a virtual three-dimensional environment. Through data analysis, simulation and intelligent decision-making can be combined. The open-source modeling framework provides a flexible experimental environment. Enable researchers to verify the effectiveness of supply chain strategies and analyze potential risk propagation under different experimental conditions, providing a scientific basis for risk identification and response

In data processing and machine learning applications, researchers use open-source data analysis and deep learning tools to complete data cleaning, feature extraction, model building and optimization. Machine learning libraries provide algorithms to support demand forecasting, cluster analysis and dimensionality reduction processing. Deep learning frameworks can build multi-layer neural networks to analyze structured and unstructured data. Algorithms can identify complex correlation patterns and potential risks in enterprise operation data, market conditions, supply chain node information, and sensor data. Researchers, in combination with operational research optimization tools, apply the prediction results to inventory management, production planning, and transportation scheduling, providing scientific guidance for supply chain strategies in a dynamic environment The integrated development environment records the data processing, model training and visualization processes, ensuring the transparency of research and the reproducibility of experiments, and systematically enhancing the scientificity and reliability of risk early warning.

Large language models have expanded the capacity for supply chain risk analysis. Researchers access general language models through API interfaces to quickly process literature, case texts, and unstructured data, extract information, and analyze event trajectories. They build intelligent question-answering systems and decision support agents, integrating enterprise data and external information for real-time risk monitoring and strategy optimization. The system can automatically detect potential anomalies and key risk nodes, providing timely and accurate references for supply chain risk early warning. Researchers pay attention to data security and the protection of sensitive information when using it. They ensure data integrity and confidentiality by locally deploying computing resources or security protocols. Artificial intelligence technology enhances data analysis

capabilities, simulation experiment efficiency, and model decision-making levels in supply chain risk early warning. Provide technical support and practical basis for the management of complex supply chain networks and the early identification of potential risks.

4.3 Research process design and system implementation

In modern supply chain research, artificial intelligence technology has become an important tool to support risk early warning and optimized decision-making. Research teams can establish a complete research process, integrating problem definition, theoretical analysis, data integration, model development, experimental verification and result evaluation, to dynamically identify and predict potential risks in the supply chain network. In the early stage of research, the team needs to clarify the goals and core tasks with a problem-oriented approach, design operational research plans around key issues in supply chain operations such as cost control, process efficiency, and risk resilience, and use artificial intelligence methods to enhance data processing capabilities and decision analysis capabilities, providing a foundation for subsequent model design and experiments. Researchers should pay attention to the industry development trends and actual operational difficulties during the problem definition stage, and at the same time identify the bottlenecks that are difficult to solve by traditional methods. They should create new value in the supply chain optimization, risk management and scheduling links through artificial intelligence.

During the method selection stage, researchers should determine strategies based on research objectives and problem characteristics. Whether using data analysis, simulation, or hybrid methods, the system boundaries, key variables, data features, and evaluation indicators should be clearly defined. And plan the functions of artificial intelligence in research, such as prediction modules, optimization engines or decision support systems, while designing algorithm structures, parameters and training schemes to make the technical solutions match the research goals.

During the data collection and processing stage, the research team should integrate supply chain operation data, market information, sensor data, enterprise documents and industry reports, standardize the data, correct outliers, extract features and reduce dimensions to ensure that the analysis results are reliable and interpretable. When handling multi-source heterogeneous data, the team needs to establish an efficient management system and abide by data privacy and security regulations. Sensitive information is anonymized or desensitized to comply with legal requirements. During the model development and experimental stages, the team is required to embed artificial intelligence algorithms into the research framework. By training machine learning, deep learning or reinforcement learning models, the models can learn decision-making patterns, predict risks and optimize strategies in a dynamic environment. Multiple rounds of simulation and data verification are conducted in the experiments. Compare the performance of artificial intelligence methods with that of traditional methods, evaluate the accuracy of cost, efficiency and risk prediction, record key indicators and model outputs, analyze the rationality and robustness of decision-making, and present the model basis through interpretability analysis to provide support for theoretical summary and practical application.

During the stage of organizing and disseminating research results, the research team should organize the research process and findings into academic papers or technical reports, and achieve research sharing through public data and algorithms, which is convenient for peers to reproduce and expand the research, while enhancing academic influence. The team can go through a complete process from problem definition to model implementation and then to result sharing. Artificial intelligence enhances the risk early warning ability of the supply chain. At the same time, it promotes theoretical innovation and practical application, enhances the comprehensive capabilities of scientific research teams, and provides support for the intelligent, scientific and sustainable

development of supply chain management.

5. Conclusions and Prospects

Artificial intelligence systems can integrate data from multiple sources and establish analytical models to monitor the operational status of the supply chain. Artificial intelligence technology can identify potential problems before risks arise and respond quickly. Credit assessment models have demonstrated advantages in supply chain finance. The fund management system can optimize fund flow, the logistics management platform can coordinate transportation and inventory, and the anomaly detection system can identify abnormal behaviors. Enterprises can obtain reliable data support and make more scientific management decisions through artificial intelligence. As the application scope of artificial intelligence expands, insufficient model transparency will reduce the trust of managers. Data security and privacy protection measures are still not perfect. The predictive ability of algorithms in response to economic fluctuations and policy adjustments is limited. Technological reliance may bring new risks and increase the uncertainty of the supply chain. Enterprises need to promote the integration of artificial intelligence with Internet of Things, blockchain and digital twin technologies, and establish a comprehensive perception and collaborative management system through multi-source data interaction and real-time monitoring. The research achievements of management, economics and computer science can be integrated and applied to the improvement of risk early warning models, while formulating unified data standards, algorithm norms and regulatory systems. The advancement of artificial intelligence technology and the establishment of systems will help enterprises enhance their risk prevention and control capabilities, optimize operational efficiency, and promote the development of supply chains towards intelligence, stability, and sustainability.

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