# Fundamental cost of ownership for private blockchain solutions

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EY

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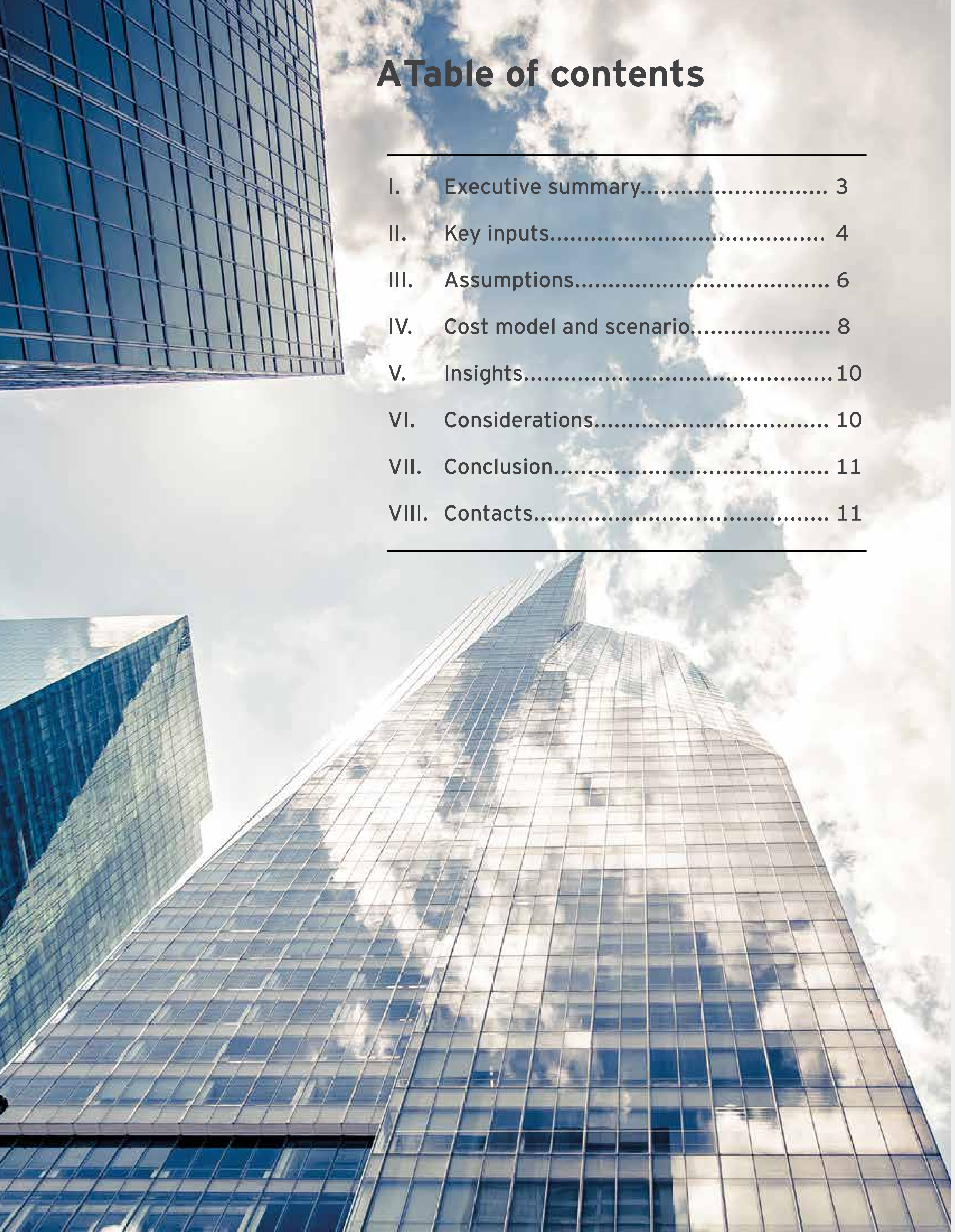

