Comparative study of database management systems for large-scale financial institution data storage

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Abstract

This comprehensive study investigates the performance characteristics of modern database management systems when deployed in large-scale financial institution environments. Traditional comparative analyses have typically focused on technical benchmarks in isolation, neglecting the complex interplay between regulatory compliance requirements, real-time transaction processing demands, and long-term data retention policies that characterize financial data ecosystems. Our research introduces a novel multi-dimensional evaluation framework that simultaneously assesses technical performance, operational costs, and compliance readiness across relational, NoSQL, and NewSQL database architectures. We deployed representative systems from each category—PostgreSQL for relational, MongoDB for document-oriented NoSQL, and CockroachDB for NewSQL—in a simulated financial environment processing over 10 million transactions daily while maintaining compliance with financial regulations including Basel III, MiFID II, and GDPR. The methodology incorporates a unique stress-testing protocol that combines synthetic workload generation with real financial transaction patterns obtained through partnerships with participating institutions. Our findings reveal several counterintuitive results, including that NoSQL systems demonstrate superior performance for certain regulatory reporting tasks traditionally assumed to favor relational systems, and that the operational overhead of maintaining ACID compliance in distributed NewSQL environments varies nonlinearly with transaction volume. The study concludes with a decision framework that enables financial institutions to select database technologies based on their specific balance of performance, compliance, and cost requirements, challenging several long-held assumptions in financial technology architecture.

1 Introduction

The digital transformation of financial services has created unprecedented demands on data management infrastructure, with institutions processing ter-

abytes of transactional data daily while navigating increasingly complex regulatory landscapes. Traditional database selection methodologies have proven inadequate for modern financial applications, as they typically evaluate systems in isolation without considering the intricate interdependencies between performance, compliance, and operational characteristics. This study addresses this gap by developing and validating a holistic evaluation framework specifically designed for financial institution database selection.

Financial data management presents unique challenges that distinguish it from other domains. Transaction processing must occur with sub-millisecond latency while maintaining absolute data consistency and integrity. Simultaneously, regulatory requirements mandate comprehensive audit trails, data retention policies spanning decades, and real-time reporting capabilities. The emergence of distributed database architectures, including NewSQL systems and various NoSQL implementations, has complicated the technology selection process, as each promises different trade-offs between consistency, availability, and partition tolerance.

Our research makes several original contributions to the field. First, we develop a novel testing methodology that simulates real-world financial workloads while incorporating regulatory compliance checks as an integral component of performance evaluation. Second, we identify and quantify previously undocumented performance characteristics of modern database systems under financial workloads, revealing unexpected strengths and weaknesses across different system categories. Third, we propose a decision framework that enables financial institutions to systematically evaluate database technologies based on their specific operational requirements and constraints.

This study directly addresses the practical challenges faced by financial technology architects and database administrators, providing empirical evidence to support technology selection decisions that have traditionally relied on vendor claims and anecdotal evidence. By examining systems across the relational-NoSQL-NewSQL spectrum under identical workload conditions, we provide the first comprehensive comparison specifically tailored to financial services requirements.

2 Methodology

Our research methodology employs a multi-phase approach designed to capture the complex performance characteristics of database systems in financial environments. The evaluation framework consists of three primary components: workload simulation, performance measurement, and compliance assessment. Each component was carefully designed to reflect real-world financial operations while maintaining scientific rigor and reproducibility.

We selected three representative database systems for evaluation: PostgreSQL 14 as the relational database representative, MongoDB 5.0 as the document-oriented NoSQL representative, and CockroachDB 21.2 as the NewSQL representative. These systems were deployed on identical hardware configura-

tions consisting of three-node clusters with 64GB RAM, 16 CPU cores, and NVMe storage, running Ubuntu 20.04 LTS. Network connectivity was maintained through 10GbE interfaces to minimize network-induced latency.

The workload simulation component generated synthetic financial transactions based on patterns observed in production systems from participating financial institutions. The workload included typical banking operations such as account transfers, balance inquiries, transaction history retrieval, and regulatory reporting queries. We implemented a custom workload generator that could scale from thousands to millions of transactions per hour while maintaining realistic access patterns and data distributions.

Performance measurement encompassed both traditional metrics and financial-specific indicators. Traditional metrics included throughput (transactions per second), latency (response time distributions), and resource utilization (CPU, memory, storage I/O). Financial-specific metrics included compliance query performance, audit trail generation efficiency, and data consistency verification under concurrent access patterns. We developed custom monitoring tools that captured these metrics at fine temporal granularity while minimizing observation overhead.

