



The Role of Blockchain Technology in Oil Supply Chain Management Companies and Their Traceability

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دور تقنية البلوك تشين في شركات إدارة سلسلة توريد النفط وإمكانية تتبعها

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Abstract:

There are many parts to the supply chain in the oil and gas sector, including searching, producing, moving, processing and getting the resources to users. Such complexity usually leads to difficulties that include data being hard to see, inefficiency, fraud risk and problems meeting regulations. Using blockchain technology which keeps data secure, public and permanently recorded, has become key to boosting supply chain operations in this field. The study looks at how blockchain helps increase the transparency, traceability and efficiency of operations in the oil industry. Using surveys, interviews and case studies, the authors of the research consider what is happening within the company as well as in the wider environment when studying blockchain implementation. It is clear from the results that blockchain assists in faster transactions, increases data accuracy and restores trust between participants. Using smart contracts, companies can automate certain operations, bypass intermediaries and keep everything up to date through constant audits. Relevant examples are from BP and pilot projects in Nigeria and Pakistan which highlight the usefulness and limitations of using blockchain. Nonetheless, mass adoption continues to be blocked by high setup charges, uncertainty in the laws and insufficient professionals with the skills needed. Still, the study found that blockchain is likely to help improve the oil supply chain by ensuring it is safer, more transparent and runs more efficiently. It suggests that blockchain should be introduced bit by bit, that important IT investments should be made and that all sides should cooperate for its most effective use. These results open the door for other studies on how blockchain might be used more broadly, work with older systems and impact the economy and the environment for years to come.

Keywords: Blockchain technology, Oil Supply Chain, Oil Supply Chain Management, Oil and Gas Industry.

المخلص

تتألف سلسلة التوريد في قطاع النفط والغاز من أجزاء متعددة، تشمل البحث والإنتاج والنقل والمعالجة وتوصيل الموارد إلى المستخدمين. وعادةً ما يؤدي هذا التعقيد إلى صعوبات تشمل صعوبة الاطلاع على البيانات، وانخفاض الكفاءة، ومخاطر الاحتيال، ومشاكل الامتثال للأنظمة. وقد أصبح استخدام تقنية البلوك تشين، التي تحافظ على أمان البيانات وكونها متاحة للعمامة ومسجلة بشكل دائم، عاملاً أساسياً في تعزيز عمليات سلسلة التوريد في هذا المجال. وتبحث الدراسة في كيفية مساهمة البلوك تشين في زيادة الشفافية وإمكانية تتبع العمليات وكفاءتها في قطاع النفط. ومن خلال الاستبيانات والمقابلات

ودراسات الحالة، يدرس مؤلفو البحث ما يحدث داخل الشركة وفي البيئة الأوسع عند دراسة تطبيق البلوك تشين. ويتضح من النتائج أن البلوك تشين يُساعد في تسريع المعاملات، ويزيد من دقة البيانات، ويعيد الثقة بين المشاركين. وباستخدام العقود الذكية، يُمكن للشركات أتمتة بعض العمليات، وتجاوز الوسطاء، وتحديث كل شيء من خلال عمليات تدقيق مستمرة. ومن الأمثلة ذات الصلة شركة بي بي (BP) والمشاريع التجريبية في نيجيريا وباكستان، والتي تُبرز فائدة قيود استخدام البلوك تشين. مع ذلك، لا يزال التبنّي الشامل لهذه التقنية يواجه عقبات بسبب ارتفاع رسوم الإعداد، وعدم اليقين في القوانين، ونقص الكفاءات المؤهلة. ومع ذلك، وجدت الدراسة أن تقنية البلوك تشين من المرجح أن تُسهم في تحسين سلسلة توريد النفط من خلال ضمان أمانها وشفافيتها وكفاءتها. وتُقدّر الدراسة تطبيقها تدريجيًا، والاستثمار في تكنولوجيا المعلومات بشكل كبير، وتعاون جميع الأطراف لتحقيق أقصى استفادة منها. تفتح هذه النتائج الباب أمام دراسات أخرى حول كيفية استخدام البلوك تشين على نطاق أوسع، والعمل مع الأنظمة القديمة، وتأثيرها على الاقتصاد والبيئة لسنوات قادمة.

