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NARRATIVE/SYSTEMATIC REVIEW/META-ANALYSIS

Moving Beyond Proof of Concept and Pilots to Mainstream: Discovery and Lessons from a Reference Framework and Implementation

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Abstract

Blockchain technology is a radical innovation with the potential to disrupt and re-imagine more collaborative established business structures and processes. Significant advances, particularly in the payments space, include newer, faster, and less costly options for moving money. The underlying blockchain technology can be used for broader use cases spanning several verticals, including healthcare – although its adoption here is less than complete. Numerous proofs-of-concept and pilots have been executed and are increasing, although enterprise blockchain applications in healthcare at the production scale enabling transformative constituent processes are limited. In this article, the authors analyze the blockchain in healthcare literature for critical success factors and add practitioner views on crossing the chasm from proof-of-concept and pilots to a transformational scale. We explore 24 articles for key inflections for scale and highlight the need for a multifaceted execution framework to resolve the practical barriers to enabling reimagined network-based blockchain use cases for efficiencies, particularly in disparate health systems such as the U.S. In addition, we introduce the blockchain discovery framework to make this emerging technology meet the mainstream operations at scale systematically and in a stair-stepped and future-proofed manner, addressing practical stakeholder concerns. Finally, the authors present a reference case study discovered through the framework of one such healthcare administrative process for a scaled reimagined implementation. Healthcare executives and portfolio managers will benefit from these insights and help to increase the enterprise adoption of this inevitable technology of the future.

Plan Language Summary

This article presents a practitioner's view of operating in emerging technology, exploring and advancing blockchain-based transformation in healthcare. Blockchain technology is maturing quickly, with financial technology (aka fintech) leading the way with efficient options for moving money, particularly in the public permissionless blockchain segment. The underlying technology allows for a broader set of capabilities, including provenance, data sharing, immutability, non-repudiation, and auditability, which provides for complete rethinking of existing business processes. These features can help to reimagine a more comprehensive set of use cases in many disciplines, including healthcare. However, enterprise adoption needs to catch up.

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Most enterprise blockchain efforts are run with a small group as a technical exploratory function alone or as a lofty functional aspiration but with sparse technical resources without the execution support structure. Most business processes that could be collaborative with blockchain and allied technologies are still unilateral. In the permissionless space, the number of healthcare projects is a tiny fraction compared to the other verticals, and even they are not deemed commercially successful.[1]

There are a myriad of proofs-of-concept (POC) and pilots that accomplish a specific task – predominantly proposing or solving a technical hurdle. In healthcare, trying a newer collaborative function, typically in a peer-to-peer manner at a small scale, might work but subsequently struggles for wider mainstream adoption. Despite the enthusiasm and thousands of proposals, POCs, and pilots, only 5% – 8% make it to enterprise mainstream.[2,3,4]

As blockchain and emerging technologies practitioners, the authors have observed reasons for limited adoption beyond the typical causes cited – technical, regulatory, privacy, and incentives. Hence, this article aims to look at the systematic reviews of blockchain in healthcare from the perspective of finding specific attributes for inflectional scale, adding additional success factors, and addressing gaps from a practitioner's viewpoint to move beyond concept proofs and pilots. The need for a discovery framework for mainstream blockchain adoption is discussed. The use of the framework components in identifying and overcoming common hurdles to find conducive use cases and actual operational success factors is discussed in a healthcare setting. A reference payor business process implementation reimagined using this framework is presented.

Purpose

For this work, the focus is not on what can be done using blockchain in healthcare generally (e.g., high-level use cases, laboratory proof, or a small-scale pilot). Instead, the focus is on what is deployed or deployable in blockchain implementations or what can be designed to run in non-blockchain environments that can be easily adapted to blockchain networked implementations at scale.

It is not the authors' intent to present a comprehensive systematic review but to leverage earlier systematic reviews and other literature and industry information reports on blockchain in healthcare adoption at scale. Although this effort summarizes the general classifications over time, the focus is on specific challenge and success attributes, including those that are newly emerging and some from a practitioner's viewpoint that becomes important at the execution level to make the technology work but is yet to be documented in the literature.

To summarize, the purpose is to (1) understand the barriers and classifications from the literature and add additional perspectives as an enterprise blockchain in healthcare practice, (2) present a multifaceted framework based on the authors' experience in healthcare and blockchain technologies, to address the barriers and progress toward mainstream scale, and (3) share the lessons from using the framework concepts on a reference healthcare implementation.

Scope and Definition

This work leverages peer-reviewed blockchain in the healthcare literature articles and adds industry reports from other practitioners as viewed through the lens of mainstream adoption at scale. As a starting point, "scale" is defined by the number of constituent users impacted and the magnitude – typically hundreds of thousands of healthcare constituent users or hundreds of staff in the business-to-business case.

The goal is to collect information from articles and industry reports, prioritizing systematic and scoping reviews on adoption, articles on barriers to adoption scaling up POCs and pilots, and articles on adoption metrics and maturity levels.

The specific questions addressed include:

1. Do systematic reviews measure and explain the adoption of blockchain in healthcare?
2. Do the blockchain adoption metrics as a transformative force converge to healthcare quadruple aim[5] at scale measurably?
3. Are there gaps? How can a practitioner's view help progress toward the desired mainstream impact? Can the best practices be templated? Can they be customized?

The Findings section summarizes the inferences from the literature in a traditional narrative style and articles indicating elements of scale inflection points are discussed. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow charts are included in the Methods section to help expand scoping and systematic reviews.

The authors add practitioners' views in response to the inference from the literature and contemporary practice inputs from other sources collected from web searches toward the specific objectives. The article then discusses the adoption barriers, success factors, their classification and trends, and any gaps, including practitioner's views. The authors analyze the need for a multifaceted framework and the lessons from its use in a blockchain implementation case study.

Although not entirely within the scope of this work, our motivation is to quantify blockchain efforts as full life cycle benefits eventually and the scale impact to measurably relate blockchain as a transformative force contributing to the quadruple aim[5] of healthcare. The quadruple aim[5] represents the widely cited and accepted health system goals for enriching patients' experience, improving population health, reducing overall healthcare costs, and reducing the burden on healthcare staff.

Methods

A literature search was initiated to identify peer-reviewed journals, conference articles, industry reports, and other information sources from other practitioners. Four scholarly databases were chosen: PubMed, an important database for

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healthcare-related literature; IEEEXplore for efforts toward standards to advance technologies; and Scopus and Web of Science, two large databases that have material from a variety of peer-reviewed journals. They are also chosen to balance the depth and the breadth of the objectives.

