Validation of a Supply Chain Innovation System Based on Blockchain Technology

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Abstract*—Technologies play a pivotal role in achieving competitive advantage and operational efficiency. This paper explores the transformative potential of blockchain technology within the context of supply chain operations. While the theoretical promise of blockchain as a secure, transparent, and decentralized transaction recording system is undeniable, practical adoption in supply chain systems remains ensnared in skepticism and caution. In the dynamic field of global supply chain management, the adoption of cutting-edge technologies is critical for securing a competitive edge and enhancing operational efficiencies. This paper delves into the revolutionary impact of blockchain technology on supply chain operations, acknowledging its theoretical benefits as a secure, transparent, and decentralized system for recording transactions. However, it also notes the cautious approach towards its practical implementation within supply chains due to prevailing skepticism. This investigation aims to unravel the efficacy of blockchain in enhancing security, efficiency, accuracy, and cost-effectiveness within supply chain systems. By bridging theoretical aspirations with practical realities, this study sheds light on both the advantages and constraints of incorporating blockchain into supply chain management. The application of a blockchain-based system in this research demonstrates significant enhancements in supply chain processes and supplier selection within a decentralized framework. Key performance indicators underscore the system's robustness and utility. Furthermore, the deployment of smart contracts, facilitating automatic verification of data modifications and access rights, underscores the platform's capability in handling diverse operations. Despite ongoing concerns regarding blockchain's performance and scalability, this study observes a positive trend towards overcoming these challenges. the findings contribute to the growing body of knowledge on blockchain technology, marking a significant leap forward in its application within the realm of supply chain management.

Keywords*—Supply chain management; blockchain technologies; traceability; security validation; business validation

I. Introduction

In the evolving landscape of global supply chain management, the integration of innovative technologies stands as a cornerstone for competitive advantage and operational efficiency. As outlined in the previous chapters, the potential of blockchain technology to transform the very foundation of supply chain operations has garnered significant attention. Its promise of a secure, transparent, and decentralized system for recording transactions is undeniably groundbreaking. Yet, while the theoretical advantages of blockchain are aplenty, its practical adoption into the supply chain systems remains mired in skepticism and caution [1,2].

This skepticism, as discussed earlier, stems from several key shortcomings regarding the reliability, scalability, and cost-effectiveness of blockchain-based supply chain systems. Traditional supply chains, while not without flaws, have established reliability and familiarity that blockchain systems must surpass to be considered viable. Concerns about the high computational costs, the energy consumption associated with blockchain operations, and the integration complexity with existing systems further exacerbate these doubts [3,4] Additionally, scalability issues pose a significant hurdle, as the current blockchain technology may struggle to handle the vast number of transactions typical in global supply chains efficiently [5].

he importance of addressing these concerns lies in the transformative potential blockchain holds for enhancing transparency, reducing fraud, and improving traceability within supply chains [6]. If these technological and practical barriers can be overcome, blockchain could herald a new era of efficiency and security in supply chain management.

Historically, attempts to integrate blockchain into supply chains have been limited by a few critical factors. Previous solutions often failed to provide a balanced approach that sufficiently addressed both performance and cost-effectiveness [7]. Moreover, many proposed models lacked the necessary scalability to support large-scale operations, making them impractical for widespread adoption [8]. This paper aims to differentiate itself by presenting a novel approach that prioritizes these aspects, proposing a blockchain-based supply chain system designed to optimize security, efficiency, accuracy, and cost-effectiveness.

The key components of this approach include a comprehensive analysis of current blockchain capabilities, empirical validation through real-world case studies, and a detailed exploration of methodological frameworks that can support scalable and sustainable integration. Specific limitations of this study, such as the focus on industries and the constraints of current blockchain technology, will also be discussed to provide a balanced perspective [9,10,11]. By bridging the gap between theory and practice, this chapter aims to provide a holistic understanding of the feasibility and viability of blockchain's role in future supply chain innovations. The subsequent sections will navigate through empirical studies, methodological approaches, and real-world case analyses, ensuring a comprehensive validation of

blockchain's potential in revolutionizing supply chain operations.

II. Literature Review

A. Operability of Python Program for Supplier Selection in Blockchain-based Systems

The integration of Python programs for supplier selection within blockchain-based supply chain systems has been a subject of research interest. A Python-based algorithm for supplier evaluation, emphasizing its adaptability within blockchain frameworks [12]. This approach streamlines supplier selection processes, enhancing transparency and traceability in procurement activities [12].

While Python programs offer flexibility, challenges in operability exist. A relevant study [13] highlights the need for standardized interfaces to ensure seamless integration with blockchain platforms. Additionally, another study discusses the importance of considering diverse supply chain environments, suggesting that customizable Python modules may enhance adaptability across different industry sectors [14].

B. Validity and Performance Evaluation of Blockchain-based Supply Chain Systems

Security remains a paramount concern in blockchain-based supply chain systems. The author in [15] examines the cryptographic aspects of blockchain, emphasizing the role of smart contracts in ensuring the validity and integrity of transactions. However, [16] argues that the human factor in smart contract execution may introduce vulnerabilities, necessitating continuous validation protocols.

Evaluating the performance of blockchain-based supply chain systems involves assessing various metrics. The author in [17] proposes a comprehensive framework encompassing transaction speed, consensus mechanisms, and data integrity. The author in [18] extends this discussion, emphasizing the importance of scalability metrics and real-time data access for evaluating the practical viability of blockchain in dynamic supply chain environments.

C. Integration of Python Programs and Blockchain for Enhanced Supply Chain Operations

Empirical studies on the integration of Python programs and blockchain shed light on real-world applicability. The author in [19] presents a case study demonstrating improved supplier selection accuracy through Python algorithms within a blockchain-based supply chain. This approach not only enhances operational efficiency but also addresses concerns related to data accuracy and transparency.