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# I. Executive summary

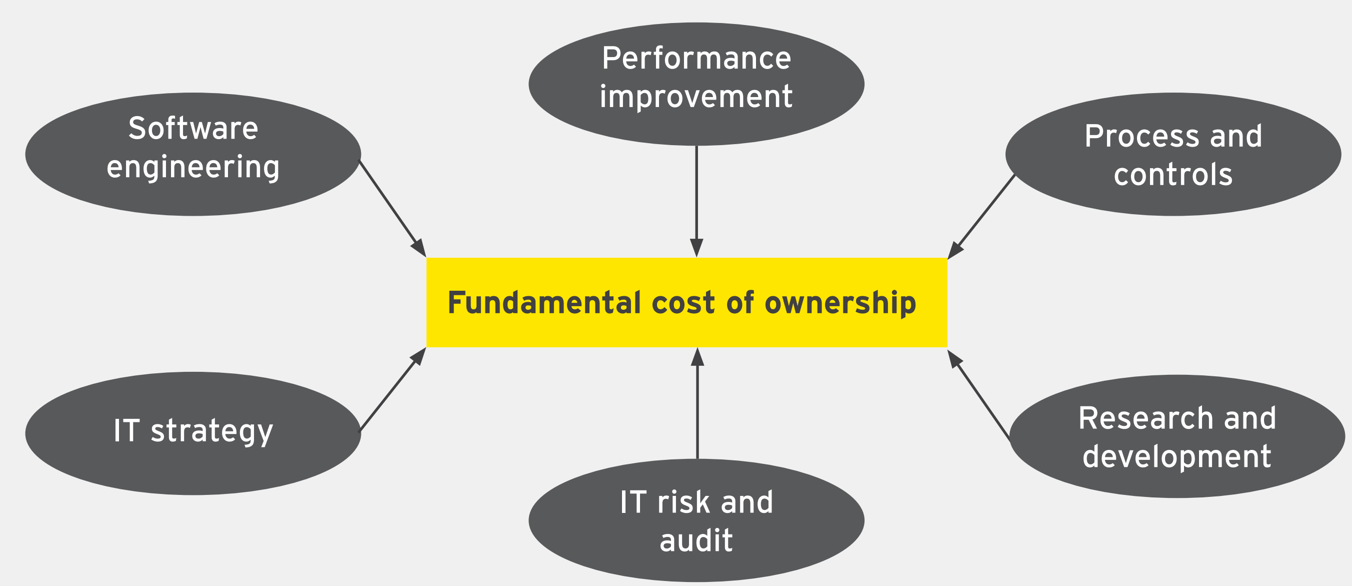
Blockchain technology is touted by many as the be-all-end-all solution for the digital transfer of value. Volatility in the price of major cryptocurrencies such as bitcoin and Ether, accompanied by a wave of institutional investments primarily from the banking industry, has continued to fuel widespread participation in a market once dominated and controlled by cryptographers and engineers. Today, solutions are being built to experiment with payments, supply chain management and provenance, identity management, property rights and post-trade settlement.

Public blockchains, the most common form of the technology, enable collaboration and permission-less access to an assortment of products and services. Contrarily, private blockchains are developed and operated within controlled environments and with permissioned access. Although less ubiquitous, private blockchains serve as useful and efficient exploratory tools for enterprises aiming to reduce operational costs and simultaneously adopt a more digitized approach to processing transactions.

Despite the technology's popularity, particularly as it relates to corporate adoption, several basic questions remain unanswered at the institutional level, driving skepticism and resistance from business managers. While research and development teams at large organizations have ideated blockchain use cases, few working scalable solutions have materialized.

This paper lays the groundwork for answering one of the most important questions asked by business leaders today: **what would a production-scale private blockchain solution cost for my organization?**

With new projects and upgrade proposals released regularly and a limited history of implementations to leverage, forecasting a reliable one-size-fits-all cost framework for a production-scale implementation is currently difficult. So, to begin answering this question, the EY Blockchain Team used data from global client proof-of-concept and pilot engagements, as well as internal platform builds, to develop a framework for understanding and forecasting the costs of a production-scale, commercial private blockchain platform.



