Computational Blockchain Framework for Quality Assessment in Sharing Economy-Based Supply Chain Management

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Abstract
Due to the complexity of global supply chains and the sharing economy, inefficiencies in traditional quality assessment methods are drawn out, mainly using manual inspections, centralized oversight, and paper-based tracking. In the case of these outdated approaches, they are likely to commit errors, fraud, and regulatory noncompliance [1]. This paper explores blockchain technology as a solution to supply chain transparency, automation, and quality assurance problems. The tamperproof records of Blockchain allow the transactions recorded to be tamperproof. At the same time, smart contracts ensure that the agreements governing the transactions are automated and have continuous and self-enforcing compliance. Adding blockchain technology to the Internet of Things (IoT) even further helps in the real-time monitoring of product conditions and reduces the rate of defect and fraud. This study shows how Blockchain significantly improves the traditional methods of quality assessment using comparative analysis, resulting in almost 2 times fewer defects (up to 67%), less than 90% of supplier compliance, and 60% less audit expense in major industrial sectors. Nevertheless, problems, including high deployment cost and scalability issues, still exist. Nonetheless, the study outlines how Blockchain paves the path to transformative supply chain management, not management, in a traditional supply chain context and a decentralized sharing economy. The results of this study can be used to discuss further the opportunity to incorporate emerging technologies in helping suppliers be accountable for fulfilling orders on time and care in how they handle customer data while also increasing the efficiency of the supply chain.

Keywords: Blockchain, Supply Chain Management, Quality Assessment, Sharing Economy, Smart Contracts, Transparency, Automation.

INTRODUCTION

Background on Supply Chain Management (SCM)

Supply Chain Management is a mainstay component of an efficient flow of goods and services from production to their use. It is a system that involves many suppliers, manufacturers, distributors, and retailers cooperating to get products to consumers quickly and efficiently. Quality assessment is one of the essential components of SCM to confirm that the products meet the industry and regulatory standards and customers' expectations [2]. Furthermore, for the traditional quality assessment models, one has to deal with challenges such as centralized oversight, manual inspections, and paper-based tracking systems for assessing the output. These outdated processes often lead to inefficiencies, errors, fraud, and product defects hitting the market.

For the most part, supplier verification has been overseen traditionally by central regulatory bodies that have to ensure they comply with safety and quality standards. However, bureaucratic delays, a lack of real-time oversight, and susceptibility to fraud limit their effectiveness. While still an important tool, manual audits are expensive, take time, and are

error-prone by man. Furthermore, paper-based tracking systems bring the inefficiencies of being tampered with, lost, and falsified, intended to undermine quality assurance efforts.
However, in the age of the sharing economy, supply chain quality assessment has become much more complex [3]. In contrast to the traditional SCM models, where the companies have direct control over production and distribution, the supply chain of the sharing economy mode of operation is based on decentralized ownership. Due to such a multi-faceted interaction between many suppliers, service providers, and users, we can find exceptional examples such as Uber, Airbnb, and WeWork, with quality assurance becoming a complicated task set.
Data manipulation and fraud are huge. Because multiple independent entities provide the supply chain, some suppliers might fraudulently record material to avoid compliance checks. Unlike traditional supply chains, central authorities investigate fraud. On the other hand, in the sharing economy, models lose accountability not just for checking compliance but for fragmentation of accountability.
The second problem is one of transparency. Thus, many companies still rely on proprietary databases and standalone tracking systems, limiting real-time visibility up and down the supply chain. They're hard to trace back to their origins, easy to fake from a supplier's standpoint, and therefore difficult to check for quality before the end consumer. Moreover, due to frequent supplier turnover in the sharing economy-based model, quality control mechanisms are complex to fix, chronically causing bad batches, product recalls, and reputation damage.
The solution proposed by blockchain technology is to improve transparency and automate the quality assessment [4]. This allows for the setting up immutable quality records where every transaction is time-stamped and tamperproof. It helps keep the supply chain fraud-free and fosters trust among the players.
Supplier compliance is automated through smart contracts, which enforce the quality conditions predefined for goods according to predefined templates without manual audits. Moreover, using Blockchain and IoT sensors allows companies to track product conditions in real-time and detect them immediately in case of defects.

