Optimizing Resource Management in Algerian Traditional Brick Manufacturing (SNG) Using Blockchain-Based Smart Contracts with Solidity

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***Abstract*—Resource management is the strategic process of efficiently planning, organizing and controlling resources, such as: time, money, materials and personnel to achieve organizational goals. Different crucial roles are played by it, such as waste minimization, cost reduction, time protection, energy conservation, and productivity enhancement, while sustainability and adaptability in dynamic environments are ensured. In summary, it is a process regarded as essential for the achievement of long-term success. In addition, optimizing resource management is a critical challenge across all fields, particularly in the industrial sector, where inefficiencies lead to negative impacts. Effective strategies require balancing resource allocation, energy consumption and production output while maintaining sustainability. Advances in technology, such as Artificial Intelligence (AI), Internet of Things (IoT) and blockchain offer promising solutions to enhance efficiency and revolutionize the whole of the industrial field. In our study, we discuss the implementation and local adaptation of a Blockchain-driven inventory and production management solution, based on a smart contract model that is already operational in other countries but not yet adopted in Algeria (Batna) uniquely tailored for a traditional brick manufacturing industry. Modular Smart Contracts will form part of this system (where challenges like inefficiencies, lack of trust, waste, and high costs persist), enabling a number of operational needs-from the raw material management, production oversight, to inventory administration. These Smart Contracts of integration in the study measure how Blockchain can enhance transparency, efficiency, and reliability in managing the resources at different stages of the brick production process.**

Keywords- Optimization; Blockchain; Smart contracts; Resource management.

I. INTRODUCTION

The manufacturing industry is a cornerstone of global economies, driving innovation, creating jobs and supporting economic growth through the production of goods using labor, machinery and advanced technology [1]. Resource management [2] [3] plays a crucial role in the industrial sector, ensuring optimal use of materials, energy, and labor while reducing costs and environmental impact [4]. However, traditional industrial systems face numerous challenges, including inefficiencies in resource allocation and reliance on manual processes that are error-prone and time-consuming, leading to waste and increased costs. Limited integration between departments or supply chain stages creates communication gaps and operational silos, while dependence on intermediaries and centralized control increases risks, delays, and downtime. These systems also lack transparency, making it difficult to monitor operations effectively and ensure data security. Furthermore, outdated infrastructure struggles to scale or adapt to changing market demands or technological advancements, hampering growth and competitiveness. High operational costs and environmental inefficiencies further hinder efforts to achieve sustainability and long-term success. Since its emergence in 2008 [5], blockchain technology has provided effective scientific proposals, some of which have been implemented on the ground and some of which are still under development. Moreover, reliance on Smart Contracts has led to offer innovative solutions by enabling secure, decentralized and automated processes that address these limitations [6].

This paper focuses on developing a blockchain-based system for a brick factory, demonstrating how Smart Contracts can streamline operations, enhance resource utilization and transform industrial practices for greater efficiency and transparency. It is organized as follows: Section 2 offers an overview about the appearance of Blockchain and Smart Contracts in the scientific field and its applications in Inventory Management (IM). Section 3 describes the need for Smart Contracts for brick factories and its key features. Section 4 gives us a case study in an Algerian factory named New General Society “SNG”. Results and discussions appear in Section 6. The final section presents the conclusion and future work.

II. LITERATURE REVIEW

A. Overview of Blockchain and Smart Contracts

The fast advancement of technology has resulted in revolutionary developments, altering industries and reinventing how people communicate [7], trade, and trust in a digital environment. Among these innovations, Blockchain technology and Smart Contracts stand out as game-changing tools that offer unprecedented security, transparency, and efficiency in modern processes. Blockchain, often known as the backbone of digital trust, provides a decentralized and immutable framework for recording transactions and managing data. Its distributed structure eliminates the need for middlemen [8], resulting in a system that prioritizes transparency and security. In addition, Smart Contracts, which are self-executing agreements [9] inscribed directly on the blockchain, add a layer of automation that simplifies procedures, reduces costs, and maintains reliability.