The initial search identified literature on blockchain in healthcare, leveraging summarizations by an earlier systematic review,[6] starting with keywords (i.e., "health," "ledger," "blockchain," "system," "insurance," and "medic"). For the specific purpose of this article, the keywords "health," "ledger," and "blockchain" sufficed. This initial search yielded 1,110 documents across the four databases searched: PubMed 917, IEEEXplore 34, Scopus 1,568, and Web of Science 51. After removing duplicates, the search produced 2,570 records from the four databases.

The search was narrowed using additional keywords and combinations (e.g., "systematic," "scoping," "case," "proof-of-concept," "pilot," "adoption," "challenges," "methodology," and "framework") within the results of earlier searches. The results were further screened by careful analysis of the title and the abstract, and if deemed relevant, inclusion/exclusion factors were determined. Emphasis was placed on systematic and scoping reviews and articles indicating attributes of scale, challenges, adoption, frameworks, etc., not individual POCs and pilots of specific technical, functional, or policy aspects or overgeneralizations that did not have execution scale context. Hence, the rationales for inclusion were Reason 1: systematic or scoping reviews, Reason 2: the article covers adoption metrics, challenges, and success factors, and Reason 3: the articles suggest specific attributes as the pivotal factor for scale. A PRISMA flow chart of the process followed is shown below in Figure 1.

In addition to these database searches, a web search for pertinent industry articles from other practitioners and industry reports was sought. Eight such reports or website references were added, and they are called out in the PRISMA flow chart. In total, 34 articles were pursued for final review.

Summary of Findings

The number of overall studies increased over time. Still, it mostly was POC, pointed technical or functional case studies, proposals, opportunity assessments, or use cases that had not scaled yet. Some systematic studies reviewed

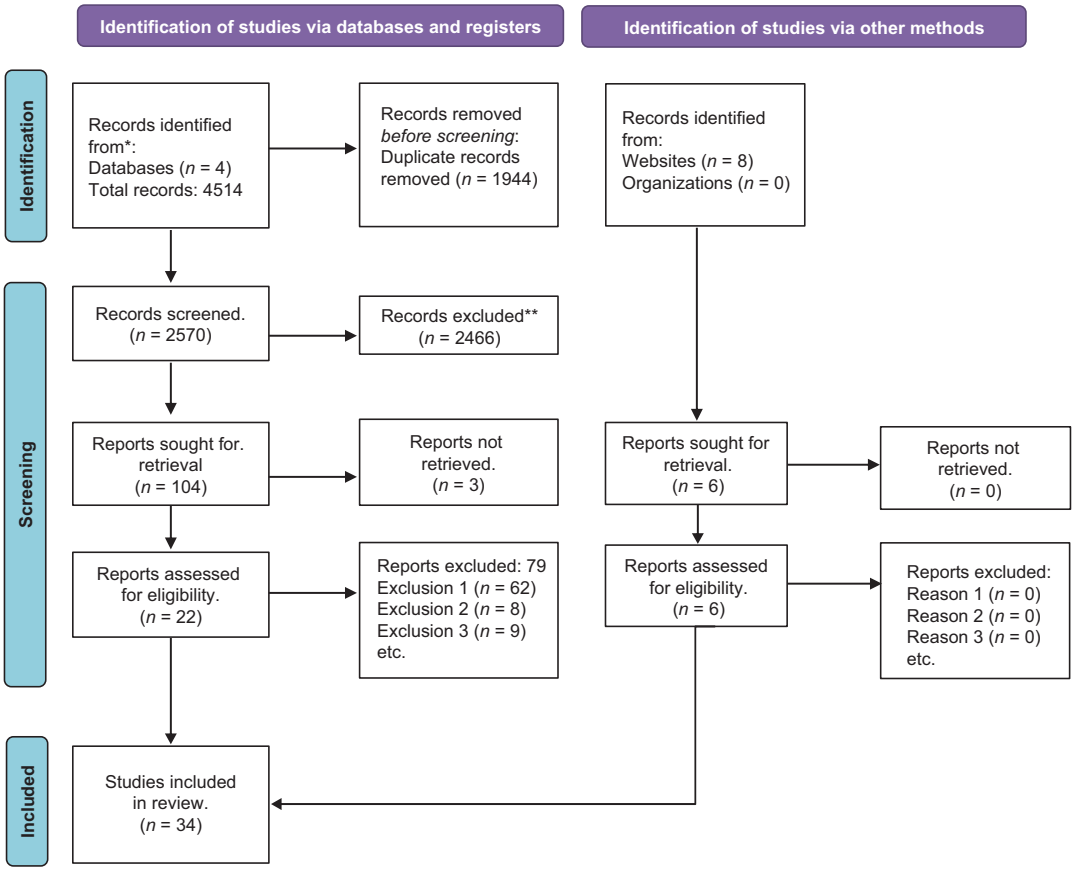

Fig. 1. The PRISMA flow chart of the process followed to identify peer-reviewed journals, conference articles, industry reports, and other information sources from other practitioners. Four scholarly databases were chosen: PubMed, EEEXplore, Scopus, and Web of Science. PRISMA: Preferred Reporting Items for Systematic reviews and Meta-Analyses.

were related to those targeted areas. This was evidenced in executing the inclusion and exclusion process.

Although the number of publications and their generalizations are significant from the authors' perspective, summarizing the true inflection points and their timeline was more valuable for the objectives. Hence, the findings are organized in chronological narration to summarize and help answer the current objectives of the article.

The Bitcoin whitepaper was published in 2018 and is still the opening context for most publications. For adopting blockchain in healthcare, the debut and recognition of Ethereum and Hyperledger platforms in 2015 and 2016 could be considered the starting reference point. Publications and systematic reviews would lag the developments by 1–2 years, and hence, the time buckets are classified as follows:

Early Stage

A systematic review by Agbo et al.[7] in 2019 summarizes earlier work and discusses blockchain use cases in general until then, calls out Medication Reconciliation (MedRec)[8] and Guardtime as notable implementations and indicates the scale of healthcare blockchain implementation Guardtime to be 1 million users referring to other reviews.[9,10]

Systematic reviews by Hussein et al.[11] in 2019 classified blockchain efforts into six categories: data security, integrity, privacy, authentication, and interoperability, and recommendations for potential users. Meinert et al.[12] in 2019 also suggested a systematic review and indicated the main areas of focus on data, interoperability, and scalability. Most work was concentrated on handling electronic health data records. Systematic reviews[3,4,13] revealed the possibilities and limitations and suggested design choices in blockchain implementations for efficient healthcare, including a hypothetical national health system.