# II. Key inputs

Four inputs predominantly impact the costs of a private blockchain solution and depend entirely on the objectives an organization aims to accomplish. There are additional inputs to consider, but for the purpose of simplicity and standardization, only the most influential are highlighted here:

- Transaction volume
- Transaction size
- Node hosting method
- Consensus protocol

**Transaction volume** relates to the amount of activity performed on a blockchain. Transaction volume requirements determine the scalability characteristics a blockchain solution should possess for particular use cases. For example, a blockchain to facilitate payments at a large bank would likely have a significantly higher transaction volume than a blockchain to track each intermediary's touch in a supply chain. In these scenarios, the technology is being utilized for different purposes: the payments blockchain would likely be implemented to gain efficiencies, while the supply chain blockchain would likely be implemented to provide transparency and visibility into the process.

The speed of a database system is measured by its transaction "throughput," referring to its transaction volume per second. For reference, at the time this paper was written, the Ethereum network, with the highest volume of any permission-less blockchain, supported 10 to 15 transactions per second, or approximately 1 million transactions per day. Understanding an implementation's probable transaction throughput enables adopters to clarify many other cost drivers and should be one of the first cost inputs to determine.

**Transaction size** refers to the storage requirements for one unit of value transacted on the network. Transaction size primarily impacts storage costs, cloud costs and transaction review costs. Transaction-size data from blockchains such as bitcoin, Ethereum and Monero was used to determine the transaction-size input options. These blockchains have varying transaction sizes because of the difference in their use cases (e.g., Monero's added privacy features lead to a significantly larger transaction size). Specifically, the input depends on the amount and complexity of data required for each transaction, as well as on-chain and off-chain data storage practices. As an example, applications that require the use of smart contracts to execute agreements based on programmable conditions result in a larger transaction size than applications that facilitate the transfer of value, such as payments or securities.

**Node hosting method** refers to the chosen method for storing a blockchain platform and all of its ancillary technological requirements. Although organizations generally apply a hybrid infrastructure, for the purposes of costing different scenarios, the three most common stand-alone methods are the following:

- On-premise (new systems) — blockchain infrastructure and application(s) are built and maintained on entirely new hardware systems
- On-premise (existing technology) — blockchain infrastructure and application(s) are built and maintained on existing hardware systems
- Cloud-based — blockchain infrastructure and application(s) are built on cloud IT systems

Decisions here impact security, privacy and cost. As an example, on-premise (existing technology) hosting will likely result in lower up-front costs but higher annual expenses, while on-premise (new technology) hosting will likely involve more expensive up-front costs but the potential to realize more cost efficiencies in the future, as new systems will result in fewer integration issues and higher productivity. Therefore, deciding the appropriate node hosting method is driven by not only the use case but also an organization's current technology infrastructure, investment appetite and security requirements.

**Consensus protocol** refers to the method of verifying the legitimacy of blocks of transactions. The following consensus protocols are utilized by both public and private blockchains:

- Proof of work uses a large amount of computing power to mine blocks of transactions.
- Proof of stake uses financial assets as an incentive to mine blocks with integrity.
- Proof of authority allocates the responsibility of verifying blocks to specified participants.
- Byzantine fault tolerance employs a voting system, usually within private blockchains, through which consensus is met once identical responses are received from trusted nodes.

The type of consensus protocol used depends on an organization's current situation and objectives. Each option offers different levels of decentralization, security, power consumption and hardware requirements. Participants in a public blockchain may implement proof of work to ensure that blocks (and therefore, transactions) are verified with computational integrity rather than based simply on authorized permission. However, a computationally intensive consensus protocol such as proof of work results in higher electricity costs, higher hardware costs and greater processing times for transactions executed on the system.

