Date of publication June 22, 2025, date of current version June 22, 2025.
Digital Object Identifier 10.21608/pesj.2025.391487.1034

Technical letters,

A Comprehensive Study on Blockchain Adoption for Improved Transparency and Efficiency in Petrochemical Industries

Abbas A. Ezzat

Petrochemicals Engineering Department, Faculty of Engineering, Pharos University in Alexandria (PUA), Egypt;
abbas.ezzat@pua.edu.eg

Abstract: Basically, Petrochemical industries comprise of multiple know-how owners, suppliers, and end users throughout the industry supply chain system and rely on extensive network to bring their products and services to competitive markets. Each supplier maintains their ledger in compliance with their policies and procedures separately. As a result, most business transactions are inefficient, expensive and vulnerable. Inefficiencies result from the duplication of a single contract by each participant in the supply chain. In fact, the time it takes for each participant to record and reconcile transactions can slow down the flow of capital and revenue recognition throughout the entire supply chain. Nowadays, the petrochemical industries are facing challenges due to crude oil price volatility, and complex financial situations. This, in addition to the high cost of upstream industry developments, coupled with downstream efficiency Challenges. Therefore, petrochemical industries are gradually shifting toward intelligence and digitalization for attaining high KPI's. The petrochemical industries are facing challenges in this era. Due to crude oil price volatility, the high cost of upstream industry developments, coupled with downstream efficiency challenges forces downstream companies to reduce costs. Therefore, strategy modification is needed in how such companies conduct business transactions economically and efficiently. The application of Block chain technology has been developed recently to deal with strategy modifications and how such companies conduct business transactions & data security economically and efficiently. The industry network structure connects suppliers, partners, distributors and customers, and operates across geographies and regulatory boundaries. The present study covers the prospects of applying block chain technology in petrochemical related industries.

Keywords: Block chain technology; petrochemical industries; business transactions; downstream efficiency Challenges

I. Introduction

Due to crude oil price volatility, the high cost of upstream industry developments, coupled with downstream industry efficiency, and challenges is forcing oil and gas downstream industries to reduce costs in an economic and efficient regime. The application of block chain technology is an approach to face these challenges. This approach is based on geographic, political and operational realities, along with the scale of investment required within the industry. Therefore, strategy modification is needed in how upstream and downstream companies conduct business transactions economically and efficiently. On the other hand, since petrochemical industries are based on developing technologies with complex configurations, industrial companies cannot exist in isolation since they rely on extensive supply chain networks which can connect suppliers, partners, distributers and customers and operates across different geographic locations.

the application of block chain technology in petrochemical industries is considered as a system integration approach through engineering, procurement, construction management, and other key service supplier relationships. It shall enable automated business transactions become more sophisticated, and that industry networks could

evolve into self-governing cognitive business networks economically. The expected outcomes are increases in their profitability in today's economic situation and well improvements in KPI's.

II. Theories of Blockchain Technology

A. Concept of blockchain

Essentially, block chain is a kind of mode to manage transaction processing through transparent rules to construct non-tampering and traceable block chain data structure. It is an application mode combining computer technologies such as distributed data storage, consensus mechanisms, peer-to-peer transmission, and encryption algorithms. The biggest innovation of block chain technology is that transactions are no longer stored in the central database. The system is based on Peer-to-peer application, where the computers in each node in the network have equal status, each node has the same network power, and there is no centralized server. All nodes share information through specific protocols. This means that, in the block chain model, transactions can be conducted directly between two parties without third party intervention, and all transaction data are stored in the distributed blockchain.

