A Methodological Analysis of Blockchain-Based Smart Contracts in International Trade

Asif Bhat[1], Rizal Mohd Nor[1], Md Amiruzzaman[2], Md. Rajibul Islam[3]
[1]Kulliyah of Information and Communication Technology International Islamic University Malaysia Kuala Lumpur, Malaysia
[2]Department of Computer Science, West Chester University, PA, USA
[3]Department of Computer Science and Engineering University of Asia Pacific
bhatasif.17@gmail.com

Abstract. When trustworthy computing is necessary, several applications use blockchain. Trade finance is one of these fields that might greatly benefit from a decentralized method of conducting transactions. This study gives the first evaluation of Accepire-BT, a software platform designed for the practice of collaborative Trade Finance. Smart contracts enforce the suggested solution using Solidity, the core programming language of the Ethereum blockchain. Remix and MetaMask were used to assess the performance of the Rinkeby test network. Per cycle, smart contracts need less than one minute, according to the findings of the early test. Also included is a discussion of the fees associated with using the public Ethereum Rinkeby network.

Keywords— Trade Finance, Blockchain, Smart Contracts.

I. Introduction

Recent articles [1-3] examine the role blockchain technology plays in company operations, cultural issues, and other disciplines, such as international trade, which has been the subject of much controversy. This article examines international trade, corporate procedures, and paper-based market activities. Paper-based market activities include exchanges of information, assets, and products and a payment sequence to simplify trade financing. Historically, a centralized Letter of Credit (L/C) payment system has been a source of legitimacy and authority for business partners. However, system speed, processing performance, and vulnerability to malicious modifications are significant drawbacks [2-3].

As one of the most effective means of assuring the continuation of the reproductive process, the introduction of diverse, innovative techniques in trade finance will address present economic issues. Consequently, the inaccessibility of trade credit to refill small and medium-sized businesses' operating cash is often felt keenly. One of the few factors is a lack of appropriate tools to clarify and alleviate asymmetrical knowledge concerns. In addition, the growth of trade finance faces several additional obstacles, chief among which is the dynamism of the number of transactions associated with trade financing. External variables such as interest rates and regulatory changes, as well as internal constraints such as regional capital and the requirement for depreciation, influence system development [2]. Second, it is challenging to implement trade finance in the global supply chain. Implementation takes substantial vendor efforts and careful integration with the organization's financial, purchasing, and IT departments. Thirdly, it is difficult for participants to get rewards. Suppliers, customers, and financiers are independent decision-makers who seek to maximize revenue considering unequal systems, costs, and uncertainties. These autonomous profit maximizations also result in poor supply chain output.

This article presents the lessons learned from the prototype implementation of blockchain technology in a trade finance framework. We implemented the prototype on the Ethereum blockchain. The critical contribution of this paper is the methodology and analysis of blockchain-based smart contracts in trade finance, as well as a discussion of how blockchain and comparable smart contract technologies may simplify corporate operations. Additionally, the significance of smart contracts in improving trade finance operations is investigated, and the value they provide in procedure redesign. Utilizing the test network (Rinkeby), which is now one of the most prominent blockchains, including smart contracts, performance was evaluated. Additionally, we assess the associated financial costs. In addition, the study was organized utilizing a Design Science Research (DSR) framework analogous according to [4], in which the critical concept of design science is the artifact: an object with physical or social characteristics.

A. *Problem Statement*

Trusting computing is an essential requirement of trade finance, and blockchain-based smart contract technology can fulfill the requirement. However, there are different approaches available in the blockchain-based smart contract domain. Therefore, there is a need for an appropriate evaluation technique to analyze and evaluate which type is suitable for trade finance-related transactions. This provides a methodology to analyze the blockchain-based smart contracts for international trade finance.

Following is a description of the structure of this work: Section II provides the literature study on smart contracts, Section III details the methodology used, and Section IV contains the results of the experiments conducted. The Data and Preliminary Results are discussed in Section V. Section VI closes the document.