# III. Assumptions

There is little historical data available on the costs of private blockchain solutions. Therefore, our process to develop a cost framework included:

- Benchmarking costs against existing technologies such as electronic data interchange and cloud IT
- Benchmarking costs against data available for public blockchains such as Bitcoin, Ethereum and Monero
- Seeking feedback from developers, R&D specialists and blockchain business-development professionals

While we used this process to determine the hardware costs, computing power costs and storage costs associated closely with blockchain implementations, an often-overlooked cost category critical for a cost model is governance-related costs. Given the lack of large-scale production solutions with well-documented governance costs to draw from, governance-related assumptions embedded in the model were formulated by examining comparable IT implementations and adjusting the data for the unique characteristics of blockchain technology and its market. Wherever applicable, EY's experience with previous and current blockchain projects was also leveraged to determine cost assumptions.

As an example, the documentation and record-keeping costs associated with each user of the system was estimated by averaging the market data from well-established IT implementation projects. Those averages were then adjusted for the incremental differences in requirements due to the fact that blockchain technology is in its early stages. Under the assumption that documentation should be optimized rapidly over time given the technology's inherent record-keeping functionality, a decreasing step function was incorporated. Similar assumptions were made for items such as hourly instructor costs, annual user turnover and training hours per end user.

The following key assumptions were formulated and incorporated into the model to enable standardization of the forecasting of costs across a variety of solutions:

Onboarding cost forecasts assume 10 full nodes and 250 end users. These are key assumptions that also underlie several calculations throughout the model, including cloud costs and user education costs. Public blockchain networks require a large number of dispersed full nodes verifying transactions to prevent certain malicious activity, such as a 51% attack. On the contrary, private blockchain solutions assign the responsibility of verifying transactions to a select group of individuals. Therefore, the number of full nodes is not linked directly to the number of users or transaction volume of the platform, but is instead linked primarily to a) the number of members in a consortium and/or b) the minimum number of nodes necessary to mitigate the risk of collusion from a first-line-of-defense perspective. While each organization's full node and user breakdown will deviate, based on existing private blockchain implementations, the assumption of 10 full nodes and 250 end users represents a reasonable average and portrays realistic costs for the majority of implementations.

The on-premise (new systems) node hosting method also requires an assumption pertaining to hardware costs. These hardware costs assume that enterprise-grade servers will be acquired to facilitate the storage of transaction data for an extended period of time, with the capacity to manage increases in transaction size or volume.

Cloud cost forecasts, per data collected from a major cloud provider, assume one virtual machine (VM) per full node at an average cost of $2,000 per VM. Unlike the onboarding costs detailed previously, remaining cloud costs, such as those for storage capacity and transaction storage, directly depend on transaction volume and transaction size.

Ongoing maintenance cost forecasts assume that, on average, an organization requires a full-time employee dedicated to blockchain technical support. This assumption, as well as the ongoing education costs per user, annual user turnover and hardware administration costs, which are all also included in ongoing maintenance, is based on existing data from comparable technology implementations.

Monitoring cost forecasts are based on two basic, but important, assumptions: $15 in quality review costs per 100,000 transactions and $1,495 in annual network assessment costs. Both figures were reviewed with multiple internal teams and assessed based on the quality assurance and audit costs of existing engagements.

Because of the early stages of enterprise blockchains, governance costs could initially be unnecessarily high. Basic system-inherent controls, such as the distributed nature of blockchain, reduce the need for audit reviews, redundant backup processes and disaster recovery programs, compared with a normal IT upgrade. However, departmental managers might still be skeptical and tolerate additional costs as a result.

