Financial evaluation framework for blockchain implementations

Mehmet Demir
Department of Computer Science
Ryerson University
Toronto, Canada
mehmet.demir@ryerson.ca

Ozgur Turetken, PhD
Ted Rogers School of Information Technology Management,
Ryerson University,
Toronto, Canada
turetken@ryerson.ca

Alexander Ferworn, PhD
Department of Computer Science
Ryerson University
Toronto, Canada
aferworn@ryerson.ca

***Abstract*— Blockchain technology is at its hype. Organizations are trying to implement blockchain based solutions. At least, they are thinking of blockchain as a solution platform for some of their business problems. There are some problems that find solution very effectively on blockchain, such as cryptocurrencies. But most other problems have alternative solution. Majority of these problems are currently solved by using other technologies.**

Blockchain in most cases seems to provide a different solution with added benefits. In that case, does it worth to use blockchain? Do companies benefit enough form using blockchain? Does blockchain technology help companies to save on costs?

This paper introduces a framework to help organizations evaluate the blockchain implementations financially. Each organization has its own criteria and conditions. Therefore, each evaluation is to be done by the organization on its own project with its own criteria. Our novel contribution is a framework to follow while evaluating blockchain solutions.

Keywords—Blockchain, financial evaluation

I. INTRODUCTION

Blockchain is becoming a critical priority for enterprises [1]. With the tech giants embracing and enabling it [2], more enterprises are considering to adopt blockchain solutions to improve their business capabilities or modernize the current technology stack. Similar to any new technology adoption, benefits and costs of the implementation depend on numerous parameters mostly specific to the adopting organization as well as the target solution. For each blockchain, for each set of participants, and as a solution to various target business problems, there can be different costs and benefits of implementing a blockchain.

In the literature, there is no study providing a framework to decision makers aiding financial assessment of their blockchain implementation projects. With the lack of structured framework, executives can simply get carried away with the hype and make inaccurate estimations about the financial aspects of the blockchain implementation. With financial factors of the blockchain implementations, it is also possible to compare this new technology with the alternative techniques and tools.

Our novel contribution is providing this financial evaluation framework. This paper presents a structured framework to evaluate the cost and benefits of the targeted blockchain solution. This framework evaluates different aspects of the blockchain project and results in a set of formulations that will detail the overall financial model. Since the value of each detail depends on the project details, it is not possible to calculate a resulting monetary amount. However, following the framework will leave the only remaining task to be placing numeric values on the items.

This paper structures the evaluation process by dividing the overall scope into focus areas. The first area of evaluation is on what purpose blockchain serves in the target architecture. The second area is focusing on the features that blockchain provides. The third area is focusing on the costs that blockchain potentially reduces. The fourth area is other environmental factors and motivation. Finally, the fifth area is the actual implementation and operational costs.

At each focus area, we present the related factors to be considered in the evaluation. We prefer a cumulative approach to the value statement of each area. Therefore, the financial value related to the area is the weighted sum of the values from each factor. The value of the factor is relative to others in the organization. Two organizations can use different values for a factor. At the least, the financial gain from the factor benefit different organizations differently. For example, for a large size, high profit, mature company, the value of retiring legacy systems can be very high. On the other hand, a young start-up would see nearly no value in this factor. An organization can value the same factor differently year over year according to their budget and strategic direction.

The weight of a factor is defined by a specific project or use case. For the same organization that value the factors in a uniform way, these values would contribute to the overall value with respect to the use case. For a use case under observation, the weight of the same factor would be defined with the scope of the project.

$$V_{area}\,(x) = \sum_{i=1}^{num\ of\ factors_x} (w_{xi} * v_{xi})$$

$$V_{financial}\,(u) = \sum_{focus\ area=1}^{5} (v_{area}(focus\ area))$$

After going through all these five areas, an evaluator can have a profound understanding of the factors forming the financial value. When the analysis is complete, the detailed explanation of the components and have an understanding of the unified framework, this paper will continue with a use case and demonstrate the application of the framework. The application of the framework will still be on a high level as presented use cases are still theoretical. However, the evaluation would give an idea that applying blockchain is better.

