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Modelling the Process of Building Digital Security in Commodity Markets using Blockchain

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Abstract
Blockchain technology is acquiring momentous popularity in commodity markets over the past few years. A commodity can be regarded as an article of trade between an importer and exporter nation. Several types of commodities—such as agricultural (*i.e.,* wheat, soyabean, corn, rice, spices, oil, meal products, sugar, dairy, marine, and plantation) and non-agricultural (*i.e.,* base metals and petroleum products)—can be traded. The process of commodity trading or shipment between nations involves several actors like *exporters*, *customs*, *importer*, *insurance*, and *importer bank* and activities like *bills of lading*, *letter of credit*, *factoring*, *exporting credit*, and *insurance*—which are paper based, interdependent, and require human involvement. Blockchain, on the other hand, is a decentralized and distributed ledger technology that is open, immutable or tamperproof, efficient, verifiable, and permanent. The integration of blockchain in commodity markets can revolutionize the entire trading or shipment process. Considering the abovementioned problems, this study attempts to offer a solution by performing business process modelling in commodity markets using blockchain. The inferences made in this study prove to be quite promising wherein paper-based trading processes can be replaced with paperless trading processes via smart contracts—self-executable codes—which operate on top of blockchain, thereby eliminating intermediaries or middlemen and improving not only efficiency but also transparency of existing trading processes.

Keywords: Blockchain, Commodity Markets, Digital Security, Process Modelling, Systems Approach.

1. Introduction

In recent years, blockchain technology (BCT) has been gaining significant traction in the field of commodity markets. A trade item—commonly referred to as a commodity—is a physical asset utilized as a raw material for manufacturing products. Fundamentally, commodities include metals, food, and similar items essential for daily use, and they have geographical marketability [1, 2, 3].

A blockchain is a decentralized system where transactions are grouped into blocks, with each block containing a timestamp and a reference to the preceding block, creating the structure known as a blockchain. BCT guarantees that every individual's version of the ledger remains not only synchronized but also distinct. While data can be added, it is impossible to erase.

The core concept driving this technology is the safeguarding of data integrity and autonomy. Transactions conducted using blockchain can occur at the speed of light, linking locations separated by significant distances in mere fractions of a second.

Originally serving as the foundation for cryptocurrencies, blockchain has now extended its reach with the utilization of distributed ledgers projected to experience fast and noteworthy expansion in the upcoming years. Furthermore, BCT application has been extended to a number of sectors, including the commodity trading industry.

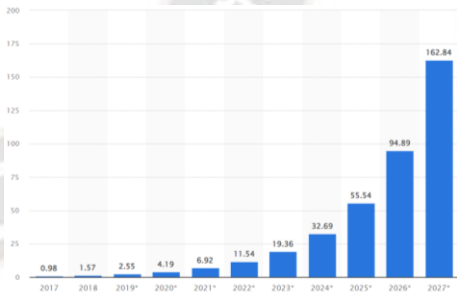

Fig. 1: BCT market size worldwide (2017–2027) (U.S. billion $) [4]

Figure 1 illustrates that the global blockchain market had a valuation of $0.98 billion in 2017, and it is expected to expand significantly, reaching ~ $162.84 billion by 2027.

The integration of BCT into commodity markets has the potential to greatly improve both transparency and traceability of commodities, all the while lowering costs.

As the commodity trading ecosystem comprises various participants, each maintaining their own copies of the blockchain, this facilitates the ability to review transaction statuses, pinpoint errors, and ensure accountability amongst counterparties. Consequently, BCT provides a robust, reliable, and immutable audit trail of activities within commodity trading markets.

BCT integration in commodity trading has helped to overcome issues pertaining to procedure enhancement and data conspicuousness.

As per [5], it is projected that the global supply chain will reach a total of USD 14,180 million by 2028. This forecast indicates a strong compounded annual growth rate (CAGR) in revenue, which is expected to be ~63.90% during the forecast period.

The remainder of the manuscript is as follows. Section 2 focuses on a comprehensive study of existing literature for building digital security in commodity markets using blockchain. Section 3 explicates on business process modelling in commodity markets using blockchain. Section 4 demonstrates implementation about business process modelling in commodity markets, and lastly, Section 5 focuses on results and discussion, and Section 6 concludes the study with scope for future work.

2. Literature Review

A great deal of literature has been carried out for modelling the process of building digital security in commodity markets using blockchain. Some of them have been specified below.

Sharma, Khalil, and Daim [6] conducted a study that delved into the adoption of BCT within the agricultural supply chain. Their research specifically compared adoption trends between developed nations like the Netherlands and Oregon and developing nations like Saudi Arabia and India. To analyze the factors influencing adoption, they employed interpretive structural modelling (ISM) and decision-making trial and evaluation laboratory (DEMATEL) techniques. The study aimed to unveil the hierarchical structure and causal relationships among these influencing factors. While their investigation revealed disparities in the enabling factors amongst the four nations, the authors emphasized that policies emerge as the pivotal drivers of BCT adoption within agricultural supply chains. Moreover, they asserted that the findings from their study could be applied globally, suggesting that the insights gained are not limited to the specific regions under examination.

