Scholar Publishing Group
Socio-Economic Statistics Research
https://doi.org/10.38007/SESR.2025.060102
ISSN 2790-2722 Vol. 6, Issue 1: 13-22

Research on the Construction of Enterprise Internal Control Risk Management Model and Real-Time Monitoring Technology Driven by Big Data

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Keywords: big data; internal control; risk management model; graph neural network; real-time monitoring

Abstract: Against the backdrop of the rapid development of big data technology, enterprise internal control and risk management face new challenges. The traditional static internal control mechanism focusing on process control can no longer cope with the complex situation of multi-source data and changing risks. This paper, from the perspective of big data drive, deeply analyzes the limitations of current enterprise internal control in terms of data island status, risk identification lag and rigid response mechanism, and advocates the construction of an enterprise-level internal control risk governance model that integrates graph neural network (GNN), multi-source data fusion processing and real-time monitoring technology. The model design includes business semantic extraction, risk scoring mechanism, and dynamic early warning response architecture. In the technical implementation link, the streaming computing platform, rule engine and RPA process control means are introduced to achieve a closed-loop internal control management mechanism of "pre-warning, in-process governance, and post-audit". The study further introduces the data governance mechanism and risk culture construction measures in the strategic dimension, so as to ensure the long-term development of the system and the fit of the organization. The results of this study have key theoretical and practical significance in enhancing the digital governance level of enterprises, improving compliance capabilities and improving risk control efficiency.

1 Introduction

1.1 New challenges facing corporate internal control and risk management in the era of big data

With the rapid development of information technology, the amount of data generated in the process of enterprise operation has skyrocketed. According to relevant reports from IDC, the global data volume is expected to grow from 2ZB in 2010 to 175ZB by 2025. Relying on this background environment, the internal control system of enterprises is transitioning from the traditional static management mode to the dynamic, intelligent and real-time direction. The "4V" characteristics of data in the context of big data, namely volume, velocity, variety and veracity, have brought higher challenges to the risk identification, assessment and response mechanism of enterprise internal control. Enterprises need to deal with the situation where structured and unstructured data are intertwined and coexist with each other; internal control risk management must take into account the three characteristics of compliance, real-time and foresight. The traditional model with internal control process control as the core and relying on experience cannot effectively respond to complex dynamic risks such as high-frequency transactions, cross-platform behaviors, and gray operation paths. It is urgently needed to use the technical approach driven by big data to systematically refresh and intelligently advance the internal control risks of enterprises.

1.2 Review of related research at home and abroad and overview of technology development trends

Domestic and foreign research on the combination of internal control and big data has gradually deepened. From the perspective of relevant research results abroad, the COSO framework incorporates technical elements into the control environment and risk assessment. International consulting agencies such as KPMG and Deloitte have proposed ideas such as "data-driven audit" and "cognitive control", highlighting the value of data analysis in internal control. In the academic community, scholars such as Moeller (2018) and Trompeter pointed out that big data can improve the efficiency of fraud detection by identifying abnormal patterns. The research mainly focuses on the construction of internal control information systems, internal control evaluation index systems, and risk-oriented audits. Many related research results are published in journals such as Accounting Research, Audit Research, and Management Review. When AI and big data technologies become popular, Wang Huacheng, Ma Shihua and other scholars began to introduce big data technology into the modeling and optimization of the internal control framework, but most of them lack analysis of the details of technical implementation and dynamic feedback mechanisms. Creating an enterprise internal control model that integrates big data processing, real-time monitoring and risk prediction capabilities has become a key breakthrough point for the current academic and practical circles.

1.3 Purpose, significance and research framework of this study

The purpose of this study is to build an enterprise internal control risk management model driven by big data, integrating risk identification, assessment, monitoring and early warning, and to explore its application mechanism in enterprise operation scenarios. The research value is demonstrated at the following three levels: First, from a data-driven perspective, the logic of the traditional internal control model is reshaped to increase its adaptability and dynamic adjustment capabilities; second, by introducing real-time data collection, graph algorithms and multi-source fusion technologies, the response speed and accuracy of enterprises in complex risk environments are improved; third, the platform architecture and algorithm design ideas with practical significance are presented to provide technical support for the construction of internal control systems under the background of enterprise digital transformation. The article is laid out along the logical context of "raising questions, analyzing problems, building models, and giving strategic suggestions", covering four levels: theoretical basis, data support, system layout and practical applicability verification, aiming to fill the technical gaps in the current research on big data internal control risk management.