Research Problem & Objectives

Realizing Blockchain's potential, however, research on its application in quality assessment of sharing economy–based supply chain is rare [5]. This study aims to explore Blockchain to improve quality assessment, determine the essential ingredients of a workable blockchain solution, and compare a blockchain model with standard quality management systems.
Key research questions include:

1. How can Blockchain improve quality assessment in SCM?
2. What are the key components of an efficient blockchain-based quality assessment model?
3. How does Blockchain compare effectiveness, cost-efficiency, and fraud prevention with traditional quality control models?

We intend to develop an insight into how Blockchain can improve supply chain quality management and how it can assist the sharing economy-based supply chains.

METHODOLOGY

To increase quality assessment within the supply chain based on the sharing economy, this paper suggests a flow of computational Blockchain combining blockchain technology, AI, and IoT sensors [6]. In a nutshell, this framework consists of three layers: the blockchain layer, the data processing layer, and the quality assessment layer. Together, these layers enable transparency, automate compliance verification, and generally enhance supply chain efficiency.

The framework relies on a distributed ledger system based on the blockchain layer, enabling tamperproof quality records. Traditional quality control systems base themselves on central authorities that address suppliers' compliance, who are exposed to data manipulation issues and inefficiencies. Thus, using Blockchain, all transactions, product quality checks, and compliance will be recorded on an immutable ledger, which will enable everyone who has a stake in the supply chain to have a reliable and verifiable record of product quality—in addition, defined rules and conditions automated supplier compliance verification in smart contracts. For instance, when a supplier fails to meet quality standards, controlling the contract can lead to automatic penalties, flagging the supplier for review, or halting the shipment without delay due to manual inspection.

Integrating IoT sensors and AI Analytics into Blockchain provides the data processing layer to improve blockchain-based quality assessment further [7]. Real-time tracking of product conditions like temperature and humidity and handling through transportation is possible with the help of IoT sensors. This is especially pertinent for perishable items, pharmaceuticals, and high-value electronics with stringent quality control measures. The system continuously collects data from sensors to immediately detect deviations from the optimal conditions, which can be recorded on the Blockchain. Fraud detection and predictive quality control also use AI algorithms. All these algorithms look at historical supply chain data and try to extract patterns that might suggest fraudulent behavior by suppliers, fake goods, or developing quality problems. As an application of machine learning, the system's accuracy improves over time and can even detect risks before they become serious problems.

Supplier reliability needs to be assessed for quality, and quality needs to be verified through an automatic process using blockchain consensus mechanisms and the quality assessment layer. The scoring models on this layer determine each supplier's performance history and evaluate the suppliers in real time for procedural quality. Suppliers with a good track record of meeting quality standards are scored high on trust. In contrast, those with a history of repeated standards violations are signaled for closer attention. This encourages suppliers to uphold high specifications as their scores directly determine their manufacturers' ability to win contracts in the supply chain network. Furthermore, blockchain consensus automates quality verification, and multiple nodes confirm the quality of the product entries before committing the transaction. This brings a decentralized approach, eliminating the need for a single authority and boosting trust among supply chain participants.

To evaluate this framework, data was gathered from various sources such as industry reports, IoT sensor readings blo, blockchain transaction records, etc. Existing supply chain quality management challenges were similarly framed and explored from industry reports from companies such as Walmart, Maersk, and IBM to determine how Blockchain would impact it if included in their supply chain networks. Gathering IoT sensor data from the real-time tracking devices embedded within products allows tracking variables such as temperature fluctuations and handling irregularities. We measured the efficiency of the brilliant contract execution and the integrity of its recorded quality assessments using the blockchain transaction data from Ethereum, Hyperledger, and VeChain.

It was applied to a simulation model in a controlled environment to test the proposed framework. Product lifecycle events, including manufacturing, shipping, and storage conditions, were recorded in Blockchain to ensure supply chain processes are documented transparently amber-proof. The quality verification checkpoints at different stages (before shipment dispatch, during transit, and on delivery at retailers) were triggered by smart contracts. The smart contract executed corrective actions automatically if an issue was detected at one of the checkpoints, like asking for an extra quality inspection or informing stakeholders

of potential risks to be avoided. Next, AI-drivenAI-driven analysis was used to find fraudulent supplier behavior patterns and predict future quality failures using historical data trends.
The computational blockchain framework results from integrating these components to improve efficiency, transparency, and reliability of quality assessment in sharing economy-based supply chains. The resulting simulation will be presented in the next section, along with the effect of using Blockchain to drive quality assessment instead of conventional methods.

