



Research on the Innovative Transformation of Scientific Research Financial Management Driven by Digital Intelligence

A Practical Exploration Based on Intelligent Financial Cabinets

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Abstract. Under the context of traditional models encountering bottlenecks in scientific research fund management, this study constructs a three-dimensional framework of "Mini-App Interaction (MAI) – Background Task Orchestration (BTO) – Data Governance Architecture (DGA)" to explore innovative applications of intelligent financial cabinets. The research conducts a comprehensive analysis of the system architecture and functional design of intelligent financial cabinets. The system architecture encompasses three core components: the WeChat Mini-App interface, a backend management platform, and data interaction mechanisms. It integrates advanced features such as smart document delivery, order retrieval, and closed-loop feedback, optimizing the entire workflow of financial operations. Empirical results demonstrate that intelligent financial cabinets significantly enhance the efficiency of research fund management by enabling full traceability of operational records. Additionally, they foster business-finance integration through digital data provenance and drive the transformation of financial services. Future developments will integrate artificial intelligence and blockchain technologies to further advance the digital transformation of research fund management, offering valuable insights for other domains.

Keywords: Digital intelligence; Scientific research financial management; Intelligent financial cabinets

1 Introduction

1.1 Research Background and Problem Statement

In the field of scientific research fund management, the traditional management model faces significant bottlenecks, and its management efficiency is difficult to effectively support the practical needs of refined management. The complex reimbursement approval process forces scientific researchers to spend a large amount of time on invoice

sorting, form filling, and cross - departmental coordination, seriously squeezing the time resources for core scientific research work ^[1]. At the same time, the time lag in data feedback at the management end leads to the inability to synchronize the information on the use of funds in real - time, directly affecting the scientific nature of budget control and resource allocation decisions. When there are abnormal expenditures of funds, the lack of a traceability mechanism makes it difficult to locate problems and determine responsibilities ^[2].

The Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences (hereinafter referred to as IGA) has constructed a fund management ecosystem based on intelligent financial cabinets by implementing a "trinity" financial digital transformation plan. This system relies on the efficient collaboration of intelligent terminal devices, mobile application platforms, and cloud management systems to achieve digital closed - loop management of the entire process of scientific research funds. This practice not only effectively solves the operational pain points of the traditional management model but also provides a replicable and popularizable system solution for the digital transformation of financial management in scientific research institutions ^[3].

1.2 Research Framework and Innovation Points

This research constructs a three - dimensional theoretical model of "Mini - App Interaction (MAI) - Background Task Orchestration (BTO) - Data Governance Architecture (DGA)" (as shown in Figure 1). This model contains three logical dimensions: In the interaction dimension, users establish a real - time interaction channel with the intelligent financial cabinet through the WeChat mini - app to achieve core business functions such as document delivery reservation, status query, and pick - up notice, effectively improving operation efficiency and human - machine interaction experience; in the coordination dimension, relying on the system - level integration architecture of the intelligent financial cabinet, the financial system, and the scientific research project management system, the automatic flow of business data and the multi - platform collaborative processing mechanism are realized; in the data governance dimension, a data - driven decision - support system is established, and a full - process control model covering data collection, processing, and analysis is constructed.

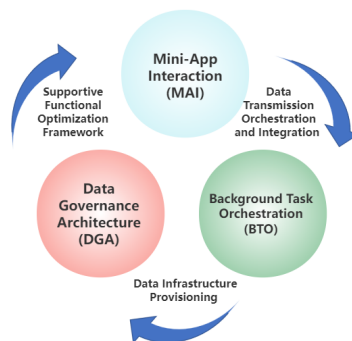


Fig. 1. Three - Dimensional Collaborative Architecture Diagram of Business - Finance Processes Driven by Intelligent Financial Cabinets

2 System Architecture and Functional Design of Intelligent Financial Cabinets

2.1 Overview of System Architecture

The system architecture of intelligent financial cabinets is composed of the WeChat mini - app end, the background management platform, and the data interaction mechanism to form a complete service system. The WeChat mini - app end, relying on the convenience and wide coverage of the WeChat ecosystem, provides zero - threshold access. Users can quickly access it through WeChat and integrate three core functions: scanning code for delivery, real - time progress tracking, and return order processing. Scanning code for delivery can automatically match the information of reimbursement documents, avoid manual errors, and improve operation efficiency; real - time progress tracking helps users keep track of the status changes of documents in the review, circulation, and archiving links at any time; when processing return orders, the system automatically pushes a notice with review opinions and the pick - up cabinet number, forming a business loop.