Agarwal *et al.* [7] introduced a traceability framework based on BCT for the textile and clothing industry. Their proposal aimed to tackle issues such as information imbalances and limited visibility within the industry. The study not only laid out the concept of how supply chain partners interact and the organizational-level network structure but also detailed smart contract implementation and transaction validation rules at the operational level. The primary goal of their research was to enhance transparency and ensure product quality for consumers while fostering trust amongst supply chain participants through technology-driven means. Additionally, the authors emphasized that a blockchain-based traceability system would empower all partners within the supply chain, granting them the capabilities to track their network's history and promote a transparent and sustainable supply chain [8].

Taherdoost and Madanchian [9] conducted a systematic review encompassing the period from 2012 to 2022 to examine emerging business models powered by BCT. Their analysis included 75 journal articles, allowing them to assess the current landscape of blockchain-based business models, identify unanswered research queries, and suggest prospective directions for further exploration. The authors observed a notable upward trend in blockchain-driven business strategy adoption, envisioning a transformation in traditional frameworks. They posited that blockchain innovation is poised to pave the way for novel approaches in business model development. Furthermore, the authors emphasized the increasing integration of non-fungible tokens (NFTs) and play-to-earn (P2E) concepts within the realm of corporate project development, potentially reshaping existing business models.

Turjo *et al.* [10] directed their attention towards blockchain and smart contract integration into traditional supply chain management systems. Their goal was to enhance various aspects of supply chain. A key objective was to reduce the reliance on third-party intermediaries within the supply chain. While the primary focus of the study was to infuse a greater sense of security in individuals during payment processes, the authors implemented a peer-to-peer encrypted system alongside smart contracts. Ultimately, their research aimed to demonstrate the highest levels of safety, transparency, and operational efficiency within supply chain.

Rana *et al.* [11] introduced a model designed to enhance the performance of digital supply chain through BCT integration. Their proposed model leveraged a combination of Ethereum blockchain and InterPlanetary File System (IPFS) to uphold traceability, transparency, and trustworthiness within the supply chain.

In [12], an expansion of conventional systems methodologies went beyond the operations of individual companies to encompass the entire supply chain. This extension led to the adoption of a systems approach for analyzing supply chains and enhancing their overall performance.

Tsolakis *et al.* [13] conducted a study that delved into the concurrent utilization of artificial intelligence (AI) and BCT within the context of supply chains. Their objective was to expand the operational capabilities of supply chains while promoting sustainable development and data monetization. To achieve this, they specifically examined the tuna fish supply chain in Thailand. In their research, the authors meticulously examined end-to-end operations of supply chain, scrutinizing physical material processes as well as data handling. Their focus was on envisioning how the combined implementation of AI and BCT could be applied to enhance the supply chain. They systematically mapped out various business processes and system-level interactions to gain insights into the flow of materials, data, and information within the supply chain. The outcome of this mapping exercise highlighted the pivotal role of AI and BCT in managing digital supply chains. Furthermore, the impact on sustainability and data monetization was determined to be contingent on parameters and objectives set by the stakeholders involved in the system. The authors also put forward a unified framework that delineated the key data elements requiring digital handling through the implementation of AI and BCT-enabled food supply chains. This framework aimed to facilitate value delivery. In conclusion, the authors anticipated that their empirical approach would be valuable for both academic research and practical decision-making. It would support the study and implementation of digital interventions aimed at achieving sustainability and data monetization within supply chains.

Rajeev and Dilip [14] conducted a study that investigated the interplay amongst supply chain management practices, BCT, and supply chain performance within the Indian dairy industry. Their study presented a conceptual model that depicted how BCT acts as a mediator in the connection between supply chain management practices and the overall performance of the supply chain. To analyze their proposed model, the authors employed structural equation modelling (SEM) and utilized software tools such as SPSS and AMOS V24. The study involved collecting responses from the top four executives of Indian dairy processing units. The sample size was originally intended to be 476, and judgmental sampling was employed to select these units. However, the study received completed questionnaires from 286 respondents, which were subsequently used for data analysis.

Lee and Khan [15] focused on the usage of BCT in energy trading, especially in crude oil trade. They were of the opinion that BCT and smart contracts can support responsible sourcing and reduce information asymmetry in energy commodity markets. Moreover, the authors focused on various types of blockchain that could be applied on the energy trading market along with their advantages and disadvantages. Lastly, the authors considered legal issues, potential solutions, and BCT impact on UN's Sustainable Development Goals and how a Green FinTech application can be built.

3. Business Process Modelling

Business process modelling is a method used by organizations to visually represent, analyze, and improve business processes. It helps in understanding how various activities, tasks, and resources are interconnected with each other within an organization to deliver products or services. In other words, business process modelling offers a systematic approach for not only understanding, documenting, and improving processes but also increasing operational efficiency, enhancing communication, and adapting to changing business environments.