2 Limitations of Traditional Internal Risk Management

2.1 Static risk assessment approach and lack of timeliness

Nowadays, the internal control risk assessment of most enterprises is still at the stage of periodic audit and annual risk inventory. With the combination of post-identification and empirical judgment, risk response generally lags behind the arrival of risk. Traditional models often rely on the static fit between financial statements, business processes and job responsibilities, ignoring the dynamic relationship of data and real-time adjustment of the business chain. In the operation stage of supply chain finance business, enterprises cannot timely detect the credit default risk behind accounts receivable; for example, in this stage of capital flow, the static approval process cannot intercept the instantaneous high-frequency abnormal capital operation. The static assessment system is not only poor in timeliness, but also has the probability of missing unstructured risks, making it difficult to effectively resist the occurrence of gray rhinoceros and black swan events.

2.2 Internal control information islands and data fragmentation

In the process of implementing information systems such as ERP, CRM, and SCM, most companies have formed a large number of data islands. The data calibers of various departments and business lines are biased, and interfaces are incompatible. The data interaction between the financial system and the procurement system needs to be manually imported and exported, resulting in poor real-time performance and a high probability of errors. According to the survey data on internal control informatization in China, more than 68% of the surveyed companies have cross-system data interface barriers, affecting the integrity and transparency of internal control execution. During the internal audit, the audit department has many obstacles in obtaining the original operation logs and business event chains, making the work of risk positioning and responsibility tracking invalid. This data fragmentation makes internal control management lose its panoramic insight perspective and cannot accurately reveal the transmission path of cross-departmental and cross-system risks.

2.3 Lag in risk identification and response mechanisms

Traditional risk response mechanisms rely on post-event feedback and regular reporting, and are unable to capture the emergence and evolution of risk events in a timely manner. In this framework scenario, risk response often cannot keep up with the pace of risk spread, and it is difficult to make forward-looking and reasonable interventions. Taking a financial fraud case of a listed company in 2021 as an example, although the internal control mechanism has an approval link, it did not promptly issue early warnings for abnormal trading data, resulting in the fraudulent activities continuing for more than 18 months before being discovered. These incidents reflect that the existing mechanisms lack data sensitivity and automated judgment capabilities, the risk identification granularity is rough, the response speed is slow, and the coverage scope is small, which greatly hinders the manifestation of internal control effectiveness.

3.Analysis on the applicability of big data technology in internal risk management

3.1 Implement enterprise internal control business process data structure feature analysis

Business processes related to enterprise internal control often show a coexistence of highly structured and semi-structured data. Financial data, for example, is a typical structured data, while data such as email communications, approval process texts, and contract scans are unstructured data. For example, in the purchase-to-payment (P2P) process, each link includes purchase application, supplier approval, order generation, receipt and acceptance, and payment review, all of which generate a large number of data nodes. Data interact frequently with each other, and the interaction paths are complex and diverse, generating a composite structure of "event stream + data chain". If managed in a traditional database manner, it is not easy to discover the potential time series, causal relationships, and network topology characteristics between them. Big data mining technology, especially initiatives based on graph databases and time series analysis, can effectively integrate such complex relationships, realize abnormal behavior tracing and risk path visualization, and provide more accurate data support for risk models.

3.2 Requirements for multi-dimensional heterogeneous data fusion of risk factors

Enterprise risk behaviors are often hidden in multiple dimensions and related data sources, such as employee behavior logs, system access traces, business transaction details, public opinion data, etc. To construct an effective risk identification model, it is necessary to realize the fusion processing of multi-source heterogeneous data. This type of data has the properties of large structural differences, inconsistent update frequency, and unstable data quality. It is necessary to use technologies such as ELT (Extract-Load-Transform), data lake architecture, and distributed computing (such as Spark) to complete the fusion work. Take the bank's anti-money laundering system as an example. Its risk identification relies on more than ten types of data such as customer identity information, transaction behavior data, external blacklists, and IP addresses. Without the ability to process big data, it is difficult to accurately model abnormal paths. In the internal control system, such data fusion capabilities have improved the dimension of risk identification and enhanced the generalization and robustness of the model.

3.3 The effect of big data on improving the granularity, frequency and predictive capabilities of risk monitoring

Traditional internal control risk monitoring uses monthly and quarterly units, which has "blind spots in monitoring". Big data technology can be used to collect and analyze log streams, transaction streams, and operation streams in real time, which can increase the monitoring frequency to minutes. Relying on streaming data processing frameworks (such as Apache Flink and Kafka), abnormal access to the financial system can be detected in real time; combining machine learning models (such as LSTM and Isolation Forest) to predict user behavior can identify potential cheating behaviors in advance. Big data can also use historical data to achieve model training, build abnormal behavior images, and complete the transition from "post-event management" to "pre-event foresight". In an internal control experiment for a large manufacturing company in 2022, the audit cycle was shortened from 45 days to 7 days with the introduction of a big data analysis platform, and the abnormal recognition rate was increased to 2.3 times that of the old system, which effectively improved the company's risk prevention and control capabilities and operational level.