II. LITERATURE REVIEW

With regard to forgeries as well as other security risks, conventional paper-based trading has its own challenges. Banks then embraced SWIFT communications and began digitizing paper-based documentation; however, this did not substantially disrupt the game. Current systems still have security vulnerabilities such as trade document confidentiality and privacy, unauthorized modifications, and credibility difficulties [5]. Other methods of obtaining a secure system are more expensive and require the presence of several third parties. Nakamoto developed blockchain as a public distributed ledger for the cryptocurrency bitcoin, which is typically handled through a peer-to-peer network [6]. Since 2008, this technology has advanced significantly, and a second-generation blockchain has been proposed by Buterin, which lets users to create very complicated smart contracts, like bills that pay themselves when a product arrives. Once confirmed, transactions on the blockchain become irrevocable, secure, permanent, and verifiable [7]. With the use of smart contracts, the blockchain may now be used to run and control decentralized systems, just as it was used to introduce a unique way of creating and trading money over the internet [8]. Blockchain technology was used by Reference [9] to develop supply chain finance, which is a subset of trade finance. Even if the technology could not completely replace the present financial environment right once, its overall effects could be both transformative and harmful.

Before Bitcoin and blockchain, the term "smart contract" existed. Szabo [10] defined a smart contract as a computerized transaction protocol that meets contractual constraints for payment, secrecy, or compliance, decreases the need for trusted intermediaries, and minimizes exceptions. For instance, he proposed digital currency protocols. This method enables online payments with the properties of paper cash while addressing divisibility and secrecy as an example of a smart contract. Later, Szabo [11] defined intelligent contracts as "the mix of protocols and user interfaces to enable organized and secure network interactions." The design of these institutions is based on their legal, economic, and technical underpinnings. Consequently, smart contracts need inter-disciplinary study. Depending on a variety of factors, the quality and utility of smart contracts in legally enforceable contracts might vary to varying degrees:

- An essential computer program that does not represent a legal contract but instead implements a specified logic.
- Computer code having certain legal qualities, i.e., a program based on legal structures with a predetermined logic that is intended to function in a particular manner; or
- Execution (in part) by computer code of a legal person (e.g., a contract) in which the computer code mimics the legal person.

Improving software and using blockchain technology are significant aspects and development goals for addressing these challenges with trade finance instruments. Through process automation and partnerships throughout the supply chain, these blockchain technologies allow businesses to unify and accelerate documentation and cash flow inside the supply chain [2].

Decentralizing running business networks will enhance accountability, real-time monitoring, and trustless player transactions [3]. Moreover, Ping IoT devices will enhance Accepire-BT's capacity to offer supply chain traceability and transaction transparency. Smart contracts are deployed to execute event-based contract conditions and agreements, such as Sales Contracts, Financial Contracts, Letter of Credit Contracts, Shipment Initiated Contracts, Shipment Received Contracts, Payment Contracts, etc., which are essential to the execution of a Trade Finance transaction. The application of blockchain in various transaction types is described in the following paragraphs.

Artifacts might include software, models, and norms, among others. The authors in [11] conceived design science research within information systems (IS) research with the integration of the following three dimensions:

- The environment, which includes people, technology, and organizations.
- The IS research that pinpoints the development and justification of artifacts; and
- The knowledge base provides the foundations and methodology to be employed in developing and assessing artifacts.

III. METHODOLOGY

We will use three-cycle [12] perspective for this investigation. This section discusses the development phases and highlights the need to assess the artifact and its commitment to the environment and knowledge base. We consider this the most suitable and relevant model for constructing the prototype for our study. As emphasized in research methodology, it is crucial to demonstrate the study's originality [12]. As seen in Fig. I, the framework comprises three significant development phases: Relevance Cycle, Rigor Cycle, and the Design cycle. Each of these phases is comprised of several components. The application of the model is shown in figure 1. This is represented by the numerous stages in each cycle of the model.

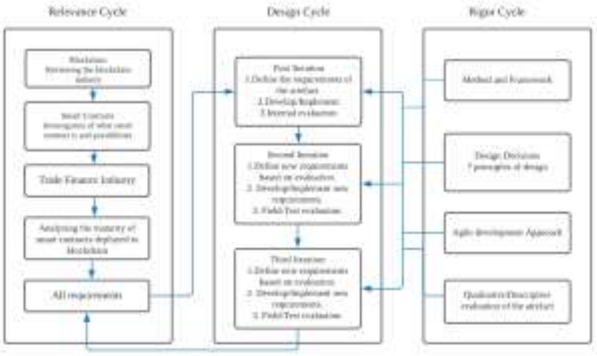

Fig. 1 Overview of the three cycles applied in this research.