B. Key Characteristics of Blockchain

Blockchain technology has six main characteristics, including: decentralization, immutability, transparency, efficiency, security and anonymity.

i. Decentralization

This feature clarifies that the block chain-based system is no longer dependent on the central processing node, which realizes the distributed recording, storage, and Data updates. The status of each node is the same, and the data blocks are maintained by the nodes with the maintenance function in the entire system.

ii. Immutability

Information cannot be changed after being verified and added to the blockchain.

iii. Transparency

Transparency is the basis for blockchain to be trusted because data record and update are transparent to the nodes of the entire network. Therefore, network-wide nodes with high transparency can be used to review, track data records, and track operations.

iv. Efficiency

The blockchain technology makes the system more transparent by distributing database records to users in the system, so it is more efficient in terms of risk, cost.

v. Security

Since the blockchain-based system has the characteristics of decentralization, the security of the entire system is safe.

vi. Anonymity

In the blockchain systems, both parties can make the transaction anonymous because the program rules in the blockchain can automatically determine whether the exchange activities between nodes are valid.

C. Cooperation with Other Technologies

Recently, the developments of artificial intelligence and cloud computing are being researched for blockchain technology developments, e.g. artificial intelligence based on blockchain uses smart contracts in terms of user equipment authorization, authentication, and value exchange to improve security. On the other hand, the combination of block chain and cloud computing will effectively reduce the cost of block chain deployment.

In a practical case, the Block chain as a Service (BaaS) system developed by the combination of blockchain and cloud computing aims to provide users with better blockchain services such as good resource management tools, customized data analysis and reporting systems.

D. High-performance block chain technology

Originally, each block chain network is a relatively independent network, and data information cannot be interconnected. However, Cross-chain technology makes block chain suitable for industries with complex scenarios such as petrochemical industries.

III. Petrochemical industry blockchain system

Petrochemical industry can be divided into three main classes, namely, primary, intermediate, and end materials. primary class covers feedstocks and raw materials, The intermediate class covers intermediate petrochemical materials, such as monomers, ethylene di-chloride. The petrochemical industries include the following sections:

- Capital projects.
- Commercial trades/deals and service execution contracts.
- Supply chain / pipeline / logistics / shipping / procurement.
- Marketing and related programs.
- Trading in carbon emissions.
- Joint-venture data/accounting.
- Transfer pricing.
- Production sharing.

The intermediate products include monomers, resins, compounds, which are directed to processing units to produce finished products. The value chain of petrochemical industries can be summarized in table 1

Table 1: Depicts the value chain of petrochemical industries.

Primary section	Intermediate section	Downstream section
Natural Gas/Crude oil feedstocks	Primary petrochemical materials	Compounding and composite processes
Primary operations	Intermediate petrochemical feedstocks	Petrochemical end products
Conversion processes	Intermediate Storage and conditioning	Storage and handling of end products

IV. Petrochemical Industry management System:

In general, the management system of petrochemical industry plants can be classified into three aspects:

- Reconciliation and paper work impacts.
- High risk of inefficiency in transactions.
- Third party management costs.

Also, petrochemical industry executives need to understand how best to extract value from block chain technology and develop an adoption strategy.

The following criteria should be considered in the application of block chain technology:

A. Business operations position

considering the highest-value opportunities:

i. *Globally accepted standards achievements*
- Exploring the role of alliances and how profit pools might be redistributed.
- Consider the blockchain as the new business environment and collaboration as the optimal way of working.

ii. *Business Scale's lines and applied revenue models*

Looking for new sources of revenue as business models, e.g. explore how blockchain might extract further value from other technologies, such as the Internet of Things, and cloud computing

V. Bloch chain aspects in petrochemical industries

Since the petrochemical industry is a multilink industry, a large number of transactions and contracts are involved in these phases, resulting in a large number of reconciliation work and tracking work.

A. Smart contracts

A kind of contract that records terms with computer language instead of legal language. The smart contract can receive transaction requests from outside and generate new transactions. The results can be updated for the status of the ledger and cannot be forged and tampered once confirmed. Smart contracts can greatly reduce paperwork, simplify the process and improve efficiency.