The background management platform, as the data processing center, adopts a multi - level architecture. The data storage layer uses a distributed database to securely store user information, document data, and operation logs; the business logic layer sets up a process engine to intelligently manage the entire process of documents according to preset rules. The permission management system based on the RBAC model configures different permissions for ordinary users, financial staff, and administrators to prevent the risk of unauthorized data access^[4].

The data interaction mechanism relies on standardized API interfaces to build a two - way data channel and uses the HTTPS protocol to ensure security. The front - end operation data is serialized and encapsulated in JSON format, and after being authenticated and traffic - controlled by the API gateway, it interacts with the background service cluster in real - time. The system adopts an event - driven architecture. After the background finishes processing the data, it actively pushes the status update to the front - end through the WebSocket protocol to ensure the consistency of business data among multiple terminals and improve the efficiency and accuracy of business processing.

2.2 Core Functional Modules

The intelligent financial cabinet system realizes full - process digital management through three core functional modules:

Intelligent Delivery Management Module.

Relying on WeChat Mini - App's scanning interaction technology, the system generates globally unique digital identifiers using the UUID algorithm to ensure the full - life - cycle traceability of business documents. The dynamic cabinet allocation mechanism supports the combined delivery of multiple invoices. Users can complete batch document storage through a single scan, significantly improving business processing

efficiency. The integrated sensor matrix enables contactless identity authentication and automatically activates the exclusive storage compartment. In abnormal situations, the intelligent supplementary order mechanism can retrieve historical business data in real - time to maintain the integrity of the business data chain.

Intelligent Pick - up Management Module.

Adopting WeChat identity authentication and the RBAC permission control model, it authorizes financial staff to open and close cabinets with one click via mobile terminals. The batch pick - up function automatically generates an electronic task list to support visual tracking of document processing status. The full - dimension operation log completely records the pick - up time, operator, and number of documents, forming an auditable business trajectory. The system integrates three security mechanisms: biometric recognition, dynamic verification codes, and electronic authorization, and is equipped with a retention alert system to achieve dynamic cabinet resource scheduling and optimize turnover efficiency.

Intelligent Feedback Loop System.

It constructs a dual - path closed - loop management architecture: the forward process realizes the automatic archiving of electronic vouchers and the instant push of approval results, while the reverse process generates rectification task work orders through a digital annotation engine. When audit anomalies are detected, the system automatically issues a task instruction set containing correction specifications. After users complete the revisions and submit them again, it triggers an automated review process. This closed - loop mechanism achieves transparent business process management, reduces the frequency of manual intervention through standardized processing paradigms, and ensures the achievement of business processing timeliness and compliance control indicators.

3 Business Process Optimization and Business - Finance Coordination Paths

3.1 Reengineering of Business - Finance Coordination Processes

The intelligent financial cabinet reconstructs the reimbursement document delivery process via WeChat Mini - App at the submission phase. Users generate unique digital identifiers through QR code scanning, establishing a full - process traceability system. The system employs intelligent decoupling technology to mitigate delivery anomalies caused by budget data discrepancies. After sensor - based biometric authentication, users can perform batch submissions of related documents. An intelligent resubmission mechanism with redundant verification algorithms ensures data integrity during exceptional scenarios.

At the review stage, financial personnel conduct digital audits by associating complete data sets through unique IDs after online identity verification. Abnormal documents trigger the annotation module for precise issue localization, supporting bulk returns to form rectification task packages. Users receive standardized correction instructions via the Mini - App, and revised submissions automatically initiate the secondary review loop.

During the return order phase, financial staff initiate reverse logistics through QR code scanning, with real - time cabinet status updates. Three authentication methods are provided: WeChat biometric recognition, dynamic verification codes, and electronic authorization. A demurrage alert system activates after five days of uncollected returns, triggering dual - channel reminders (Mini - App + SMS) to optimize cabinet resource turnover efficiency [5].