II. BENEFITS

A. What is the role of the blockchain in the target architecture?

Blockchain implementations typically have at least one of the following roles in the overall solution. Alternatives are incremental in functionality and value. The first one is the most straightforward choice, and it is the most replicable structure with conventional techniques. Therefore, it is the least value. While the last one is the most complicated, and if the business problem requires it, it is the most valuable. Every consecutive choice will build more features, and conventional techniques would gradually be inefficient to replicate the added value.

1) ..is a shared information database

Blockchain technology implementations often are seen as a shared database [3]. Participants of the blockchain issue their transactions to the database. Moreover, the transactions are communicated to all participants to be formed into blocks and get persisted. All participants access the same records. There is a single version of the information.

2) ..is a distributed information database

Each transaction, and then when transactions bundled, each created block is communicated to all participants, and each participant updates their copy of the database. This behavior is the same as a distributed database [4]. This behavior compares to a no-SQL document database where each block is a document with all the metadata as fields.

All participants have access to all records. Even if a participant is not online for a time frame, when this participant comes online, can download all missed blocks from other participants. A brand-new participant takes longer to catch up by downloading a larger number of blocks. Blockchain becomes distributed, replicated, and a single version of the truth.

3) ..is a validated immutable transaction database

Even though there are multiple versions of the blocks in the time of creation, consensus eliminates the invalids, duplicates or misfit. Depending on the underlying digital assets, there can be specific business logic in the validation. There are also infrastructure requirements about signatures, encryption, and data format checking as part of validation. Validation and consensus make the data more secure, valid, relevant, and trusted. After the validation, each node appends the new block to the chain. The blockchain is called an append-only database [5] since previously validated blocks in the blockchain are not updated with new transactions, simply the new states are appended as new transactions included in the new block.

4) ..is an integration platform with a validated immutable transaction database

Participants of a blockchain network collaborate over the blockchain network by sharing information in the form of transactions. The seller, the buyer, banks, factory, the land transportation company, ports, shipping companies, the receiving port, customs, delivery company, and destination receiver all issue transactions for order, bank-letter-o-guarantee, production of an item, custodianship of the traveling item, customs documentation, receipt or arrival, and payment. Some participants may also benefit from these communications without actively issuing transactions. Insurance companies have a stake in the loss and damages. Government officials have governance interest on audit, taxation, and duty. Blockchain is an integration platform [6] for all these participants.

5) ..is an immutable business process management database

Smart contracts add custom application capabilities to the blockchain. In business process management systems (BMPS), business process entities, and the business rules defined around them form a business process. The business rules control interactions and interactions create/update instances of the business process entities. A BPMS blockchain [7] contains entity instances with their metadata waiting for their next interaction. Smart contracts are a collection of attributes and code with the same behavior as above. Participants instantiate smart contracts. Interactions change their state with the coded logic of the smart contract. After each interaction, the next block created contain updated attributes and metadata of the contract until subsequent interaction.

6) Financial model reflection – Value of the solution

$$V_{area}\begin{pmatrix}\text{Role of the}\\ \text{blockchain}\\ \text{in the target}\\ \text{architecture}\end{pmatrix} = \sum_{i=1}^{5}(w_i * v_i)$$

$$i = \{shared\ database, distributed, validated, integration, BPM\}$$

Fig. 1. Value statement of the role of the blockchain

After defining the purpose of the blockchain in the target architecture, its estimated value becomes an input to the financial model. Shared, distributed, and replicated databases have minimum incremental value as similar features can be obtained by implementing conventional database solutions. Validation of the transactions, immutability, having an integration platform, and running business processes have more and more value. Advance roles in this scale usually include and goes with the less advanced ones. A validated immutable transaction database is assumed to be distributed, replicated, and shared. The formula adds a value of all the roles, but the value of each role should be calculated incrementally as the value is based on what it builds on top of the previous category of the role.

B. *What are the desired features that blockchain implementations bring to the solution?*

Literature [8] indicates that several features of blockchains can turn in to financial benefits. This paper list the main ones below to create a model that asks whether the desired solution needs these features. If a feature is needed, the overall financial model will include the monetary value of having this feature.

1) Enhanced monetary integration – smart contracts

A blockchain project can have integration with other blockchains. Most notable examples of this integration are when a business process blockchain is in integration with a digital asset such as cryptocurrencies. This integration introduces automatic monetary settlements capability to business activities. There is no need for separate invoicing, itemization of invoices with business activities, double checking, payments related to order, settlements, and clearinghouse. There is no two different understanding of business events. There is no clearinghouse about them. No intermediaries to settle. No bank-to-bank transfer, No “Did you send?” “Did you receive?” "What happened to payment?" questions. Monetary integration minimizes payment risks. Instant settlements become possible and available.

