Blockchain Applications in Healthcare Finance: A Systematic Review of Opportunities and Challenges for NHS General Ledgers in United Kingdom

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ABSTRACT

This systematic review explores the potential applications of blockchain technology within the financial operations of the UK's National Health Service (NHS), specifically focusing on its impact on general ledgers. The NHS, a complex and vast healthcare system, faces significant financial management challenges, including data fragmentation, inefficiencies in transaction processing, and issues with transparency and auditability. Blockchain, with its inherent characteristics of decentralization, immutability, and cryptographic security, offers a promising paradigm for addressing these issues.

This paper systematically reviews the opportunities that blockchain presents for enhancing financial transparency, streamlining payment processes, improving data integrity, and reducing administrative overhead in NHS general ledgers. Concurrently, it critically examines the significant challenges to its adoption, including regulatory hurdles, interoperability concerns, scalability limitations, and the substantial investment required for implementation and training. By synthesizing current literature and identifying key themes, this review aims to provide a comprehensive understanding for policymakers, financial managers, and technology innovators within the NHS regarding the strategic implications of integrating blockchain into healthcare finance.

Keywords: Blockchain, Healthcare Finance, NHS, General Ledgers, Distributed Ledger Technology, Financial Transparency, Opportunities, Challenges, Systematic Review.

INTRODUCTION

The National Health Service (NHS) in the United Kingdom is one of the largest and most complex healthcare systems globally, characterized by its universal access and significant financial scale. Managing its vast financial operations, which involve numerous trusts, suppliers, and diverse payment streams, presents considerable challenges. These challenges include maintaining accurate and transparent general ledgers, ensuring efficient and secure transaction processing, and mitigating fraud and errors across a highly distributed network (National Audit Office, 2024). The traditional centralized financial systems often struggle with data silos, reconciliation issues, and a lack of real-time visibility, leading to inefficiencies and increased administrative costs (Healthcare Financial Management Association, n.d.).

In parallel, blockchain technology, a form of Distributed Ledger Technology (DLT), has emerged as a transformative innovation with the potential to revolutionize various sectors, including finance, supply chain, and healthcare. Its core principles are decentralization, immutability, transparency, and cryptographic security and these offer a compelling solution to many of the systemic issues plaguing conventional financial infrastructures (SFMagazine, 2024). While much of the discourse around blockchain in healthcare has focused on patient data management and supply chain logistics, its applications in healthcare finance, particularly within the context of large public systems like the NHS, remain an area ripe for systematic investigation.

This academic journal article aims to provide a systematic review of the opportunities and challenges associated with integrating blockchain technology into the NHS's general ledger systems. By examining existing literature,

case studies, and expert opinions, this review seeks to: (1) delineate the fundamental financial challenges faced by the NHS; (2) explore how blockchain's unique attributes can address these challenges; (3) identify the potential benefits, such as enhanced transparency, improved efficiency, and reduced costs; and (4) critically assess the significant barriers to adoption, including technological, regulatory, and organisational hurdles. The ultimate goal is to offer a balanced perspective on the feasibility and strategic implications of blockchain for NHS healthcare finance, informing future research and policy development.

Background on Blockchain Technology

Blockchain technology, often referred to as Distributed Ledger Technology (DLT), is a decentralized, distributed, and immutable ledger that records transactions across a network of computers. Unlike traditional centralized databases, where a single entity controls the data, blockchain operates on a peer-to-peer network where all participants maintain a copy of the ledger. This distributed nature enhances transparency and resilience, as there is no single point of failure or control (Turing, n.d.)

