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An Informatics-Enabled Logistics Service System for Cross-Border Medical E-Commerce: Evidence from China–Kyrgyzstan Collaboration

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Abstract. The challenges that are involved in the China-Kyrgyzstan Medical E-commerce Innovation Project include the allocation of resources in an uneven manner, the lack of data standards in a multi-tier medical management, which prevent effectively collaborating and conducting e-commerce operations in the pharmaceutical supply chain. In this paper, a three-stage management model is developed using theory of medical management collaboration and digital governance model: data-driven-process integration-intelligent monitoring. Standard drug procurement and inventory management is done through the Enterprise Resource Planning (ERP) system. Second, cross-departmental and cross-institutional business processes are integrated on a Business Process Management (BPM) platform to provide a real-time data exchange between various parties. Lastly, there is the introduction of Artificial Intelligence (AI) algorithms which are used to optimize pharmaceutical demand forecasting and schedule logistics. The project was tested at the same time in Jiangsu and Bishkek, Kyrgyzstan. After the system went live, overall operational efficiency improved by 30.1%, drug procurement cycle shortened by 42.6%, inventory capital occupancy rate decreased by 8.8 percentage points, and information flow time was shortened by 41.8%. This model effectively improves the collaboration and responsiveness of the medical e-commerce system, providing replicable experience and pathways for the management and implementation of innovative medical e-commerce projects.

Keywords: Medical E-Commerce; Project Management; Digital Collaboration; Resource Optimization; Intelligent Decision-Making

1. Introduction

With the context of the rising medical collaboration between China and Kyrgyzstan, the two nations have a sharp contrast in the healthcare systems concerning policy orientation, resource distribution, and the level of digitalization. This is an experimental situation in designing and establishing models of cross-border medical e-commerce practices. In the context of the multi-tiered healthcare system, the variation in data standards and process barriers between various hospitals, pharmaceutical companies, and regulatory departments limit the systematic relationship of information, logistics, and capital flow and create management and technical challenges to the sustainable development of pharmaceutical e-commerce.

As a research vehicle, this paper examines how in the context of disparities in bilateral medical management, information system- process restructuring may result in institutional compatibility and resource complementarity, which involves experience in applying regional medical cooperation within the framework of the Belt and Road Initiative. The integration of ERP and BPM platforms creates a dynamic feedback loop between information and processes, which enhances the collaborative mechanism of governance between organizations and allows creating more connections between medical resources and information flows within the e-commerce platform system.

The innovation of this paper lies in breaking down the disconnect between management and technology in the field of medical e-commerce. By introducing the prediction and scheduling mechanism of artificial intelligence algorithms, intelligent analysis and process execution are deeply integrated, establishing a management system with self-learning and adaptive capabilities for the pharmaceutical supply chain. Meanwhile, the project has developed a scalable and replicable operating model, providing the medical e-commerce industry with a digital transformation path that is both feasible and strategically guiding.

2. Related Work

Medical project management is becoming increasingly complex under the background of systemic reform and informatization. How to achieve efficient coordination and risk control in the context of limited resources and multiple objectives has become an important issue in promoting the optimization of the medical system. Yang et al. analyzed the problems existing in medical project management and put forward reasonable suggestions and measures based on the existing problems to promote the sound and healthy development of medical cooperation projects (Yang et al., 2021). Lv explored the management of outsourced medical projects of hospitals based on information systems and proposed a management mechanism for outsourced medical projects suitable for their own medical institutions (Lv, 2020). Li et al. aimed to explore the impact and role of the hospital-government cooperation infection control alliance project management model on the quality of hospital infection management in primary medical institutions (Li et al., 2025). Zhou et al. aimed to explore the practical application and effect of learning from the third-party SPD management concept and using ordinary consumable smart cabinets and Internet of Things technology in the management of medical consumables (Zhou et al., 2025). Mo and Li ensured the standardization and scientific nature of the clinical trial process of medical devices by effectively integrating resources, actively communicating and coordinating, responding quickly to needs, optimizing service processes(Mo & Li, 2025), and strictly managing risks, thus contributing to the high-quality development of clinical trials of medical devices and effectively protecting and implementing the rights and needs of all parties involved in the clinical trial of medical devices, including sponsors, institutions, researchers, and subjects. Sassykova aimed to summarize the literature on the application of project management in the healthcare field (Sassykova, 2023). Relevant literature was retrieved using academic databases such as PubMed, Cochrane Systematic Reviews Database, and Embase. Mısırlıoğlu and Murt aimed to emphasize the importance and necessity of project management in the healthcare field (Mısırlıoğlu & Murt, 2024), thereby promoting the formation of a project management culture in the healthcare industry. Geraidine and Silva aimed to explore the relationship between the healthcare ecosystem and project management through academic literature (Geraidine & Silva, 2025). Gomes et al. proposed and tested a mediation model that showed that organizational maturity could promote the success of medical information system projects that adopted project management practices in the healthcare field (Gomes et al., 2022). Ambo et al. explored the challenges faced during the website launch process, including performance and stability issues, and how project managers can use the Project Management Body of Knowledge (PMBOK) to manage and resolve these challenges (Ambo et al., 2023). Existing research focuses on mechanisms and models, and systematic research on cross-organizational collaboration, data fusion and dynamic monitoring is still insufficient. Further research should be conducted on the depth of practice and the level of technology integration.