This section investigates the foundations of Blockchain and Smart Contracts, including their essential characteristics, applications and synergies when combined. Understanding these technologies enables us to address long-standing difficulties in areas such as supply chain management, banking, healthcare, and so on. This preamble serves as an introduction to a world where technology promotes trust, efficiency and creativity, paving the path for a more linked and safe future.

We began browsing for literature relating to Blockchain and Smart Contracts and data was acquired from the Scopus and Google Scholar databases. We looked at just scientific publications published in English since 2024. After the screening step, we rated irrelevant publications based on duplication, title, abstract substance, etc. To choose the target objects, we were quite careful about several key features. Table I outlines the main key features of Blockchain (BC) and Smart Contracts (SC).

TABLE I. SAMPLE OF KEY FEATURES OF BC AND SC.

Aspect / Key Features	Blockchain	Smart Contracts
Decentralization	Data is shared across multiple nodes, removing reliance on a central authority [10].	Operates on decentralized networks, ensuring independence from central intermediaries [15].
Immutability	Data cannot be altered or deleted once recorded, ensuring a tamper-proof system [11].	Contract terms and conditions cannot be modified after deployment, ensuring integrity [16].
Transparency	Transactions and data are visible to authorized participants, fostering trust [12].	Contract terms are accessible to all authorized participants, enhancing transparency [17].
Security	Cryptographic techniques and consensus protocols protect data from unauthorized access [13].	Transactions and conditions are securely validated within the blockchain environment [18].
Automation	Enables the use of Smart Contracts for self-executing processes [14].	Automatically executes predefined actions when conditions are met, reducing manual intervention [18].
Cost Efficiency	Reduces intermediaries, lowering operational and transaction costs [8] [16].	Minimizes the need for third-party involvement, cutting down costs associated with execution [18][19].

B. Applications of Blockchain in Inventory Management

Inventory Management (IM) covers a wide range of fields that ensure efficient control, tracking, and distribution of goods within an organization. Table II summarizes some fields of Inventory Management and their potential relationship with Blockchain (BC).

TABLE II. RELATIONSHIP BETWEEN IM AND BC.

Field of IM	Blockchain footprint
Stock Control	Improves transparency and accuracy in stock levels by providing real-time transaction updates and reducing human errors or discrepancies in inventory data [20].
Inventory Tracking	Enables secure, real-time tracking of goods from suppliers to customers, enhancing accuracy and reducing fraud or tampering [21].
Supply Chain Management	Provides a transparent, auditable, and immutable record of all transactions in the supply chain, enhancing traceability, efficiency, and reducing delays or fraud [22].
Order Management	Streamlines order management by recording and verifying every step, ensuring accuracy and reducing disputes between suppliers, distributors, and customers [23].
Demand Forecasting	Provides transparent historical sales data and transactions, enabling the prediction of future inventory needs [24].
Warehouse Management	Enhances warehouse management efficiency by providing a comprehensive record of goods movements, improving operations, and reducing human error [25].
Inventory Replenishment	Smart Contracts automate inventory replenishment by triggering reorders when stock thresholds are met, ensuring timely restocking without human intervention [23].
Stock Auditing and Reconciliation	Ensures that inventory data is unaltered, facilitating audits and reconciling discrepancies between physical inventory and system records [26].
Returns and Reverse Logistics	Records the history of returned items, ensuring their proper processing, tracking, and potential re-entry into inventory, while minimizing fraudulent returns [27].
Risk Management	Enhances supply chain resilience by providing transparent records and mitigating risk through smart contract automation [28].

C. Research Gaps

Our analysis highlights a significant gap in the existing research on traditional brick factories in our region, largely due to the limited adoption of emerging technologies that could improve traceability and transparency. To address this gap, a comprehensive examination of the specific challenges and opportunities within this manufacturing sector is necessary. Furthermore, incorporating innovative concepts, such as Blockchain technology and Smart Contracts could pave the way for new solutions designed to reduce energy consumption, enhance the traceability, transparency, sustainability of brick IM.