2) Greater transparency

Transparency is the extent of openness and information sharing. For a corporation, it is the extent to which activities and information are observable by external entities. In conventional systems, the governing body decides the level of transparency. Each organization decides the set of sharable information for themselves, and the selection reflects what this company claims to be the truth. While there are many trustworthy corporations, names such as Enron, WorldCom, Bernie Madoff, and AIG would suggest that every claim cannot be trusted. Every corporation to be the trusted authority about its information is functional but not dependable.

Moreover, in the business ecosystem, there are multiple parties in each interaction. This multiplicity results in multiple versions of information. Whenever a conflict arises between parties, usually each party would claim that their version of the information is the truth. Such conflict between otherwise trusting parties is expensive to solve, sometimes so expensive that conflicts can be avoided by merely accepting write-offs.

Information manipulation can also originate from higher entities. Authoritarian governments and their extensions may censor the information or manipulate it. A new government can update the truth recorded by the past authorities and replace it with new information serving new interests.

Since transactions and blocks are shared between nodes in a blockchain implementation, transparency is a natural feature of blockchains. This constant transparency policy can prevent the conditions mentioned above and can avoid related damages. Even though the transparency is a feature, if the policies require, it does not need to be uniform for all data. Where necessary, the participants can combine blockchain technology with data encryption to enable various levels of transparency on different categories of data.

3) Enhanced security

If the control logic of a system is exposed and hacked, there can be system-wide damage limited to the system resources. Hackers took control of giant construction cranes [9] and showed that central controls mean a single point of attack. Attackers concentrate on this single point, and the protection of the resources forming this single point becomes too expensive or too restrictive. Blockchains are built on the distributed architecture where the loss or capture of a single resource is not threatening the greater system. The distributed architecture of blockchains makes DDOS attacks very infeasible. When a small number of the participants turn malicious, the rest of the blockchain has the power to cut them out of the system. Digital signatures and tamper resistance characteristics of the blockchain also make sure each block of the chain remains unchanged after its creation. Since there is no single point of attack and since the data corruption is not possible due to the digital signatures and tamper resistance, hackers do not have a chance to attack, update the data, or destroy any information.

Furthermore, on data security, encryption is a natural option for the blockchain data. Since the blockchain system and participants are well-equipped with the tools of cryptography, using encryption is possible when required. This ability allows the participants to share data without compromising data security. In the age of cloud computing, blockchains also help to ensure the data is encrypted and resides untouched in the cloud infrastructure of third-party vendors.

Permissioned and private blockchains use a role-based security layer that restricts the operations to roles and data to privileged users on that specific data. Besides advantages of the distributed architecture, shared data, access security, role-based security and data security, blockchains can use no-knowledge-proofs to enable a level of encapsulation where business use cases require anonymity or pseudonymity.

4) Improved end-to-end traceability and assurance

Whether it is for export market requirements, product recall management or counterfeit prevention, traceability is essential for reducing risks [10]. Livestock, food, automobiles, and diamonds are known products with regulations, restrictions, and emergency management such as recalls. Their provenance is vital to avoid items with the uncertain origin and to prevent supporting any illegal entities.

Logistics channels are backbones for economic activity. Blockchains can trace the journey of goods from the start to the end. Blockchains help to trace all the parties involved in the business with their complicated relationships with various aspects of business, such as financing and insurance.

Blockchains bring improved access to business information transparently and reliability. With blockchain’s inclusive nature towards information sources, more and detailed information can be collected. All aspects of the business process can be traced end-to-end with the blockchain. With IoT sensors added to the information sources, details collected can fulfill assurance requirements for many businesses. Blockchains can answer the question: What really happened?

5) Increased process efficiencies and speed

Peer-to-peer communication is the building block of blockchain technology. Compared to layered systems with intermediaries and platforms that require clearinghouse style settlement activities, blockchains promote peer-to-peer interaction. Blockchain capabilities also enable granular handling of records. Businesses with blockchain infrastructures can avoid error-prone bulk operations where error handling is a challenge. Individual processing also enables healthy transactions to be processed much faster while unhealthy transactions suffer from their own issues.