Mid Stage

In 2020, Chukwu et al.[6] compared seven systematic reviews to his systematic review and classified the assessment attributes into eight buckets: Bibliometric, Functional, Security, Privacy, Performance, Architecture, Cost, and Standards. He reported reviewing 143 blockchain articles in healthcare work in several countries, including the U.S. He reported that only 5% (7 of those 143 efforts) discussed real-life implementation, pilot testing, or implementation evaluation. A scoping review[14] in 2020 concluded that the exploratory work of blockchain in healthcare is real, but it is still in its infancy.

Numerous researchers continued trying to understand blockchains and blockchain in the context of other allied technologies. Results and opinions started to get mixed, and the following two studies summarized opposing views.

The digital study[15] in 2021 tied blockchains to digital technologies overall and potentially life-saving personal journeys and national electronic health records. This notable high-profile article suggested limitless possibilities but no long-term clinical outcomes had yet been seen. However, work by Yeung[8] in 2021 contends that no serious scholarly attempt has been made to evaluate how blockchain technologies can be applied to real-time contexts in healthcare. On the technical side, it raises serious questions on all available blockchain network models, which need continuous research and potentially newer hybrid architectures. As per the article, blockchain transformation in healthcare faces multidimensional complexities not only technical but also issues with cooperation among companies, organizational structures, and support, and concludes that blockchain technologies are unlikely to revolutionize healthcare soon.

Recent Stage

In the mid-stage, numerous articles reported similar findings, but a few started to identify new attributes and classes as opportunities, threats, and success factors. A 2022 systematic review by Saeed et al.[16] registered the importance of blockchain technology to be deployed in conjunction with artificial intelligence (AI), machine learning (ML), and the Internet of Things (IoT). It quantified the importance of solving for the data volume in healthcare. A scoping review by Abu-Elezz[17] called out technical improvements but added that attention should be paid to an important new threat of social acceptance of blockchain technology in healthcare.

In 2022, Al Shamsi et al.[11] studied blockchain adoption. Although their study is not about healthcare only, they cite healthcare and report strong findings. Key takeaways from his research confirm adoption is still limited, blockchain projects only get executed due to top management's direction, and there is a dearth of empirical research in domains other than supply chain. He argues for more studies and adoption models.

In the recent stage, the author notices a trend in the search for the all-elusive enterprise blockchain adoption in healthcare in various targeted studies. These studies are on individual areas in value creation,[18] technology for decentralized identities,[19] and the interplay of factors on top of the techno-functional focus on medical records, with factors such as regulation through a data marketplace.[20] Efforts are underway to draw attention to the progress made on more than 40 proposals for data management of medical records and gaps in the interplay of privacy, technology through a survey,[22] and user and operator readiness.[21] These efforts reveal additional social and economic variables even if those gaps were to be filled, while new high-level use case proposals

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continue to be called out as possibilities. For example, use cases are recognized in claims processing[22] and avoiding ransomware issues with public blockchains[23] in different geographies, which can be served by earlier solutions sharing key execution insights along with these new scale adoption insights in public and enterprise blockchain settings.

A 2022 healthcare value study[18] indicates healthcare's value creation by blockchain is possible and is enabled by three factors: improving service interaction, impacting actors' engagement, and fostering ecosystem transparency. It points out that limited standards in the blockchain vocabulary are a concern. In addition, the author observes that the key findings related to blockchain in healthcare adoption are not often covered in general systematic reviews. Still, they surface in the reviews of the earlier identified categories or research that targeted specific issues. For example, a study by Khan[20] discusses how regulation developments can be leveraged to adopt capabilities such as MedRec by transitioning from Sharing to Selling on a data marketplace. Another study also examines sharing medical records that had not seen adoption scales by indicating findings in stakeholder readiness from a business measures angle.[24]

While progress continues with earlier identified variables in the search for adoption, the following key studies point to newer issues and variables that practitioners face in assimilating work performed so far, channeling them for future work and relating it to the desired healthcare systems outcomes.

One such key comprehensive data quality review in 2023[25] highlights known issues in data quality but in newer manifestations from traditional interoperability and makes a case for blockchain-based data provenance as huge for adoption, citing American Health Care Data Management.[26] The report also specifically calls attention to the dearth of research in blockchain in healthcare and suggests looking for cross-vertical learnings.

The maturity model study by Akbar et al.[27] in 2022 takes a software and process approach and prioritizes the key success factors for blockchain in healthcare efforts. The top few in that list are a culture of collaboration, standards, clarity of high value, and prioritized use cases. Technical scalability ranks last. A recent Systematic Review[12] in 2023 on adopting blockchain in healthcare across nations also remarks that little attention has been paid to internal and external factors critical to adoption and argues for more research on adoption theories and models. Of the 33 adoption factors, blockchain knowledge and awareness and perceived benefits to relative advantage in healthcare are in the top quadrant, along with privacy, regulations, and policies as dominant factors and trust as a variable in prioritizing further work for high adoption.

Practitioner's Perspective

The corresponding author is an experienced technology and digital transformation executive who has spent more than 15 years in healthcare and another decade in business optimization and supply chain and international trade management systems. The author has been holding multiple leadership roles in technology management, innovation management, and emerging technologies and has been part of several industry workgroups in healthcare, including health level seven (HL7), Davinci Payor-Provider collaboration groups, Healthcare Information and Management Systems Society (HIMSS) task forces, and as an advisor and a voting member prioritizing research at the Center for Advancing Research in Financial Technology. The footnote at the end of this article has more information about the authors. The following section is the author's perspective, synthesizing the research information presented so far from the literature and combining it with his views and understanding of fellow practitioners' views through professional relationships by presenting prevalent stakeholder viewpoints on blockchain in healthcare.

Blockchains enable peer-to-peer exchange that provides the trust needed for the stakeholders, eliminating the need for a third party in between that had been providing the trust factor. It is a horizontal innovation that cuts across verticals. It started from a decentralized movement that wanted an efficient way to move money without intermediaries, and the technology has seen use in cryptocurrencies, decentralized finance (DeFi) protocols, and non-fungible tokens (NFTs) and is continuing to mature. There is a public and a private topology to it; both have been trying to achieve results in solving problems related to healthcare using the same technology that has seen notable success in fintech use cases. However, the results are mixed.