III. Methodology and Case Study

A. Description

SNG (Société Nouvelle Générale) is a private company founded by the Spanish firm Equipceramic in 2013. However, in 2019, a number of socio-political events took place. The facility was nationalized from private ownership in order to support the growth of Batna, Algeria's building materials sector. The company specializes in manufacturing and delivering construction materials. On the ground at the factory site, such change in developments did not cease production and sales. This plant went into a public auction in April 2024. Currently, SNG has 135 employees working in a variety of departments and services, all of whom are under general management. The location of the factory between 3 provinces (Batna, Setif, and Khenchla) puts it in a strategic position to take advantage when it comes to logistics and distribution. The factory is divided into three zones with an area of 75,000 m^2 each (Raw Material Park, Manufacturing Workshop, Equipment and Spare Parts Warehouse, and Finished Product Storage). The continuity of SNG's operational ability despite ownership changes proves its vital role in Batna's industrial ecosystem. The factory has a daily production capacity of around 10,000 bricks; this is positive potential to integrate our Smart Contracts.

B. Manufacturing Process

Brick production involves several key stages, as illustrated in Figure 1.

Figure 1. Manufacturing Process of SNG.

1. Extraction: Mechanically extract clay from the ground to deliver it to the park.
2. Preparation: The raw clay is homogenized by crushing, mixing, refining, and moistening.
3. Shaping: To get the required characteristic textures materials (mixture of clay, sand and water) and formed into bricks.
4. Drying: To ensure sufficient strength for stacking and burning, the bricks are dried under regulated conditions, bringing the moisture content down to around 2%.
5. Firing: The bricks are fired in a tunnel kiln, where the bricks go through physical and chemical transformations at high temperatures. After that, the product will gradually be heated with controlled cooling using natural gas. This process stabilizes the brick structure.
6. Storage: The final product is packed for storage and ready for transportation and distribution.

C. Implemented Model for Local Context

The Business Process Model and Notation (BPMN) 2.0 is a standard graphical representation for business process modeling. Figure 2 is a diagram presenting the resource management process in SNG in three major steps after extraction/procurement and before sales/marketing, namely: Parc, Main Manufacturing (Production, Spare Parts Warehouse), and Storage. Parc is in charge of providing clay and sand to prepare the raw material, resolving shortages, and keeping track of such data. Main Manufacturing produces products and maintains quality by means of repair and inspection using the equipment provided by the Spare Parts Warehouse. After the control quality step, the qualified products are then forwarded to Storage. This will also enable IM levels in storage for sales later. Decision gateways, information flows, and data logging ensure synchronized communication and efficient workflow.

The reason why Smart Contracts are excellent for designing decentralized applications (DApps) to manage SNG resources is their security and automation of the execution of the agreement as a computer program. The immutability of the Blockchain ledger increases the confidence of every transaction of the recorded resources, hence it is tamper-proof and dispute-free. Blockchain with Smart Contracts revolutionize resource management by forcing accountability, cost reduction, and scalability.