Methodological approaches for validating blockchain-based supply chain systems are critical [20]. Advocate for a multi-faceted evaluation framework encompassing security audits, performance simulations, and usability assessments. The author in [21] suggests incorporating machine learning algorithms to predict potential bottlenecks and optimize blockchain performance, contributing to a more holistic system evaluation.

To synthesize, it is evident that the integration of Python programs for supplier selection within blockchain-based supply chain systems offers potential benefits in terms of transparency and efficiency. However, challenges in operability and the need for rigorous validation persist. Future research should focus on refining Python-based algorithms, addressing security concerns, and developing standardized frameworks for evaluating the performance and validity of blockchain-based supply chain systems in diverse industrial contexts. This review provides a foundation for the subsequent chapters, contributing to a nuanced understanding of the practical implications of combining Python programs and blockchain technology in the realm of global supply chain management.

III. Research Methodology

The research methodology adopted for this study begins with an extensive exploration of existing academic and industry literature as explained in Fig. 1. This initial phase delves into the performance, security, and cost-efficiency of blockchain-based supply chain systems, contrasting them against traditional systems. By scrutinizing various publications and research articles, insights are gained into the potential benefits, challenges, and applicability of blockchain technology in modern supply chain management. Parallel to the examination of blockchain systems is an exploration into the realm of Multi-Criteria Decision Making (MCDM) systems for supplier selection. The central thrust here is to understand the security level that has been leveraged in this supply chain management system, the methodologies that have proven most effective, and the challenges that may arise in their implementation. A detailed investigation is conducted to comprehend the strengths, weaknesses, and the broader implications of these blockchain-MCDM couple frameworks.

Transitioning from theory to application, the research then delves into the synergy between these MCDM systems and blockchain-based supply chains. A primary focus is on understanding the integration challenges and advantages of embedding these systems within a blockchain framework. This amalgamation of technologies promises an unprecedented level of transparency, security, and efficiency in supplier selection. Gap analysis forms the crux of the methodology. Key questions drive this phase: How does a blockchain-based supply chain system fare in terms of security, accuracy, and cost-effectiveness compared to its traditional counterpart? A deep dive is made to study the operability between the developed MCDM system and the blockchain-based supply chain system.

Following the literature and gap analysis, practical application steps are initiated. The MCDM system is actualized using Python programming. The resultant system undergoes rigorous validation. For the blockchain platform, security tests using tools like Remix, Solhint, Mythril, and Smart Check form the first layer of validation. Subsequently, business, and operational implications such as time analysis, cost analysis, and transparency analysis are assessed. The culmination of the research methodology circles back to its foundational objectives, extrapolating the contributions, future perspectives, and overarching conclusions derived from the study. This methodology ensures a holistic, rigorous, and relevant exploration.

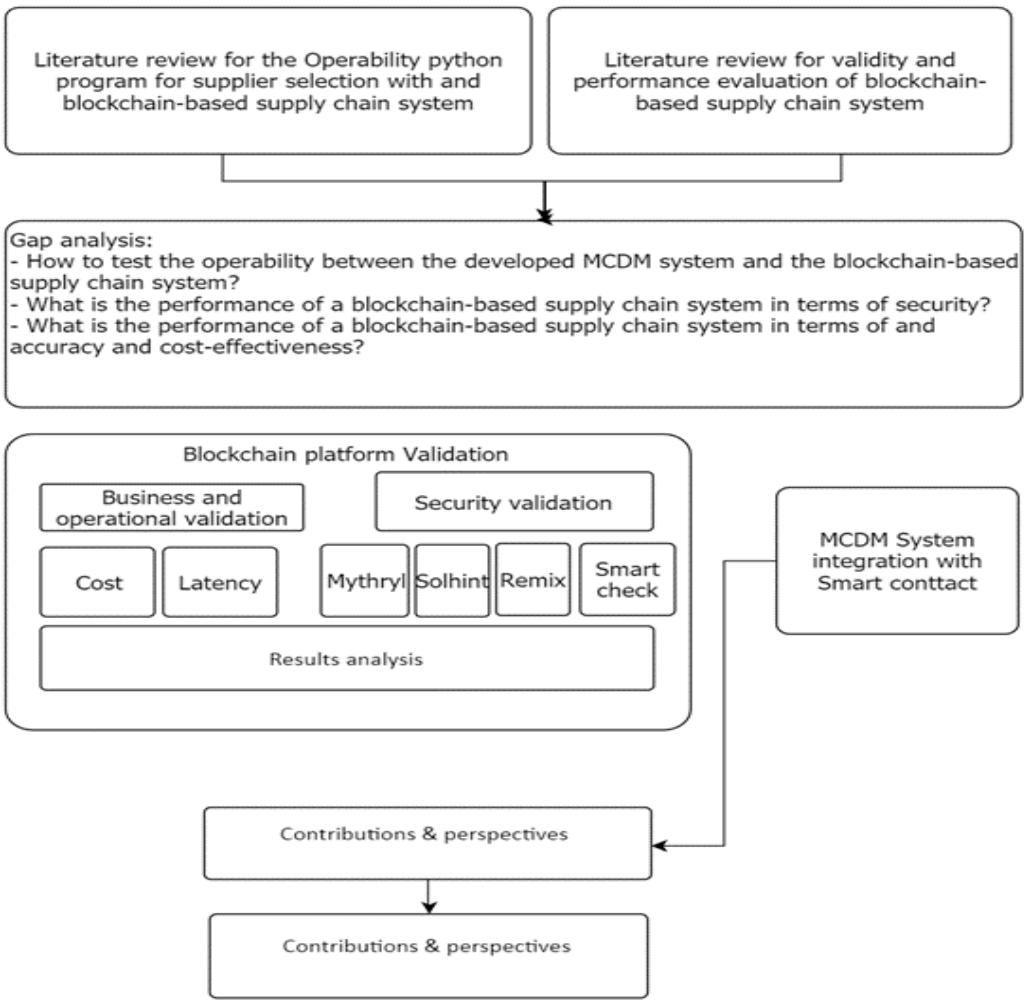

Fig. 1. Research methodology for the validation of supply chain system based on blockchain technology

IV. Technical Validity

Technical validation stands as a pillar of credibility when assessing the tangible impact and efficiency of a blockchain-based supply chain system. Such validation is vital to separate the theoretical potential of technology from its practical viability.