Industry Perspective

From the overall industry perspective, the view depends on the stakeholders and their position, which could be very subjective. The author takes a balanced view between the industry Forbes article,[28] citing Bureau of Industry and Security (BIS) research indicating that blockchain in healthcare will save "100 billion dollars per year in 2025." Another industry metric website, Statista,[29] claims modest activity regarding deployable blockchain applications.

The author also thinks that healthcare efforts can and should learn from other verticals,[30] like finance, which is consistent with his cross-vertical efforts. He has also observed some of the issues reported by other practitioners on alarming failure rates,[2] and the challenges and outlook.[31]

The author keeps a "cautiously optimistic" note and, in general, is excited about the possibilities the technology brings and finds more importance in connecting the findings in the literature, sharing the industry findings, and moving forward with mechanisms to increase success.

Response to Research Question Objectives

Table 1 revisits and responds to the research objectives based on synthesis from the literature findings and the author's perspective of industry observations.

Need for Execution Framework in Blockchain in Healthcare

In the initial stages, some of our efforts were also a broad-stroke assessment of the application of blockchain technology, with high-level assumptions on how it could be used and technology-based prove-outs. Several use cases were proposed, and technical component development started with little comprehensive understanding of the full ecosystem level functional context, business and enterprise architecture, organizational and change management aspects, and possible inter-enterprise friction and technical and business scale adoption factors. The results were remarkably similar to what was reported.[2] This typically causes frequent starts/stops, loss of confidence, and threatens sustainable innovation resulting from our earlier cycles.

A few issues that reviews[27,32] reported from their source interviews were also realized, along with other learnings in the author's blockchain experience in the contemporary period in one of the healthcare deployments.

After frequent starts/stops of predominantly technical efforts, it was recognized that unless a true end-to-end process is tried at scale from where the legacy enterprise systems and processes stand in their maturity, the true potential of blockchain-based transformation would not be enabled. A structure with the characteristics listed in Table 2 is needed. New critical success factors surfacing, like trust, etc., will require more information captured in usage patterns that blockchains can add value to. We observed "trust but verify" operational patterns that could be turned into "trust and use."

Blockchain in Healthcare Discovery Framework

Presented here and illustrated in Figure 2 is a framework for blockchain in healthcare efforts.

Blockchain in the healthcare discovery framework is generic and has been assembled after examining healthcare data and information flow patterns. It provides a structure from conception to execution for practitioners. It is maintained at the GitHub URL[33] and the wiki URL. Its early use has been instrumental in identifying and executing a multiparty process in the healthcare payor setting but continuously evolves, including cross-vertical learnings.

Importance of the Framework in the Reference Case

The framework and the reference case are noteworthy because they operate on blockchain transformation constructs on underlying healthcare data. However, by the sheer number of memberships across the providers, the payor flows can accelerate identifying scale-related success factors in healthcare. The reference case explored an administrative function but with a high economic impact on the stakeholders because of its potential for administrative efficiencies. Administrative waste accounts for the major portion of waste not attributed to clinical care.

Table 1. Response to the research objectives based on synthesis from the literature findings and the author's perspective of industry observations

Question	Response
Do systematic reviews measure and explain the adoption of blockchain in healthcare?	• No, not yet. • The adoption studies are just starting and, in fact, show the need has just been realized in 2022 and 2023, and earlier than that, there was no real measure. • The overall systematic reviews in blockchain in healthcare focused on the technical dimension, predominantly and are highly speculative. • Various other factors affecting adoption are surfacing.[27,32] • There are still nascent measures.
Do the blockchain adoption metrics as a transformative force converge to healthcare quadruple aim[5] at scale measurably?	• The response to the earlier question automatically means No to this question as well. • Moreover, there are no documented ways to map how much of overall health system performance can be attributed to blockchain, what characteristics of blockchain map to which improvement metric and to define the targets.
What are the gaps, and how can a practitioner's view help to make progress toward the desired impact mainstream? Can that be templated for best practices and customized?	• Significant gaps exist in defining the structures and methods needed for blockchain adoption in general and specifically for healthcare at various levels. • These will be called out in the next few sections. A framework that helped in a reference case in healthcare will also be discussed.

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Identifying such use cases, which can convince the stakeholders to proceed to scale, will help understand success factors for more complex use cases such as clinical care.

The reference case is an administrative benefits function, a multiparty use case with comparatively lower friction. Still, it has higher operational cost avoidance value, particularly if the accuracy and audibility are high, and the algorithmic support can also easily delineate cases that need a human-machine loop.

Organizational

A particularly important part of the framework is to model and capture top management support, multilevel stakeholder support, and internal and external stakeholders in order to clearly articulate the engagement, learning, and transformation process conducive to blockchain-based transformation.

The primary concept was to start with the end state in mind and have a network view always, in every touchpoint with an incoming work request (right to left) as opposed to most blockchain efforts, which had a primary motivation of technical exploration only (left to right) shown in Figure 2. The framework realized blockchain needed evangelism in enterprise contexts and needed continuous budgets and efforts to sustain the innovation. The framework had the following themes: team and execution structures.

Themes

It is important to note that blockchain technology is not isolated but must be in concert with the enterprise's overall data quality and data reliability picture.

Leadership Messaging

Leadership messaging repeatedly stress the following notions.

Blockchain Mainstream

Any blockchain work request evaluation internally or externally will come along with its scale definitions with the touchpoints.

Adoption Experiments at Scale

The intent was to understand the overall scale metrics, operational constraints, or bias identified immediately. The operation function reimagined will have a 360-degree evaluation with the ecosystem partners. For example, the

Table 2. A structure with the following characteristics is needed to realize the true potential of blockchain-based transformation

Characteristics	Defined
Organizational	Blockchain efforts need expanded support at all levels, internal and external, as study results[32] indicate, along with clearer objectives.
Technical	Gaps exist in benchmarking shared data, shared processes, and documenting differential designs as best practices for current and future needs. The technical stack itself is rapidly maturing, and few frameworks are available, primarily an evaluation between Hyperledger and Enterprise Ethereum. Scalability benchmarks in Hyperledger and Ethereum are improving, but beyond those, the evaluation frameworks or guidelines are also rapidly outdated. Standards are lacking as well.[18]
Functional	The "Network vs. Database" attribute[27] is not just a technical implementation detail but rather an investigative theme to discover and potentially dis-intermediate complete functions. This needs a different mindset, structure, and guidelines to elicit software development life cycle requirements.
Regulatory and Privacy	Design patterns for privacy and compliance are critical to scalable adoption.

