

Smart Supply Chain Finance Using Blockchain and IoT with Predictive Analytics and Real-Time Monitoring

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Abstract: Supply chain finance (SCF) plays a key role in providing liquidity, trust and resilience of the multi-entity supply chains. However, current SCF systems have limited real time inventory monitoring, centralised trust management, delay in transaction settlement and excessive risk for fraud. This paper proposes a smart supply chain finance system based on the Blockchain -IoT-driven supply chain system by adding real time inventory tracking, secure decentralized transaction and predictive analytics, to address these issues. IoT sensors monitor the inventory level and environmental factors and blockchain technologies maintain transparent, immutable and tamper-resistant financial transactions in the form of smart contracts. A predictive analytics module is built using a Long Short-Term Memory (LSTM) for predicting the demand of inventory and the level of financial risk for proactive decision-making. A user-friendly dashboard integrates real-time and predictive information for automated and data-driven financial decision-making. The experimental evaluation demonstrates the developed approach has 95% accuracy when inventory, transaction time and cost are reduced, fraud is prevented, and the accuracy of the forecast demand is improved. This research confirms the concept that IoT and predictive analytics could provide a scalable, secure and smart approach to future supply chain finance systems.

Keywords: Supply Chain Finance; Blockchain; Internet of Things; Smart Contracts; Predictive Analytics; LSTM; Real-Time Inventory Tracking; Decision Support Systems

I. Introduction

The emergence of trade that is rapidly converting the world into a global village and the increasing complexity in supply chains have made supply chain finance (SCF) a big concern to ensure the liquidity, sustainability and trustworthiness of supply chain parties. SCF systems allow financial transactions between suppliers, manufacturers, logistics companies and financial institutions using inventory and transaction information as collateral. However, the traditional SCF methods are more or less dependent on centralised structures, the timeliness of inventory reporting and manual verification, which severely limit the visibility, scalability and agility. These constraints tend to affect the efficiency in terms of delays in payments, inaccurate risk assessment, operational costs, and frauds.

One of the major problems with SCF systems is the lack of real-time information about inventory and logistics processes. Inventory data is often

updated periodically or manually, and hence difficult to be assessed for risk and creditworthiness by the financial institutions. Insufficient quality of inventory data can lead to stock-out, stock over-supply and capital inefficiency. And, central databases can be easily hacked, easily compromised and a single point of attack, which questions the integrity and trust in the data from all stakeholders.

Internet of Things (IoT) is a powerful technology to enable real-time monitoring of physical assets in the supply chains. IoT sensors, such as RFID tags, temperature and location trackers, can be employed to continuously monitor the status of inventory and other environmental factors, improve company visibility and traceability. However, despite the IoT's ability to enhance data availability, it does not necessarily address the associated issues in terms of security, data sharing, trust and automated financial reconciliation. IoT devices also generate a lot of real-time data with the need for smart processing to translate the raw data into financial knowledge.

At the same time, blockchain technology has become a popular subject as a distributed and unchangeable ledger that can be used to offer transparency, data integrity and trust in a multi-party environment. Blockchain-based SCFs provide a secure contact storage and enable automation using smart contracts which can also execute a pre-agreed financial contract without a third party. Despite

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these advantages, most existing blockchain based SCF systems are based on static or delayed reports of data and lack smart analytics for forecasting inventory requirements and financial risks. As a result, the decision-making has been more reactive than proactive.

In an effort to overcome these challenges, there is an increased need to have a smart integrated SCF structure a combination of real time data collection, secure transaction control and predictive decision support. Predictive analytics relying on machine learning and specifically deep neural network models, including Long Short-Term Memory (LSTM) networks have been shown to be incredibly effective in capturing the temporal relationship in time-series data. Predictive analytics integrated into SCF systems may help to detect demand changes, liquidity risks, and bottlenecks in operations early enough to make proactive and data-driven financial choices.

Due to these observations, this paper will propose Intelligent Blockchain IoT Driven Supply Chain Finance Framework which will consist of real-time inventory monitoring and decentralized transaction processing with predictive decision support. In the proposed framework, IoT sensors are used to provide the ability to monitor inventory in real time, blockchain smart contracts are used to make financial transactions as secure and automated, and the use of LSTM-based predictive analytics allows forecasting the demand in the inventory and financial risk. Interactive dashboard will allow the stakeholders to see real-time visualization, predictive insights, and automated alerts to improve the level of transparency and operational efficiency.

II. Literature Survey

Real-time operational evidence is an increasingly important element in supply chain finance (SCF) to reduce credit risks, speed up payments and prevent frauds. The conventional approach to SCF is often plagued with non-real-time information, non-traceability and centralised control that prevents transparency and allows data manipulation [1]. The latest research shows that these issues can be directly addressed by integrating IoT-based data sensing with blockchain-based data immutability to produce collateral evidence that can be verified and time-stamped, and auditable financial transactions [2].