3. Methods

3.1. Physical Service Capabilities

In the China-Kyrgyzstan medical e-commerce project, logistics service capabilities encompass three key dimensions: delivery timeliness, transportation reliability, and traceability transparency. Delivery timeliness requires medicines to be delivered accurately within the specified timeframe, which is particularly important for temperature-controlled and urgently needed medications. Transportation reliability involves cold chain assurance, shockproof packaging, and transportation safety management to ensure the quality of medicines is not compromised during distribution. Traceability transparency utilizes IoT technology and a blockchain system to achieve full-process monitoring and traceability of medicine flow. The project integrates warehousing resources and the transportation network through an ERP system, coordinates cross-border logistics nodes such as customs clearance and quality inspection certification between China and Kyrgyzstan using a BPM platform, and dynamically optimizes delivery routes and capacity allocation using AI algorithms. This multi-dimensional logistics service capability development improves the on-time delivery rate and reduces transportation losses in cross-border pharmaceutical logistics, effectively supporting the service commitments and user experience of the medical e-commerce platform.

3.2. Data-Driven Management

During the system architecture design phase, considering the weak foundation of Kyrgyzstan's medical information system and its reliance on manual operations, the ERP platform was used as the core carrier of medical e-commerce informatization (Pan & Dias, 2024). Strong connection between the procurement, inventory, and finance modules was able to provide a single data processing level, the difference between the two countries with regard to medical e-commerce development was narrowed due to a single data interface and smart algorithms (Kaur, 2023). Some basic drug coding rules were applied as constraints in the procurement process whereby the supplier directory, drug packaging specification and procurement batches were numbered uniformly (Pang, 2023). The system automatically matched the past price changes in procurement and delivered dynamic procurement suggestions. The introduction of the inventory management module gave birth to multi-warehouse parallel logic whereby a batch number traceability algorithm is used to determine the status of drug inventory. Real time inventory information was sent to the finance module of a distributed database (Muratalieva, 2024). The financial processing aspect applied the timestamp mechanism of transaction logs to ensure the integrity of income and expenditure records, which are automatically matched with inventory inflow and outflow data to create settlement documents, which is effective in eliminating errors in the manual entry (Zhang, 2025). Table 1 shows a small portion of standardized drug procurement, inventory, and financial data.

Table 1: Small Portion of Standardized Drug Procurement, Inventory, and Financial DataC:\GPT-5-Chat

Drug Code	Purchase Unit Price (CNY)	Batch Number	Inventory Quantity (Boxes)	Financial Settlement Amount (CNY)	Supplier Code
MD-001	12.50	A2301	1450	18125.00	S-045
MD-002	8.20	B1143	2300	18860.00	S-032
MD-003	16.90	C0765	980	16562.00	S-058
MD-004	6.70	D2210	3120	20904.00	S-025
MD-005	9.80	E1908	1750	17150.00	S-011
MD-006	14.40	F1546	1280	18432.00	S-039

During system operation, ERP continuously performs dynamic analysis on procurement plans and inventory turnover parameters. The model updates the procurement threshold based on the time series data of drug demand, realizing automatic drug replenishment decisions. The platform interacts with the BPM (Business Process Management) system through interface services to ensure the timeliness and accuracy of cross-module data synchronization, thereby forming a high-precision data closed loop for actual transactions in medical e-commerce.