A. Validation by Primary Tests

1) Ownership verification: A primary concern in blockchain contracts is the concept of ownership to prevent unauthorized access and manipulation. The steContract integrates an onlyOwner modifier, ostensibly designed to restrict certain functionalities exclusively to the contract owner. The examination confirmed that this modifier was judiciously invoked in pertinent functions, such as addSupplier and addUnitOrder. In fact, this control is insured in the main code of the smart contract using the only owner as explained in the Fig. 3 hereafter.

While the blockchain deployed as illustrated in the following Fig. 2, several trials to change the owner or to perform tasks that only the owner is authorized to do were performed without success (Fig. 3, 4 and 6). The owner is still the same as shown in Fig. 5.

2) AddOrder and changeorderstatus function assessment: The integrity of the supply chain is hinged on the accurate representation of order statuses. Consequently, thoroughly the changeOrderStatus function was tested to validate its logical coherence using accounts that logically are not allowed to change those data. The function displayed adherence to the stipulated conditions, ensuring precise status transitions based on the user invoking it and the conditions presented. Hereafter fail results to those modification (Fig. 3 and 6).

3) Quantity adjustments in the addunitorder function: A cornerstone of the supply chain system is the accurate reflection of product quantities post order placements. Multiple scenarios were simulated and found that the addUnitOrder function adjusted quantities appropriately, corroborating its reliability (see Fig. 7 hereafter).

4) Access constraints on the orderevaluation function: The sanctity of order evaluations demands restricted access. The OrderEvaluation function was subjected to tests and verified that only the contract owner could execute it, thus bolstering confidence in its restricted accessibility.

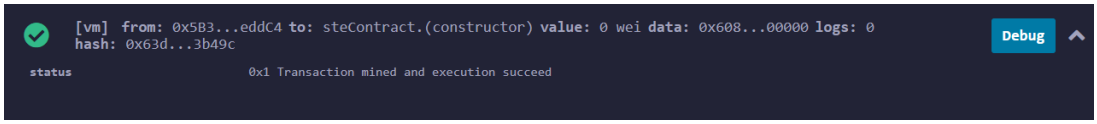

Fig. 2. Deployment of the smart contract

```
modifier onlyOwner() {
    require(msg.sender == owner, "Only Owner can add order!");
    _;
  }

  modifier onlyOwnerOrSupplier(address _supplierAdress) {
    _;
  }
}
```

Fig. 3. OnlyOwner function for controlling order creation

```
Order[] public allOrders;

function addSupplier (address  _supplierAdress, string memory _SupplierName) external onlyOwner(){
    // can only be called by Owner
    allSuppliers[_supplierAdress]._address = _supplierAdress;
    allSuppliers[_supplierAdress].name = _SupplierName;
}
```

Fig. 4. OnlyOwner function for controlling suppliers' insertion

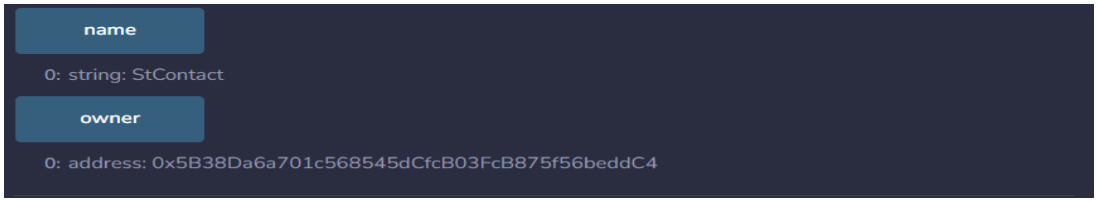

Fig. 5. Ownership of the smart contract

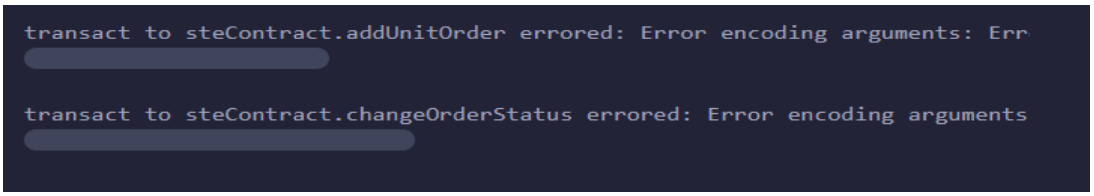

Fig. 6. OnlyOwner function for controlling order creation

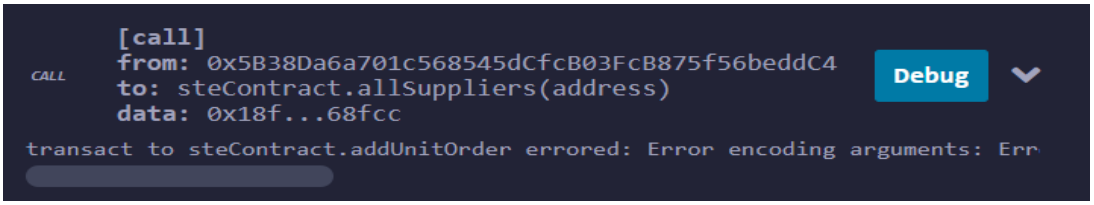

Fig. 7. Trials failure to change the order of the status and adjustment in AddUnitOrder

B. Security Validation by Relevant Tools

1) Secutrity test using solhint: In the security analysis of the deployed Ethereum smart contract, the Solhint tool was employed, a linter that provides both security and style guide validations. The analysis is an automated process that reviews the smart contract's code against a series of predetermined rules and best practices. Solhint scans the code, identifies potential vulnerabilities, and suggests improvements for code quality and security. The findings from the Solhint analysis are as follows in the Fig. 8:

- Compiler Version Mismatch: The contract is compiled with version 0.8.23, which does not meet the specified semantic versioning requirement of 0.5.8. This discrepancy can lead to unexpected behavior as compiler versions dictate the language syntax and features available as well as the bytecode output.