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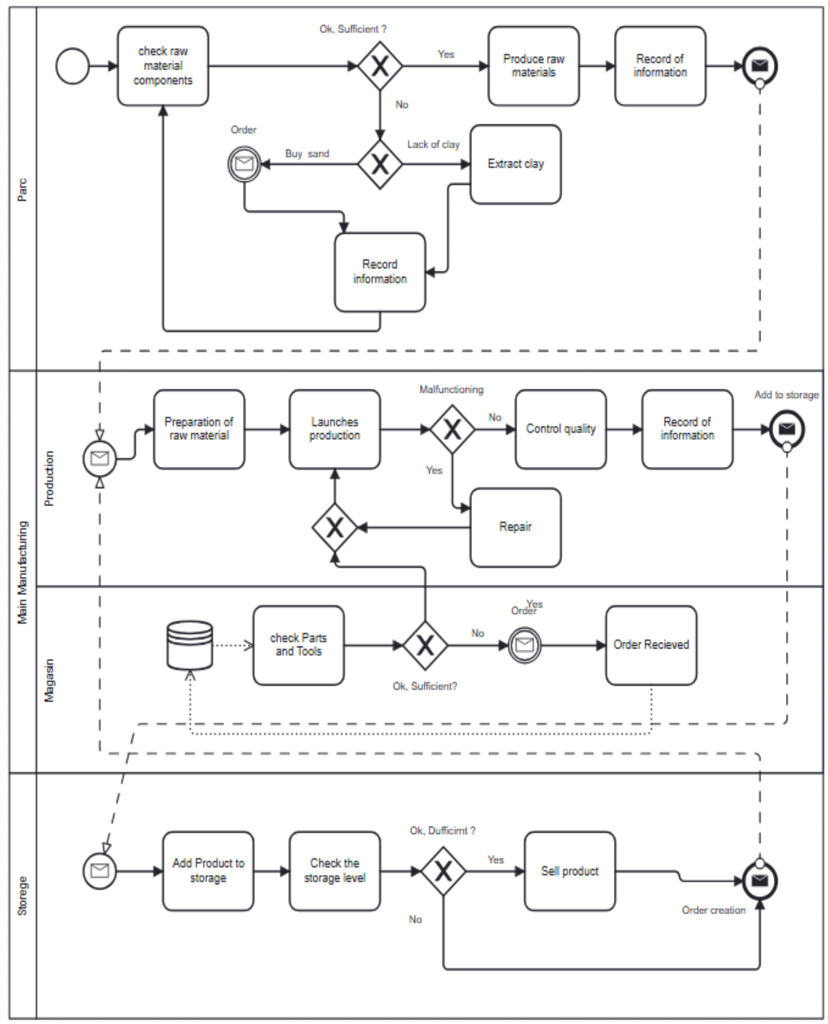

Figure 2. SNG's BPMN 2.0 Resource Management Diagram.

In this paper, we propose a model based on the combination of Smart Contracts based Blockchain with the goal of enhancing resources management in SNG while accounting for the shortcomings of SNG's traditional access data system. First, given the traditional nature of the factory, we propose several suggestions that help our DApps platform ensure effective and accurate management of resources and access data. One suggestion is to install smart sensors of different types (from truck weighbridge, to shape sensor, temperature and humidity sensors, etc.) that will display IoT data in real time at each stage of the process. Also, since the financial aspect of BC technology is prohibited in Algeria, we aim to overcome these constraints by theorizing solutions tailored to the factory's specific context. The decentralized application (DApp) is designed using a blockchain-based architecture (Figure 3), such as Ethereum. It employs smart contracts written in Solidity to automate various process functions [29], serving as the backend. Tools and libraries from the Node.js ecosystem, such as npm and Web3.js, are used to integrate the smart contracts into SNG's system.

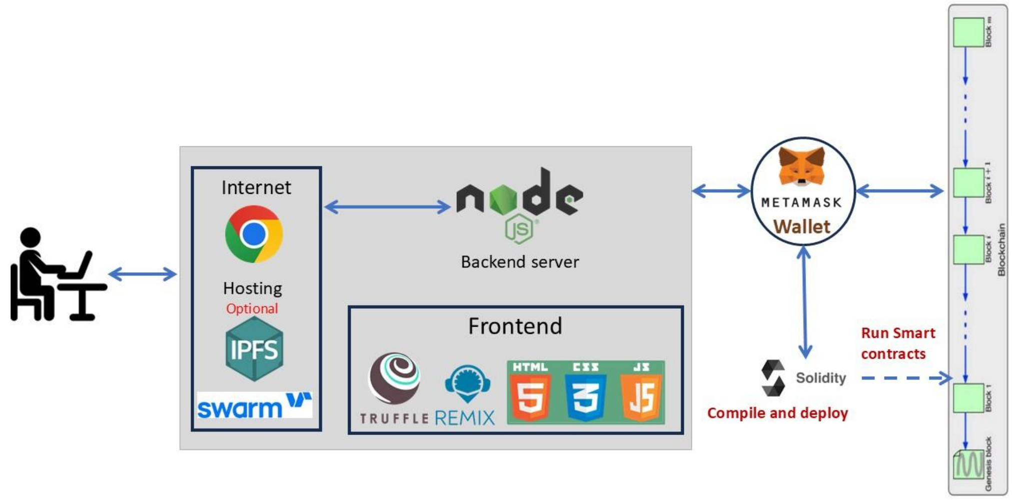

Figure 3. Architecture of our Decentralized Applications (DApps).