# IV. Cost model and scenario

A general cost model can be reasonably constructed using the assumptions and inputs previously discussed. To demonstrate the costing methodology, see the example scenarios below, which are based on inputs, assumptions and outputs incorporated in the model framework. The costs associated with the development of the infrastructure and application(s) are excluded, as projects' time-to-completion and expertise requirements will vary. Costs are separated into four major categories, with many declining over time in accordance with the experience curve:

- Onboarding – costs associated with deploying new hardware, training new employees (users) and documentation
- Cloud and hosting – costs primarily related to storing the solution, such as cloud storage
- Ongoing maintenance – costs required to preserve the integrity of the system, such as hardware administration
- Monitoring – costs associated with testing and auditing the system for assurance purposes

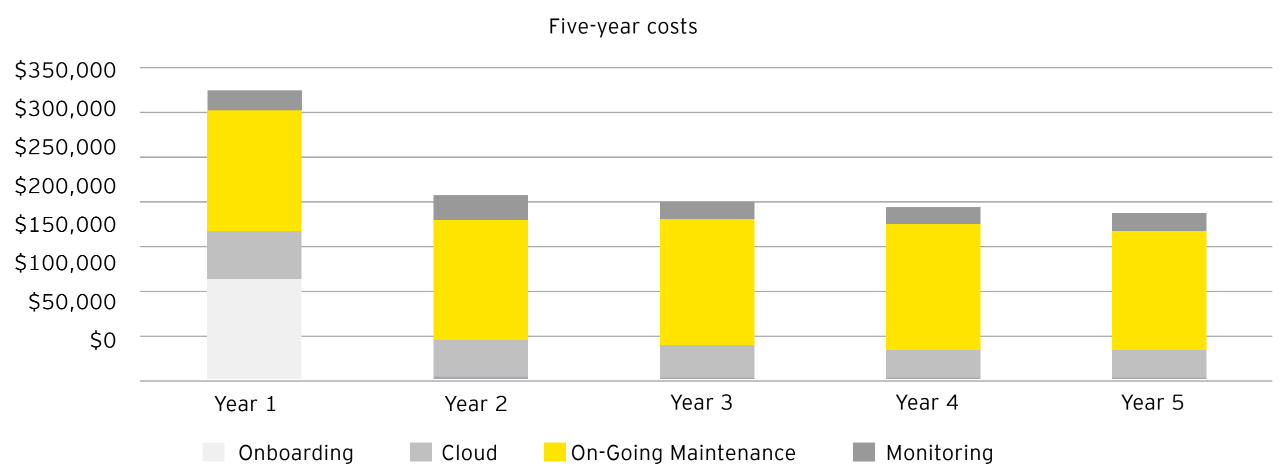
A majority of the costs have a decreasing total and unit cost over time in accordance with the experience curve.

| Inputs | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 |
|---|---|---|---|---|
| Daily transaction volume | 250,000 | 50,000 | 500,000 | 500,000 |
| Transaction size | Large – 500 bytes | Medium – 250 bytes | Small – 150 bytes | Medium – 250 bytes |
| Node hosting | Cloud-based | On-premise (existing technology)* | On-premise (new systems)* | Cloud-based |
| Consensus protocol | Proof of work | Proof of authority | Byzantine fault tolerance | Proof of stake |

*Fully on-premise solutions assume $0 cloud

Scenario 1

| | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
|---|---|---|---|---|---|
| Onboarding costs | $115,146 | $3,880 | $3,688 | $3,506 | $3,335 |
| Cloud costs | $50,006 | $42,756 | $36,557 | $31,257 | $26,725 |
| Ongoing maintenance costs | $142,280 | $142,014 | $141,755 | $141,505 | $141,263 |
| Monitoring costs | $19,663 | $18,773 | $17,928 | $17,125 | $16,362 |
| Total costs | $327,095 | $207,423 | $199,928 | $193,393 | $187,685 |




Scenario 2

| | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
|---|---|---|---|---|---|
| Onboarding costs | $97,720 | $3,868 | $3,676 | $3,495 | $3,323 |
| Cloud costs | $0 | $0 | $0 | $0 | $0 |
| Ongoing maintenance costs | $140,640 | $140,456 | $140,275 | $140,099 | $139,927 |
| Monitoring costs | $4,233 | $4,096 | $3,966 | $3,842 | $3,725 |
| **Total costs** | **$242,593** | **$148,420** | **$147,917** | **$147,436** | **$146,975** |