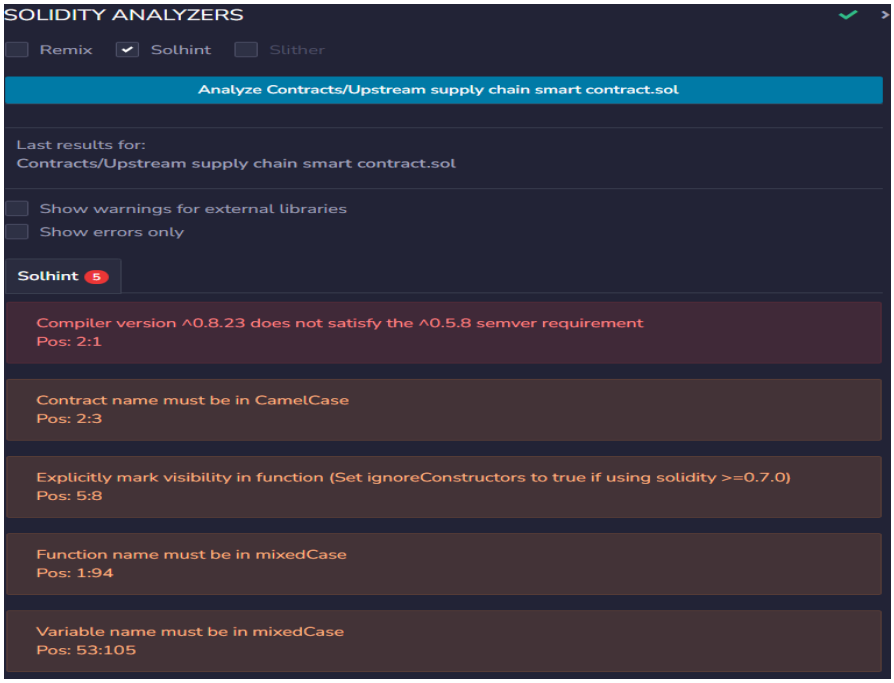

Fig. 8. Solhint analysis security results

- Naming Conventions: The contract has not adhered to the Solidity naming conventions which stipulate that contract names should be in CamelCase, and variable and function names should be in mixed Case. This is crucial for readability and maintainability of the code.
- Function Visibility: There is a recommendation to explicitly mark the visibility of functions. This is a critical security practice in Solidity to prevent unauthorized access to functions. If the contract is using a version of Solidity greater than 0.7.0, it is suggested to set ignoreConstructors to true.
- Mixed Case Violations: The analysis detected instances where function and variable names did not follow the mixed Case style. This is part of the Solidity's style guide to improve code clarity.

The warnings identified by Solhint, while important for maintaining code standards and readability, do not directly indicate deeper security vulnerabilities within the blockchain application. Compiler version compatibility and naming convention issues are largely syntactical and do not necessarily compromise the integrity or security of the smart contract's functional operations. Similarly, the advisory to explicitly declare function visibility is a best practice to avoid unintended access, but it does not inherently suggest that the contract's functions are currently exposed or vulnerable. Hence, these warnings, although highlighting areas for improvement in adherence to best practices, do not reflect on the solidity or resilience of the contract against malicious exploits. It is important, however, to address these issues to enhance the overall quality and robustness of the code, thereby preemptively fortifying against potential indirect risks that could arise from poor readability or future maintenance challenges.

2) Security test using remix: The Remix tool, another integral part of the smart contract security protocol, has presented findings that are more indicative of potential efficiency and cost concerns rather than direct security vulnerabilities (Fig. 9). The analysis flags several functions with "infinite" gas requirements, which points to the presence of loops or operations within these functions that could consume excessive amounts of gas, risking transaction failure if they exceed block gas limits. This condition typically arises from loops that iterate over dynamic arrays without a fixed number of iterations or from operations that modify large areas of storage, such as clearing or copying arrays.

Additionally, Remix has highlighted a practice concerning constant, view, and pure functions. It suggests that certain functions could potentially be declared as view or pure to indicate that they do not modify the state, which would reduce their gas cost when called.

The tool also points out the use of similar variable names that could cause confusion, though this does not directly affect the contract's performance or security. Lastly, it recommends using assert and require statements correctly to handle conditions and errors robustly.

These Remix findings are crucial for optimizing the contract's gas consumption and ensuring that it is cost-effective to execute. They also underscore the need for clear, maintainable code. However, these issues are not typically associated with vulnerabilities that could be exploited by attackers but should be addressed to prevent inadvertent contract failures and to enhance the user experience by ensuring transactions are processed efficiently.