A. *Relevance Cycle*

The relevance cycle focuses on two distinct elements. The first section identifies the pieces necessary to construct a solution and define a problem [13]. Our study's relevance cycle is comprised of three aspects of our literature research: a review of blockchain technology, smart contracts, and the present business model of the trade finance sector. Determining the artifact's construction needs is the second step in our relevance cycle. There are two components to this phase. First, we understand how the deployment of smart contracts on the blockchain works, and then we apply the relevance cycle by merging the various aspects.

B. *Design Cycle*

Using the rigor cycle's frameworks, we create the artifact during the design phase. We evaluate the item against the relevance cycle's prerequisites. After each development phase, we employ the assessment process established in the rigor cycle to analyze and determine the next iteration's requirements [14].

C. *Rigor Cycle*

The rigor cycle of this research comprises the methodological framework, the design choices, and the qualitative and descriptive assessment of the item [15]. This study uses design science research as its methodological framework and, as indicated, employs the three-cycle design perspective [12] to construct the artifact. The rigor adds to both the development cycle's structure and design choices [16]. In this phase, the assessment methodologies for the design cycle are introduced. These assessments will serve as the foundation for the subsequent iteration [17].

1) *Data Gathering*

Our study focuses primarily on qualitative data research, the evaluation of methodological research, and frameworks. The preferred framework three-view design cycle [1] is used to construct a prototype. Due to the novelty and innovation of the technology, the theory employed in this work is acquired qualitatively from a few sources. An extensive study of publications, websites, and books about blockchain technology was used to compile the collected data.

The present design will be evaluated through each iteration of the design cycle. The authors in [1] also cite this as a crucial and essential aspect of design science study. We will evaluate the prototype in numerous ways throughout the design cycle.

In this investigation, there will be three iterations. According to [6], the authors will conduct an internal evaluation of the first iteration utilizing functional black-box testing. The potential of blockchain technology, which will be explored in the initial development phase, will be discussed.

The second and third iterations are evaluated using a scenario assessment technique [18]. The second step of assessment is the first iteration tested in the field. We will conduct in-depth interviews with trade finance sector professionals. We will have a better understanding of the trade financing procedures through the responses to each of the interviews. Considering the specialists' suggestions, we will adjust our prototype. The third iteration will include the essential lessons from the second iteration and will be re-evaluated by both the evaluators from the second iteration and new evaluators. This will guarantee that we have both fresh eyes on the artifact and confirmation from prior iteration users that the latest design solution has resolved past assessment difficulties. The individuals who will test our prototype are located via our network of individuals with primary trade finance expertise. This should generate further thoughts and ideas, which we will then evaluate.

Multiple areas of trade finance are enhanced by blockchain technology. This study examined the effect of blockchain-based trade finance, focusing on the L/C payment process. Thereby focusing on six major dimensions of the blockchain: transparency, (ii) information transmission, (iii) traceability, (iv) cost, (v) disintermediation, and (vi) the incorporation of the Internet of Things.

Cost is one of the most important aspects of supporting procedures for L/C financing. Companies have committed large amounts in cross-border transactions to reduce administrative data associated with international commerce. In other payment methods, such as inter-company trade credit, handoffs across shipping channels have reduced process flow efficiency and weakened corporate competitiveness. In contrast to current payment methods, the blockchain will simplify and reduce the cost of business transactions.

The primary rationale is that centralized service providers are less expensive. The elimination of paperwork compensates for significant global trade-related cost reductions. With its unchangeable shared record, the blockchain guarantees considerable cost reductions. Additionally, manual paper-based procedures are drastically reduced, minimizing the time and labor required to handle papers. The instance of Maersk provided practitioners with confidence in how electronic assets and records are transported across borders [1]. From the standpoint of transaction cost economics, blockchain implementations often leverage their potential to lower associated costs, such as those linked to search, negotiation and policing.

Following this section, the migration costs and transaction fees for each smart contract implemented in a trade finance transaction are established.

IV. EXPERIMENT

The following technological decisions are made to implement our Ethereum smart contracts written in the Solidity programming language. This section explains the methods used to implement our trade finance-specific smart contracts.

1) *Experiment Setup*

The Remix is a browser-based Integrated Development Environment (IDE) for designing, executing, and debugging smart contracts. It is managed and developed by the Ethereum foundation. Remix allows Solidity developers to build smart contracts without a dedicated development environment since the web interface has all the necessary components. It simplifies the interaction with deployed contracts without requiring a command-line interface.