3.3. Process Integration Mechanism

The design of the BPM platform is to reconstruct the process heterogeneity between multiple nodes of medical e-commerce systems as the main contradiction. The system dynamically models each business link of drug procurement, quality inspection, warehousing, settlement and delivery by defining a unified process modeling language (PML) (Zhang, 2024). The model metadata is stored in the middleware service layer in JSON Schema format to ensure semantic recognition and data interoperability between different systems (Meng, 2021). Cross-department business collaboration is achieved through the event-driven mechanism triggered by the BPM engine middleware. When drugs are transferred from procurement to acceptance and warehousing, the system broadcasts the process status identifier to the monitoring modules of the pharmacy department, finance department and logistics department through the message queue to achieve state transmission without delay.

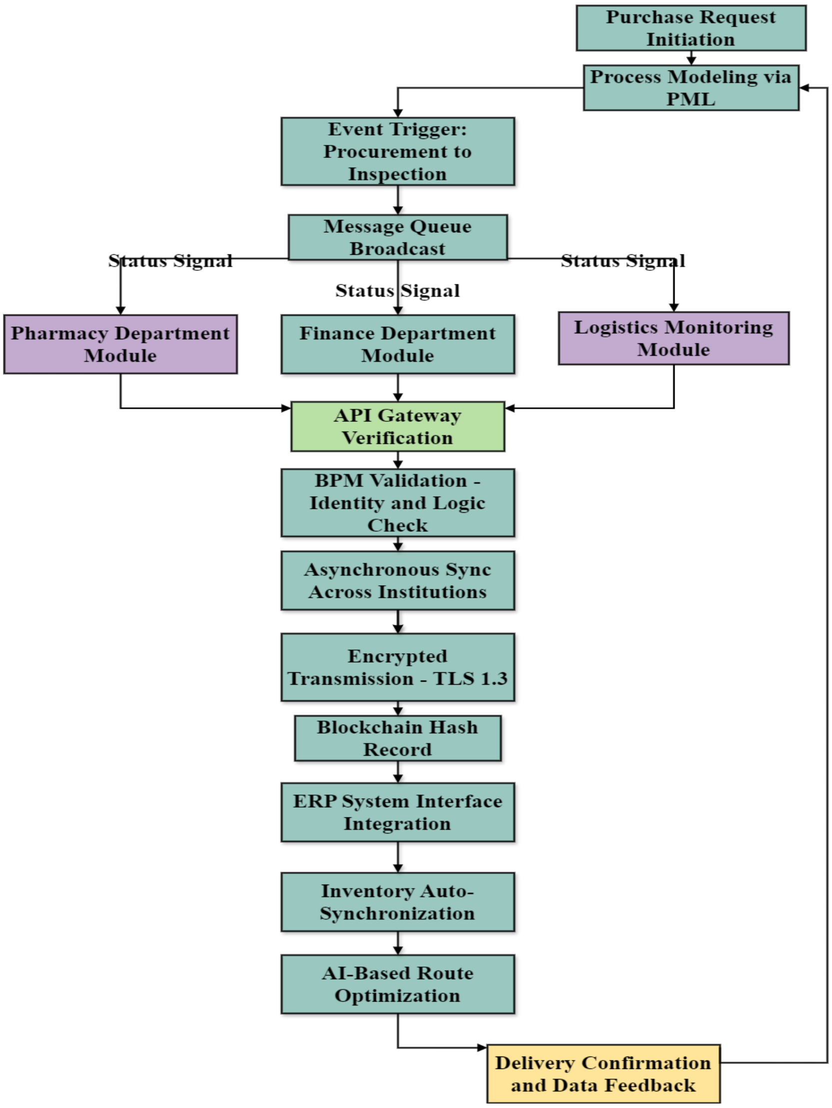

Fig.1: Details of the process integration mechanism

The platform's process synchronization service utilizes an API Gateway for unified access control. Each request packet includes a user identifier and a time signature, which is verified by the BPM verification module to confirm identity and match workflow logic (Zakirova, 2025). To address the timeliness issue of data exchange between medical institutions, the system employs an asynchronous synchronization mechanism. Data packets across institutions are transmitted using lightweight encryption (TLS 1.3) and embedded with blockchain-style hash records to ensure the traceability of the data synchronization process (Azimqulov, 2025).