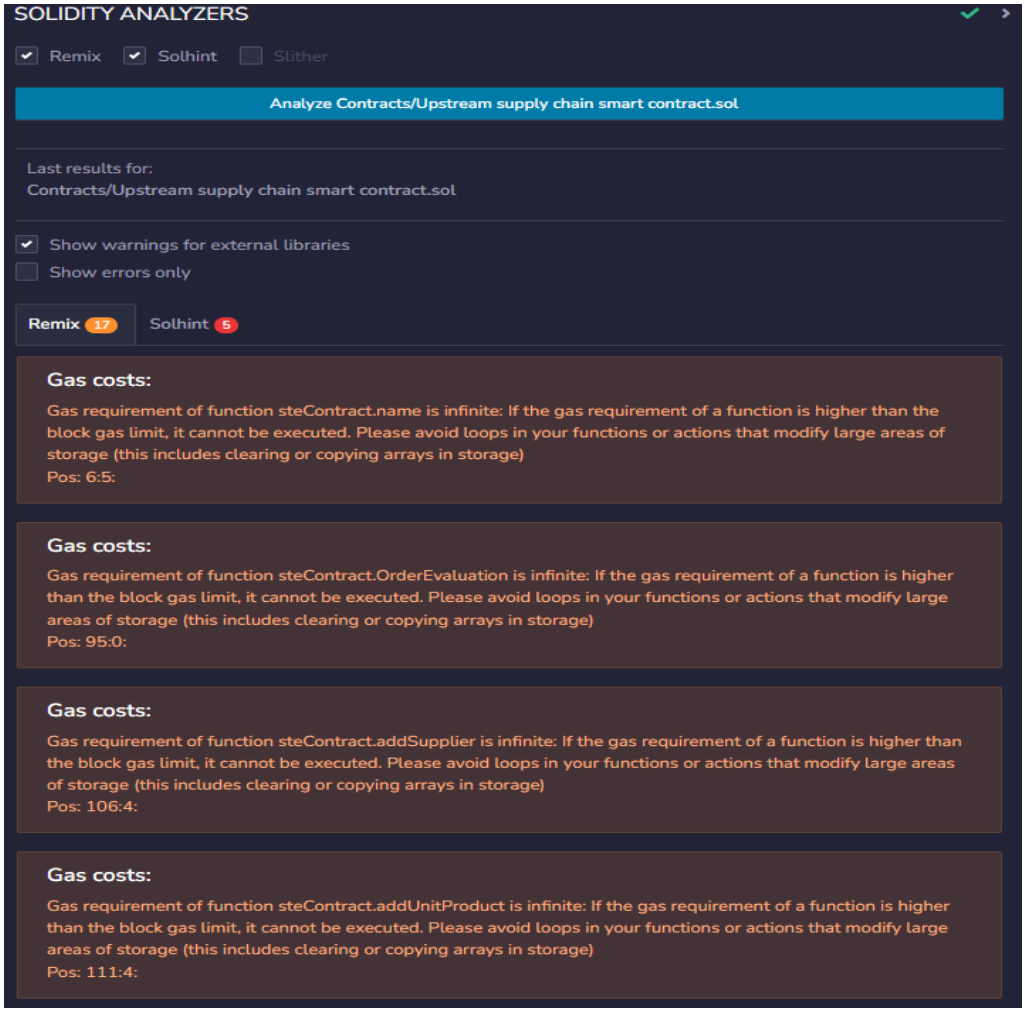

Fig. 9. A part of Remix analysis results

3) Security tests using mythril and smart check: The security analysis conducted using Mythril and SmartCheck tools offers additional perspectives on the smart contract's safety and correctness (Table I).

Mythril detected an issue classified as "Uninitialized State Variable" (SWC-109) with medium severity. It raised a concern that the state variable owner might be left uninitialized after contract creation. The contract design, however, intentionally defers the initialization of owner because it is set to represent the company and is assigned during deployment based on a specific company account. While Mythril flags this as a generic potential risk, in this case, this design choice does not pose a security risk due to the controlled deployment environment and this unique operational context.

SmartCheck highlighted a concern regarding "Assert Usage for Checking Invariants" (SWC-110), advising that assert statements should not be used for conditions that might fail during normal contract operation due to the risk of causing unexpected behaviors. Instead, require should be utilized for such conditions. This feedback is valuable for improving the robustness of the contract. It is generally good practice to use assert for conditions that should never fail unless there is a bug in the contract, while require is used for input validation or to ensure proper response to external failures. This recommendation will be considered to fine-tune this error handling, thereby preventing any misuse of assert that could lead to gas exhaustion if the conditions are not met during execution.

Both tools contribute to a more nuanced understanding of the smart contract's behavior, and while they have identified areas for improvement, these do not directly indicate high-risk vulnerabilities within the system. The recommendations will be incorporated to refine the smart contract, ensuring that all state variables are correctly initialized, and that error handling is properly implemented to maintain the security and efficiency of this blockchain application.

Our meticulous evaluation, facilitated by those diverse tools, has furnished valuable insights into the security posture of the blockchain system. While largely secure, the few identified vulnerabilities have been critically examined, and measures are underway to either rectify or validate them as intentional design choices. This multilayered security review underscores the commitment to uphold the highest standards of blockchain security and integrity.

TABLE I. SECURITY TEST RESULTS

	Vulnerability	Comment
Mythril	Uninitialized State Variable: Description: State variable owner might be left uninitialized after contract creation. Function: constructorSWC ID: SWC-109 Severity: Medium Recommendation: Ensure all state variables are initialized during contract creation.	By the conception of this system, the owner is unique and refers to the company. The value of the owner is populated based on the company account. This point does not impact the security of the constructed blockchain system, as it's intentionally designed this way to cater to this specific use case.
Smart check	Usage for Checking Invariants: Description: Using assert for conditions that might fail during normal contract operation can cause unexpected behaviors. Function: Not Found (hypothetical) SWC ID: SWC-110 Severity: Warning Recommendation: Use require for conditions that can fail during regular contract operation.	The recommendation provided by SmartCheck has been noted and taken into consideration. The necessary modifications will be implemented to ensure the security and efficiency of those contract operations.