Graphical User Interface (GUI) plugins are abundant in Remix, facilitating a rapid development cycle. This study employs The Remix across the whole contract preparation process. It is a robust open-source framework for developing browser-based solidity contracts. It is designed in JavaScript and supports browser use, browser usage with local execution, and desktop editions. Remix IDE contains modules for, among other things, testing, debugging, and deploying smart contracts.

Solidity is the language used to build smart contracts. Solidity is a high-level, object-oriented programming language for creating smart contracts. Smart contracts are known to manage Ethereum State accounts' behavior. Solidity is designed for Ethereum Virtual Machine and is inspired by C++, Python, and JavaScript (EVM). Solidity is statically typed and provides, among other things, libraries, inheritance, and sophisticated user-defined types. In this study, version 0.7.5 of Solidity is utilized.

We choose a decentralized file storage strategy, implying there should be no local databases or dispersed data centers. This is one of the major differences between a centralized, or distributed data storage design as the data stored is controlled by a single entity. In our case, there is no single control of transactions as well as the data being stored, including files used in the transactions. This is where IPFS platform comes into play where there is no layer in our system that are centralized, not even the data storage. By hosting files on IPFS, the file storage component of our artifact is decentralized. Obviously, before adopting this, some technical considerations must be taken, such as ensuring that only the appropriate individuals can view the information. Note that while IPFS is a decentralized method of keeping files, it does not enforce any form of security in viewing the files. This is where a combination with blockchain can add value as encryption can be done via private keys held on individual wallets. Hence the issue of authentication is self-maintained by each user and files can be encrypted using each decentralized wallet. The IPFS is a network and protocol intended to offer peer-to-peer storage and sharing mechanism for content-addressable files in a distributed file system. IPFS, like Torrent, lets users both receive and host material. A decentralized system is meant for user operators who possess a portion of the total data to develop and distribute a robust file storage system instead of a centrally hosted server. IPFS provides a paradigm for content-addressed, high-performance block storage with content hyperlinks. This is a simplified Merkle DAG, a data structure that allows for constructing versioned file systems, blockchains, and a permanent web. IPFS authenticates itself through a hash table, a block exchange, and a namespace. There is no single point of failure, and nodes are not required to have mutual trust [14]. IPFS is decentralized like a blockchain, and security is guaranteed by the IPFS "link" that produces uniquely each time a document is modified.

MetaMask is used to test smart contracts in this research. MetaMask was created in response to the need for Ethereum-based websites that are both safe and accessible. It regulates account management and links the user to the distributed ledger. It's used to test smart contracts and interfaces with Remix. If EPR systems need short-message communication, the Whisper protocol is used.

1) *Deploying Smart Contracts*

In our experiment, we established the three smart contracts shown in Fig. 2: sales, finance, and letter of credit.

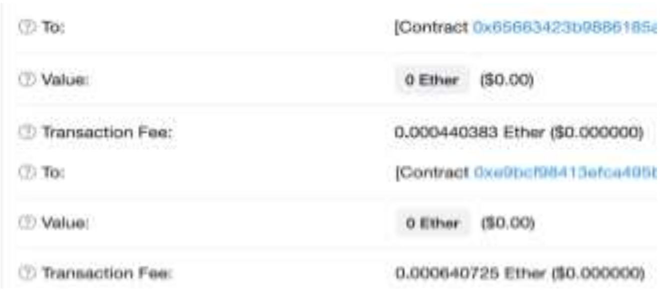

Fig. 2 The Sales, Financial, and Letter of Credit Smart Contract deployed on the Rinkeby Ethereum Test Network with corresponding transaction fees.

A smart contract instance must be distributed on the network before triggering it. These contracts incur a one-time payment for deployment. The total cost of migration for all three contracts is 0.00138554 + 0.000440383 + 0.0006407250 ETH, or about $1,358 (1 ETH = $550.75 USD).

V. Results

To estimate the cost of each implementation, the Ethereum Solidity Code's Remix, MetaMask, and Rinkeby Test Networks were used to compute each method's transaction fee. When a function is executed, the Remix console records the transaction cost.