The decentralized application (DApp) primarily operates on-chain, ensuring transparency and immutability of core processes through smart contracts. To enhance scalability, efficiency, and reduce costs, we adopt a hybrid architecture that combines both on-chain and off-chain components (Figure 4). For secure decentralized storage, stakeholders can use communication protocols such as IPFS or Swarm. Users interact with the smart contracts through development environments like Remix IDE or Truffle. Additionally, we have developed a user-friendly web interface using HTML and JavaScript. All interactions between the blockchain and users are securely facilitated by a wallet application, such as MetaMask, which serves as a trusted intermediary.

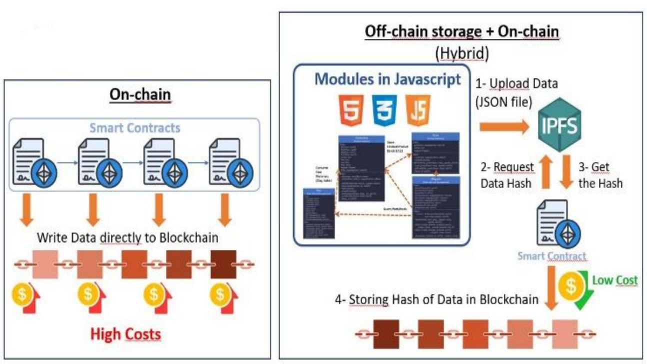

Figure 4. Architectures (On-Chain VS Hybrid).

D. Implementation

We used the Remix IDE, an online integrated development environment, to write, debug, and deploy smart contracts for resource management at SNG using Solidity on the Ethereum blockchain. Remix offers an intuitive interface with built-in tools for compilation, testing, and deployment, simplifying smart contract development [30].

As illustrated in Figure 5, the system comprises four main modules or interfaces: Magasin, Production, Parc, and Storage. The first three, Magasin, Parc, and Storage, share similar core functionalities, such as adding or removing items, updating quantities, and emitting events. However, they differ in terms of constructors, input parameters, and capacity constraints. Each module can also invoke specific functions, for example, the 'panne' function is triggered to indicate a malfunction.

The Magasin manages the inventory of tools, equipment, and spare parts used in the workshop. The Parc module handles the supply and tracking of raw materials such as sand and clay. Finally, the Storage module is responsible for the storage and sale of finished products, including "Brick 8" and "Brick 12". Finally, the Production module is dedicated to managing the manufacturing process of products such as Brick 8 and Brick 12. It utilizes external interfaces, namely IParc, IStock, and IMagasin, to interact with the other modules. Through these interfaces, it coordinates the consumption of raw materials, oversees the creation of finished goods, and updates inventory records accordingly.

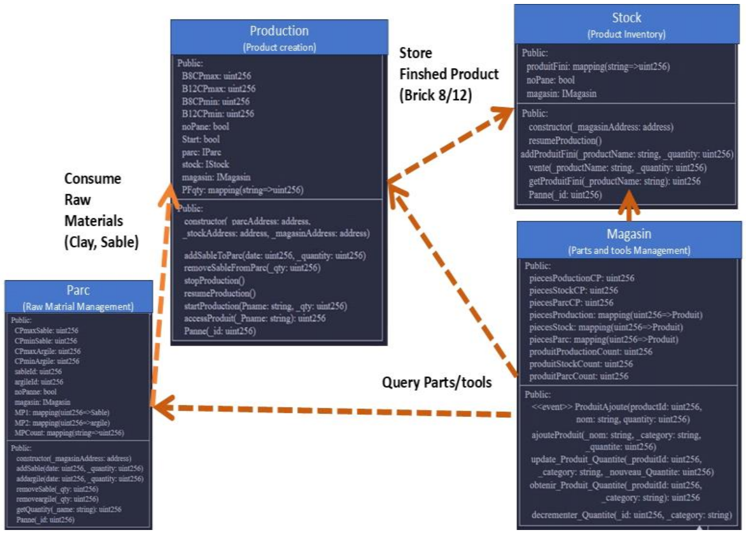

Figure 5. Simplified UML SNG resource management.