6) Sharing economies

Sharing economy pioneers are disrupting businesses. Inactive resources and capabilities are included in the economy resulting in greater benefits to more people. Current examples suggest retired people, homemakers or students can drive their underutilized cars to earn like a cab driver, take care of other people's pets to utilize their time, rent their underutilized guestrooms or bicycles sitting in the garage. Newly created authorities built the current examples. Market conditions and benefits provided to participants are under the control of these companies. Payments, commissions, and fees are collected and distributed. Availability of these intermediaries is essential for service to continue without disruption.

Blockchain is the next version of sharing economies coming out for total disruption [11]. Ability to do peer-to-peer transactions is going to open more opportunity and benefits for masses. Sharing economies equipped with blockchain have significant advantages for large companies as well. Outsourcing well defined and distributed tasks remove the need for procuring, hiring, and allocating resources. These resources, such as personnel, comes with additional costs such as benefits, insurance, planning, management, and payroll. Changes can further disrupt these complicated systems and replace the intermediary authorities with the help of blockchain technology.

7) Financial model reflection – Value of the features

$$V_{area}\left(\begin{array}{c}Desired\ features\ that\\ blockchain\ implementation\\ brings\end{array}\right)=\sum_{i=1}^{6}(w_i * v_i)$$

$$i=\left\{\begin{array}{c}monetary\ integration, transparency, security,\\ traceability, efficiency, sharing\ economies\end{array}\right\}$$

Fig. 2. Value statement of the desired features of the blockchain

These features are possible to obtain with blockchain implementation. Each feature's corresponding value would be estimated financially based on the use case. Assigning a value to some of these features is harder for some than others. For example, the value of transparency tends to be recognized under other subjects such as reduced conflicts. Some features may not be usable for the target business use case. For example, traceability may apply to identifiable assets more than commodities. Valuation of efficiency, speed, and security is possible with comparisons with alternative solutions. Monetary integration may not be implemented immediately when the project starts. There may be proper cryptocurrency or other financial instruments at the time of blockchain establishment. However, the ability to implement the integration in the future is valuable as well. Smart contracts and cryptocurrencies enable a type of business process integration that is hard to achieve by conventional means. Above all other features, sharing economies is a mega feature that gives businesses an Uber like reach towards involving partners, allocating resources, and tracing operations.

III. COSTS

A. Which costs does blockchain reduce?

Benefits also come in the form of cost reductions. This paper lists the potential cost reductions that organizations can benefit from. Evaluation of each cost reduction opportunity and estimation of the monetary value creates an input to the financial model.

1) Removal of the intermediaries

Systems integration, especially on the international level, is full of intermediaries. For example, the Swift system is an intermediary for more than 10000 institutions in more than 200 countries. Operations in this system depends on the mediators called correspondent banks, as well as the swift system. The intermediaries increment fees. It takes several workdays to complete the transfer with minimum transparency of where the money is at a specific moment. Technologies that intermediaries require can also be proprietary. Each member organization takes on technology implementation cost of technologies that the Swift system requires. There are operational costs, such as transaction fees. Commissions and fees build up as there are more hops in the transfer. Similar cases of intermediaries and related costs exists in supply chain industry where geographically distributed companies conduct business without common standards. The lack of common languages and standards creates a gap in processes and are occasionally filled by third party intermediary companies [12].

2) Streamlining clearinghouse structures and settlement processes

Clearinghouse structures take part in both sides of the trade. Stock trade is a simple example where stock exchange clearinghouse processes deliver money to the seller and stocks to the buyer by receiving it from the other party. Clearinghouses resolve conflicts and simplify the complexity of the market for the participants. Stocks, commodities, and bonds markets may seem simple at their straightforward trading, but each market has their complexities such as options, futures, and derivatives. While their service is valuable for their industry, clearinghouse structures and settlement processes are obvious targets of the new age of disruption.

Peer-to-peer versions of the same businesses are more flexible, innovative, and independent. Since peer-to-peer implementations avoid clearinghouses and intermediaries, these processes save from commissions that intermediaries charge for the provided trust and settlement processes.

3) Reducing settlement time and the time value of money

The time gap between the delivery of goods/services and the issuance of the payment is a risk. Reducing settlement time can reduce the risk. With instant payments, there can be more confidence and willingness for trade. Money in-transit also means cost as there is time-value of the money. For one trade this cost can be negligible, but considering the volume of trades, the lost time-value of money is significant. Instant settlements

both help organizations on the cash flow, and reduce loan interests paid as a result of delayed income.