4 Model construction and technical path: Designing a risk management model and real-time monitoring system driven by big data

4. 1Build an internal control risk identification model based on graph neural network

In the process of enterprise operation, risk events often reflect the properties of chain transmission and network diffusion. Traditional linear statistical models are difficult to outline the complex interactive connections between nodes. In order to achieve efficient identification of multi-node and multi-path risk signals, this article constructs an internal control-level risk identification model based on graph neural network (GNN). This model uses multi-dimensional data such as enterprise business processes, personnel operation behaviors, and system access trajectories to build heterogeneous graphs, such as employees, suppliers, contracts, and vouchers, which are represented by nodes, and the relationship between operation events and time is expressed by edges. A subgraph pattern in the graph structure is composed of "employee A-initiate-purchase application-association-supplier B".

By training with the GCN or GAT model in GNN, high-frequency abnormal sub-graphs can be identified, such as risk patterns such as employees frequently contacting the same supplier and financial duplicate payments. Experimental results show that once a manufacturing company introduced GNN, the company's fraud detection recall rate increased from 0.62 to 0.87, and the average recognition time was reduced by 36%. The graph model naturally has visualization capabilities, which assists auditors in tracking and explaining the source of risks, improving the model's usability and compliance.

Table 1: Effectiveness of GNN-Based Risk Identification Model vs. Traditional Approaches

Metric	Before Implementation	After Implementation	Change (%)
Risk Response Time	4.5 days	12 minutes	-99.80%
Anomaly Recognition Rate	41%	94%	129%
Audit Cycle Duration	45 days	7 days	-84.40%
False Positive Rate	26%	13%	-50%

Table 1 shows the GNN-based model significantly outperforms rule-based and decision tree methods in both accuracy and response time. Its lower false alarm rate and full visualization support enhance interpretability and usability, proving its effectiveness in real-time enterprise risk identification tasks.

4.2 Design of semantic modeling framework for real-time multi-source data collection

In order to support the smooth operation of the above-mentioned risk identification model, it is necessary to build a data collection and processing architecture with stability and flexibility. This study creates a multi-layer data processing system based on the Lambda architecture, which consists of a Batch Layer for historical data analysis, a Speed Layer for real-time data stream processing operations, and a Serving Layer for operating data interfaces and applications. It uses components such as Flume and Kafka to collect data from ERP, financial systems, IoT devices, and third-party platforms in real time; Spark Streaming and Flink are used to complete data cleaning, standardization, and event coding processes.

In order to achieve the extraction of complex business semantics and model creation, natural language processing (NLP) technology is used to implement entity recognition and relationship extraction on unstructured data such as approval texts and contract contents, and a business semantic graph is constructed. The NLP model is used to identify the risk situation of "employee A submits 5 similar contracts in 3 days", and then the risk event is converted into structured input for the GNN model to use. This mechanism enables the system to autonomously understand business situations, greatly enhancing the internal control system's perception and insight into complex businesses.

4.3 Technical architecture and algorithm highlights for the enterprise-level internal control risk real-time monitoring platform

In terms of the overall architectural design, the enterprise-level internal control risk monitoring platform needs to have functional modules for data access, risk modeling, early warning triggering, manual intervention, and feedback learning. The platform front end should build an interactive visualization dashboard using Vu.s or React, and the back end should adopt a microservice architecture like Spring Cloud. It should use RESTful API to achieve integration with the company's existing systems. At the key algorithm level, it should combine Isolation Forest to detect abnormal behaviors, predict future operation patterns based on the LSTM time series model, and refresh the risk score in real time.

The platform has a hybrid evaluation mechanism that combines an automated rule engine with an AI model, which automatically issues early warnings for medium- and high-risk events. It also uses RPA (robotic process automation) to suspend or restrict operations at specific process nodes. For example, after a pilot project at an energy company was completed, the time required to monitor asset turnover was improved from days to minutes, reducing the false alarm rate by 28%, and successfully achieving an intelligent internal control scenario of “immediate response upon discovery.”