الكلمات المفتاحية: تقنية البلوك تشين، سلسلة توريد النفط، إدارة سلسلة توريد النفط، صناعة النفط والغاز.

Introduction

Different parts of the economy such as transport, manufacturing, energy and the chemical industry, are backed by the global oil and gas industry. But this industry operates with a complex supply chain that consists of many suppliers, transporters, processors and distributors [1]. Due to its complexity, the oil supply chain experiences several problems, including challenges with showing how things move, a high risk of dishonest activity and the urgent requirement to monitor events in real time. Data must be shared and collaborated on throughout the supply chain, as stakeholders from different places and with different rules work together [2]. Blockchain technology which allows data to be safely and openly managed without a single point of control, appears well suited to solve these problems. This study investigates how blockchain can improve the tracking, honesty and security of the oil supply chain. The study seeks to outline a framework that proves how blockchain can create efficiency, reliability and accountability in oil supply chains. Blockchain can overcome these problems by supplying a safe and permanent way to record transactions and manage data [4]. Blockchain does things differently than databases by allowing everyone to share one secure, verifiable ledger for transactions. The use of blockchain makes it possible for all participants in the supply chain to receive a dependable record of all transactions, helping increase transparency and cut down on errors and frauds [5].

Advantages of Blockchain in the Oil and gas Industry

Because the oil and gas industry's contracts are so large and complex, it is often hard to address disputes when things go wrong. It brings smart contracts and smart trades by turning standard paper contracts into digital format. Because of its visibility and ability to serve as an audit trail, blockchain works to reduce fraud and the chances of disputes. Additionally, using blockchain helps international payments occur quickly and affordably, eliminating the need for a third party wherever oil and gas are traded [5,6]. Besides, the security of blockchain allows it to help with record and supply chain management systems.

Scope of the Study

In this article, Author pays close attention to the oil supply chain by studying the roles of oil producers, refineries, distributors and regulators. These different actors all experience unique problems related to data transparency and obeying regulations which is why they are important figures to consider in this study of blockchain technology. A questionnaire will be used to gather input from these stakeholders about the advantages, problems and opinions they hold about blockchain. Analyzing these opinions will help the study explain if and how blockchain fits in with this industry.

Literature Review

Blockchain mainly relies on cryptography, consensus mechanisms and smart contracts to ensure safe, unchanging and automated transactions can happen. Blockchain's power comes from storing data securely and permanently, making it valuable in areas like finance, healthcare and the supply chain where trust, safety and openness matter [7,8]

The Use of Blockchain in The Area of Supply Chain Management

Supply chain management (SCM) includes planning activities such as finding raw materials, making products, moving them and distributing them. In oil and gas industries, SCM is made challenging by several parties involved, distances between them and the need to stick to strict regulations. Because

traditional SCM systems usually focus operations using one central data source, communication can become less efficient, transparency is lost and the system may have security issues. Reliable function of these systems depends on trusting relationships, but such agreements can be broken, resulting in fraud or error. So, traditional supply chains encounter many obstacles [5-9]. Because data is often not shared openly, it becomes tricky to watch goods move through the supply chain and confirm the accuracy of information. Problems arise when information is managed by hand and financial transactions must be compared and sorted. Hacking, fraud and changing data can easily occur with centralized systems that handle sensitive information. Through blockchain, everyone involved in the supply chain can reference a permanent ledger controlled by no single organization [8-10].