In the context of commodity trading where timely and accurate trade execution is critical, business process modelling plays a crucial role in streamlining operations, reducing risks, and ensuring compliance with industry regulations. Moreover, it helps traders and organizations better manage the complexities associated with buying and selling commodities in the global market.

A conceptual framework for commodity trading using blockchain involves outlining the key principles, components, and processes for implementing BCT in the commodity trading industry. Blockchain has the potential to revolutionize commodity trading by providing transparency, security, efficiency, and traceability to the entire trading ecosystem. A high-level conceptual framework for a blockchain-based commodity trading system includes BCT (*i.e.*, decentralization, immutable ledger, transparency, and smart contracts), participant network (*i.e.*, traders, regulators, banks and financial institutions, logistics providers, and quality assurance entities), key processes (*i.e.*, trade initiation, matching and confirmation, payment and settlement, quality assurance and inspection, logistics and delivery tracking), security and identity, regulatory compliance, and analytics and reporting. Detailed information for the same can be found in [16].

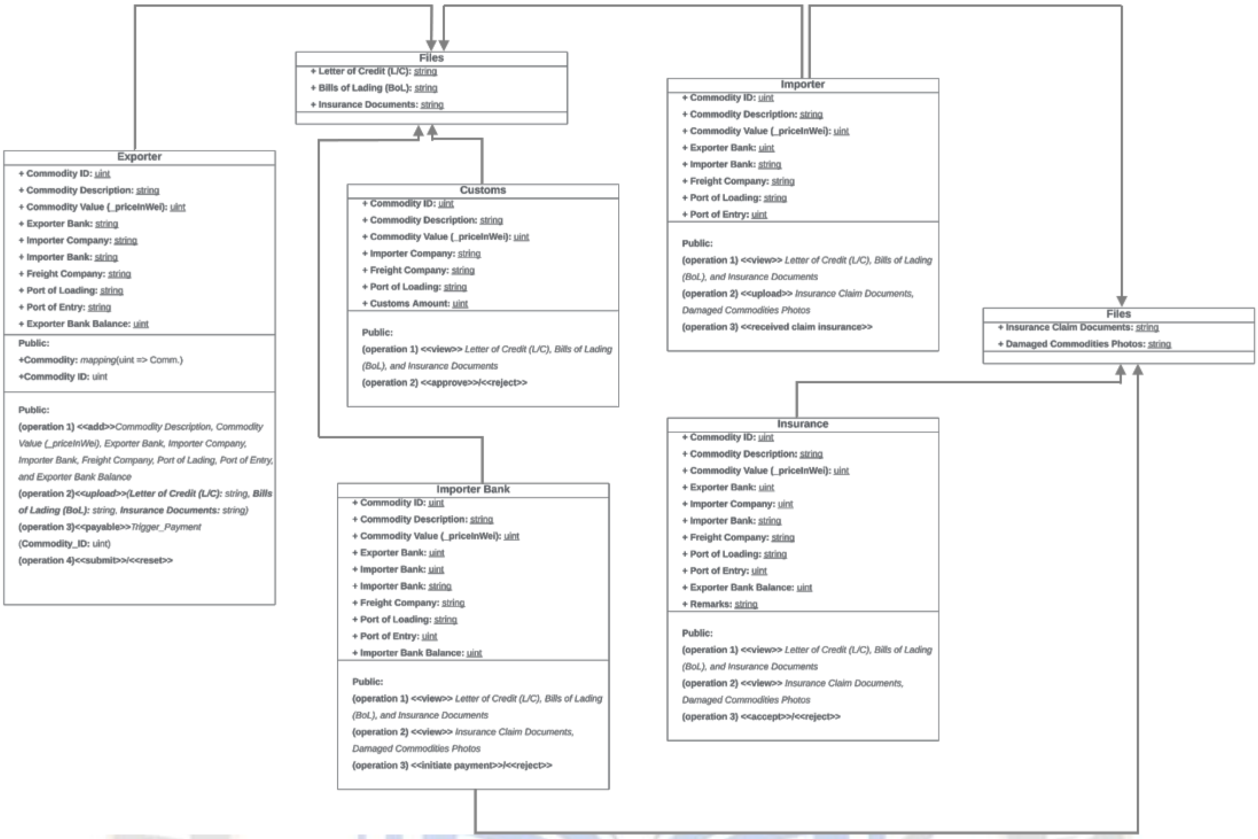

Fig. 2: Process modelling for building digital security in commodity markets using blockchain through systems approach