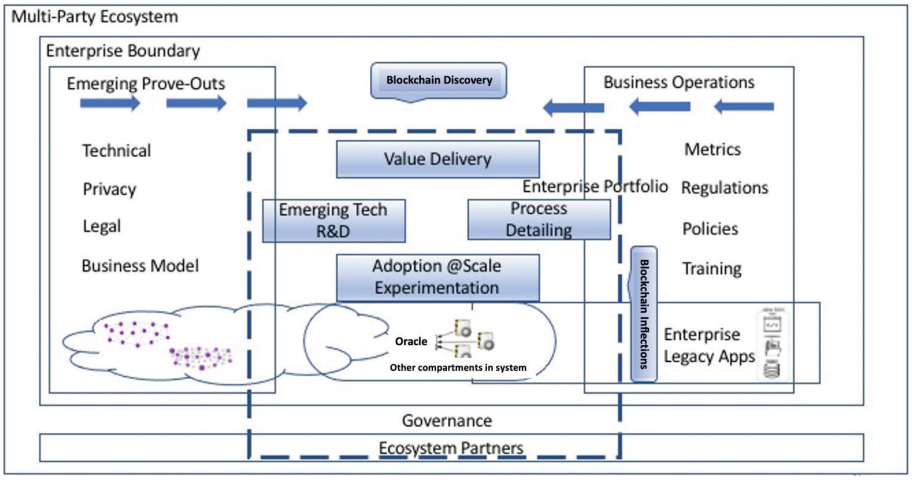

Fig. 2. A framework for blockchain in healthcare efforts. R&D: research and development.

true sources of those data elements incoming are reasoned out. These experiments addressed, "what happens if the flow is restructured," and "what if the degree of separation of the transaction is reduced and data at source are pursued instead"? These experiments helped elicit the hard and probing questions, and any proof needed was not only technical but also assessed for scale from an operational context.

The advantage of this approach was always to be ahead of the next opportunity to capitalize on should there be an advancement in the overall technical function of the enterprise along with forward-looking partners.

Educate-Evangelize-Experiment

Blockchain Forum

One of the biggest challenges, as also evidenced by studies,[27,32] is a lack of technical experience. As part of the execution template, there must be ongoing exercise at various levels – not just a technical function. The forum's activities include blockchain messaging, massive open online *courses* (*MOOCs*), workshops, lunch-and-learns, and happy hours at every opportunity, internally and externally.

Partnerships

The resource templating is set up for partnerships, gig workers, and academics.

Portfolio Messaging

With the adoption experiment at scale always having a pulse of potential asks, the next opportunity to leverage emerging blockchain technology was introduced to evaluate major investments into legacy environments.

Future-Proofing

Future-proofing is a pull strategy for advancing emerging business models based on innovative technology providing exponential advantages. The future-proofing template does the architectural due diligence to ensure the designs were set up so that enough investments could be moved to emerging needs instead of legacy designs. Emerging tech investments are not just for reducing technical debt but also for allowing operations for network-based reimagining business operations.

Stair-Stepping

Stair-stepping is a push strategy to continuously move away from older systems as much as the newer technology allows for transforming processes. The stair-stepping template sets up the building blocks even if full implementation on the blockchain is not immediately possible due to technical uncertainty. The stand-alone components were designed for easy blockchain extensibility, which could be advanced further as the blockchain-to-enterprise connectivity matures.

Careful futureproofing and stair-stepping make operational teams comfortable taking calculated risks while constantly reimagining blockchain-enabled business transitions.

Blockchain Constructs – Network First

The template cultivates the habit of evaluating soapboxes/hackathons/brainstorming and regular work along these constructs.

It must be observed that all data need NOT be stored on the blockchain; just enough data to do business with the counterparties increases the chances of success and driving efficiency. An overall data fidelity strategy helps prioritize the right chunks of work and iteratively progress on a consistent source of truth over time and on-demand reconciliations.

Provenance of Process and Data

Using templated questions to evaluate provenance, timestamping, and knowing "who did what" or "what was done when" would eliminate the need for reactive analysis time spent in excessive processing and inaccurate data in the current processes.[25] These provenance structures directly address and help the issues raised in the review.[25]

Consensus Lens Evaluation

This is a key evaluation that answers whether the decision-making involves (or) should involve the counterparties. These evaluations help identify multiparty processes and the granularity of the level of data sharing. For "No to Low friction" processes, entities can rely on and agree to the provenance documented even by the counterparties to reduce the administrative burden on themselves.

Network Visualizations

Visualizing data in network graphs helps reimagination.

Trust

In situations where counterparty data are consumed, is it used directly (or) does it have verification routines? It is not uncommon for enterprise processes to re-run validations with minimal incremental benefits, hence reducing efficiencies. Specifically, there were many such instances in the healthcare setting where the template was assessed.

Source of Truth

The source of truth checkpoint template analyzes if the data originate from a primary or a secondary source[25] and whether there has been traceability back to the originating source.

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End-Point Events

Explicit questioning and constant analysis reveal how many connection touchpoints emit or consume events. This is particularly important for the Internet of Things endpoints as well.

Connectivity Maps

For "*n*" participants in a network, the number of connectivity links could be as high as "*n*" (*n* - 1) / 2, and along those links, it is not uncommon to see multiple rounds of either electronic request-response data, or events being emitted, for example, claims status or eligibility requests. The connectivity maps help capture and rationalize blockchain designs.

Touchpoints Metrics

How many partners are connected through which channels? Is there a forest of one-to-one (1–1) connections? These could be electronic or manual transaction types. The number of transactions documented per unit of time helps channel these designs.

Privacy

Privacy designs can range from designs answering minimal data to private data channels to zero-knowledge proof implementations, along with other privacy tokenization mechanisms. It is important to clearly understand the whole picture, the boundaries, and the cloud infrastructure.

Friction Maps

In situations where any parties have concerns beyond privacy and regulations, it is important to document them in terms of friction maps for analysis. There are numerous situations where the same pain point is happening on the counterparty side, where there could be a subset of low-friction items that both parties might want to solve.