4) Removing obstacles such as missing documentation

Multiple participants in the business process usually mean multiple inputs, multiple hops, and chain of events as well as incremental information. International shipping of goods needs at least eight pieces of documentation [13]. This requirement means eight pieces of documents that need to be validated, protected, and verified. It also means multiple chances that a document will be missing, and the shipment will stall. Each delay is lost time and money. Perishable goods have even higher risks and preservation costs. Corporations can estimate these costs as they are usually apparent as a loss even when they are not traceable in detail

5) Removing the burden of proof and removing lawyer fees to defend

For business processes that lack single authority or for simple interactions that were designed to be based on trust, at the time of conflict, there is a cost for collecting proof and finding the truth. Most processes continue smooth and optimized when everything happens as expected, and no extraordinary events occur. However, when things go as unexpected, it is hard to know what exactly happened. Authorities who typically control the flow of information are considered to be trustable. Parties use their records as proof when things are unrolling as planned. However, if an authority is responsible for the delay, damage, mishandling, and harm, then the authority's records lose reliability. Blockchains add significant value by carrying an immutable ledger and providing proof of the series of events.

6) Reduction of insurance rates

Insurance companies are stakeholders for almost the majority of actions and activity in the western world. Insurance companies suffer from the inefficient exchange of information, inefficient risk profiling, fraud, and manual processing. Organizations that carry their business on the blockchain based solutions can negotiate better rates as the risk of fraud is less, exchange of information is efficient, fraud detection is easy, liabilities are explicit, data sources are united, and processes are reasonably automated. [14]

7) Financial model reflection – Value of the cost savings

$$V_{area}\begin{pmatrix}\text{Costs that}\\ \text{blockchain}\\ \text{reduce}\\ \text{or remove}\end{pmatrix} = \sum_{i=1}^{6}(w_i * v_i)$$

$$i = \begin{Bmatrix} middleman, settlement, lost\ TVM, \\ obstacles - missing\ docs, evidence\ collection, insurance \end{Bmatrix}$$

Fig. 3. Value statement of the costs reduced or removed by the blockchain

Which of these costs apply to the business, and whether they are reduced or removed in the blockchain solution needs to be identified and accounted for in the financial model? These details depend on the nature of the business.

B. What are other factors and the motivation for implementing a solution?

There are some other factors which are the custom realities of the organization or the solution. Blockchain value estimation must consider the answers to these questions such as whether there are existing systems to be replaced, whether the human resources are ready for the technology, whether the laws and regulations are for or against the blockchain based solution, and whether the industry members sharing a motivation are essential drivers and parameters.

1) Existing systems in place.

If there is a system in place for the business, there will be additional costs for system replacement. Migration of old records to the new blockchain solution, migration of participants to the new integration points, potentially running both systems side-by-side for a period and decommissioning old systems are typical costs.

2) Uncomplying partners

There is a risk that some collaborating parties would not or cannot integrate with the blockchain solution. Developing adaptors for these parties will eliminate the risk but introduces more development, testing, and operational costs.

3) The pain of change - Starting a new business on a new technology

If the blockchain based business model is new for the corporation, there is a risk that the design of the new solution on the blockchain model will have incompatibilities. It will need iterative processes, multiple implementations, and improvements before the system to work at its ideal performance.

Corporations also should not underestimate the impact of transparency on their people. Having all activities on the transparent and permanent database may make the workforce feel getting on more liabilities. Transparency makes people obey the rules and avoid acting outside of them even if there is a benefit for the customer with a small bend of the rules. This inflexibility may be for or against the business model, especially from customer satisfaction and exception handling angles.

4) Compliance with laws and regulation.

If there are regulations that blockchain solution can comply more efficiently, it would be a great motivation for using the technology. For example, if the Canada Deposit Insurance Corporation (CDIC) would require the financial institutions to integrate into a blockchain system to collaborate and communicate, not complying may result in penalties.

5) Industry trends

If an industry is migrating to a blockchain solution for collaboration between the member businesses, there would be extra motivation with added benefits on standardization. If all banks are sharing customer information on a blockchain, every bank will try to join for providing the potential advantages to their clients.