Figure 2 shows a comprehensive process modelling in commodity trade for building digital security using blockchain through systems approach. The *exporter*, *customs*, *importer*, *insurance*, and *importer banks* are the five major entities involved in the entire commodity trading process. Imagine a standard national or international trade scenario in which the entities mentioned are interconnected through a private blockchain network. In this network, transactional data is automatically copied and synchronized across all nodes whenever a new transaction occurs. It is important to emphasize that the ledger containing information is consistently updated across all network nodes. To kickstart a smart contract within this context, the exporter takes the initial step by uploading all pertinent documents, including *letters of credit*, *bills of lading*, and *insurance records*, into the designated application. After completing the document submission, the exporter proceeds to submit the smart contract. Upon submission, the transaction is transmitted to the blockchain for processing. Transactions keep on pending on a network until they are mined by a miner. When a miner mines the transactions then only the transaction is added to the blockchain. On successful addition of the transaction to the blockchain leads to the generation of a unique address wherein details/information is stored on a public ledger. Thus, a tamperproof smart contract is created by the exporter. Second, the customs view and verify the files that are uploaded by the exporter and then either approves or rejects the smart contract. If the smart contract is accepted, then the custom fee is approved on the blockchain. Third, in case if the products/goods or services are damaged, then the importer uploads insurance papers and proof-of-damaged (PoD)-related documents. Fourth, an insurance company evaluates the claim in accordance with the terms and conditions (T&Cs) outlined in the insurance policy. Depending on the insurer's determination, if the claim meets the criteria and is approved, the process of initiating and executing the payment takes place on the blockchain. Fifth, the importer bank looks for shipment completion. Once the importer authenticates shipment receipt, the importer bank initiates payment and transaction is processed on the blockchain. Successful payment completion implies that the smart contract is fulfilled and suitable amount is deducted from an importer bank's balance.

4. Implementation

The proposed system is implemented using truffle and react wherein the programming language used is solidity.

- **Truffle:** It is a popular development framework for building decentralized applications on blockchain platforms like Ethereum. Truffle offers a comprehensive set of tools designed to simplify the tasks of smart contract development, testing, and deployment for developers working on decentralized applications [17].

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- **React:** It is a valuable tool for building the front-end components of blockchain-based applications, including decentralized applications. It helps developers create user-friendly and interactive interfaces for users to interact with the blockchain, access blockchain data, and perform transactions.
- **Solidity:** It is a programming language tailored for creating smart contracts on the Ethereum blockchain. It plays a critical role in enabling the execution of self-executing, trustless agreements, and powering decentralized applications on blockchain networks.
- **Remix:** It is an integrated development environment (IDE) and web-based tool that is specifically designed for smart contract development on blockchain platforms with a primary focus on Ethereum. It is a popular choice among developers for writing, testing, and deploying smart contracts.

```
// SPDX-License-Identifier: MIT
pragma solidity ^0.6.0;
contract ItemManager{
 enum SupplyChainSteps{Created, Paid, Delivered}

 struct S_Item {
 ItemManager.SupplyChainSteps _step;
 string _identifier;
 uint _priceInWei;
 }
 mapping(uint => S_Item) public items;
 uint index;

 event SupplyChainStep(uint _itemIndex, uint _step);

 function createItem(string memory _identifier, uint _priceInWei) public {

 items[index]._priceInWei = _priceInWei;
 items[index]._step = SupplyChainSteps.Created;
 items[index]._identifier = _identifier;
 emit SupplyChainStep(index, uint(items[index]._step));
 index++;
 }

 function triggerPayment(uint _index) public payable {
 require(items[index]._priceInWei <= msg.value, "Not fully paid");
 require(items[index]._step == SupplyChainSteps.Created, "Item is further in the supply chain");
 items[_index]._step = SupplyChainSteps.Paid;
 emit SupplyChainStep(_index, uint(items[_index]._step));
 }

 function triggerDelivery(uint _index) public {
 require(items[_index]._step == SupplyChainSteps.Paid, "Item is further in the supply chain");
 items[_index]._step = SupplyChainSteps.Delivered;
 emit SupplyChainStep(_index, uint(items[_index]._step));
 }
}
```

Fig. 3: Smart contract code snippet for *ItemManager* using solidity

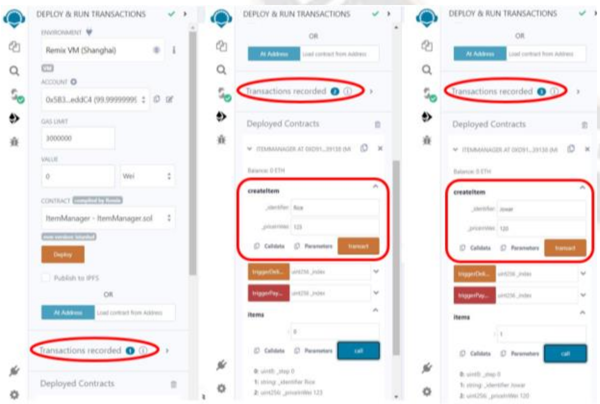

Fig. 4: Addition of commodities/items using *Remix*

From Fig. 4, it is evident that it is possible to add items/commodities and pay and move them forward in commodity markets and trigger a delivery.

The IDE used is remix (https://remix.ethereum.org). For instance, from the figure, we can see that the commodity added is 'Rice' and the price in wei is 123.

In a similar manner, another commodity added is 'Jowar' with 120 as the price in wei. On clicking the 'transact' button, a transaction hash is generated, as shown in Fig. 5.

The main purpose of implementing such a system is to build a blockchain-based commodity market trade solution, carry out automated dispatch of commodities upon payment via smart contracts, and collection of payment without any middlemen.