V. BUSINESS AND OPERATIONAL VALIDATION

The business and operational validation is performed following the same stages done in a relevant study [22] and adapted to this system which is different in terms of architecture and functionalities, but the principle and purpose is the same for latency and cost evaluation.

To respond to the last question of the evaluation process, the codes were deployed in the Remix IDE on the Ethereum platform. The storage and deployment of the smart contract into the Ethereum blockchain require some gas. The cost of these transactions is paid to this time in ether. Mainly, three categories of gas prices are available for ETH Gast [23] (see Fig. 10, 11 and 12). The experiment is performed using Remix - Ethereum IDE version 0.37.3 to provide resources for transactions, an account on METAMASK Portfolio is created (Fig. 10). The account has been funded to start the transactions.

The account was linked to the Remix platform - Ethereum IDE. Gas limits are useful for optimizing the gas used to provide a safety mechanism, as sometimes buggy code can continue to consume unnecessary gas for execution [23]. The gas price is used when it is the price that allows for faster transactions. Transaction costs always increase when gas prices increase (Fig. 13 and 14). In this case, the contract is first created at the address "0xd3d382b49dcca0da7dadb17ea5c9af4777d68fcc".

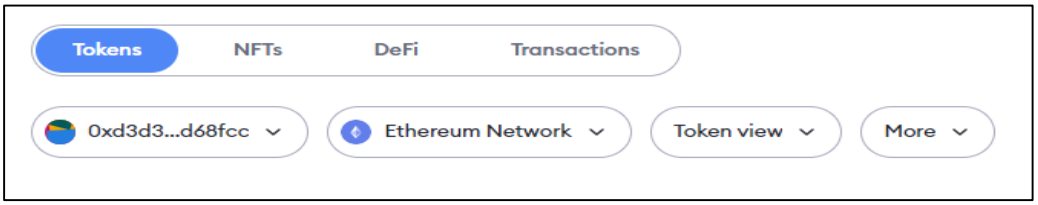

Fig. 10. Account created for sourcing transactions

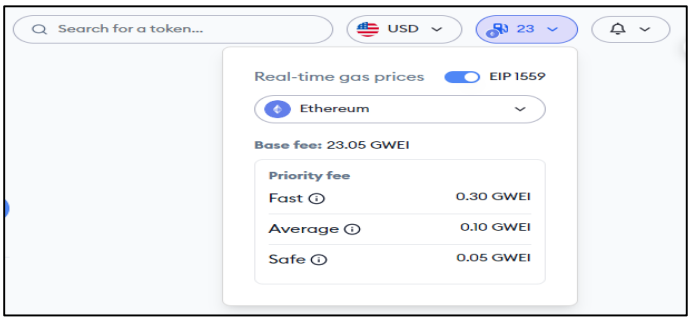

Fig. 11. Available price level on MetaMask account

Fig. 12. Cost of transaction according to Gas option

Fig. 13. Association of MetaMask account with Remix Etherium IDE

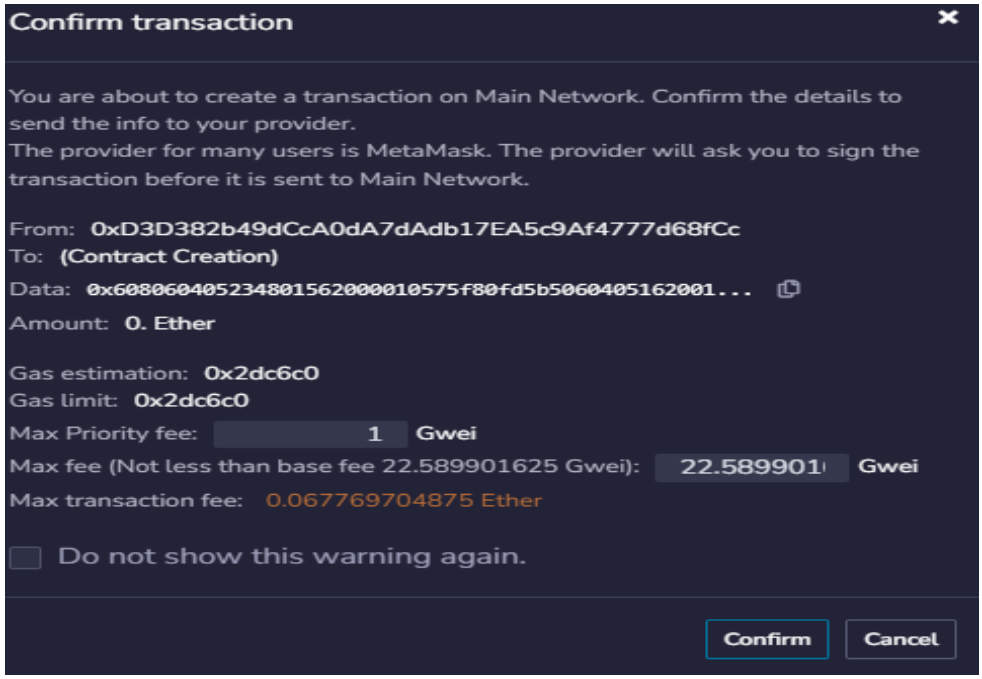

Fig. 14. Blockchain deployment confirmation and relative cost

Incorporating a multi-faceted evaluation framework, including performance simulations and security audits, further strengthens the system's robustness [24]. Additionally, leveraging machine learning algorithms to predict potential bottlenecks can optimize blockchain performance, contributing to a more comprehensive system evaluation [25,26]. Comparative analysis between blockchain-based and traditional supply chain systems also provides insights into the practical benefits and limitations of blockchain technology in this context [27,28,29]. To simulate, other wallets corresponding to the suppliers are created (S1, S2, S3 and S4). This experiment is done for three scenarios as explained in in the following Table II hereafter.