6) Financial model reflection – Other factors

$$V_{area}\ (\text{Other factors}) = \sum_{i=1}^{5}(w_i * v_i)$$

$$i = \begin{Bmatrix} Legacy\ systems, uncomplying\ partners, pain\ of\ change, \\ laws\ and\ regulations, industry\ trends \end{Bmatrix}$$

Fig. 4. Value statement of other factors

These factors are the most challenging to quantify. If there are legacy systems, or if business partners are not willing to join a blockchain solution or company human resources are feeling

blockchain as a threat, there would be resistance and costs. There can be a veto or resistance against these new principles introduced by the blockchain technology. Laws, regulations, or industry trends towards blockchain would be positive motivation and increased perceived value.

C. *What is the cost of implementing or operating a blockchain solution?*

Previous sections in this paper list the fundamental motivations, related benefits, and costs as the perceived values for the benefits and estimated cost reductions are significant drivers for change. This section will detail the cost of procuring the blockchain solution and listing the operating expenses.

1) Public vs. permissioned/private blockchains are different in their operational requirements

Public blockchains allow any participant to join the blockchain and take part in the block creation and consensus. Since the participants are not authenticated and limited, there is an open and limitless race to create the new block. In order to have only one winner of this race, there are consensus mechanisms that blockchain networks employ. Proof of Work (PoW) is the most well-known mechanism that forces the block creator to solve a cryptographic puzzle before broadcasting the new block. Bitcoin cryptocurrency uses this mechanism, and it is infamous for the amount of wasted energy. Some would argue that as long as the overall system is healthy, energy lost in the competition is not a waste. Others are especially worried if one blockchain can lose an amount of energy as high as the consumption of a developed nation, what would be the consumption if there would be a lot more public blockchains. Proof of Stake (PoS) is another mechanism that distributes the responsibilities of block creation with the weight of the stake one has in the system assuming that more stake one holds, more it would protect the system. PoS and other lower energy consuming mechanisms are emerging. PoW is still the most reliable mechanism, and most valuable public blockchains use it.

Public blockchains with PoW requires much processing power and energy for infrastructure to support that processing. If one decides to join such blockchains and take an active role such as block creation, it will require extensive computing infrastructure and will be reflected in the electricity bill as well. If a participant is only interested in issuing transactions, even if the public blockchain is using PoW, this participant does not need to do mining. There would be other mining nodes doing mining for the incentives.

2) Cost of participating in a blockchain

There is no strict definition of being a part of a blockchain. Also depending on the blockchain type and volume of transactions, requirements would change. Assuming the target project already has the remaining infrastructure, blockchain related additional infrastructure is limited to becoming a full node. A full node has and receives all the transactions and blocks. It is possible to refer to the Bitcoin network for estimation of the cost and estimate on the similarity to infrastructure requirements of bitcoin full-nodes [15]. These requirements are a desktop or laptop with an updated version of its operating system, 200GB free disk space, 2GB RAM, and faster than 50KB internet connection. These are relatively simple requirements that are possible to procure at less than $1000. There are several resources where the cost of running a full node is reported to be less than $100/month [16].

Permissioned blockchains are implementations where at least the fundamental operations on the blockchain are restricted to some authenticated participants. If participation is completely restricted, they are also called private blockchains. Authenticating clients for blockchain access also enables authorization and allows assigning different roles to participants in the blockchain ecosystem. One of the most critical roles is the block creator. This vital role can be restricted to the more trusted parties in the blockchain. Cost of running a permissioned blockchain is low. Amazon web services have some pricing for the hosted blockchain services. The prices from this vendor can be a benchmark where there is no other infrastructure cost. For a HyperLedger blockchain, the price of running two nodes is estimated to be less than $2/hour for a production network. Procuring a test network costs approximately 30% of the price of a production network.

These costs of a simple infrastructure based on commodity hardware can be considered low compared to expenses in most projects where the scope includes a complete standalone infrastructure. Blockchain software can run on various platforms. Therefore, hosting decisions are mainly related to the infrastructure policies of organizations. If policies direct running the blockchain software on specific infrastructure such as on legacy platforms like mainframes, there would be a much higher entry cost for the project.

3) Do you need new hardware? Are the technologies involved demanding more processing power?