Blockchain's Role in Addressing Supply Chain Issues

Blockchain enhances supply chain management in several ways [10-12]:

- **Transparency:** Blockchain provides all participants with real-time access to the same data, improving trust and collaboration between suppliers, manufacturers, distributors and customers. Each participant can verify the integrity of the data without needing a central authority.
- **Traceability:** One of the most significant advantages of blockchain is its ability to track products throughout their lifecycle. In the oil industry, blockchain can be used to track oil from the point of extraction, through its transportation, refining and distribution processes, ensuring that the entire journey is transparent and verifiable.
- **Security:** Blockchain's cryptographic algorithms ensure that data entered the blockchain is secure and cannot be altered. This makes it highly resistant to hacking, fraud and unauthorized access.
- **Smart Contracts:** Blockchain enables the use of smart contracts, which are self-executing contracts with predefined rules. In supply chains, these contracts can automatically trigger payments, shipments or compliance checks when specific conditions are met, reducing the need for intermediaries and speeding up processes.

Blockchain Technology in the Oil Supply Chain

Current State of the Oil Supply Chain

The oil supply chain is divided into three main sectors [13-15]:

- **Upstream:** This includes exploration and production activities, where companies search for oil reserves and extract them. The complexity of upstream activities is often due to the geographical dispersion of oil fields and the need for highly specialized equipment and operations.
- **Midstream:** This involves the transportation and storage of oil. Midstream activities often face challenges related to logistics, safety and environmental concerns. Oil is typically transported through pipelines, ships or trucks, making it vulnerable to leaks, theft and accidents.

The sector handles refining oil, preparing it and getting it to end users. Oil is changed into gasoline in the downstream industry and delivered to the general public. Because there are many parties and a lot going on, it isn't always easy to keep things transparent, secure and smooth. A big issue in the oil industry is fraud, changed data, theft and poor tracking. EVERYONE can use blockchain to confirm changes to the ledger immediately as they occur [16,17]. Because information in traditional oil supply chains is not always transparent, there is often confusion about deals and activities among companies. Because every transaction is recorded securely on Blockchain in a ledger, anyone can view that information. As a consequence, everyone can see the progress of payments, inspect contracts and monitor oil products being shipped in real time. Moreover, blockchain can record all movements of oil products from when they are produced until they reach their final customer. In this process, the oil forged at a well can be watched through refining and on to the customer. Since product traceability is very efficient here, it is hard for someone to steal or alter them. With smart contracts, companies involved in the oil supply chain are able to create automated processes. Unlike contracts, smart contracts can pay out as soon as oil arrives at a refinery or is placed in storage. For this reason, tasks get done easier and are more efficient.

Blockchain in Oil and gas Supply Chain Case Studies

British Petroleum (BP) Blockchain Pilot Project

BP is one of the first oil and gas companies to use blockchain. BP tested using blockchain to improve the clarity and speed of oil deals. To monitor oil trades from start to finish, the project applied blockchain technology. Blockchain was found to greatly reduce the time involved in reconciling and managing paperwork [16-19]. A research project in Nigeria looked at how blockchain technology affects the way energy companies work together in the supply chain. It was found that the use of blockchain made it simpler for supply chain members to work together, thanks to access to real time transaction data. It is important to discuss Pakistan's oil and gas supply chain transformation in the next section. There are serious issues relating to ineffective supply chains and security for Pakistan's oil and gas businesses. Using blockchain in this industry could increase transparency, help lower operating expenses and improve the ability to trace products. Solutions built on blockchain technology have been introduced to help Pakistan's oil supply chain partners share data in real-time and become more integrated.

Potential Problems Facing the Use of Blockchain in the Oil Industry

Nevertheless, several issues are making it tough for blockchain technology to be widely used in the oil and gas sector. Different levels of technological infrastructure prevent blockchain from being set up in all parts of the world where oil businesses are active. There are numerous regulations the oil industry must factor in and they differ by country. It can be difficult to use blockchain while meeting the requirements of several legal rules [19-21].