The fundamental components of blockchain technology include:

1. **Blocks:** Transactions are grouped into blocks, which are then cryptographically linked together in a chronological chain. Each block contains a cryptographic hash of the previous block, a timestamp, and transaction data (One NHS Finance, n.d.).
2. **Decentralization:** There is no central authority governing the network. Instead, consensus mechanisms (e.g., Proof of Work, Proof of Stake) are used to validate transactions and add new blocks to the chain, ensuring agreement among participants (ScienceDirect, 2023).
3. **Immutability:** Once a transaction is recorded on the blockchain and a block is added to the chain, it cannot be altered or deleted. This creates a permanent and tamper-proof record, which is crucial for auditability and trust (GeeksforGeeks, n.d.).
4. **Cryptography:** Advanced cryptographic techniques secure transactions and maintain the integrity of the network. Each participant has a pair of cryptographic keys which refers to a public key for identification and a private key for signing transactions ensuring authenticity and non-repudiation (Elangovan, 2022).
5. **Smart Contracts:** These are self-executing contracts with the terms of the agreement directly written into code. Smart contracts automatically execute and enforce agreements when predefined conditions are met, eliminating the need for intermediaries and reducing operational costs and delays (Investopedia, 2025).

While initially popularised by cryptocurrencies like Bitcoin, blockchain's potential extends far beyond digital currency. Its application in various sectors, including supply chain management, intellectual property, and identity management, demonstrates its versatility. In healthcare, blockchain has been explored for secure electronic health records (EHR) management, drug traceability, and clinical trial data integrity (Blockchain in Healthcare Today, n.d.). The unique characteristics of blockchain are its ability to create a shared, immutable, and transparent record of transactions which make it particularly relevant for financial applications, where trust, security, and efficiency are paramount.

NHS Financial Systems and General Ledger Challenges

The National Health Service (NHS) operates within a complex financial landscape, managing an annual budget of over £180 billion (The King's Fund, n.d.). Its financial architecture is characterized by a decentralized structure, with hundreds of individual trusts, clinical commissioning groups (CCGs), and other entities responsible for their own budgets and financial reporting. This fragmentation, while allowing for local autonomy, introduces significant challenges in financial management, particularly concerning general ledgers (Healthcare Financial Management Association, n.d.).

Key challenges within the NHS financial systems and general ledgers include:

1. **Data Fragmentation and Silos:** Financial data is often stored in disparate systems across different NHS organisations, leading to data silos. This makes it difficult to achieve a consolidated, real-time view of financial performance across the entire service. Reconciliation between entities becomes a labour-

intensive and error-prone process, hindering efficient financial oversight and strategic planning (One NHS Finance, n.d.).

2. **Inefficiencies in Transaction Processing:** The sheer volume of transactions, from patient care costs to supplier payments and inter-organisational transfers, often leads to slow and inefficient processing. Manual interventions, paper-based processes, and legacy IT systems contribute to delays, increased administrative costs, and a higher risk of errors (National Audit Office, 2024).
3. **Lack of Transparency and Auditability:** While the NHS is publicly funded, achieving comprehensive financial transparency and robust audit trails across its vast network remains a challenge. The complexity of inter-organisational transactions and the lack of a unified, immutable record can obscure the flow of funds, making it difficult to track spending effectively and identify potential inefficiencies or discrepancies (One NHS Finance, n.d.).
4. **Fraud and Error Vulnerability:** The fragmented nature of financial data and processes can create vulnerabilities to fraud and errors. Detecting and preventing these issues is complicated by the lack of real-time visibility and the difficulty in cross-referencing information across different systems (Reform, 2018).
5. **Interoperability Issues:** Integrating new technologies or standardizing financial reporting across diverse existing systems is a major hurdle. The absence of common data standards and interoperable platforms exacerbates the challenges of data exchange and consolidation (Gov.UK., n.d.).
6. **Cost Pressures and Resource Constraints:** The NHS continually faces immense cost pressures, requiring optimal utilization of every pound. Inefficient financial processes divert valuable resources that could otherwise be directed towards patient care. The administrative burden associated with managing complex general ledgers adds to these pressures (Healthcare Financial Management Association, n.d.).