The BPM engine achieves unified data scheduling through interface binding with the aforementioned ERP system (Rashid & Sarwar, 2025). When the procurement process status updates to "Inbound Completed," the system automatically synchronizes the inventory to the other medical institution's distribution module and triggers an AI algorithm to calculate the optimal delivery route, reducing duplicate inbounds and delayed delivery (Zitong, 2024). Details of the process integration mechanism can be seen in Figure 1.

Figure 1 shows the data integration mechanism of multi-department collaboration in the medical e-commerce system. After the purchase request is modeled by PML, it triggers the event-driven process. The status is synchronized to the pharmacy, finance and logistics modules through the message queue. Cross-institutional data synchronization is completed through API gateway verification and encrypted transmission (Tran & Canh, 2025). Blockchain records ensure traceability. Finally, it is linked with the

ERP system interface to realize automatic inventory synchronization and AI-optimized delivery, forming a closed-loop feedback loop (Binsar et al., 2025).

3.4. Intelligent Monitoring and Optimization

Based on AI algorithms, time series prediction and optimization scheduling models are integrated to complete the dynamic monitoring of pharmaceutical demand and resource allocation. The platform adopts multi-dimensional input variables, including historical purchase records of each institution, seasonal incidence rate, drug inventory turnover time and delivery lag rate, to construct a time series prediction matrix. The demand prediction model is trained based on the Long Short-Term Memory (LSTM) network structure. Its objective function is based on minimizing the Mean Absolute Percentage Error (MAPE):

$$\text{MAPE} = \frac{1}{n}\sum_{t=1}^{n} \left| \frac{D_t - \hat{D}_t}{D_t} \right| \times 100\% \tag{1}$$

The predicted demand output from the model is passed as input variables to the resource scheduling module. The system calculates delivery routes and warehousing allocation schemes through a constrained optimization model. The logistics scheduling algorithm introduces a linear weighted multi-objective function, incorporating transportation costs, time delays, and equipment utilization into the synchronous solution process:

$$\min Z = \alpha C_t + \beta T_d + \gamma(1 - U_r) \tag{2}$$

C_t is the transportation cost per unit time, T_d is the delivery delay duration, and U_r represents the utilization rate of vehicle and warehousing resources. Parameters α,β,γ are automatically adjusted from historical operational data to balance drug delivery speed and cost efficiency. The system captures inventory fluctuations and traffic conditions in real time. When the predicted deviation exceeds a set threshold, it automatically triggers re-optimization calculations and updates scheduling instructions to the ERP system via the BPM interface. The ERP system provides real-time inventory data, order information, and supplier resources, while the BPM platform integrates cross-departmental processes such as procurement approval, warehousing and outbound delivery, and transportation scheduling. The integration of the two forms a unified data platform, eliminating information silos (Diana & Robert, 2025).

3.5. Project Implementation Path

The four comprehensive medical institutions each in Jiangsu Province and Bishkek, Kyrgyzstan were chosen as the experimental group and four institutions of the same size without system deployment as the control group to achieve comparability of business organization, type of drugs and frequency of purchases. The experimental sample introduced an integrated ERP and BPM platform, and the sequence of the deployment consisted of system environment set up, data standardization import, interface debugging module, and the deployment of the AI monitoring service. All institutions were cleaned and imported to a single data warehouse with historical records of every transaction and a cross-institutional message middleware was developed in order to provide real-time synchronization. Once the platform was in place, BPM was used to initiate the procurement, warehousing and settlement process within the experimental group with process logs and inventory information finally being written to the ERP database, AI monitoring module was used to facilitate the demand forecasting in the background and delivery optimization suggestions could be made. The control group preserved its initial mode of a manual and decentralized information system, gathering no more than operational data to analyze it and compare it. The pilot period was six months in total, during which the system operation status, data transmission delay, and personnel operation logs were also a part of the process monitoring used to evaluate the possibility of deployment and process synergy.