Scenario 3

| | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
|---|---|---|---|---|---|
| Onboarding costs | $105,564 | $15,338 | $14,535 | $13,810 | $13,155 |
| Cloud costs | $0 | $0 | $0 | $0 | $0 |
| Ongoing maintenance costs | $142,340 | $136,467 | $130,952 | $125,762 | $120,864 |
| Monitoring costs | $26,058 | $23,594 | $21,377 | $19,381 | $17,585 |
| **Total costs** | **$273,962** | **$175,399** | **$166,864** | **$158,953** | **$151,604** |

Scenario 4

| | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
|---|---|---|---|---|---|
| Onboarding costs | $101,282 | $3,874 | $3,682 | $3,501 | $3,329 |
| Cloud costs | $26,409 | $22,581 | $19,308 | $16,509 | $14,116 |
| Ongoing maintenance costs | $140,968 | $140,767 | $140,571 | $140,381 | $140,194 |
| Monitoring costs | $30,314 | $28,876 | $27,511 | $26,214 | $24,982 |
| **Total costs** | **$298,973** | **$196,098** | **$191,072** | **$186,605** | **$182,621** |

The original model has been posted to EY's GiftHub repository, and all parties are encouraged to fork, edit and improve it based on their unique experiences: https://github.com/EYBlockchain/fundamental-cost-of-ownership

# V. Insights

Despite differing inputs for the four scenarios above, the majority of total costs do not differ significantly between use cases. With the exception of large variances in project size, changes in even critical inputs have only limited impact on the dollar value of procurement-related costs. The cost breakdown included in the model indicates that this is primarily because of the large governance costs, such as education and quality control considerations, which are unavoidable regardless of the type of implementation. These costs unquestionably remain the largest cost driver, regardless of the technology specifics.

Further, blockchain is unique in that all of the participants share the costs of implementation and maintenance. Unlike traditional, centralized IT systems, each entity only has to fund the nodes that they operate. In a hypothetical consortium of 500 members, certain members will choose to run their nodes on premise, while other members will choose to run theirs in the cloud. Therefore, while this model can be used to calculate the "all-in," or sum of the relevant costs for all participants in the network, it can also be used to calculate the portion of a subset of members.

The limited financial impact of altering inputs does not detract from the importance of the choice of those characteristics. Implementation decisions and system characteristics should reflect organization-specific requirements, including security, scalability, counterparty and hardware requirements. In accordance with the inputs in Section II, the cost model results further the importance of measuring non-monetary costs and benefits associated with implementing a blockchain.

# VI. Considerations

Blockchain is still in early development. With few to no large-scale production implementations yet, any cost forecasting model will depend on assumptions and benchmarking data until the market matures further and pricing becomes more accurate.

There is a wide range of possible use cases for blockchain technology. Different applications will have specialized technological, governance and regulatory requirements. As an example, a platform to track derivatives trades is expected to have higher quality assurance costs than a platform to send micro-payments directly to developers



# VII. Conclusion

Discussed in this paper are the key drivers and assumptions taken into consideration to formulate a fundamental cost-of-ownership model for a private blockchain implementation. Leveraging this guidance, IT managers can quantify the financial impact of specific input decisions. While the direct financial impacts of these decisions are limited, the nonfinancial implications are significant.

Ultimately, the substantial costs of training, audit and technical support highlight the importance of appropriate governance processes and practices.

The lack of transparency in the blockchain space continues to give managers pause when they consider the technology. A comprehensive fundamental cost-of-ownership model shines a light on the rarely discussed cost drivers associated with a blockchain implementation and provides a clearer picture of what to expect. With further input from the blockchain community, EY will incorporate feedback from various organizations to help mature the framework.

Blockchain is a transformative technology with the potential to impact businesses across all verticals. Informed cost estimates for private blockchain solutions naturally bring the technology one step closer to widespread commercial adoption.

# VIII. Contacts



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