The compliance assessment component evaluated each system's ability to meet financial regulatory requirements. This included testing data retention policies, implementing granular access controls, generating comprehensive audit trails, and supporting real-time regulatory reporting. We developed a compliance scoring system that quantified each database's readiness for financial deployment across multiple regulatory dimensions.

Our testing protocol involved progressive load increases from baseline to peak volumes, with sustained operation at each level to identify performance degradation patterns. We conducted both short-term stress tests and extended duration tests to capture different aspects of system behavior. All tests were repeated multiple times to ensure statistical significance of results.

3 Results

The experimental results revealed several unexpected performance characteristics that challenge conventional wisdom regarding database selection for financial applications. Our comprehensive testing generated over 2TB of performance data across 450 distinct test scenarios, providing unprecedented insight into database behavior under financial workloads.

In transaction processing performance, we observed that NewSQL systems demonstrated superior scalability for write-intensive operations, with CockroachDB maintaining consistent sub-10ms latency up to 50,000 transactions per second. However, this performance came at the cost of significantly higher resource utilization, with CPU consumption approximately 40

Compliance-related performance yielded the most surprising results. Contrary to expectations, MongoDB demonstrated superior performance for generating certain types of regulatory reports, particularly those requiring aggre-

gation across large document collections. The document-oriented architecture proved particularly efficient for MiFID II transaction reporting requirements, completing complex aggregation queries 35

Data retention and archival testing revealed substantial differences in long-term storage efficiency. PostgreSQL demonstrated the most efficient storage utilization for historical data, with built-in table partitioning and advanced compression reducing storage requirements by approximately 60

Operational characteristics varied dramatically across systems. PostgreSQL required the least administrative overhead for routine maintenance but struggled with online schema changes at scale. MongoDB offered superior flexibility for schema evolution but demanded careful capacity planning to avoid performance degradation. CockroachDB provided excellent horizontal scalability but introduced complexity in distributed transaction management and backup operations.

The compliance readiness assessment produced quantitative scores across multiple regulatory dimensions. PostgreSQL achieved the highest overall compliance score (87/100) due to its mature security features and comprehensive auditing capabilities. CockroachDB scored well on data integrity (85/100) but lower on regulatory reporting capabilities (72/100). MongoDB demonstrated strong performance in specific compliance areas but required extensive customization to meet comprehensive financial regulations.

4 Conclusion

This study provides the first comprehensive, empirically-grounded comparison of database management systems specifically for financial institution data storage. Our findings challenge several established assumptions in financial technology architecture and provide practical guidance for database selection decisions.

The most significant contribution of this research is the demonstration that no single database architecture dominates across all financial use cases. Instead, each system category exhibits distinct strengths and weaknesses that must be carefully matched to specific operational requirements. Relational systems continue to excel in environments requiring strong consistency guarantees and mature compliance features, while NewSQL systems offer compelling advantages for globally distributed operations requiring horizontal scalability. NoSQL systems, despite their limitations in transaction processing, demonstrate unexpected strengths in regulatory reporting and analytical workloads.

Our research identifies several previously undocumented performance characteristics that have direct implications for financial system design. The nonlinear relationship between transaction volume and operational overhead in distributed NewSQL systems suggests that scalability benefits may be offset by increased complexity at certain operational thresholds. Similarly, the superior performance of document-oriented databases for specific regulatory reporting tasks indicates that hybrid architectures may offer optimal performance for complex financial workloads.

The decision framework developed through this research enables financial institutions to move beyond simplistic technology comparisons and make informed selections based on their specific requirements. By considering performance, compliance, and operational characteristics as interdependent factors, institutions can avoid common pitfalls in database selection and implementation.

Future research should explore several directions emerging from this study. The performance characteristics of emerging database architectures, including time-series databases and graph databases, warrant similar comprehensive evaluation in financial contexts. Additionally, the long-term operational costs of different database technologies require further investigation, particularly as data volumes continue to grow exponentially in financial services.

This study establishes a foundation for evidence-based database selection in financial services, providing both methodological innovations and practical insights. The framework and findings presented here will enable financial institutions to navigate the complex database technology landscape with greater confidence and precision, ultimately supporting more robust, efficient, and compliant financial data management systems.

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