Fig. 5: Addition of commodities/items and generation of transaction hash

```
// SPDX-License-Identifier: MIT

pragma solidity ^0.6.0;
import "./ItemManager.sol";
contract Item {
uint public priceInWei;
uint public paidWei;
uint public index;
ItemManager parentContract;
constructor(ItemManager _parentContract, uint _priceInWei, uint _index) public {
priceInWei = _priceInWei;
index = _index;
parentContract = _parentContract;
}
receive() external payable {
require(msg.value == priceInWei, "We don't support partial payments");
require(paidWei == 0, "Item is already paid!");
paidWei += msg.value;
(bool success, ) = address(parentContract).call{value:msg.value}(abi.encodeWithSignature("triggerPayment(uint256)", index));
require(success, "Delivery did not work");
}
fallback () external {
}
}
```

Fig. 6: Smart contract code snippet for *Item* using solidity

Apart from the generation of transaction hash, a smart contract address for every item/commodity added gets generated. For instance, for 'Rice' with 123 wei, the address generated is "0xd840735F4B6A0D1AF8Fa48EcE560f4778c007397", as shown in Fig. 7.

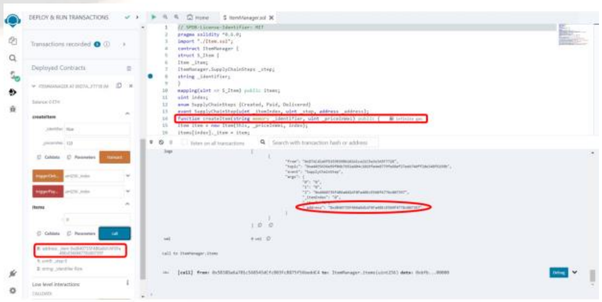

Fig. 7: Smart contract address of *Item*

An importer/customer needs to be given an address of the '*Item*' smart contract created during '*createItem*' & the

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customer will be able to pay directly by sending a certain amount of *Wei* to the smart contract.

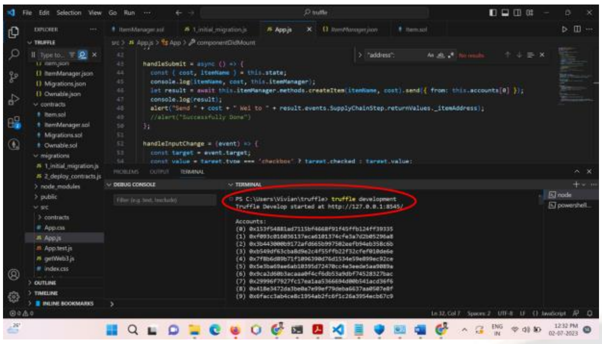

Fig. 7: Use of *Truffle* development environment

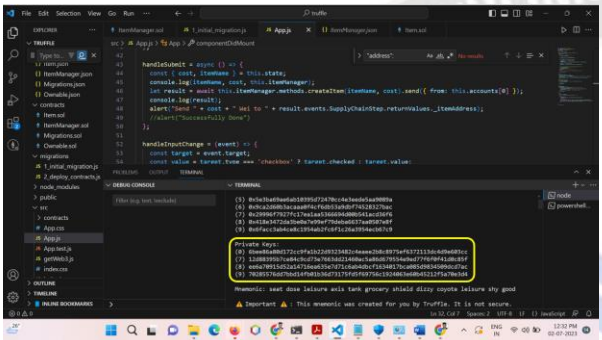

Fig. 8: Private keys in *Truffle*

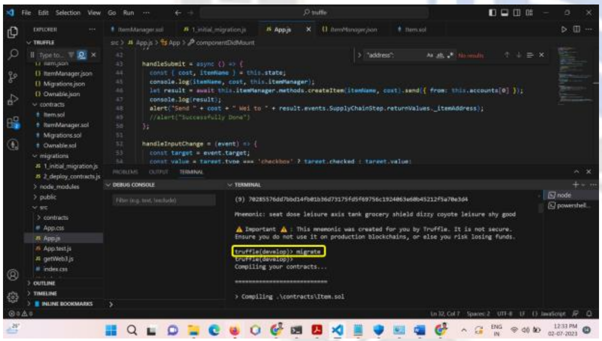

Fig. 9: Migration of *Truffle*

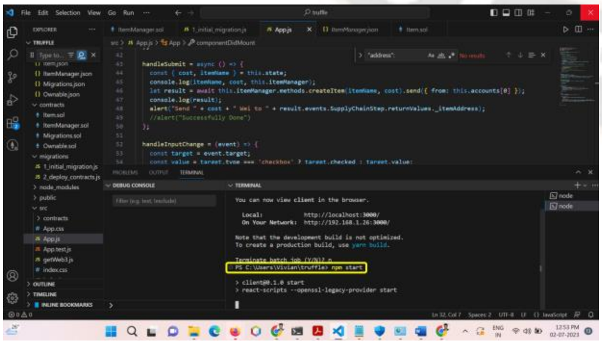

Fig. 10: Start of node package manager (npm)

Truffle being a popular development framework for building decentralized applications in order to create, test, and deploy smart contracts offers 10 pre-funded accounts for testing purposes to carry out transactions, as shown in Fig. 7. Truffle 'develop' command is mainly used for setting up a local blockchain, instant deployment, testing, and offering an interactive console. In addition, private keys (i.e., cryptographic keys) are provided by Truffle in order to control and access Ethereum accounts, which could either be externally owned accounts (EOAs) or contract accounts. Private keys are fundamentally associated with EOAs, which are controlled by individuals or entities and can be used for various purposes such as signing transactions and managing assets.