1) Gas Cost

The gas price at the time of this study was 0.000000001 ETH (1 ETH = 550.75 USD), and the transaction volume per second was 15 TPS. The formula for calculating the transaction fee is shown below in equation (1) where tc = transaction cost, n =number of characters, gc = gas per character > 0, gp (gas price) = 0.000000001 ETH and tf = transaction fee.

$$\left(t_c + (n * g_c)\right) * g_p = t_f \qquad (1)$$

TABLE I

CONTRACT, FUNCTIONS, AND ASSOCIATED COST

Contract	function	Trans Cost	Gas Price (ETH)	Trans Fee (ETH)	*Cost (USD)
Sales	setSalesContract	106384	1E-09	0.00010638	0.06
	**addOrder	176983	1E-09	0.00017698	0.10
	createInvoice	109016	1E-09	0.00010902	0.06
	confirmInvoice	43758	1E-09	4.3758E-05	0.02
	confirmOrder	47653	1E-09	4.7653E-05	0.03
	orderExists	0	1E-09	0	0.00
	cancelOrder	45495	1E-09	4.5495E-05	0.03
	receiveOrder	43734	1E-09	4.3734E-05	0.02
Financial	setFinancialAgreementParties	127510	1E-09	0.00012751	0.07
	confirmAgreement	44678	1E-09	4.4678E-05	0.02
Letter of Credit	initializeContract	169459	1E-09	0.00016946	0.06
	addDocument	68518	1E-09	0.000177	0.10
	getNumberOfDocuments	0	1E-09	0	0.00
	getDocumentID	0	1E-09	0	0.00
	IsDocumentValid	0	1E-09	0	0.00
	validateDocument	45242	1E-09	4.5242E-05	0.02

The costs associated with each function call have been compiled and are shown in Table 1. To the next decimal place, the price for total calls to sales functions is about $0.31, the cost for financial services is approximately $0.09, and the cost for Letter of Credit functions is roughly $0.22. Due to the usage of variable-length strings, some functions do not have a fixed cost. This is notably true for the Table 1 function **addOrder, which relies on an order's size. The cost of certain functions is zero since they do not handle any data and merely return a result.

VI. Discussion

Every node must process all transactions, and the whole state of every account balance, contract code, and storage must be saved, etc., which is one of Ethereum's most prominent scalability issues [13-16]. Although this provides a high level of security, scalability is so severely limited that a blockchain cannot process more transactions than a single node [21].

The development of a new system in which a restricted number of nodes are required to evaluate just a part of transactions is a potential solution to this problem. If there are sufficient nodes to validate each transaction, the system will stay safe while also being able to perform transactions in parallel. This method is called sharding [22]. The fundamental concept underpinning sharding is the division of the global state of accounts, including external and contract accounts, into smaller units known as shards [23].

In more advanced forms of sharding, transactions may also affect other shards and request data concurrently from the state of many shards. Each shard receives its own set of validators, and not all shards need validation by these validators [24].

Using a tweaked version of the GHOST protocol and a quicker block time, Ethereum eliminated most security losses. However, the blocks must still propagate over the network, a somewhat lengthy process. For more transient propagation, the block size must be reduced, so Ethereum can only handle roughly 15 TPS despite a block time as short as 15 seconds.

Ethereum is Turing-Complete, and the network must handle random data processing activities and likely store vast amounts of data. In contrast to Bitcoin, Ethereum is thus developing the most promising scalability solutions [26].

Using IoT devices referred to as Ping Assets [27] in combination with a decentralized oracle referred to as ChainLink [28], Accepire-BT guarantees transparency, reliability, and traceability.

We claim that the smart contract alone will not address all the difficulties in the supply chain, but it will help ensure transparency and combat fraud in secure transactions. The technology has not yet attained its full potential, but research is ongoing to make it more effective.

VII. CONCLUSION

This study introduces a blockchain-enabled trade finance model and examines smart contracts. Using smart contracts to regulate trade finance enables transparent and automated actions that direct stakeholder participation. Blockchain's trade finance may provide answers for fraud, confidence, audibility, accountability, processing time, and expense. With the use of blockchain platforms like Accepire-BT, it is possible to assert that the mechanism of traditional trading may be expedited and improved. With the security characteristics offered by blockchain technology, it can establish trust across networks. It preserves the integrity of the shared information and facilitates process tracking. To secure the validity of international commerce, it is necessary to implement several rules and standards. Using blockchain may improve the auditability of international trade and significantly simplify the purpose of safeguarding society and the economy. In conclusion, we assert that blockchain will bring about profound changes in international commerce and trade financing.

A proof-of-concept outlining the implementation of the blockchain-powered trade finance model in Ethereum using Solidity will be published in future work. In addition, we may verify the model further by adding practitioners into our research process. Before a particular smart contract can be incorporated into a live blockchain, it must be optimized for network and transaction costs.

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