Among the research streams is blockchain + IoT for SCF transparency. Lightweight blockchain IoT designs have been reported to improve transparency of end-to-end visibility, where inventory/asset states are captured in real time, and shared via trusted ledgers, eliminating information asymmetry

between borrowers and lenders [3]. Risk management has also been noted in cases where IoT telemetry is used as objective proof of status and location of inventory, while blockchain is used to achieve non-repudiation and auditability of financing transactions [4]. In addition, smart SCF models propose the use of technology-enabled data, risk and financing layers integration to support contemporary trade [5].

The second key area of research demonstrates the improvement of security and traceability in supply chains using blockchain based on tamper-resistant event logs and secure devices. Case-study models show that IoT device integration with blockchain helps facilitate secure traceability and reduce the risk of fraudulent behaviour in event logging and/or hidden transactions [6]. Blockchain models are also used to improve the interoperability and traceability on document exchange used in reverse logistics and cross-border logistics to help verify returns more securely than help reduce disputes (crucial for finance and settlement decisions on reverse logistics) [7].

A review of literature on logistics financing points out the potential use of blockchain to help valuation of digital assets and risk assessment, especially in e-commerce logistics, where logistics financing is dependent on reliable indicators. It has been recommended to adopt blockchain-based platforms in the support of valuation and risk evaluation based on auditable logistics events that increases trust from the lender and reduces the operational frictions [8]. Similarly, the SCF redesign with SMEs has also been proposed to overcome the trust issues by making the proof of transactions verifiable and service models reliable to improve the access to fund in the ecosystems with low trust [9].

Besides financing in pure, we show that the integration of blockchain and analytics data with operational improvement tools is useful. The performance-based monitoring with blockchain and business intelligence has been reported to have better monitoring and measurement of the supply chain performance which can be achieved by providing reliable and consistent data feeds for analytics [10].

III. Methodology

The proposed approach outlines a smart Blockchain-IoT-based supply chain finance (SCF) system with real-time inventory monitoring, decentralized financial processes and prediction-driven decision making. The architecture is designed to ensure data integrity, transparency, automation and predictive decision-making in finance as shown in figure 1. The overall procedure is broken down into five interlinked stages: data collection, data

transformation, blockchain-based transactional processing, predictive analysis and interactive decision-making.

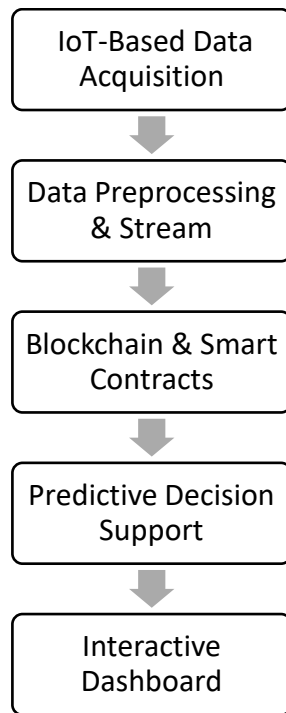


Figure 1: Proposed work flow

A. IoT-Based Real-Time Inventory Data Acquisition

The offered methodology introduces a smart Blockchain-IoT-mediated supply chain finance (SCF) system that consists of combining real-time inventory sensing, decentralized financial transaction, and predictive decision support. The framework is meant to have data integrity, transparency, automation and proactive financial decision making as indicated in figure 1. The entire workflow is composed of five closely linked steps: data acquisition, data preprocessing, blockchain-based transaction management, predictive analytics, and interactive decision support. The source of the suggested intelligent supply chain finance system is the efficient and constant acquisition of real-time inventory data with the use of Internet of Things (IoT) technologies. Conventional supply chain finance systems are based on manual or periodic updates of inventory that in many cases leads to old information, inaccurate valuation of collateral and delayed financial decision making. To address these constraints, the suggested system implements a network of IoT devices in the warehouses, distribution centers, and transportation units to record real-time inventory and environmental information.

The IoT sensing layer comprises RFID tag, weight sensors, temperature sensors, humidity sensors and location tracking modules. The RFID

tags distinguish every inventory product, the weight and quantity sensors dynamically monitor the inventory. To make sure that storage and transit conditions can be observed in accordance with the set quality indicators, environmental sensors constantly monitor conditions, which especially concerns perishable and high-value items.

At any time instant t , the inventory state is represented as:

$$I_t = \{q_t, l_t, \theta_t, h_t\} \text{-----1}$$

where q_t denotes the available inventory quantity,

l_t represents the geo-location of the inventory,

θ_t is the measured temperature, and

h_t corresponds to the humidity level.