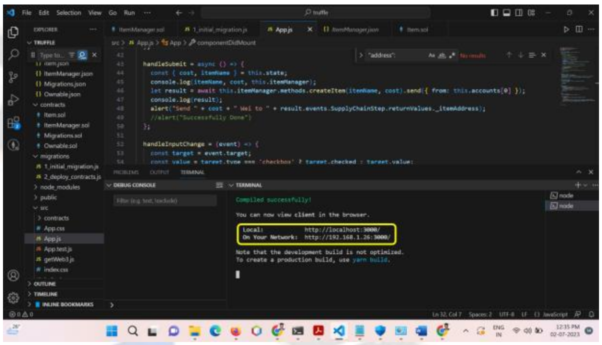

Fig. 11: Smart contract code compiled successfully with access to local host (http://localhost:3000/)

The truffle 'migrate' command is used to deploy smart contracts an individual's development environment to a target blockchain network (i.e., Ethereum mainnet or testnet). The main functionalities of this command include compilation, migration scripts, network configuration, contract deployment, migration tracking, and re-deployment.

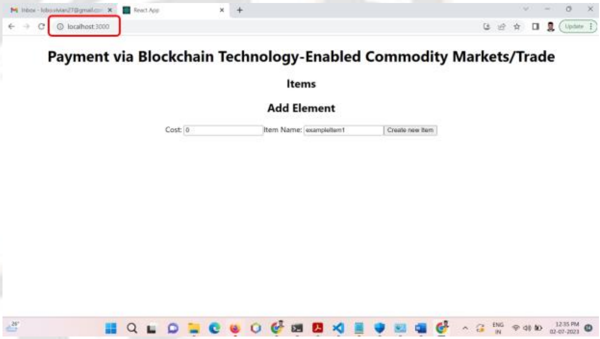

Fig. 12: Front-end using *React*

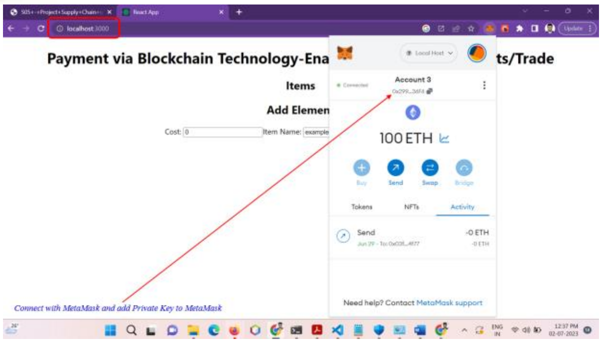

Fig. 13: Connection with *MetaMask* along with the addition of private key to *MetaMask*

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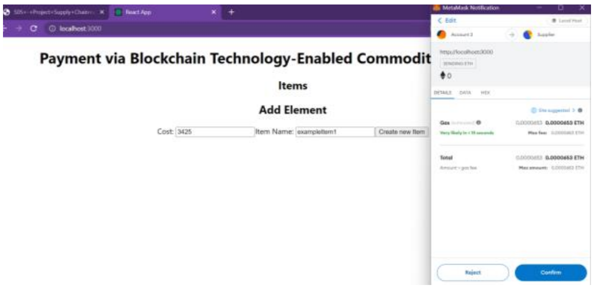

Fig. 14: Addition of a new *Item* to a smart contract

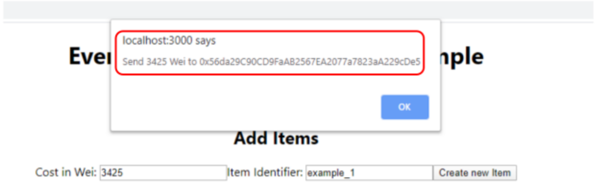

Fig. 15: Transfer of some cost (i.e., 3425) in *Wei* to a specified address (i.e., 0x56da29C90CD9FaAB2567EA2077a7823aA229cDe5)