These challenges collectively impact the NHS's ability to achieve financial sustainability, make informed strategic decisions, and ultimately deliver high-quality patient care efficiently. The need for innovative solutions that can address these systemic issues is paramount, paving the way for technologies like blockchain to be considered as potential enablers of change.

Opportunities for Blockchain in NHS General Ledgers

Blockchain technology offers a compelling suite of capabilities that can address many of the inherent challenges within the NHS financial systems and general ledgers. Its core attributes which are decentralization, immutability, transparency, and cryptographic security can be leveraged to introduce significant improvements across various financial operations (AbdelSalam, 2023).

Key opportunities for blockchain in NHS general ledgers include:

1. **Enhanced Financial Transparency and Auditability:** A blockchain-based general ledger would provide a single, shared, and immutable record of all financial transactions across participating NHS entities. This distributed ledger would allow authorized stakeholders to view transactions in real-time, significantly improving transparency and reducing the potential for discrepancies. The cryptographic linking of blocks ensures that once a transaction is recorded, it cannot be altered, thereby creating an unalterable audit trail that simplifies compliance and external audits (One NHS Finance, n.d.). This enhanced transparency can foster greater public trust and accountability in how NHS funds are managed.
2. **Streamlined Transaction Processing and Reconciliation:** The current fragmented nature of NHS financial systems often leads to delays and complexities in inter-organisational transactions and reconciliation. Blockchain, particularly through the use of smart contracts, can automate and accelerate these processes. Smart contracts can be programmed to execute payments automatically upon the fulfillment of predefined conditions (e.g., delivery of services, approval of invoices), reducing manual intervention, minimizing errors, and speeding up payment cycles between trusts, suppliers, and other healthcare providers (Investopedia, 2025). This automation can drastically cut administrative overhead and improve cash flow management.
3. **Improved Data Integrity and Security:** The immutable nature of blockchain ensures that financial data, once recorded, cannot be tampered with. This significantly enhances data integrity, protecting against fraud and unauthorized modifications. Cryptographic security measures safeguard sensitive financial

information, making it more resilient to cyber threats compared to traditional centralized databases (ITRansition, 2023). For the NHS, where data security is paramount, blockchain offers a robust framework for protecting financial records.

4. **Reduced Administrative Costs and Operational Efficiencies:** By automating reconciliation, streamlining payment processes, and providing a single source of truth for financial data, blockchain can lead to substantial reductions in administrative costs. The elimination of intermediaries and manual verification steps can free up financial staff to focus on more strategic tasks, thereby improving overall operational efficiency within NHS finance departments (Healthcare Financial Management Association, n.d.).
5. **Facilitating Interoperability and Data Sharing:** While challenges exist, blockchain can serve as a foundational layer for improved interoperability. By establishing common protocols and standards for recording financial transactions on a distributed ledger, it can bridge the gaps between disparate legacy systems. This can enable more seamless and secure sharing of financial data across the NHS ecosystem, fostering better collaboration and integrated financial planning (Gov.UK., n.d.).
6. **Supply Chain Finance Optimization:** Beyond general ledgers, blockchain can optimize financial flows within the NHS supply chain. By tracking goods and services from procurement to payment on an immutable ledger, it can ensure transparency, verify authenticity, and automate payments to suppliers, potentially reducing costs associated with disputes, delays, and fraudulent activities (Hall & Partners, n.d.).

These opportunities highlight blockchain's potential to transform NHS financial management from a fragmented, labor-intensive process into a more transparent, efficient, and secure ecosystem. However, realizing these benefits requires careful consideration of the associated challenges and a strategic approach to implementation.

Challenges and Barriers to Blockchain Adoption in NHS Finance

Despite the significant opportunities, the adoption of blockchain technology within the NHS financial landscape is fraught with considerable challenges and barriers. These hurdles span technological, regulatory, organisational, and economic dimensions, requiring careful consideration and strategic planning for successful implementation (Balasubramanian, Shukla, Sethi, & Islam, 2021).