- **Organizational Resistance:** Many companies are hesitant to adopt blockchain technology due to concerns about cost, disruption to current operations and a lack of understanding of the technology.
- **Scalability:** As blockchain networks grow, the amount of data and the number of transactions can become overwhelming, leading to concerns about scalability and speed.

Implementation of blockchain in Mellitah Oil and gas Company.

The oil and gas value chain are based on three stages: upstream, midstream and downstream. Upstream involves multiple activities, such as exploration and production of oil and gas with the help of acquiring the land rights for digging to find oil and gas reserves. Midstream SC is involved with the transportation and storage of the raw products and finally, downstream SC focuses on the refining and distribution of products. In the modern era, exploring oil and gas reserves uses the latest theological equipment, which is based on artificial intelligence (AI) [17-20]. After the exploration of reserves, production activities also consist of modern technology, such as mechanical digging and automated fracking. With the advancement of technology, oil and gas exploration and production methods developed rapidly in recent years using artificial intelligence, big data, and the Industrial Internet of Things (IIoT), such as marine digital platforms, intelligent oil and gas fields and drilling, and predictive maintenance using machine learning algorithms. Using these emerging technologies, the oil and gas industry is gradually developing in the direction of automation, digitalization and intellectualization. Unfortunately, the operational activity, especially SCM, is relatively less developed because the use of emerging technologies is limited, and this causes poor SCM, high operational costs, higher lead time and higher uncertainty [20-22].

Energy consumption

With the advancement of science and technology, the importance of oil and gas resources in promoting global economic and social progress is increasing. According to the "BP Statistical Review of World Energy" released by BP in June 2018, oil and natural gas account for 57% of total energy consumption. Moreover, global oil consumption increased by 1.8%, exceeding the average growth rate of 1.2% for three consecutive years, while the consumption of natural gas has increased by 96 billion cubic meters, reaching the fastest growth rate after 2010. However, according to "BP Energy Outlook 2019 edition", although the world is vigorously promoting the development of new energy, oil and gas will still occupy half of the world's energy by 2040. Besides, the report also pointed out that with the continuous expansion of liquefied natural gas (LNG) trade, LNG will account for 15% of total natural gas

demand in 2040. Therefore, oil and natural gas will continue to dominate the global energy market in the next 20-30 years [21-23].

As oil and gas resources play an essential role in the energy field, the technologies of the oil and gas industry have also developed rapidly in recent years, such as intelligent drilling technology, intelligent oil and gas fields and marine digital platforms [23-15]. The oil and gas industry are gradually developing towards the direction of intellectual- inaction, digitalization and automation. However, it manages- mint mode is relatively old, and it has the characteristics of low efficiency, high cost, long period and high risk. Oil and gas industry can be divided into three sections according to the market division: upstream, midstream and downstream. The upstream refers to the exploration and development of oil and gas, the midstream refers to the transportation of oil and gas and the downstream refers to the storage and sales.

Methodology

The approach examines how blockchain affects oil supply chain management by studying both the internal actions and interactions of oil supply chain firms. This way of studying will give you a full view of what goes on inside the organization and what external influences are at work for blockchain adoption.

Exploring Different Research Designs

In this research, an approach was taken that combines qualitative methods with quantitative ones. The method enables researchers to look closely at how blockchain makes oil supply chain management better by focusing on tracking, openness and efficiency. Two major parts make up my research: During internal analysis, the main things looked at are the oil company's facilities, what they can do and how prepared they are for using blockchain.

Analyses factors outside the organization

Such as rules, current trends and new technology, that influence the use of blockchain in the oil supply chain. To do an internal analysis, teams' study how well the organization can take on blockchain technology, given its assets and liabilities. Assessing the outside factors affecting a company is called external analysis. External analysis examines the influences on blockchain use in the oil supply chain from the environment around the company. The industry's role for blockchain depends on changes in regulations, the economy and technology.

How Data is Collected

Surveys

Oil companies' supply chain managers and IT professionals all received a structured survey for this purpose. The survey was put together to accumulate hard data about how adoption of blockchain occurs and everything good and bad with the technology. It collected data about organizations' preparedness, available technology and the impact of regulations.