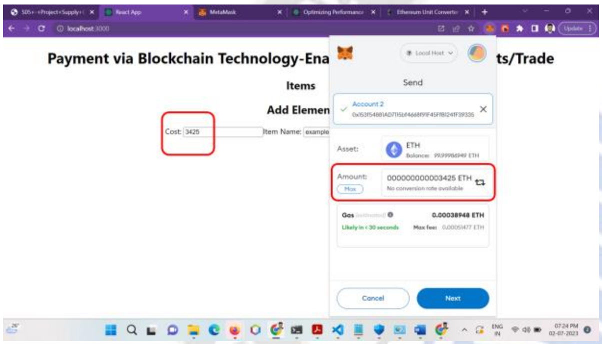

Fig. 16: Conversion of *Wei* to Ether followed by gas fee

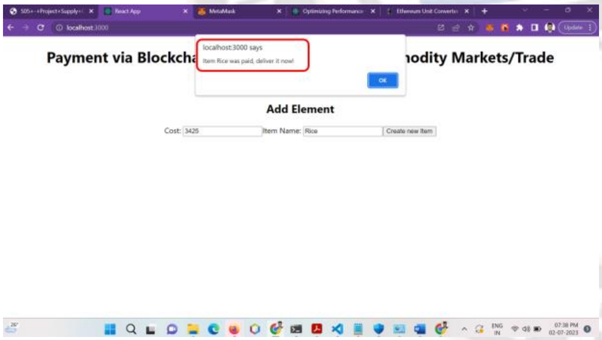

Fig. 17: Payment successful followed by the delivery of the *Item* (i.e., Rice)

5. Results and Discussion

Testing is a critical aspect of smart contract development to ensure that contracts behave as expected and are free from bugs.

Therefore, truffle development framework offers a command, *i.e., truffle test*, which is used to run test cases for smart contracts that have been written, as shown in Fig. 18.

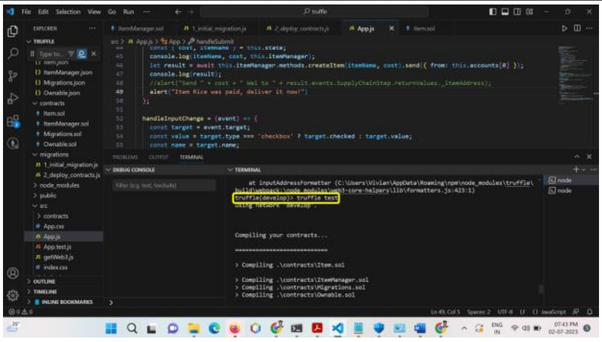

Fig. 18: Testing of smart contract in *Truffle*

Some of the main functionalities of 'truffle test' command include test scripts, test environment, contract interaction, automated testing, assertions, and test coverage.

Fig. 19 shows that the truffle test has passed/executed successfully for the smart contract that we have written. In other words, it means that the smart contract is functioning correctly as per defined specifications.

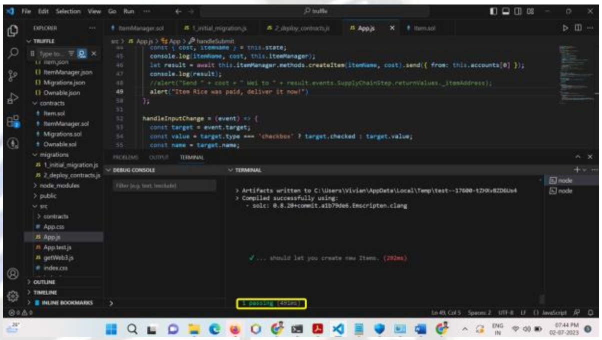

Fig. 19: Smart contract tested successfully using *Truffle* in milliseconds

6. Conclusion and Future Scope

This study employed a purposive sampling method to select key informants who possessed expertise in BCT, commodity trading, and trade finance. Purposive sampling is a widely used approach in qualitative research, where participants are intentionally selected rather than chosen randomly [18]. The selection of these key informants was based on the premise that they held specific and expert knowledge related to the subject of investigation and were willing to not only provide information but also offer valuable insights to the research scholar. The selection process was guided by the research scholar's judgment in identifying the most informative participants [18]. Furthermore, the use of purposive sampling ensured that the final sample included individuals from different categories within the sampling universe, thus representing diverse perspectives [19]. This approach aimed to reveal the unique viewpoints of participants. To ensure comprehensive and balanced discussions, representatives from various organizations were approached. Qualitative data was collected through interviews to gain an understanding of how blockchain impacts trust relationships among

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commodity trading partners with reference to trade finance. These in-depth interviews involved participants from diverse industrial backgrounds, and despite their varied backgrounds, similar responses were elicited. Interviews served as a valuable tool, enabling researchers to gain a holistic perspective on the subject by tapping into the knowledge, thoughts, and feelings of a wide range of informants [20].

Fig. 20 shows an in-depth analysis of the survey wherein six research questions (RQs) were considered keeping in mind parameters such as *security, similarity, alignment of interest, benevolent concern, communication quality,* and *predictability* with ratings of *low, medium,* and *high* indicating 1, 2, and 3, respectively.