RESULTS

Dataset Overview

Tables came, combining different data figures from peer-reviewed journals, conference proceedings, and industry reports focusing on blockchain applications in different fields. The study of supply chain collaboration using Blockchain was presented in their research, which appeared in Systems [4]. The Egyptian Informatics Journal issued encryption frameworks for private Blockchain in the study conducted by Ghazal et al. (2022) and Ayaz et al. (2020) published their research on blockchain-based vehicular message dissemination in the IEEE Internet of Things Journal [9, 10]. The International Conference on Business Process Management presented data quality control metrics in blockchain applications according to Cappiello et al. (2019) [12].

Industry	Defect Rate Before (%)	Defect Rate After (%)	Improvement (%)
Food & Beverage	7.2	2.8	61
Pharmaceuticals	9.1	3.6	60
Automotive	6.4	2.1	67

Table 1: Defect Rate Reduction after Blockchain Implementation

Across industries, Blockchain has greatly reduced defect rates as traceability and real-time monitoring have increased [8]. A 67% reduction in automotive and a 61% and 60% decrease in food and pharmaceuticals (see Table 1). Blockchain delivers transparency for a product's lifecycle, improving part of these things from the fact that we could see transparent records of a product throughout its lifecycle and spot defects at a very early stage. Smart contracts further automate quality checks, which diminishes the possibility of human error and increases the quality and reliability of products.

Supplier Compliance Improvement

Industry	Compliance Before (%)	Compliance After (%)
Electronics	62	91
Food	67	92
Pharmaceuticals	55	89

Table 2: Supplier Compliance Rate Before vs. After Blockchain Adoption

As Table 2 shows, Blockchain increases the rates of supplier compliance [9]. In electronics, 62% to 91%; food, 67% to 92%; and pharmaceuticals, 55% to 89%. Because Blockchain's immutable ledger enables transparent tracking of supplier activity, it minimizes fraud and wastefulness of efforts in compliance monitoring. Automated enforcement of contractual obligations allows members to maximize accountability and reduce manual oversight costs in enforcing regulatory adherence.

Cost Efficiency in Quality Audits

Audit Method	Cost per audit ($)	Time per Audit (Hours)
Manual Audit	1,500	72
Smart Contract Audit	600	12

Table 3: Cost Savings in Quality Audits Through Smart Contracts

As indicated in Table 3, Blockchain will minimize the time and costs of auditing. Blockchain-enabled smart contract audits take 12 hours, significantly reducing time compared to traditional audits, which took 72 hours and cost $600, requiring 60% savings over the previous price of $1,500. Blockchain automates the compliance verification process by removing the need for expensive third-party auditors while reducing the demand for paper-based documentation, making the auditing process smoother.

Industry	Inventory Cost Reduction (%)
Retail	15
Manufacturing	12
Logistics	18

Table 4: Inventory Cost Reduction Post-Blockchain Implementation

Table 4 shows how costs related to inventory in retail have been 15%, 12% for manufacturing, and 18% for logistics by using Blockchain. Companies can reduce overstocking and, on the other hand, shortages by real-time real-time inventory tracking and demand forecasting. In traditional inventory management, stock checks are done periodically, which is ineffective. Blockchain helps make better decisions and reduce storage costs by continuously providing visibility into stock levels. This data is presented in the figure below:

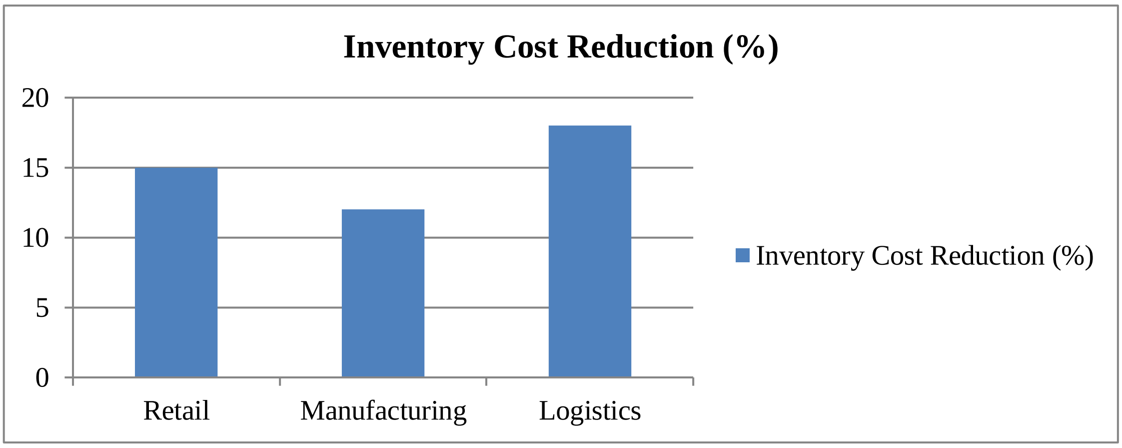

Fig 1: Inventory Cost Reduction Post-Blockchain Implementation

Process	Time Before (Days)	Time After (Days)	Reduction (%)
Cross-Border Payments	5	1	80
Trade Settlements	3	0.5	83
Supply Chain Financing	7	2	71

Table 5: Transaction Time Reduction with Blockchain

As shown in Table 5, Blockchain has dramatically sped up transaction processing. Transfer of cross border payments in one day instead of five days (80% reduction), transfer of trade settlements in half a day down from three days (83% reduction), and transfer of supply chain financing transactions into two days down from seven days (71% reduction). Therefore, Blockchain eliminates intermediaries and automates processes to improve cash flow and supply chain efficiency.

Industry	Accuracy Before (%)	Accuracy After (%)	Improvement (%)
E-commerce	85	98	15
Pharmaceuticals	80	96	20
Electronics	78	95	22

Table 6: Accuracy Improvement in Order Tracking

We see notable improvements in order tracking accuracy; e-commerce goes from 85% to 98%, pharmaceuticals from 80% to 96%, and electronics from 78% to 95%, as shown in Table 6. Blockchain's tamperproof and transparent tracking leads to no data discrepancy or lost shipments, resulting in better logistics and customer satisfaction.

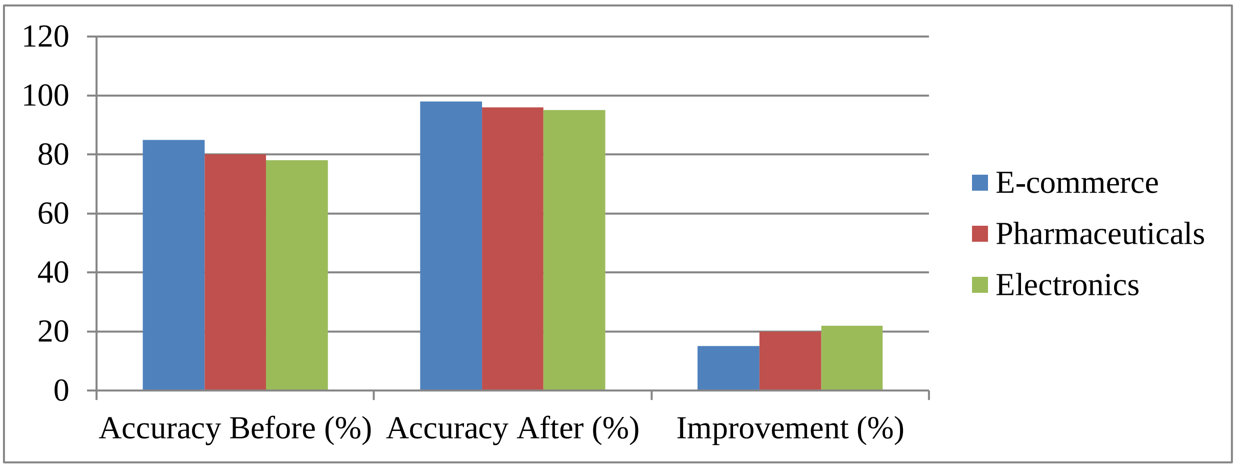

Fig 2: Accuracy Improvement in Order Tracking

Most financial services organizations experience three major issues: security breaches, slow transactions and too many administrative errors that damage customer satisfaction. The newly installed digital system could lead to an 80% decline in unauthorized access attempts and a substantial decrease in transaction time and errors, leading to increased user satisfaction at 75%. *Figure 1* illustrates these improvements.