Case Study

They offered clear cases of how blockchain can increase the openness, traceability and security of supply chains. Blockchain technology holds significant potential for the oil and gas industry, particularly in four key areas: trading, management and decision-making, supervision and cybersecurity. The subsequent subsections will analyze the potential applications of each of these four aspects. Figure 1 illustrates Oil and Gas Industry Chain.

Data Analysis

The data collected through surveys and interviews were analyzed using both quantitative and qualitative methods:

- **Quantitative Analysis:** Survey data were analyzed using statistical methods to identify patterns and correlations between blockchain adoption and supply chain performance indicators such as efficiency, cost reduction and trackability.
- **Qualitative Analysis:** Thematic analysis was conducted on interview transcripts to extract insights on the challenges and opportunities of blockchain technology. Key themes included the regulatory environment, technological readiness and the potential for smart contracts and automated processes.

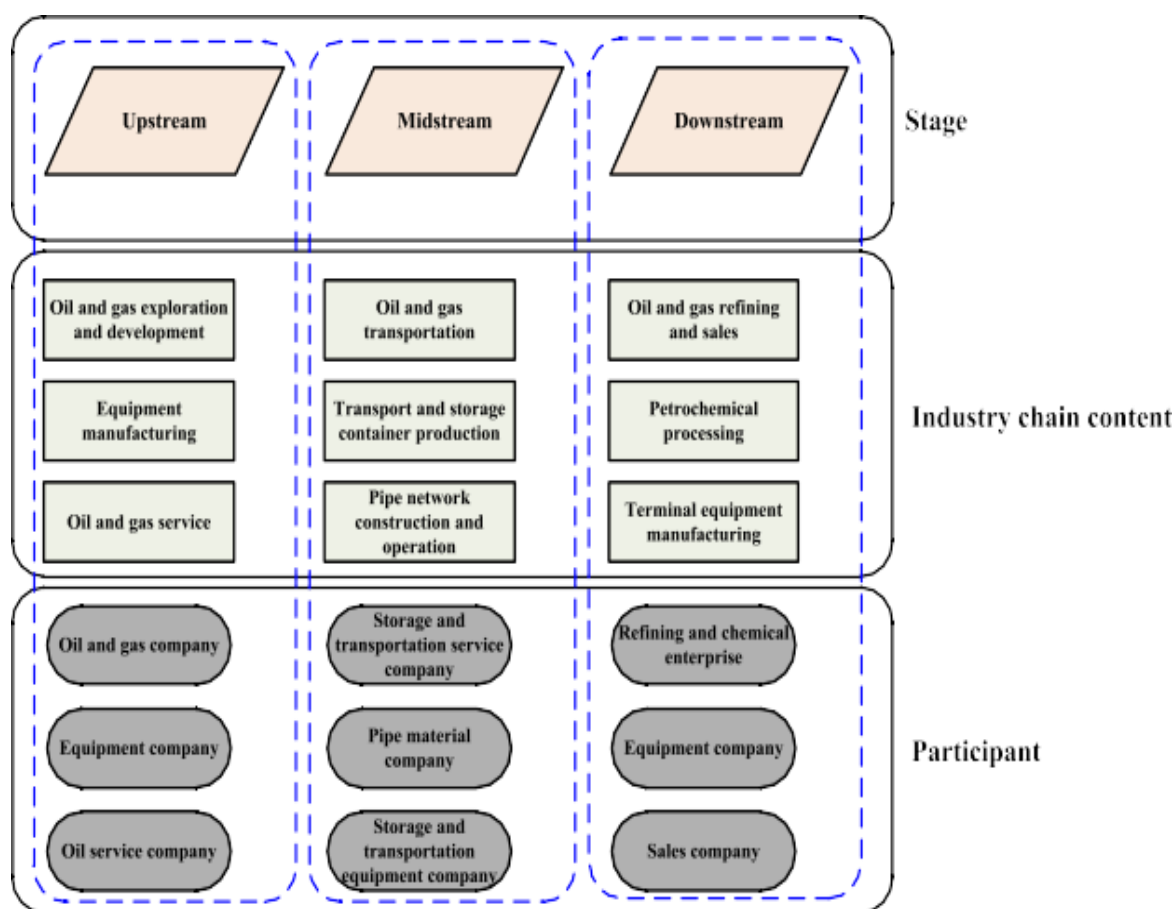


Figure 1: Oil and Gas Industry Chain.

Results and Comparisons

The results provide insight into the current state of blockchain adoption in the oil supply chain and its impact on key areas such as trackability, transparency, and efficiency. Additionally, a comparative analysis is conducted to evaluate how companies adopting blockchain differ from those relying on traditional supply chain management practices.

Results of Internal Analysis

The internal analysis focuses on organizational readiness, technological capabilities, and financial considerations for blockchain adoption within oil supply chain companies. Table 1 presents a major oil and gas blockchain projects.

Technological Infrastructure

The survey results indicate that most oil companies have some level of digital infrastructure in place, but only a few are fully equipped to integrate blockchain technology. Roughly 30% of firms said they have proper IT solutions for blockchain and 50% realized they must make major updates to their current systems. There are many companies that have doubts about the ability of blockchain to connect with their current systems.