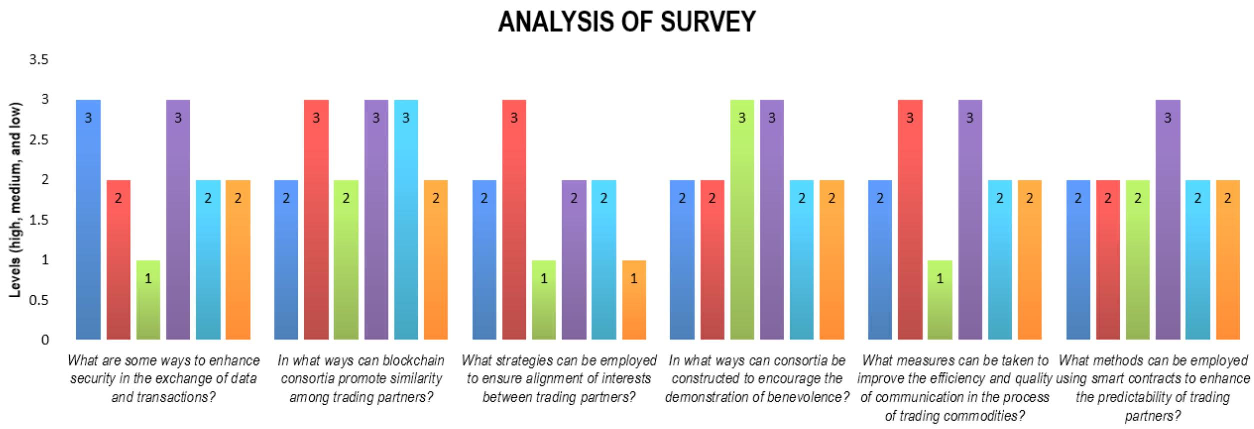

Fig. 20: Survey analysis on the basis of six research questions (RQs) with respect to the level of ratings

Presently, the majority of business transactions in both national and international commodity trade heavily rely on the participation of one or more third parties. Common methods for conducting transactions and processing payments, such as letters of credit, escrow services, and documentary collections, are extensively utilized. However, these methods share common deficiencies and drawbacks. These transactions often take place through various platforms and infrastructures provided by third-party entities. This arrangement gives rise to a host of issues, including a heavy dependence on third parties, the elongation and complication of business processes, the risk of confidential information being exposed, substantial expenses, and the potential for monopolistic control over the process [21].

Industry 4.0 technologies are increasingly taking center stage, and emerging business transactions leveraging these technologies are gaining momentum. Among these technologies, blockchain has garnered significant interest from both academia and industry in recent years. BCT provides a robust foundation for conducting secure, private, and trustworthy transactions within networks. It represents an innovative fusion of computing technologies with decentralized peer-to-peer transactions, distributed data storage, the capabilities of programmable smart contracts, automated consensus mechanisms, and dynamic encryption algorithms.

The aim of this study was to fill certain identified research gaps by proposing and introducing a peer-to-peer business transaction mechanism based on BCT and smart contracts. This mechanism is designed to create a trustless environment, allowing two parties to engage in transactions without relying on a trusted third party to act as an intermediary. Utilizing a blockchain-based mechanism not only emancipates business transactions from external dependence but also streamlines, expedites, and fortifies information security while fostering transparency. The incorporation of BCT into commodity trading carries substantial implications for both research and practical applications in various domains.

Blockchain has the potential to transform supply chain management in commodity trading by enabling the tracking of products from source to destination. This provides a wealth of data that can be analyzed and modeled to gain insights into the supply chain and identify areas for optimization. Research in this area can explore the development of new models and tools for supply chain management in commodity trading. Blockchain can increase market transparency and efficiency by reducing information asymmetry and the need for intermediaries in a trading process. Research in this area can explore the impact of blockchain on market transparency and efficiency, as well as the development of new market models that take advantage of the benefits of blockchain.

Smart contracts are a key feature of blockchain and have the potential to automate many of the steps in a trading process, reducing the need for manual intervention and increasing efficiency. Research in this area can explore the design and implementation of smart contracts, as well as the development of new verification methods to ensure their reliability and security.

The use of blockchain in commodity trading raises several regulatory and legal issues, such as the need for new standards and regulations to ensure the reliability and security of blockchain-based systems. Research in this area can explore the regulatory and legal implications of blockchain in commodity trading, as well as the development of new frameworks and standards to ensure compliance with regulations and legal requirements.

In the broader context, the integration of BCT into commodity trading holds profound implications for research and has the potential to revolutionize the industry. This transformation could manifest in heightened operational efficiency, lowered expenses, and the enhancement of transparency and security throughout the trading process.

Using the data gathered from in-depth interviews conducted for the aforementioned research questions, a thematic analysis will be conducted. This analysis aims to identify, examine, and interpret patterns of meaning within the qualitative data, specifically concerning the six dimensions of the trust model [22].

The six trust-related perspectives have been adapted to align with the current context of BCT and commodity trade finance. This adjustment is made to ensure that these perspectives are suitable for capturing and reflecting the emerging patterns observed in the interview data.

Moreover, smart contract audit could be carried out as a means to validate the developed process model that strengthens digital security in commodity markets using blockchain through systems approach.

The audit report would provide an assessment of the smart contract's security, including recommendations for improving the contract's security and reliability. Once the audit is complete, developers can use the feedback to fix any identified issues and improve the security and functionality of their smart contract, which can increase confidence in the contract and its ability to perform as intended.

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