Interoperability

In blockchain in healthcare, interoperability could mean healthcare interoperability, blockchain interoperability, or both. Most designs could pass through a Fast Healthcare Interoperability Resources (FHIR) layer for future-proofing regardless of their journey's starting point.

Standards

There are extremely limited standards in blockchain now and mostly for cryptocurrencies. However, the healthcare standards are mature enough for the parties in a multiparty ecosystem to analyze excessive chatter and make adequate business decisions to improve efficiencies so that blockchain designs can advance. Blockchain in healthcare standards can leverage and extend current healthcare standards.

Spirit of Requirements versus Requirements

These questions help elicit the true requirements in a network mode of operations instead of perceived requirements, which tend to be narrow and unilateral from one organization's viewpoint. The templates prove helpful even if the starting point is a simple checklist, which can then be extended to knowledge bases.

The blockchain constructs and templates outlined in the framework give a systematic way of understanding the data and process flow. It specifically helps the business users, leaders' architects, and developers to think about data quality, governance, source of truth, and the trust that can be attributed to the source of truth as desired in the study.[25] The data provenance, in the context of regulation compliance, privacy, and friction maps, further helps in designs to expose the minimal data needed for the business function end-to-end, to be used as peer-to-peer sources of data, and timestamped business agreements that could be trusted for use, instead of re-investigations and re-verifications, which constitute a significant source of waste. Particularly on the administrative side, they are early sources to search for low friction flows for multiparty blockchain-based collaboration.

Execution Functions

The execution included focused sub-streams and intertwined coordination to elicit uncanny insights needed to differentiate emerging technology inflection points.

Starting from Both Ends of the Framework to Design for Scale

A technical prove-out sub-stream progressed gradually, cutting down the assumptions and increasing the complexities for true at-scale business adoption. One of the key objectives for this stream was integration of enterprise systems at the ecosystem level and future-proofing technologies. The prove-out included separating foundational blockchain elements from allied technologies and designing the interplay of allied technologies, including AI models, data oracles, and orchestrators. This was especially important as technology matured rapidly to make sure designs were modular to be reassembled as the subcomponents evolved.

A cross-functional sub-stream studied the detailed flow of the existing processes, observing everyday work and process agents and a time study for each operation. The current operational metrics were noted down to granular levels.

For the reference case detailed in the following sections, the primary metric was the number of investigations conducted as a live process per subject matter expert (SME)

per day. The "before" metric was 35–70 daily investigations, one pass. The goal was to apply the blockchain discovery framework to look for efficiencies. The work for this sub-stream was to collect the requirements through the iterations, but the key differentiator was to distill the true spirit of requirements. This was critical to be able to incorporate unconstrained thinking.

Discovery of Inflection Points in Multiparty Scale – Constructs and What-Ifs

A discovery sub-stream at the heart of the effort pulled together the details, focusing on re-engineering the process in the context of multiparty collaborations. Experimentation was based on continuous feedback to critically identify what sub-components can potentially be the inflection points for the network-based designs. This would not have been possible otherwise by employing the blockchain constructs—provenance, consensus, trust, audibility, privacy, security, source of truth, and the granularity at which the decision had to be made.

The key aspect of this sub-stream was to focus on "what-if" scenarios and present the business partners with non-linear alternatives that exceed their near-future plans on legacy paths. This sub-stream incubated the re-imagination of ideas that could produce hyperefficient results.

The delivery stream assembled them into a program with a stair-stepped plan, connecting to the elements of the re-imagination goals, risk management, sustainable return on investments, exceeding operational metrics, and dependency management to accelerate time to market.

All sub-streams penetrated the enterprise as a guild, and constant information flowed between them, with very nimble iterative cycles to ship functionality that could produce quick metrics constantly.

Reference Case

A few quick iterations of the discovery framework applying the blockchain constructs helped to select a use case catering to an operational business problem at scale with a straightforward multiparty process. The use case was to coordinate benefits between payors and was a composable functional unit of business layers, including member matching and eligibility. The primary peers were payors, with other payors as external parties. There was a possibility to also model another payor internally with fewer dependencies, given the nature of the business setup, operating across multiple geographies as multiple brands. This helped try out the scale and progress to an unconstrained reimagination of the process with fewer dependencies.

The current processes revealed a set of laborious processes where the experts drain a lead for benefits coordination inquiry and go through data collation with several data feeds, portal searches, and phones. The document reads from many sources, internal and external, to figure out who will pay as the primary payor where more than one insurance was involved based on the subscriber and dependent memberships.

Discovery Framework Impact

Applying the blockchain constructs from the discovery framework in the execution mode described above surfaced the following findings:

Provenance

The information gathered from various sources on consumers having other insurance had limited documentation. Structured provenance with timestamps at a granular level, by itself, created a huge lift in the visibility and the quality of the underlying data. All provenances need not be on-chain. Off-chain detailed provenance with on-chain references to the source of truth sufficed enough.

Reconciliation

Whenever there were instances where there seemed to be conflicting information, the provenance helped in storing the most acceptable version in the source of truth repository. These reconciliations were done automatically through natural language AI tools, manually, or a combination based on the defined thresholds.

Shared Multiparty Collaboration

The end-to-end multiparty business process revealed that despite the enormous volume of data, only a small subset accounted for settling the benefits of coordination between parties if the provenance behind those elements can be fully traceable.

Friction Maps

The friction maps, along with provenance, indicated a sizable number of opportunities that fall into administrative waste, which were equally important for counterparties.

Connectivity Maps

The connectivity maps showed many instances where data sent to several sources could be reduced to the subset and hosted in a compliant and privacy-protected way on the blockchain nodes for the counterparties to consume.

Trust

Despite using third-party intermediaries that provided this function, the framework discovered that numerous operational processes had to do verification, which was administratively prohibitive because of the following reasons: (1) the data did not flow from direct peers, (2) underlying data quality issues, which could be from both ends, made them less dependable, (3) there was no notion of an agreed-upon source of truth, only indicative.

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The blockchain-based processes improved the chances of data quality from an internal perspective across different flavors of data within different enterprise departments and an external perspective across companies. Some enterprises do have a master data management. They manage an ecosystem source of truth. In healthcare, privacy and regulations add extra dimensions of complexity. The analysis through the framework indicated the business processes, the solution with blockchain constructs, and the human-AI loop that showed promise to move from "trust but verify" to "trust and use."