4. Results and Discussion

Operational efficiency is defined as the ratio of the number of standardized business processes completed per unit of time to the system resource consumption. This indicator is based on the process efficiency theory in service science and reflects the information system's support capability for business processes and resource utilization efficiency. The procurement cycle refers to the total time from the submission of a procurement request to the confirmation of drug warehousing, including the cumulative time for five stages: demand review, supplier matching, order generation, logistics and distribution, and warehouse acceptance. This indicator originates from the cycle time theory in supply chain management and directly reflects the response speed of logistics services and the agility of the supply chain. Information flow time measures the transmission delay between different system nodes, representing the complete cycle from information generation, transmission, processing to feedback, calculated using timestamps recorded by the BPM platform.

4.1. Data and Performance

(1) Operational Efficiency and Procurement Cycle

Two weeks later when the system was running stable, the test was launched. The 90 days have been used to collect data and the data sources consisted of the operation logs of ERP, processing time of BPM processes and the records of manual confirmation. Operational efficiency was determined in terms of the number of closed-loop processes in a unit time, data throughput and the rate of task completion, the procurement cycle was determined based on the length of the time, on the average latency between the submission of a purchase request and warehousing confirmation. There were no differences in the categories of drugs used, frequency of procurement, and approval levels in the experimental and control groups. The rate of sampling was 1 day. All indicators were purged of noise, cleaned, and normalized and put into a single database so that the time series data could be compared and the analysis is not distorted. Figure 2 shows a comparison of operational efficiency and procurement cycle data:

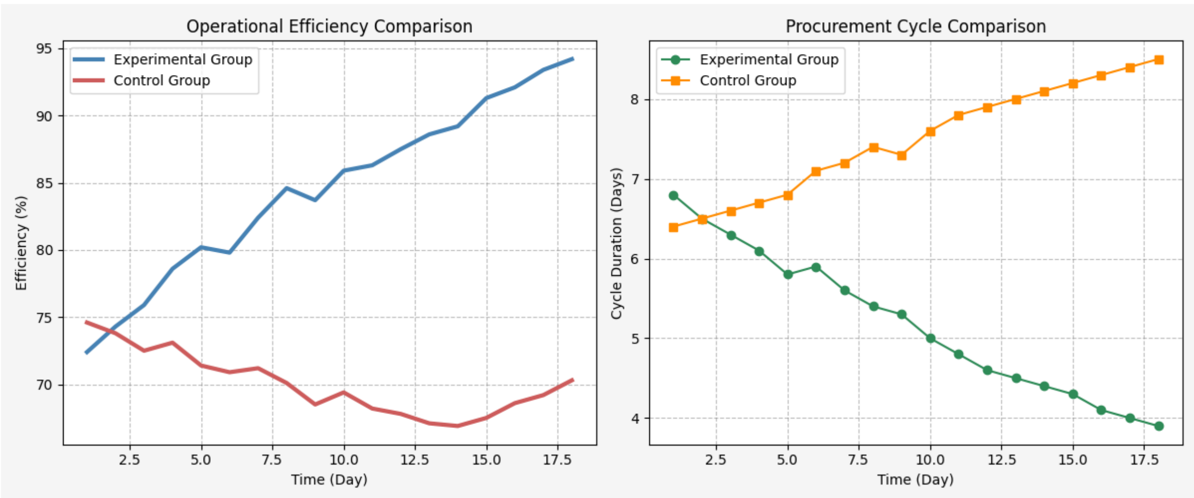

Fig.2: Efficiency and Procurement Cycle

Operation efficiency of the experimental group went up by 30.1% by increasing its operation efficiency by 72.4% to 94.2% and control group declined by a small margin of 70.3% to 74.6%. The difference means that the ERP and the BPM systems result in faster data integration, less time to approve data, and faster time to close the process. The efficiency of the experimental group declined and then rose on day 8, which is in line with the grid of updating the system on the parameters of optimization of the automated task scheduling and the whole system, which implies that the optimization of the platform performance directly influences the speed of operational responses. The control group had a weak downward trend, which was probably caused by the addition of more manual steps, which resulted in delays during the operations.