The smart contract model is comprised of the following contents:

- Input transactions and events
- Process response and its rules
- Contract value and status
- Output transactions and events

B. Decision making and Management

Block chain has important applications in decision making, such as feedstock selection, refinery/petrochemical integration, maintenance, and marketing related services. Block chain application will result in the proof of feasibility study results and can provide records that cannot be tampered with, which greatly help industry control. On the other hand, for management decision making, the application of block chain technology leads to efficient data exchange and transmission e.g. smart contracts can help automated and transparent voting application, which improve the correctness of decision making.

C. Supervision

Many petrochemical products are distributed through various channels such as producers, suppliers, contractors. The block chain can track production situation and provide transparent evaluation of the process, including asset tracking, equipment life cycle. This is considered as the main function of the block chain technology application for solving petrochemical industry KPI's evaluation and supply chain management. Table 3 shows a typical system architecture of petrochemical enterprise structure

Table 2: System architecture of petrochemical enterprise structure.

System/Priority	Architecture
IT	Corporate workplace.
IT	Server-historian-patch management.
IT	Data historian-Production controller-control room work station.
IT-SCADA	Human machine interface-operation station-engineer work station.
SCADA/OT	PLC's- Remote terminal unit-intelligent electronic device.
SCADA/OT	Sensors- Actuators.
SCADA/OT	Feed conditioning- transfer/conveying systems-Processing units

VI. Opportunities and Challenges:

Due to the decentralization and transparency, the blockchain technology will bring many opportunities to petrochemical industries. It will encounter many challenges as shown in table 3.

Table 3: Opportunities and challenges in petrochemical industries

Opportunities Challenges	Item	Cause
Opportunities	Low transaction costs	Elimination of third parties Reduced transaction costs

	Convenient transactions High transparency	Decentralized data storage& block chain tracking Data sharing is fast and convenient
Challenges	Asset integrity management Adaption to new market model supervision Trust data quality costs	Data cannot be tampered with The introduction of Block-chain will change the mode of operation of industry and related ones Block-chain technology guarantee the accuracy of data. It will involve many management systems and databases.
Opportunities & Challenges	**Item**	**Cause**
Opportunities	Low transaction costs Convenient transactions High transparency	Elimination of third parties Reduced transaction costs Decentralized data storage& block chain tracking Data sharing is fast and convenient
Challenges	Asset integrity management Adaption to new market model supervision Trust data quality costs	Data cannot be tampered with The introduction of Block-chain will change the mode of operation of industry and related ones Block-chain technology guarantee the accuracy of data. It will involve many management systems and databases.

VII. Conclusion

In summary, block chain technology has excellent potential in petrochemical industries and that there are many opportunities, and challenges, and regulatory issues. The study introduced the core theory of block chain technology. The study discusses the application status, opportunities, challenges and risks of block chain technology in petrochemical industry. Block chain technology can bring many opportunities, such as reducing transaction costs and increasing transparency.

In order to meet market and management needs, while copying with feedstock price volatility and environmental regulations, the industry shall follow block chain technology towards cross-chain, and hybrid consensus mechanisms

Reference List

[1]. Construction and application of of digital supply chain finance platform in oil and gas industry, Yanmei li, et.al, Second International Conference on Cyber-Energy Systems and Intelligent Energy, ICCSIE, May 2024.

[2]. Ajay Mittal, et.al, A short review on the application of Blockchain technology in Petroleum Industry, COSMEC-2021.

[3]. Raji Wasim Ahmed, et.al, Blockchain in Oil and gas industry: applications, challenges, and future trends, Elsevier. https://doi.org/10.1016/j.techsoc.2022.101941.

[4]. Hussain, Raed, Proquest thesis, Modeling the supply chain Swap problem in petroleum industry, EKB link resolver, 2005.

[5]. G. R. Sinha, Book editor, modern optimization methods for science, engineering, and technology, 2020.

[6]. Shuchih E. Chang, When Blochchain meets supply chain, IEEE Access, 8, pp 62478-62494, 2020.