IV. DISCUSSION AND CHALLENGES

Brick production often faces challenges related to traceability, cost control, and security. These issues underscore the potential advantages of adopting blockchain-based smart contract technology. In response, we developed a decentralized application (DApp) to manage the inventory system of the SNG brick factory, aiming to improve transparency, automation, and reliability in resource management.

Table III presents a concise comparison, based on our overall assessment, between PME Pro, the traditional application used at SNG, and the smart contract-based decentralized application at the resource management level. Traditional brick manufacturing processes typically rely on manual and centralized systems, which are time-consuming and susceptible to delays caused by intermediaries and outdated data. In contrast, our smart contract solution streamlines operations by automating workflows, supporting real-time decision-making, and minimizing the need for intermediaries. While traditional factories may consume less energy locally, blockchain networks require significantly more global energy due to their infrastructure requirements, including nodes and mining operations. However, it is important to note that several modern blockchain technologies, such as Avalanche and the upgraded Ethereum network, have significantly improved energy efficiency compared to earlier blockchain implementations. Smart contracts further enhance data security through decentralization and encryption, while also minimizing waste and fraud via precise tracking of assets and resources. Additionally, they facilitate seamless integration of communication protocols across departments and ensure transactional integrity. By eliminating intermediaries and reducing the risk of fraud or tampering, smart contracts offer a more secure and trustworthy alternative to traditional resource management methods.

TABLE III. COMPARISON PME PRO VS DAPPS

Resources Aspect	***PME Pro (Traditional Application's Brick Factory)***	***DApps with Smart Contracts (Solidity)***
Time consumption	High (Manual and delayed processes)	Low (Automated, real-time processes)
Cost	High (Intermediary costs)	Lower (Fewer intermediaries)
energy consumption	Low (Single factory operations)	High (ex: BC that uses Proof of Work, Public BC) Low (ex: BC that uses Proof of Stake, Privat BC, etc.)
Data	Centralized (Vulnerable)	Decentralized (Secure)
Physical waste	High (Ineffective tracking)	Low (Accurate tracking)
Communication	Fragmented communication across departments	Integrated and decentralized communications protocol
Automation	Manual	Automated
Risk Management	High	Low

Transaction history in our local blockchain, as an example of a smart contract, is crucial for optimizing resource management at brick factories by providing a transparent and immutable record of activities. It enables precise tracking of raw material purchases, energy consumption, and production outputs, leading to better resource allocation. Historical data also helps identify patterns, which can facilitate process improvements and reduce disputes. Additionally, transaction history supports compliance with regulations by maintaining a verifiable audit trail. It further allows the factory to forecast demand, plan inventory effectively, and avoid overstocking or shortages.

V. CONCLUSION AND FUTURE WORKS

This study highlights the transformative potential of BlockChain (BC) technology and smart contracts in addressing inefficiencies in industrial resource management, particularly within the brick manufacturing industry. Smart contracts add significant value to inventory management (IM) operations by automating processes and ensuring transparency and traceability in transactions. Consistent with previous research, we confirm that integrating both technologies can reduce costs and reliance on intermediaries, enhance operational efficiency, automate workflows, and ensure compliance with quality and safety regulations. The potential of smart contracts to optimize resource management across industries such as manufacturing is increasingly compelling. Furthermore, the use of decentralized applications (DApps) can foster improved collaboration among stakeholders while streamlining inventory and production management processes. To further enhance our work, several future directions can be considered:

- Integrating IoT sensors and real-time data logging to improve operational accuracy and synchronization.
- Exploring the use of green blockchain technologies to promote more sustainable industrial practices and foster environmentally conscious decision-making [31].
- Implementing and evaluating the system in other manufacturing sectors to assess scalability and adaptability.
- Incorporating Key Performance Indicators (KPIs) to support data-driven optimization of resource management.
- Comparing the proposed solution across different blockchain platforms, including Hyperledger and Solana, to evaluate performance, scalability, and suitability.

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