Companies discovered that beginning with blockchain was costly, but those that did saw significant savings after a while. Forty percent of corporations currently operating blockchain wound up having lower costs for documentation, fraud checks and holding up the supply chain. Blockchain technology gave different ROIs to businesses, mostly because larger organizations saw results sooner due to operating on a larger scale.

Table 1: Major Oil and Gas Blockchain Projects [20-25].

Continent	Location	Gas Oil	Stage (Mid 2018)	Name/Company	Remark
Asia	Xiamen, China	Oil&Gas	Live	Sinochem Group	▪ Simulated gasoline export from Quanzhou to Singapore.
Asia	Abu Dhabi	Oil&Gas	Test	ADNOC and IBM	▪ Aims to enhance production automation.
North America	Houston	Oil	Test	P2P Global Platts	▪ Focused on facilitating transactions, reporting.
Europe	London	Oil	Live	One Off Crypto	▪ Implementing a blockchain platform for supply chain
Africa	Chile	Oil	Test	FOIZ, S&P Global (Pty)	▪ Testing blockchain for cargo trade.
Africa	Nigeria	Oil	Live	InterOil (QO)	▪ Engaged in oil and gas trading.
Europe	Switzerland	Oil	Live	komexo	▪ Developing a supply chain management solution.

Focuses On the Regulatory Environment for The Construction Field

Regulations were discovered to have advantages as well as disadvantages. Thanks to its records, blockchain technology supports activities aimed at staying compliant with rules and regulations which comes in handy for audits and environmental control. However, since there are no regulations just for blockchain in the oil industry, this was considered to be a challenge. Since strict data privacy rules affect some countries, there has been uncertainty in regulations that delayed the use of big data. To clarify, Businesses in places with fully formed blockchain regulations (such as the European Union) were found to embrace the technology more frequently. At the same time, businesses facing unclear rules tended to be more careful, worrying about lawsuits.

Market Forces

The desire to compete advantageously was an additional reason for blockchain's rise in use. Firms struggling to compete in the oil industry because of high competition often turned to blockchain to become more efficient, limit fraud and ensure their supply chain was clearer to customers. Increased customer requests for data on how oil is produced led certain companies to make use of blockchain so they could be more accountable. In addition, Firms seeking to serve environmentally conscious markets (in Europe and North America) were most likely to depend on blockchain to assist in tracking their products and give buyers reassurance about their sustainability.