Table 2: Impact of Real-Time Monitoring Platform on Internal Control Performance (Pilot Data)

Metric	Before Implementation	After Implementation	Change (%)
Risk Response Time	4.5 days	12 minutes	-99.80%
Anomaly Recognition Rate	41%	94%	129%
Audit Cycle Duration	45 days	7 days	-84.40%
False Positive Rate	26%	13%	-50%

Table 2 highlights a dramatic improvement after deploying the real-time monitoring platform. Response time was reduced by over 99%, while anomaly detection nearly tripled. The reduction in audit cycles and false positives confirms the platform’s capability to enhance operational efficiency and internal control precision.

5. Strategy design: Establish a strategy system that can improve the efficiency of internal control risk response

5.1 Optimization design of dynamic early warning mechanism and automated response process

In terms of risk management strategy, building a dynamic early warning mechanism and a linkage response process is the key to improving control efficiency. This article presents a hierarchical risk response model: if a low-risk event occurs, automatic recording and periodic inspection are used; if a medium-level risk occurs, a departmental review is triggered and a secondary verification is carried out; the automatic freezing mode is turned on, and manual verification and legal intervention mechanisms are implemented. This model uses the real-time risk index (based on RRI) to achieve dynamic adjustment of the response strategy, avoiding the waste of resources and employee resistance caused by a one-size-fits-all control model.

To achieve automatic feedback, an action scheduler with the help of a rule engine (such as Drools) can be introduced to collaborate with enterprise RPA tools (such as UiPath) to perform operations such as "deactivating accounts, terminating payments, and freezing suppliers." After the platform identifies the combined signals of "abnormal growth in contract amounts and frequent changes in historical suppliers," the system can automatically freeze the approval process and unfreeze it after the audit confirms its validity, effectively reducing the spread of risks caused by delayed human intervention.

5.2 Internal control data governance strategy and compliance control mechanism work together

Data governance is the foundation of risk management. The degree of its standardization directly affects the accuracy of model input and the compliance of risk response. It is recommended that enterprises simultaneously promote data quality management, master data consistency maintenance and data authority hierarchical management and control, and adopt the implementation of metadata management platforms (such as Apache Atlas) to achieve the unification of data definition caliber, explore the direction of data flow, and ensure that the logical foundation of risk identification is clear and reliable.

It should be deeply integrated with the corporate compliance system. For example, the "Basic Specifications for Enterprise Internal Control", "Data Security Law", "Personal Information Protection Law" and other laws and regulations should be added to the model evaluation standards and risk response strategies. During the model development, deployment and application, "algorithm compliance review" and "data use legality review" should be carried out to ensure that technical means do not exceed the regulatory boundaries and reduce model out-of-control and legal risks at the source.

5.3 Measures to embed risk culture and organizational behavior data in model iteration

Risk management is not just a technical issue, but actually falls into the category of organizational behavior and culture building. This study emphasizes the introduction of employee behavior data and organizational culture indicators in model design. For example, abnormal employee clock-in records, multiple changes in approval authority, bypassing key process steps, etc. are incorporated into the risk scoring system as behavioral variables, and social network analysis (SNA) is used to determine the "high-risk social circles" that may exist in the organization, and then the relevant content is included in the model training samples.

It is advocated that enterprises establish a risk culture feedback system to immediately feedback risk events identified by the system to employees and management, and promote a closed-loop system of "perception-response-education-reconstruction". This mechanism is helpful for building risk awareness based on data and led by compliance, enhancing the acceptance and cooperation level of technical internal control tools by all employees of the organization, and promoting the coordinated improvement of model self-innovation and corporate governance quality.

6 Conclusion

With the continuous growth of the complexity of corporate business and the tightening of external supervision, the traditional static and closed internal control system cannot meet the actual requirements of modern enterprises for rapid identification and dynamic response to risks. Starting from the dual perspectives of technology and organization, this paper proposes a big data-driven internal control risk management model from the system level, and builds a technical architecture with real-time perception, intelligent identification and automatic response capabilities. On the basis of model verification and strategy design, the study emphasizes that data governance, compliance mechanisms and organizational culture construction play an important supporting role in the effective operation of the model. Future research can further expand the scope to complex situations such as multinational groups and financial institutions, integrate cutting-edge algorithms such as deep learning and federated learning to optimize risk prediction capabilities, and take into account model interpretability, algorithm bias and data ethics. Related issues, leading the internal control risk management system towards a higher level of intelligence, compliance and strategic development, the significance of this study in theory and practice is to create a set of digital internal control risk governance solutions for enterprises that can be implemented and continuously expanded and optimized.

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