3.2 Intelligent Return Order Management Mechanism

The reverse business process of the intelligent return order management mechanism consists of three core modules: scanning code for positioning, standardized classification of return order reasons, and random cabinet allocation. When financial staff initiate a return order, they scan the QR code of the document, and the system immediately accurately locates and, based on the scanned data, retrieves associated information such as the reimbursement subject, fund project, and amount details in real - time, laying a solid data traceability foundation for subsequent processes.

After determining the return order, financial staff select corresponding items from the standardized reason library preset in the system. This reason library is constructed based on historical review data and covers common return order situations such as abnormal document formats, missing attachments, and incorrect amount calculations. The standardized reason options ensure the objectivity and traceability of the return order basis, effectively avoid communication ambiguities, and greatly improve business interaction efficiency.

The system uses the Monte Carlo algorithm to randomly allocate the to - be - returned documents to idle storage units, dynamically balance storage resources, prevent local cabinet idleness or overloading, and ensure the security of document circulation through physical isolation. After the allocation is completed, the system automatically pushes the return order details through WeChat, including reason explanations, cabinet codes, and pick - up instructions, facilitating users to keep track of the return order status in real - time.

Practice has shown that this intelligent management mechanism has achieved remarkable results. The traditional manual processing mode has multiple - node manual verification and paper document circulation, with an average processing cycle of 24 hours. The intelligent management system, with the help of information technologies such as OCR recognition and RPA process automation, creates a fully electronic business loop, reducing the processing time to within 6 hours and increasing the document turnover efficiency by 75%. While optimizing the scientific research service response, it constructs a new financial management paradigm of "letting data run more and people

run less", providing a digital solution for the full - life - cycle management of scientific research funds.

4 Conclusions and Prospects

4.1 Research Conclusions

This study focuses on the application of intelligent financial cabinets in scientific research fund management, constructing a three - dimensional analytical framework of Mini - App Interaction (MAI) - Background Task Orchestration (BTO) - Data Governance Architecture (DGA). Through in - depth analysis of system architecture, functional design, business process optimization, and business - finance coordination paths, it is demonstrated that intelligent financial cabinets achieve real - time business - finance data interaction and closed - loop process management via tight collaboration between WeChat Mini - Apps and background platforms. This effectively addresses pain points in traditional management, including lengthy reimbursement processes, delayed data feedback, and insufficient regulatory traceability.

The system promotes business - finance integration through three dimensions:

Data Penetration: A full - link traceability mechanism from business document generation to financial processing is established. Unique digital identifiers correlate metadata such as project codes, amounts, and responsible persons, enabling precise data tracing ^[6].

Process Reengineering: A state - of - the - art closed - loop management system for Delivery - Pickup - Feedback - Return has been implemented. As soon as a submission is made through the Mini - App, the system immediately and smartly assigns delivery lockers. It offers real - time, extremely rapid review result notifications. When it comes to returns, the system reallocates lockers with great accuracy and at a much faster pace compared to before. These outstanding characteristics have significantly revolutionized the process, slashing overall processing time by a substantial margin and achieving a remarkable leap in efficiency ^[7].

Service Transformation: Passive accounting evolves into proactive decision support. Real - time progress monitoring, issue resolution via WeChat, and data - driven personalized advice enhance collaboration and decision accuracy ^[8].

This research provides both theoretical foundation and practical guidance for intelligent financial cabinet applications in scientific research fund management, offering replicable insights for digital transformation in other financial management domains.

4.2 Future Prospects

With technological advancements and increasing research management sophistication, intelligent financial cabinets will realize deeper strategic value through:

AI - powered Analysis: Machine learning optimization will enable full - dimensional research fund analysis. High - precision prediction models will estimate stage - specific funding needs, while dynamic monitoring mechanisms track expenditure flows and trigger risk alerts ^[9].

Ecosystem Integration: A Smart Cabinet + e - Voucher collaborative ecosystem will integrate e - voucher systems to create a full - cycle digital closed - loop for research projects. Electronic vouchers will enhance data transmission fidelity by 65% and enable automated validation ^[10].

Blockchain - based Security: Distributed ledgers, hash algorithms, and timestamp technologies will establish tamper - proof e - voucher repositories. Unique digital identities and audit trails will facilitate secure cross - institutional data sharing, breaking information silos ^[11].

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