Whether the infrastructure of an organization consists of a mainframe or a network of servers, it can run blockchain applications on the existing infrastructure. Base applications are not resource-intensive. Contrary to what is reflected in some resources [17], cryptographic requirements involved in being a blockchain node (not a miner) is not new and is not more than previous systems with security layers such as two-way-SSL and digital signatures in SAML assertions. The volume of the inpouring data is determinant for storage space. Depending on what blockchain contribute to the solution, all the records can be accessible all the time or space can be saved by pruning the old states of each asset that is updated with newer versions of information and state added to the chain. Blockchain participant systems may also extract the information from the blockchain and send it to other systems as streams. This method provides capabilities to browse the history of records offline, and the blockchain node may not need to access the old records other than its validation tasks.

4) Financial model reflection – Cost of implementation and operations

$$V_{area}\ (\text{Other factors}) = \sum_{i=1}^{3} (w_i * v_i)$$

$$i = \left\{ \begin{matrix} Public\ blockchain\ participation\ and\ PoW, \\ private\ blockchain\ participation, hardware \end{matrix} \right\}$$

Fig. 5. Value statement of implementation and operational costs

Implementation and operation costs are most quantifiable items in the financial model. They are highly related to the nonfunctional requirements such as the volume of data, designed scalability, number of transactions, and number of nodes per participant. Whether mining activity is necessary or not is the most significant factor, as discussed above.

IV. Financial Model

Below is the general financial model that is a combination of all the factors listed above. The process of evaluation starts with identifying whether these factors apply to the target business process. Some solutions may not apply to all businesses. Deciding whether features are relevant and whether listed cost savings are applicable would draw the financial scope of the solution.

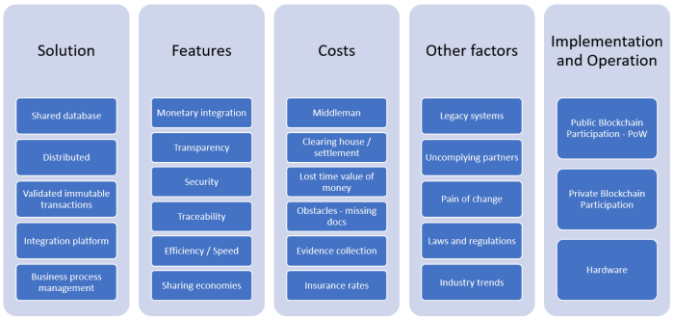

Fig. 6. Consolidated financial model chart

A. *Details of the financial model*

Even though the groups are created by bundling similar subjects based on how they factor in overall finance of the solution, some items may have an adverse behavior. For example, if the provided transparency requires further data protection measures, the cost can be reflected as a negative value on that item.

In this model, colors are used to mark the factors. Blue is the neutral color. Neutral factors are factors that do not have a significant benefit. When a factor is significant positive value on the favor of the blockchain solution, green color marks it. Red color marks negative factors.

There are multiple ways to conclude the evaluation. Initial assessment would be over the benefits vs. costs. If the green colors are dominant on the presentation, it is a positive sign for blockchain utilization in the solution. Rare cases of green factors would mean limited benefits. Similarly, a red-dominated model would mean there are several costs and should be recognized as a mismatch or as a warning on the bottom line.

After this identification of significant factors and color identification of their impact, quantification of each item and cumulation of the results should follow. Quantification can continue with the estimation of value, cost, risk, or opportunity. Sum of all values for all factors should provide overall value to consider the result of the financial model.

B. *Use case - High Volume Package Delivery*

Our use case to demonstrate our financial evaluation framework is the high-volume package delivery. In this use case, we are evaluating the blockchain technology implementation in a package delivery business. This use case assumes the company is targeting to grow their business and reduce costs.

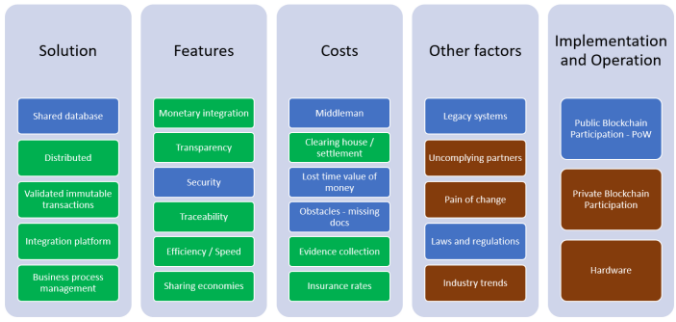

Fig. 7. Consolidated financial model chart for high volume package delivery

The assessment starts with a review of each framework factor and identifying whether it is a positive, negative, or neutral factor. The next step is to quantify the non-neutral items, and the cumulative numbers would suggest whether this solution is a "better" solution.