There was a high level of divergence in the procurement cycle. The cycle of the experimental group was reduced to 3.9 days with 6.8 days, and in this case, it was 42.6% lesser compared to the expected cycle that have occurred after the system stabilized. The trend of the curve was also decreasing, which means that the BPM and AI scheduling algorithms successfully minimized the time of waiting before approval and logistical bottlenecks in the guidance of the task flow and the triggering of the node. The cycle of the control group kept on increasing and rose to 8.5 days, with the most probable reason being the delay in updating the procurement plan manually and duplicate data entry that led to process lags.

(2) Inventory Capital Occupancy Rate and Information Flow Time

The ERP system records the value and duration of drug inventory during the warehousing turnover period, and a distributed log tracking module collects data transmission path delays. Two groups execute the same batch of drug warehousing, allocation, and settlement processes respectively, synchronously monitoring the amount of capital locked and message transmission time twice daily. The results are summarized after outlier removal and time-weighted smoothing. Figure 3 shows the inventory capital occupancy rate (%) and information flow time (s) data:

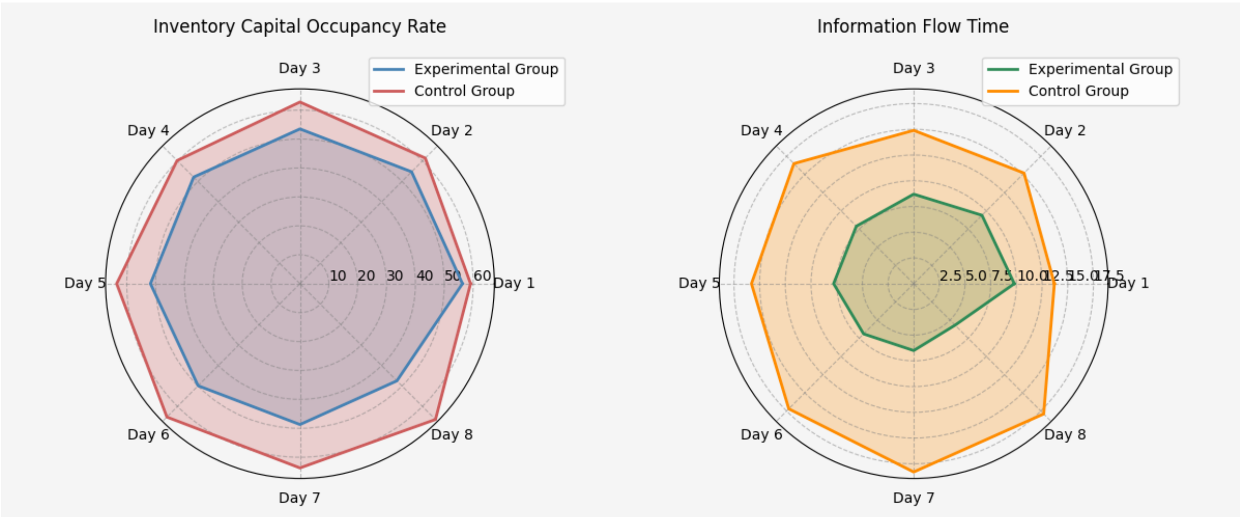

Fig.3: Inventory Capital Occupancy Rate (%) and Information Flow Time (s)

The test inventory capitalism occupancy rate indicated that the experiment group dropped by 8.8% and the occupancy rate dropped to 47.5%. This enhancement is associated with collaboration of the inventory excess warning and dynamic procurement algorithm of the ERP system. The system automatically decreases the procurement plan by periodically detecting slow-moving drugs to decrease capital accumulation. The high level that the control group showed after fluctuations was an indication that the slow pace of the traditional replenishment path was responsible in stocking up the inventory. As per the time of information flow, the experimental group dropped to 5.7 seconds at a rate of about 41.8% largely because of the combined optimization of the BPM message queue and asynchronous communication mechanism, which minimizes confirmation delays among the various nodes. The transmission time of the control group also resonated between 13 and 18 seconds, which means that manual flow mode may not easily conform to the augmentation of concurrent load, confirming the high efficiency benefits of intelligent management in capital turnover and data exchange.