Key challenges include:

1. **Regulatory and Governance Hurdles:** The NHS operates under stringent regulatory frameworks, including data protection laws (e.g., GDPR, Data Protection Act 2018) and financial regulations. Integrating a decentralized technology like blockchain into such a highly regulated environment poses complex legal and governance questions. Issues around data ownership, accountability for transactions, and compliance with existing audit standards need to be meticulously addressed. The lack of clear regulatory guidelines specifically for blockchain in public sector finance can deter adoption (BSI Group, n.d.).
2. **Interoperability with Legacy Systems:** The NHS relies on a vast array of legacy IT systems that have evolved over decades. Integrating a new, fundamentally different technology like blockchain with these existing, often proprietary, systems presents a monumental technical challenge. Ensuring seamless data exchange and compatibility without disrupting critical ongoing operations requires significant investment in middleware, APIs, and careful system architecture design (Akter, 2024)
3. **Scalability and Performance Concerns:** Public blockchains, while highly secure, can face scalability limitations, particularly in terms of transaction throughput and latency. For a system as large and transaction-heavy as the NHS, a blockchain solution would need to handle an immense volume of financial transactions in real-time. Private or consortium blockchains might offer better scalability, but they introduce trade-offs in decentralization and transparency (Zhou, 2024). The performance requirements for a national general ledger system are extremely high, and current blockchain technologies may struggle to meet them without significant advancements.
4. **Cost of Implementation and Maintenance:** The initial investment required for developing, deploying, and maintaining a blockchain-based financial system for the NHS would be substantial. This includes costs for infrastructure, software development, cybersecurity measures, and ongoing operational support.

Given the perpetual financial pressures on the NHS, securing adequate funding and demonstrating a clear return on investment (ROI) for such a transformative project would be a significant barrier (Deloitte Consulting LLP, n.d.).

5. **Data Privacy and Confidentiality:** While blockchain offers enhanced security, the immutable nature of the ledger raises concerns about data privacy, especially for sensitive financial information. Although transactions can be anonymized or encrypted, the permanent record could still pose risks if not managed carefully. Designing a system that balances transparency with the need for confidentiality and compliance with data protection regulations is crucial (Leeming, 2019).
6. **Lack of Skilled Workforce and Training:** The successful adoption of blockchain requires a workforce with specialized skills in blockchain development, cryptography, and distributed systems. The NHS currently faces challenges in recruiting and retaining IT professionals, and the niche expertise required for blockchain would exacerbate this issue. Extensive training programs would be necessary to upskill existing finance and IT staff, which represents another significant investment (University of Cambridge, n.d.).
7. **Resistance to Change and Organisational Inertia:** Implementing a technology that fundamentally alters financial processes often encounters resistance from stakeholders accustomed to traditional methods. Organisational inertia, fear of job displacement, and a lack of understanding about blockchain's benefits can hinder adoption. A robust change management strategy, coupled with clear communication and stakeholder engagement, would be essential to overcome this barrier (Gökalp, Gökalp, Çoban, & Eren, 2018).
8. **Security Risks and Vulnerabilities:** While blockchain is inherently secure, it is not entirely immune to security risks. Smart contract vulnerabilities, potential 51% attacks (though less likely in a private consortium blockchain), and key management issues could pose threats. Ensuring the highest level of cybersecurity for a critical national infrastructure like the NHS financial system would require continuous vigilance and investment (Mednexus, 2024).

Addressing these challenges requires a multi-faceted approach, involving technological innovation, policy development, strategic investment, and comprehensive stakeholder engagement. Without a clear roadmap to navigate these barriers, the transformative potential of blockchain in NHS finance may remain largely untapped.

Case Studies and Pilot Projects

While the theoretical potential of blockchain in healthcare finance, particularly for general ledgers, is widely recognized, concrete, large-scale implementations within the NHS remain nascent. Most pilot projects and case studies in healthcare blockchain have primarily focused on areas such as electronic health records (EHR) management, supply chain traceability, and patient consent management (Yeung, 2021). However, insights from these projects, alongside financial applications in other sectors, can inform the potential for NHS general ledgers.