Technological Advancements

New hybrid models and quicker consensus algorithms introduced in blockchain were seen to play a major role in the oil supply chain's adoption of the technology. When combined with emerging technologies IoT and AI, blockchain quickly collected real-time facts and helped predict what should be done to improve supply chains. Companies using both blockchain, IoT and AI had better real-time tracking and forecasting capacity. Even so, businesses that took time to use these supporting technologies did not enjoy the major advantages of blockchain.

Efficiency

Firms using blockchain technology experienced a 25% reduction in handling transaction reconciliations and organizing documents, when compared to those working with conventional systems. Smart contracts have made it possible for blockchain to fix the delays of manual work and boost the overall speed of the supply chain. Traditional supply chain management often depended on human effort which resulted in everything taking longer and given more room for mistakes.

Transparency

Stakeholders could see the transaction data in real time, thanks to blockchain which made the supply chain much more transparent. On the other hand, traditional approaches often made sure that information silos existed, causing some supply chain participants to have different data. Thanks to blockchain, there were fewer arguments between companies and their vendors or buyers, owing to real-time, accurate data. Conversely, traditional methods caused companies trouble when trying to reconcile transactions which led to more disagreements and slower work.

Trackability

Blockchain greatly increased our ability to follow products through the supply chain. Firms in the oil industry may use blockchain to closely track oil from its beginning all the way to buyers, thus decreasing fraud and guaranteeing they follow industry regulations.

Traditional supply chains were unable to track products in real time which sometimes made it hard to spot fake products and led to more theft and fraud.

Making Production More Affordable

The majority of blockchain's users saw reduced costs by handling less paper, needing fewer intermediaries and avoiding most errors. For the average business, using blockchain cut supply chain costs by around 15%, while similar businesses using old systems saw little change. Traditionally, companies relying on outdated supply chain methods paid more in day-to-day costs, as checking and validating everything manually required third-party help. There are several obstacles to using blockchain technology widely.

- **High Initial Costs:** Many companies reported that the initial costs of integrating blockchain, such as upgrading IT systems and training employees, were a significant barrier.
- **Regulatory Ambiguities:** The lack of clear regulations governing blockchain in the oil sector created hesitation among companies concerned about legal risks.
- **Interoperability Issues:** Integrating blockchain with existing legacy systems proved difficult for some companies, particularly those with older infrastructure.

Conclusion

This article aimed to understand how blockchain helps manage oil supply chains by paying close attention to transparency, trackability and efficiency. Blockchain technology can clearly address many of the problems found in older methods of managing the oil supply chain such as data tampering and issues with how supplies are tracked. It was found through internal research that tech-forward companies with leadership were more able to benefit from blockchain. They saw improvements in how smoothly they operated, how open they were and the costs they managed. Blockchain adoption was greatly affected by potential changes to regulations and the competition in the market. Those companies that face tough competition and detailed rules in their industry usually chose to use blockchain for better results. It was revealed through comparison that companies that used blockchain faced:

- More efficient operations are made possible when supply chain processes are handled with automation.
- As data is available in real-time, people can trust and be more transparent.
- Greater tracking of products makes it simpler to fight fraud and comply with regulations.
- Mainly because both manual work and the use of third-party help have been cut significantly.

Yet, because of the high upfront fees, uncertain regulations and difficulties with tech integration, the use of these technologies is not as popular as expected. Even so, once blockchain technology advances and governments create clear rules, oil businesses are more likely to include blockchain in their supply chain management.

Recommendations

This study points to a number of suggestions for oil companies interested in using blockchain.

- Improving IT infrastructure is necessary for companies to make blockchain part of their operations. Organizations are required to ensure that their previous systems can support the blockchain technology and to buy any required tools and equipment.

- Big companies should invest in teaching their workers about blockchain technology because it is still new in the oil industry. As a result, the company won't rely so much on outside consultants and the process will be much faster.
- Companies should connect with regulators to help design the rules that govern the use of blockchain technology. Because of this, the process of creating regulations will benefit, rather than hinder, the adoption of blockchain.

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