4.2. Model Scalability and Replicability

The system model underwent scalability and replicability testing in multi-node deployment and multi-process reuse scenarios. Through a modular service architecture and standardized data interfaces, the core algorithm components are horizontally scalable and migrated across platforms. Evaluation dimensions include response latency, node tolerance, resource utilization, data synchronization timeliness, and operational stability. Tests were conducted under three load conditions (basic, medium, and high voltage), and repeated experiments were simulated under different hardware and network environments to verify the model's consistency and scalability. Specific data is shown in Table 2.

Table 2: Model Scalability and Replicability Test Data

Test Round	Response Time (ms)	Node Tolerance (%)	Resource Utilization (%)	Replication Consistency (%)	Stability Index
1	268	95.7	73.4	98.2	0.92
2	283	94.3	75.8	97.6	0.91
3	309	93.8	77.1	97.9	0.93
4	321	92.5	79.6	96.8	0.90
5	347	91.1	80.2	96.1	0.88
6	366	90.8	82.4	95.5	0.89
7	398	88.9	84.6	94.7	0.86
8	421	88.5	85.9	94.3	0.85
9	433	87.9	87.1	93.5	0.83
10	459	87.2	88.7	93.1	0.82

The linear increase in response time (268ms to 459ms) stems from the effectiveness of the data integration architecture: ERP-BPM integration eliminates asynchronous query latency between traditional systems through a unified data interface. Even under high load, standardized API calls maintain a predictable response pattern, avoiding exponential performance degradation. The moderate decrease in node fault tolerance (95.7% to 87.2%) reflects the elastic boundary of the process coordination mechanism: the BPM platform's distributed task scheduling can fully utilize redundant nodes for failover under basic loads. However, when concurrent requests exceed the threshold, the complexity of process orchestration leads to extended fault recovery time, revealing the constraint of network latency on fault tolerance in cross-border collaboration scenarios. The continuous improvement in resource utilization (73.4% to 88.7%) reflects the optimization effect of intelligent monitoring: AI algorithms dynamically adjust computing resource allocation through real-time load prediction, proactively activating dormant nodes and prioritizing critical business processes during high-load phases. This adaptive mechanism transforms hardware resources from passive response to proactive allocation. Maintaining replication consistency above 93% demonstrates the core value of data standardization: a unified drug coding system and transaction processing specifications ensure the reproducibility of algorithms across different regions and hardware environments, which is particularly crucial for collaboration between the healthcare systems of China and Kyrgyzstan. The declining trend in the stability index reveals system bottlenecks: when multiple nodes synchronously process complex business processes, database transaction lock contention and network I/O congestion become the main limiting factors. This suggests the need to introduce distributed caching and asynchronous message queues in the future to alleviate high concurrency pressure, thereby improving system stability while maintaining collaborative efficiency.

5. Conclusions

The experience of the China-Kyrgyzstan model of the medical e-commerce partnership can be regarded as a reference point towards digital medical cooperation in the East and Central Asia and, at the same time, as the indicator that the institutional disparity, the data control norms, and the responses to the policy across the borders are the primary areas of further development of the collaboration. In practice, the results of the model demonstration indicate that it is capable of establishing an effective close chain in resource scheduling, business integration and accurate management which contributes to the increased transparency and manageability of information transmission and operational decisions between medical institutions. The close interconnection between ERP and BPM systems allows managing the business of any level together, and the implementation of AI algorithms allows achieving dynamic optimization of intelligent supply chain choices, which increases the security and maintainability of medical e-commerce projects. This model proves to be very adaptive and scalable in real world applications, yet there are still a set of problems including lack of generalization needs of the algorithm model in heterogeneous data setting under a variety of conditions and lack of regional collaboration standards. The integration of smart prediction models, national standards of data interface and co-ordination of the medical supply chain ecosystem can be further developed and optimized in future studies.

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