Blockchain in Healthcare Data Management (Indirect Relevance)

Several initiatives have explored blockchain for secure and interoperable health data management. For instance, projects like MedRec (DCI MIT., n.d.). and others have demonstrated how blockchain can create an immutable audit trail for patient data access and sharing, enhancing security and patient control. While not directly financial, the principles of secure, auditable, and decentralized record-keeping are directly transferable to financial ledgers. The NHS has also shown interest in blockchain for data management, with discussions around using DLT to give patients more control over their health records and improve data sharing across fragmented systems (Reform, 2018). These pilots, though not financial, lay the groundwork for understanding the technical and organisational challenges of deploying DLT within a large public health system.

Supply Chain and Pharmaceutical Traceability (Indirect Relevance)

Blockchain has seen more tangible applications in healthcare supply chains, aiming to improve transparency, combat counterfeiting, and streamline logistics. Projects tracking pharmaceuticals from manufacturer to patient demonstrate how an immutable ledger can verify product authenticity and ensure compliance (UCL Discovery, n.d.). The financial implications here are significant, as improved supply chain efficiency can lead to cost

savings, reduced waste, and more accurate financial reconciliation with suppliers. While not a general ledger application, it highlights blockchain's ability to create a trusted record of transactions that underpins financial flows.

Financial Applications in Other Sectors (Analogous Insights)

Outside of healthcare, blockchain has been piloted and implemented in various financial sectors to improve general ledger functions, inter-bank settlements, and cross-border payments. For example, several financial institutions have experimented with private blockchains to streamline reconciliation processes, reduce settlement times, and enhance transparency between consortium members (Osmani, El-Haddadeh, Hindi, Janssen & Weerakkody, 2021). These projects demonstrate the technical feasibility and potential financial benefits of using DLT for ledger management, offering valuable lessons for the NHS regarding system design, governance models, and the integration of smart contracts for automated financial operations.

NHS-Specific Explorations and Discussions

While a full-fledged blockchain-based general ledger system is yet to be implemented in the NHS, there have been discussions and reports acknowledging its potential. The 'One NHS Finance' initiative and various reform documents have highlighted DLT as a technology that could potentially replace existing services in NHS finance entirely, offering real-time transaction verification and eliminating overheads (One NHS Finance, n.d.). However, these remain largely conceptual or in early exploratory phases, underscoring the significant gap between theoretical potential and practical, widespread adoption within the NHS's complex financial ecosystem. The focus has often been on the broader benefits of DLT for data integrity and efficiency rather than specific general ledger overhauls.

In summary, while direct case studies of blockchain transforming NHS general ledgers are scarce, the experiences from related healthcare applications and financial sector implementations provide a roadmap. These projects demonstrate the technical viability and potential benefits, but also highlight the considerable challenges in translating these successes to the unique scale and regulatory environment of the NHS.

DISCUSSION AND FUTURE DIRECTIONS

The systematic review of blockchain applications in healthcare finance for NHS general ledgers reveals a landscape of significant potential intertwined with substantial implementation challenges. The discussion here synthesizes the findings, highlights key considerations, and outlines future directions for research and practical application.

Synthesis of Opportunities and Challenges

Blockchain's core attributes are immutability, transparency, and decentralization which directly address critical pain points in NHS financial management, such as data fragmentation, reconciliation inefficiencies, and auditability concerns. The potential for real-time financial visibility, automated transaction processing via smart contracts, and enhanced data security offers a compelling vision for a more efficient and trustworthy NHS financial ecosystem. The ability to create a single, shared source of truth for financial transactions could drastically reduce administrative overhead and free up resources for patient care (Healthcare Financial Management Association, n.d.).