TABLE II. TEST SCENARIO DESCRIPTION

Scenario	Descriptions
S1	Two enterprise nodes connected
S2	Three enterprise nodes connected
S3	Five enterprise nodes connected

1) Results related to latency and analysis: The data on latency for the four main functions of the blockchain is shown in Tables III and IV hereafter.

TABLE III. LATENCY (MS) SUMMARY FOR PRODUCT CREATION AND ORDER CREATION

Product creation					Order creation		
	S1	S2	S3		S1	S2	S3
Min	53	55	53	Min	75	74	75
Max	67	66	67	Max	83	84	84
Avg.	60	60	60	Avg.	79	79	79
STD	3	3	4	STD	2	3	2

TABLE IV. TLATENCY (MS) SUMMARY FOR ORDER STATUS CHANGE AND ORDER EVALUATION

Order status change				order evaluation			
	S1	S2	S3		S1	S2	S3
Min	56	57	56	Min	99,9	101	105
Max	66	67	67	Max	146	141	144
Avg.	61	62	61	Avg.	124	122	125
STD	2,9	2,8	3,4	STD	13,1	12,5	12,9

In this analysis of latency times within a private blockchain network, distinct patterns for different functions were observed. The latency for both product creation and order status change functions consistently stayed between 53 ms and 67 ms, with an average latency falling below 61 ms. The details of latency four each function provided in the following graphs generated by Google Colab compiler (Fig. 15, 16, 17 and 18).

This consistency is further evidenced by the low standard deviation values in these measurements. In contrast, the order creation function exhibited slightly higher latency times, ranging from 74 ms to 84 ms, averaging below 79 ms. The most significant latency was observed in the order evaluation function, where the times varied between 99 ms and 146 ms, averaging around 123 ms.

These results indicate that the network maintains efficient performance without scalability limitations in terms of node count. This is because nodes in this private blockchain do not require a fully connected peer-to-peer network. Interestingly, preliminary tests conducted on virtual machines mirrored these results, underscoring the network's robustness. However, it's important to note that for new nodes joining the blockchain, there's a considerable catch-up time as they must replay all transactions from the chain's inception, which can be time-consuming depending on the chain's size and transaction volume.

Although these results show positive trends in addressing performance and scalability challenges of blockchain technology, further detailed analysis is needed to understand the potential affectations towards real-world implementations. Future work should include larger-scale testing and the impact of different network configurations.