In this use case, the entire delivery resource network as well as other stakeholder business entities will share the blockchain platform. The distributed architecture of blockchains will bring the advantage of high availability. Any node in the network, including the nodes that represent the most significant business entities, is not a single point of failure. The system will continue functioning even if some nodes are down. Blockchain is a validated immutable transaction platform for this use case that will collect the sensor information in order to mark status and delivery events in each delivery task. It will also be an integration platform between the parent company and other contributors such as sub-contractors. Each contributor can run their part of the business processes on the blockchain while the standard processes that can benefit all will also reside on the blockchain.

Monetary integration adds payments processing capability as part of the business transactions. Compensation of workforce and sub-contractors will be processed in real time within the blockchain transactions. This model would work with cryptocurrencies perfectly however when it is not possible to use digital money, fiat currency payments can be recorded in this system. This would bring traceability to the payment. This blockchain solution can be a gateway to sharing economies on parcel distribution business where people who has access capacity help with individual tasks. Students in their free time can deliver parcels and get an instant compensation for their help. With the transparency and traceability that blockchain technology provides, the involvement of external parties can be traced by themselves and by the business process owners. There will be several ways to collect data, and with the evidence quality immutable transactions of the blockchain, finding proof will no longer be a burden. Peer-to-peer interactions would increase efficiencies. Newly introduced parallelism with shared economies can deliver the packages in much improved average end-to-end timelines.

Current practice of collecting mission data and bulk data uploads of the events in to the system would be eliminated. Blockchain solution is superior as at any time it will serve the

latest state of tasks. In case there is a dispute, blockchain will have an undeniable trail of evidence. If more participants are added to the blockchain such as the IoT devices at homes and perhaps homeowners' mobile devices, there would be even more events and evidence of delivery. Since the sensor data is recorded as well as all delivery events including the chain of custody, when disputes happen, the blockchain would provide enough information to analyze and detect the responsible entities. The risks in loss and damage are expected to fall or would be precisely identified, which may result in reduced insurance premiums.

There are some obstacles to the implementation as well. Blockchain implementations, in general, suffer from not reaching the tipping point on the acceptance. If the partners and subcontractors of the delivery business do not accept the idea and do not comply with the new rules, there can be an adverse effect and perhaps loss of partners. The delivery personnel may also be negative on the extreme traceability idea as they are the ones being closely monitored. Their mistakes would be exposed quickly. Industry trends currently are favoring the monopolies and closed systems for the delivery companies due to economies of scale and privacy aspects of business. Openness and collaboration that blockchain brings may not be the industry direction in short term. However, industry may change with foreseen value.

A private blockchain infrastructure would be created for this solution. Even though the cost of private blockchains is less than public blockchains, there would be an initial cost that need calculation. Technical unknowns such as how IoT devices would be connected to the blockchain require more research.

Without the details of the business environment and quantification of the values, we can only comment on the estimated importance and value of the factors. We believe the number of green factors indicate the excellent opportunity to apply new techniques and improve the business. There are several benefits listed with many cost-cutting opportunities. The strategic benefits of the sharing economies and traceability are far higher than the cost of implementation. Operational benefits of distributed systems such as high availability despite the loss of some significant systems are also invaluable.

V. Conclusion

Blockchain technology had been a popular subject. Despite numerous ideas, use cases and research in the literature, financial aspects of blockchain implementations had not been analyzed methodically.

In this paper, we provide a novel framework that evaluates different aspects of the blockchain project. Our framework results in a set of formulations that will detail the overall financial model. Since the value of each detail depends on the project details, it is not possible to calculate a resulting monetary amount. However, following the framework, the evaluator will find enough guidance to accomplish the assessment task while covering all aspects of cost/value brought by the implementation. We demonstrated this by applying the framework on high volume package delivery use case.

Next steps in our research include automation of this framework by creating a questionnaire. This automation will enable us in applying and testing the framework with a wide variety of real-world use cases.

VI. References

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