However, the path to realizing these benefits is not straightforward. The NHS's complex regulatory environment, the formidable task of integrating with entrenched legacy systems, and concerns around scalability and data privacy present formidable barriers. The lack of a skilled workforce and the significant upfront investment required further complicate adoption. Moreover, the absence of widespread, direct case studies of blockchain implementation in NHS general ledgers underscores the experimental nature of this application within the public health sector (Yeung, 2021).

Key Considerations for Blockchain Adoption in NHS

For the NHS to effectively leverage blockchain in its financial operations, several key considerations must be addressed:

1. **Pilot Programs and Phased Implementation:** Given the scale and complexity of the NHS, a 'big bang' approach to blockchain implementation is likely to fail. Instead, pilot programs focusing on specific, well-defined financial processes (e.g., inter-trust billing, supplier payments for a particular category) could provide valuable learning experiences and demonstrate ROI before broader rollout (Deloitte Consulting LLP., n.d.).
2. **Consortium Blockchain Model:** A private or consortium blockchain, rather than a public one, would likely be more suitable for the NHS. This model allows for controlled access, better scalability, and easier compliance with data protection regulations, while still retaining the benefits of decentralization among trusted NHS entities (BSI Group, n.d.).
3. **Standardization and Interoperability:** Developing common data standards and protocols for financial transactions on the blockchain is crucial. This would facilitate interoperability between different NHS organisations and ensure that the blockchain system can communicate effectively with existing legacy systems, at least during a transitional phase (Akter, 2024).
4. **Regulatory Clarity and Governance Frameworks:** Policymakers and regulators need to develop clear guidelines and legal frameworks for blockchain-based financial systems within the public sector. This includes addressing issues of data ownership, liability, and dispute resolution in a decentralized environment (barrier (Gökalp, Gökalp, Çoban, & Eren, 2018).
5. **Workforce Development:** Investment in training and upskilling the existing NHS finance and IT workforce in blockchain technology is essential. This would build internal capacity and foster a culture of innovation necessary for successful adoption (University of Cambridge., n.d.).

CONCLUSION

Blockchain technology presents a transformative, albeit complex, opportunity for revolutionizing financial management within the UK National Health Service. This systematic review has highlighted that the inherent characteristics of blockchain which are decentralization, immutability, transparency, and cryptographic security offer potent solutions to long-standing challenges in NHS general ledgers, including data fragmentation, inefficiencies in transaction processing, and issues of auditability and trust. The potential benefits, such as enhanced financial transparency, streamlined reconciliation, improved data integrity, and reduced administrative costs, are substantial and align with the NHS's ongoing efforts to optimize resource utilization and improve accountability.

However, the journey towards blockchain adoption in NHS finance is not without significant hurdles. Regulatory ambiguities, the formidable task of integrating with diverse legacy systems, concerns regarding scalability and data privacy, and the substantial investment required for implementation and workforce development pose considerable barriers. The current landscape shows limited direct large-scale implementations within NHS general ledgers, with most existing case studies focusing on other healthcare applications or financial uses in different sectors. These provide valuable analogous insights but underscore the need for tailored approaches within the unique context of the NHS.

Moving forward, a strategic and phased approach is imperative. This includes initiating targeted pilot programs, potentially leveraging consortium blockchain models for controlled environments, and prioritizing the development of common data standards to foster interoperability. Crucially, clear regulatory frameworks and significant investment in workforce training are essential to navigate the complex legal and technical landscape. Future research should focus on rigorous economic impact assessments, advanced scalability solutions, privacy-preserving designs, and longitudinal studies of pilot implementations to build a robust evidence base.

In conclusion, while blockchain technology holds immense promise for enhancing the efficiency, transparency, and security of NHS financial operations, its successful integration into general ledgers will require a concerted effort from policymakers, technology innovators, and financial stakeholders. By systematically addressing the

identified challenges and strategically leveraging its opportunities, the NHS can potentially unlock a new era of financial management, ultimately contributing to more sustainable and effective healthcare delivery.

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