Privacy

The framework identified the privacy-sensitive elements in the subset, along with the regulations and business friction; this helped to understand the design patterns to share data in a privacy-protected way. These included minimally needed data share, which is always mandated in healthcare, privacy tokenization technologies, hashing, and Merkle-trees-based comparison routines for entity matching, with additional technologies still maturing for zero-knowledge circuits.

Transaction Touchpoints

The connectivity maps, along with the multiparty collaboration opportunities, friction maps, and trust parameters, validated the designs to be run as smart contracts and made the results available on all nodes so that the unneeded chatter could be removed.

Incentives

The incentives were also a major part, and the framework helped to not only identify the economic incentives for the solution, predominantly from labor-cost avoidance, but also increasing the payment accuracy of the outbound dollars.

A rapid small-scale pilot proved the solution, and the scale parameters were determined. Yet, this transformation was a massive task and had to be planned in the context of where the enterprise technical landscape and the emerging technology were. What was clear was the blockchain-based solution would be the future state. Still, the changes will have to be introduced at a pace where the current enterprise's technical landscape and the operational change process can absorb it gradually. The framework's application proved that blockchain allows for a fundamentally different way of thinking rather than a stand-alone technical upgrade. This transformation needed a sustainable and iterative plan to roll out, considering the current technological and operational environments, budgets, and cultural shifts, where stair-stepping and future-proofing framework elements prove useful.

Inflection Point 1: First Win Documenting the Provenance

The first step was to introduce the blockchain construct of provenance for the data assets collected, and with off-chain and on-chain designs, the first minimum viable product was quickly put out. This step provided the initial quick win not only at the functional level but also by calling out the parameters to scale – number of business lines, transactions, off-chain data, number of person-hours saved, etc.

Inflection Point 2: Stair-Stepping and Future Proofing to Win Stakeholders' Confidence

The implementation was stair-stepped according to the methodology after a full study of the current decision-making process. The study revealed that the current processes were inadequate for a full decision-making loop, which needed the underlying data elements and the business logic that operates for the business context to be coordinated between the parties. That goal had various levels of complexity in the enterprise context. In this step, the complexity was decomposed into multiple layers and stand-alone components that could be run through the discovery methodology described above, and which identified the blockchain components and topologies, the data feeds into the nodes, enterprise assets including data assets, artificial intelligence (AI), machine learning (ML) models, application programming interfaces (APIs), orchestrations, aggregators, oracles, and stand-alone components.

The key thing to observe is that the blockchain-based transformation is NOT blockchain technology alone but the set of enterprise capabilities needed to realize that transformation. From a portfolio planning perspective, the stand-alone components were prioritized first to run the Software as a Service (SAAS) mode, while the blockchain-based implementation discovered key inflection points where the network topologies helped reimagine the processes.

The technical stack was assembled based on the current enterprise landscape, implications for security, privacy, legal, and a mix of blockchain development skills in Go, TypeScript languages, other enterprise development skills in cloud, data science and AI, and regular web development in familiar languages such as enterprise Java and modern web front end technologies for blockchain connectivity. Figure 3 indicates the technical architecture.

The blockchain implementation was on a private blockchain, where the data feeds connected the logical payor, other payor, and provider nodes. The implementation was on Hyperledger Fabric on the Amazon Web Services (AWS) cloud. The mainstream operational complexity needs were handled by sub-components using AWS lambda step functions – stateful orchestrators for parallel processes that could dynamically merge the needs for data

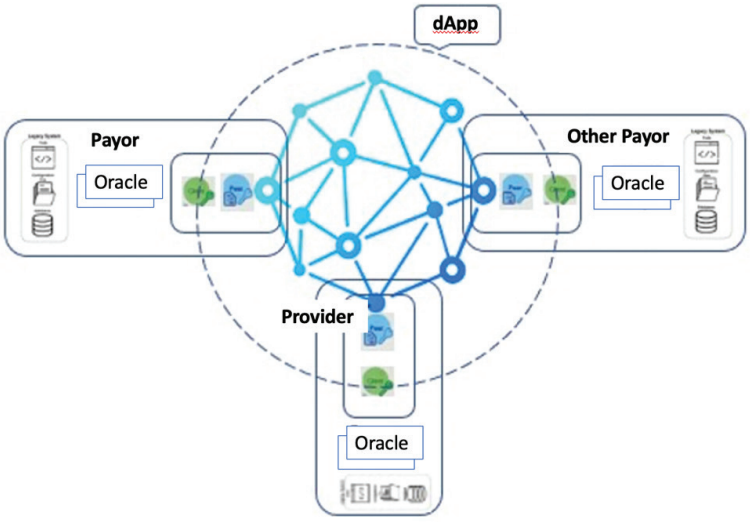

Fig. 3. Technical reference schematic.

reconciliation with data induced from the enterprise assets through AI/ML for document natural language processing (NLP), etc., and generation of standardized notes referring to the data provenance and auditability. The multimodal stand-alone components were engineered to run the same tested code without major rewrites as chain code (smart contracts) to preserve and reuse the operationally vetted integrity and overall costs.

Inflection Point 3: Deployed as Smart Contract, Actionable Information Available on All Nodes

The data feed chain code reacted to the data feeds from the nodes to execute the business rules. If the underpinned data elements for the business context were coordinated, it would generate the agreements on-chain. If not, then the data elements go to the dApp blockchain business orchestration layer that would get additional feeds from various sources and effect reconciliations needed to correct or pick the data for decision-making or to indicate inadequacy. The situations were categorized into fully automated, low-review, and high-review buckets, allowing hyper-productive task list management. The blockchain application layer facilitates the collaboration on the agreement through off-chain and on-chain routines through the oracles updating the source of truth records feeding the nodes.

Results

The methodology had rigorous value capture for appropriate metrics for usage at every logical shipping point as the business adoption evolved, as the productivity capabilities rolled out.

These include prints for data collection and provenance, business decision points, convergence metrics, updates to the source of truth, accuracy certified by SMEs, and comparisons to the process audit functions. The results before and after are tabulated in summary form for confidentiality reasons in Table 3 for a concise comparison of efficiency metrics.

The results indicated metrics across the stakeholder groups, starting from the front-line SMEs to first and second-line managers to sponsors and executive support. The throughput increased drastically, from 35 to 70 business units per SME daily to 5–10 min first pass. In addition, throughput scale increases showed exponential possibilities, with an 8–10X increase in process units, finishing the first pass in 20–30 min, based on parallel designs. The blockchain constructs gave full provenance on-chain and off-chain for all data provenance at the granular level. The SME parity tests showed greater than 99% accuracy.