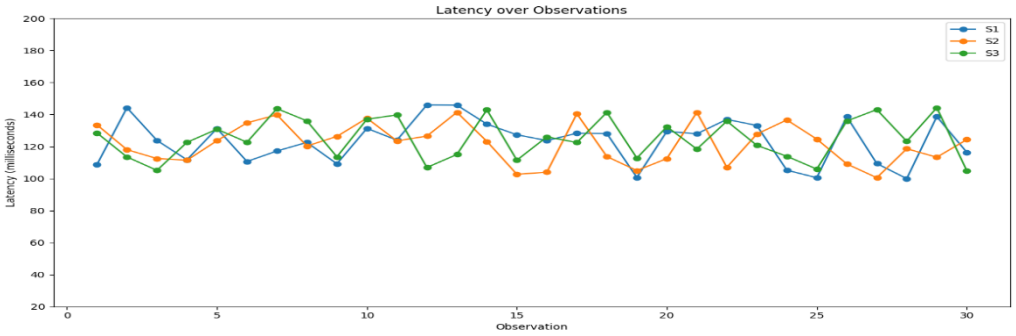

Fig. 15. Latency for order creation function

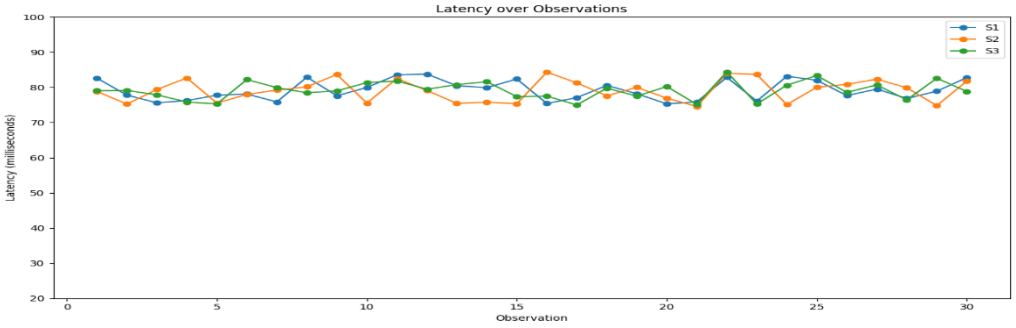

Fig. 16. Latency for order evaluation function

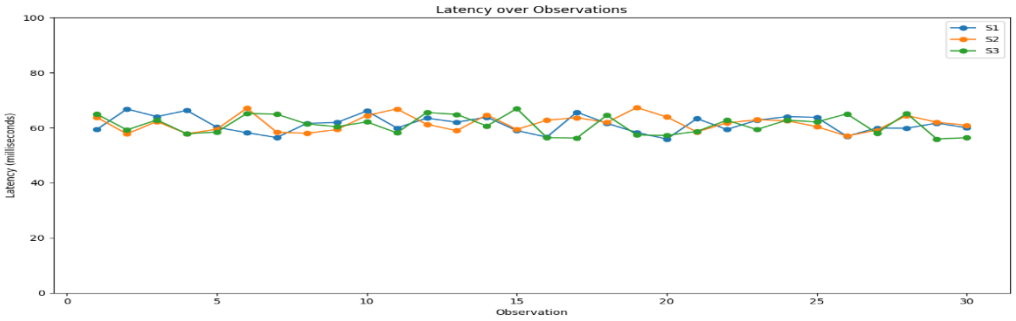

Fig. 17. Latency for order status change function

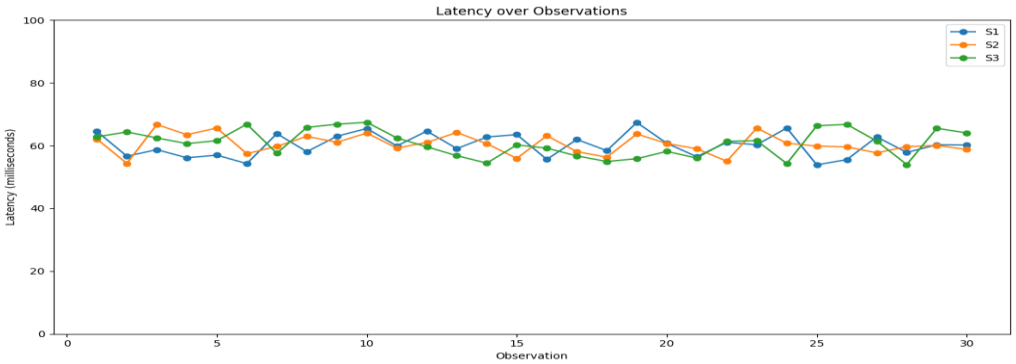

Fig. 18. Latency for product creation function.

2) Results related to cost and analysis: The transaction costs are grouped in Table V:

TABLE V. TRANSACTION COST FOR A SMART CONTRACT EXECUTION

Function	Tx fee (ether)	Tx time (s)
Contract deployment	0,15059742	15<
Product creation	0,04517923	13<
Order creation	0,06023897	13<
Order status change	0,015059742	13<
Order evaluation	0,03011948	13<

In the analysis of the transaction costs associated with deploying smart contracts and executing related functions, varied costs and execution times were observed for different functions, as detailed in Table V. Notably, the cost for contract deployment was 0.15059742 ether, taking less than 15 seconds. The function for product creation incurred a fee of 0.04517923 ether and took under 13 seconds, like the order creation function, which had a fee of 0.06023897 ether. The order status change function was comparatively less expensive at 0.015059742 ether, also completed in less than 13 seconds. Additionally, the order evaluation function required a fee of 0.03011948 ether and was executed within the same time frame.

These costs and times reflect the varying computational resources needed for each function. The higher cost for certain functions, such as contract deployment and order creation, can be attributed to their more complex nature and the larger amount of data processed. Overall, the total cost associated with the contract was a sum of the individual costs for each function, each contributing to the efficiency and effectiveness of the smart contract operations in the blockchain network.

In the assessment of this blockchain performance, incorporating both MCDMS and smart contract, noteworthy results were observed. It demonstrated low latency for enterprise nodes connecting to the network and responding to various actions such as creating suppliers' lists, creating and updating product lists, executing orders, following order, evaluation orders. On the other hand, the model presented an acceptable transaction cost for executing smart contracts, with costs like 0.06023897 ether for order creation and 0.015059742 ether for order status change, each completed in less than 13 seconds.

This blockchain and smart contracts-based platform facilitates the automatic verification of conditions for accessing or modifying each data entity. Smart contracts can be deployed to define the permitted uses of data, authorized software applications, individuals, or businesses that can access the data, time constraints, and access pricing. As a result, this decentralized data-sharing platform becomes invaluable for sharing various types of user data, including user models and user-contributed data. It addresses key issues such as privacy, user control, and incentives, allowing users to establish proof of ownership and provenance for their data, share data without relinquishing control or ownership, incentivize data sharing, and maintain full transparency and control over who accesses their data, when, and for what purposes in press [27,28].

However, it's important to note that criticisms of blockchain-based approaches often center around their performance and scalability, particularly for the public Ethereum blockchain. Yet, the rapid advancement of this technology, through strategic combinations of blockchains, is leading to performance levels that are increasingly acceptable for broader applications.

A comparative analysis between traditional supply chain systems and blockchain-based systems should be included to better highlight the strengths and weaknesses of each approach. Additionally, while the analysis shows promising results, the study's limitations include the potential catch-up time for new nodes and the scalability issues in real-world, large-scale implementations.

VI. CONCLUSION

In conclusion, the comprehensive analysis and implementation of a relevant blockchain-based platform reveal significant advancements in supply chain management and innovative and sustainable suppliers' selection within a decentralized framework. The performance metrics, including low latency and efficient memory usage for the data-sharing model, coupled with the manageable transaction costs of the user incentive model, underscore the platform's robustness and practicality. The deployment of smart contracts demonstrates the platform's capacity to handle various functions effectively, from contract deployment to order evaluation, each with distinct computational requirements and associated costs.

This platform stands out in its ability to seamlessly integrate blockchain technology with smart contracts, offering

automatic verification of access conditions and modification rights for each data entity. It provides a solution to the perennial challenges of privacy, user control, and incentives in data sharing. Users gain unprecedented control over their data, ensuring proof of ownership, maintaining sovereignty, and benefiting from transparent and incentivized data sharing mechanisms.

While acknowledging the ongoing concerns regarding the performance and scalability of blockchain technologies, especially in the context of the public Ethereum blockchain, the findings indicate that these challenges are being progressively addressed. The evolving landscape of blockchain technology, through innovative combinations and optimizations, is paving the way for platforms like ours to achieve performance metrics that are not only acceptable but also conducive to widespread adoption.

This study, therefore, contributes a significant leap forward in the application of blockchain and smart contracts for data sharing. It sets a precedent for future developments in this field, encouraging continued exploration and refinement of these technologies to harness their full potential in various sectors. As blockchain technology continues to evolve, it is poised to revolutionize how data sharing, privacy, and user incentives are approached in the digital age.

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