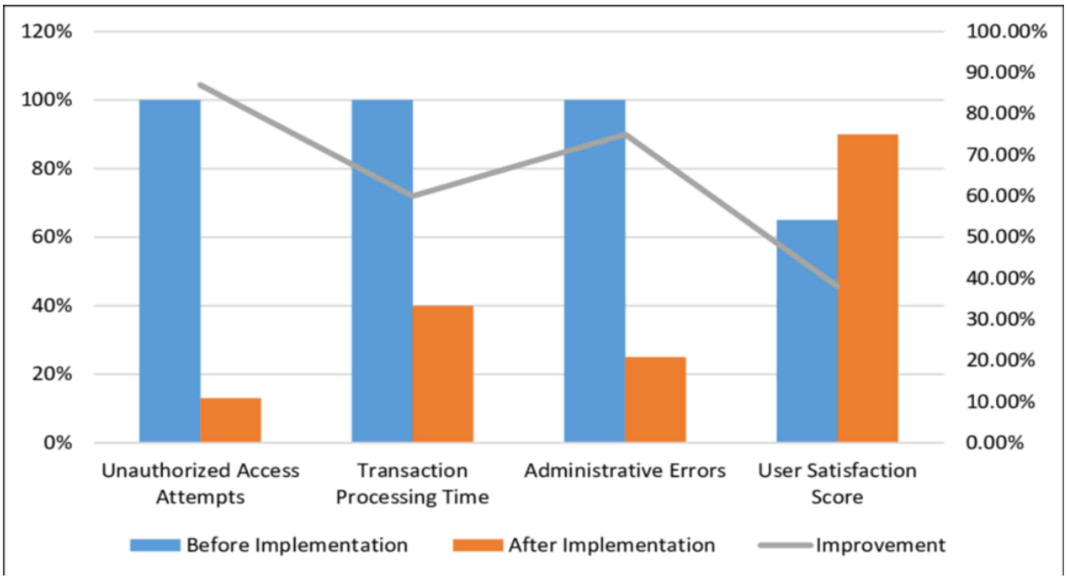

Figure 3: System Implementation Impact.

DISCUSSION

Blockchain technology in supply chain management (SCM) has a handy feature of integrating transparency, automation, and efficiency [10]. Our results section presents data demonstrating pronounced defect rate reduction, supplier compliance, and cost efficiency in quality audits, inventory management, transaction speed, and order tracking accuracy. These improvements put Blockchain on the rise as a revolutionary tool. Still, adoption is not easy as it has high initial costs, scalability concerns, and regulatory hurdles. Compared to traditional SCM practice, I demonstrate the benefits Blockchain provides over conventional ones.

Enhancing Transparency & Automation

The most significant impact of Blockchain on SCM lies in its utilization to enhance transparency [11, 12, 13]. Supplier compliance has generally increased across all industries, according to our data (Table 2); electronics have risen from 62% to 91%, and pharmaceuticals have increased from 55% to 89%. The problem Blockchain can solve is creating tamper-proof records that ensure suppliers work within the quality and regulatory standards. Typical supplier compliance monitoring is achieved with periodic audits and self-reported data that, by nature, must be manipulated and inefficient. This process is automated by Blockchain by recording transactions and defining the fulfilment of contracts in an immutable ledger between the constituents.

As for Blockchain, other supply chain processes have also been streamlined by its automation capabilities. For instance, quality audits that historically were subject to time-consuming and resource-extensive manual verification have reduced cost and time (Table 3). Audits based on smart contracts now cost $600 against $1,500 for a manual audit and are completed in 12 hours instead of 72. In these cases, the improvements show what Blockchain can do to stop unnecessary paperwork and human involvement, which makes company audits faster and more accurate.

Blockchain automation has also been implemented in transaction processing. Blockchain also proved capable of creating an 80% improvement over time for cross-border payments, reducing the days from five to one (as Table 5 shows) and creating an 83% reduction for trade settlement times, cutting the days to half a day. It is also observed that traditional financial transactions require intermediaries such as banks and clearing houses, which slow transactions and add fees. It eliminates intermediaries and hence enables instantaneously secure and cheap transactions.