Also, the application was designed for hyper-productivity designs that are fully configurable for the business managers to fine-tune the automation and human loop for needed classifications of review gradient – fully automatic to low review to high review. This also facilitated process auditors, as they could have closer control of historic timestamps on any data flows and business decisions and the full explainability tied to the source of truth as opposed to fragmented unstructured notes in multiple legacy systems (Table 4). The stair-step methodology also paved the way for consistent returns throughout the journey, including the tandem network implementation in the blockchain stage net. Overall, the methodology and implementation gave about 30 X returns in 18 months.

More importantly, the methodology and the implementation were helpful in further increasing awareness within the enterprise. The executive feedback was positive and the response was to expand the discovery to additional use cases. But, as indicated in the introduction, to scale across multiple use cases and the enterprise application set, the concepts must have sustainable support for an

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Table 3. Results: concise comparison of efficiency metrics

Before	After	Impact
Per day per SME time taken for 35–70 units of process function First pass • Not easily discernable • Time studies only reported pieces of work and were hard to synthesize Hence, meaningful business metrics were-tracked only at the overall load limit	Per day per SME time taken for 35–70 process units First pass • 5–7 minutes first pass. Typically • 60% – 70% Fully Automated • 15% – 20% Human-Machine Loop • 25% – 10% Manual (with visual support)	SMEs • Appreciated the reduction in their workload
Per day per SME time taken for 35–70 units of process function was 8 hours	Per day per SME time taken for 35–70 units of process unit Was reduced to: • 5–7 minutes first pass • 2–4 hours for all complete	SMEs • Appreciated the reduction in their workload.
Linear throughput scale • More units of work needed more SME capacity	Non-linear throughput scale • 400 units (8–10 x) First pass • 20–30 minutes	Second-line managers • Increased personnel flexibility
Scale: 2 Major business lines Major inventory pileup • Human demand always greater capacity	Scale: 2 Major business lines Impact • Payment accuracy for 1.2M members/year Inventory • Reduced rapidly • No build-up	Majority of stakeholders • Efficiency increase

SME: subject matter expert.

Table 4. Results transformation capabilities: before and after

Before	After	Impact
Labor-oriented processes	Efficiency-oriented processes	Sponsors • Tie-in to overall enterprise ask
Batched-up processing with accumulating piles • Reactive	Gradual movement to on-demand process-ing reducing piles • Move to proactive	Front-line managers • Metrics improved
No provenance and traceability • With unstructured bits and pieces assembly	Full provenance and traceability • Down to the granular level of data elements	Process auditors • Recreation variability reduced
Divergent processes	Converging processes	Process managers • Leads engaged in re-imagination
Functionally oriented mindset	Start of collaboration and network-oriented mindset	Overall • Early signs of overall culture changes • Needs sustainability

extended enterprise thinking across the enterprise at all levels, particularly the end users with clear transition plans for their roles as the hyper-efficiencies are achieved. There must be support for portfolio allocations for evolving the networks, which is a task of its own, and our efforts make a compelling case to step up enterprise's efforts on blockchains for collaborative processes. This effort gave key insights and inflection points for the blockchain to continue the case-making.

Key Insights and Inflection Points

The initiative proved and corroborated hypotheses based on the discovery. Based on the healthcare payor processes perspective, the main inflection point discovered was the

use of blockchain technology for off-chain and on-chain data provenance and agreements for key decision points on multiparty use cases between payors and other payors. The blockchain chain-based multiparty transformation is NOT an isolated exercise. Still, it must accompany allied technologies such as off-chain data assets, provenance, AI/ML, cloud technologies such as serverless, and event messaging.

The free-form structures of the network allow for participants to have context-based participation with needed governance as it evolves, as opposed to multiple front-loaded constraints that could frequently be a deterrent. As the other entities engage, the inflection points on the network increase. For example, additional network participants like members or providers can potentially contribute key missing data. In this regard, blockchain technology increases data quality and fidelity at the edges close to the source. Privacy-enhancing technologies are also advancing at a higher pace, which is another important inflection point for blockchain technology, as it now opens up collaborations that were not possible before.

Conclusions

This article analyzed the overall landscape of blockchain-based transformations and the success rates through a literature search, other industry reports, and fellow practitioner experiences trying to scale business use cases mainstream beyond concepts and pilots. Best practices were realized and assembled into the framework and have been evolving. For one such use case, the framework was deployed in steps to convince stakeholders of the scale of discovering and executing the inflection points to eventually produce hyper-efficiencies based on blockchain technology. The results of this effort exceeded expectations in proving hyper-efficiencies based on the blockchain constructs of provenance, real-time events, and collaborative decision-making involving multiple parties in a staging environment.

From the healthcare payor processes perspective, there is enough evidence for "no friction to low friction" possibilities with ecosystem partners to be deployed using blockchain technologies today. One key takeaway is that, even though the technology is still maturing, this effort demonstrates and underscores the need for healthcare enterprises to take a broader and bolder look into the blockchain and allied emerging technologies. This can be done without making blockchains the front-and-center technology initiative but by focusing on its transformation possibilities. The blockchain transformation is a multifaceted effort that needs support from all levels for a future-proofed strategy and enterprise portfolio planning vis-à-vis other project allocations. This technology has all the underpinnings for re-arranging the healthcare landscape.

Future Work

The authors analyzed literature for reports on typical blockchain project adoption barriers, including technical, legal, regulatory, operational, and organizational aspects. The article indicated the recent trend in literature to realize new success attributes and metrics for blockchain adoption. The report demonstrated that blockchain is not just a technological change but a fundamentally different way to reimagine business. It has immense potential but needs a framework with differentiated capabilities and templates. The framework and the results it had created in one deployment setting were provided. The crux is to implement enterprise transformations methodically, applying blockchain constructs and always being able to leverage opportunities to expand scale. Further work can expand this effort into more extensive studies in the future. The generic framework[33] is expected to continue to evolve in other healthcare settings and learn from other verticals to drive best practices for adoption.

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in healthcare. The framework is generic knowledge in blockchain and healthcare; no data were specifically collected. The reference implementation results are summarized generically as an example considering deployment confidentiality and used only to advance generic blockchain in healthcare best practices.

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