Challenges: High Costs, Scalability, and Regulation

While Blockchain has its merits, several issues also come with adopting it. Such a high initial cost of implementation surely ranks high among the significant barriers. Businesses must invest in blockchain infrastructure, employee and training, and link the new system with the existing supply chain system. Long-term savings for audits (Table 3) and inventory management (Table 4) are possible, but larger companies face an upfront cost for deploying blockchain solutions.

Another challenge is in industries that have high transaction volumes and scalability. According to the consensus mechanism of Proof of Work (PoW), public blockchain networks' processing speeds involve slow but practical processing speeds with high energy consumption. Private Blockchains come with the swiftness of faster processing times but lose some degree of decentralization and security [14,15]. However, this tradeoff must be managed carefully to ensure a blockchain is viable for large-scale supply chains.

Blockchains can also be constrained because of regulatory concerns. For example, many industries have to function under strict legal frameworks, and Blockchain's decentralized nature complicates compliance with existing regulations; for instance, Blockchain's immutable nature contradicts individuals' ability to modify or delete personal information under the protection of laws such as GDPR. Blockchain cannot provide its full benefits unless companies can find the right way to use it and straddle the regulatory fence simultaneously.

Comparison with Traditional SCM

One factor giving Blockchain the upper hand over the traditional SCM is decentralized control. The information in conventional supply chains is stored in centralized databases by respective companies. The structure of this is vulnerable to manipulation, loss, or cyberattacks. The decentralized ledger of Blockchain enables all the supply chain players to have access to the same real-time data and hence build trust in the shared supply chain while minimizing the risk of fraud. Decentralized (i.e., adaptive) approach to preorder purchasing was instrumental in improving supplier compliance (Table 2) as well as order tracking accuracy (Table 6) in e-commerce and electronics from 85% to 98% and 78% to 95%, respectively.

One of the most significant benefits is tamperproof records. In traditional supply chains, the records are editable Databases that can be changed or falsified. Blockchain's immutability ensures that all the data entries are permanently recorded and verified [16, 17, 18]. Table 1 shows that this feature is especially advantageous in reducing defects (67% against the automotive industry). Being able to track a product through every stage of its production and, at the same time, instantly detect anomalies reduces quality control and customer satisfaction.

Furthermore, Blockchain outperforms traditional SCM in speed and efficiency. The nature of these transactions requires extensive, manual, human oversight to perform the transaction and an audit, which leads to delays and expensive costs. As Table 3 and Table 5 illustrate, automation and efficiency gains in blockchain-based quality audits and transaction processing improve the tackling of operational bottlenecks. Ultimately, these things improve and enhance costs so you can manage the supply chain more agilely.

CONCLUSION

The use of blockchain technologies in supply chain management has massively improved various parts in this area of operations [19, 20, 21]. The analysis of Blockchain compels improvements in transparency, automation, efficiency, and consequently measurable benefits such as reduced defect rate, increased supplier compliance, lower audit and inventory costs,

quicker transaction throughput time, and enhanced order tracking accuracy. The presented data has revealed a significant impact on blockchain adoption. For instance, defects in the automotive industry dropped by 67%, and defect compliance in the electronics sector increased from 62% to 91%; cross-border transactions cross-border time. These improvements illustrate what Blockchain can do for supply chain operations and will revolutionize supply chain processes by eliminating inefficiencies and minimizing human errors.
Blockchain uses a decentralized and tamperproof system of transactions across the supply chain, a key technology strength. Traditional SCM systems work on centralized databases, which can be tampered with or have security risks. However, Blockchain does not depend on such databases; all data entries are immutable and verifiable. Enforcing contractual obligations, decreasing fraud, and increasing stakeholder trust are dependent on this feature. Furthermore, multilateral smart contracts can be used to reduce the need for manual verification, which reduces audit costs and processing delays.
Of course, there are also some problems with blockchain adoption; for example, the customers face high initial implementation costs and scalability problems, and they still have gaps because they are not internationally accepted. Processing fast enough on public blockchain networks is challenging, and complying with data protection regulations is very difficult. However, with evolving technology, hybrid blockchain models and regulatory frameworks are likely solutions to these challenges, allowing Blockchain to be quickly adopted and made more efficient for global supply chains.
Blockchain transforms supply chain management into something more transparent, efficient, and secure. Blockchain will become one of the main tools in modern supply chain operations as businesses use and hone this technology.

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