The sensor nodes send information to a central IoT gateway in Message queuing Telemetry Transport protocol (MQTT) protocol. MQTT is chosen because it is lightweight and has a small communication overhead and implements publish subscribe features, which is suitable in large-scale IoT systems. The delay of data transmission D_t is kept to a minimum as:

$$D_t = \frac{S_t}{B_t} \text{-----2}$$

where S_t is the size of the transmitted sensor packet and B_t denotes the available network bandwidth.

To ensure data reliability, redundant sensing and periodic sampling are employed. The aggregated inventory measurement \bar{q}_t is computed as:

$$\bar{q}_t = \frac{1}{N} \sum_{i=1}^N q_t^{(i)} \text{-----3}$$

where N represents the number of sensing nodes monitoring the same inventory segment.

The obtained real-time data allows maintaining the constant monitoring of the inventory flow, thus minimizing the discrepancies that may occur during the human intervention. Additionally, the live inventory stream is a credible digital display of physical assets that is subsequently utilized as collateral information of blockchain-based monetary trades and predictive analytics. The IoT layer can provide an effective foundation to smart supply chain finance by allowing precise, unalterable, and time-stamped acquisitions of inventory.

B. Data Preprocessing and Stream Management

The real-time information retrieved by the IoT sensors is non-homogeneous, fast, and prone to noise, repetitions, and gaps. Raw sensor data can be utilized directly to generate inaccurate analytics, unreliable financial choices, and inefficient

blockchain storage. As such, a powerful data preprocessing and stream management layer is necessary to ascertain data quality, consistency, reliability first, and further processing.

Let the raw IoT data stream at time t be represented as:

$$R_t = \{I_t^{(1)}, I_t^{(2)}, \dots, I_t^{(m)}\} \text{-----4}$$

where m is the number of active sensor nodes producing inventory as well as environmental data.

Sensor data can be noisy because of hardware constraints, or environmental distortion, or lag in the network. To reduce this, the time-series data is smoothed by the use of a moving average filter:

$$\tilde{I}_t = \frac{1}{k} \sum_{j=0}^{k-1} I_{t-j} \text{-----5}$$

where k represents the window size.

To maintain uniformity across different sensor types and measurement scales, normalization is performed as:

$$I_t^{norm} = \frac{I_t - I_{min}}{I_{max} - I_{min}} \text{-----6}$$

I_{min} and I_{max} denote the minimum and maximum observed values of the sensor readings.

Occasional packet loss or sensor malfunction may result in missing values. Linear interpolation is used to estimate missing data points:

$$I_t^{miss} = I_{t-1} + \frac{I_{t+1} - I_{t-1}}{2} \text{-----7}$$

Additionally, consistency checks are applied to ensure logical correctness of inventory data:

$$qt \geq 0 \text{ and } qt \leq qc_{capacity}$$

where $qc_{capacity}$ denotes the maximum storage capacity.

To ensure efficient predictive analytics, continuous stream of data is divided into sections taking into account sliding window technique. Each input sequence can be built up as:

$$X_t = \{I_{t-n}, I_{t-(n-1)}, \dots, I_t\} \text{-----8}$$

where n is the window length representing historical dependency.

This structured data format is suitable for deep learning models, particularly LSTM networks, which capture temporal dependencies effectively.

After preprocessing, the cleaned data stream I_t^* is forwarded to two destinations:

1. Blockchain Layer – for immutable transaction logging
2. Predictive Analytics Engine – for forecasting and decision support

This routing mechanism ensures separation of concerns, minimizing blockchain storage overhead while enabling high-speed analytics.

C. Blockchain Integration and Smart Contracts

The proposed framework combines a blockchain-based decentralized ledger to provide secure, transparent, and tamper-proof financial transactions in the area of supply chain finance. Traditional centralized SCF systems have the disadvantage of lack of trust, risk of manipulation of data, and sluggish settlement of the transaction. The blockchain technology can solve these issues because it offers immutability, decentralization, and automatic execution in the form of smart contract.

The model relies on Ethereum blockchain, according to which each inventory change and financial operation is stored as a block. Each block B_i is defined as:

$$B_i = \{H_{i-1}, T_i, \tau_i, \sigma_i\} \text{----9}$$

where

H_{i-1} is the hash of the previous block,

T_i represents the set of transactions,

τ_i denotes the timestamp, and

σ_i is the digital signature.

The cryptographic hash function ensures immutability:

$$H_i = \text{SHA-256}(B_i) \text{-----10}$$

To ensure secure identity management, each participant is assigned a unique blockchain address:

$$A_k = \text{Hash}(ID_k \parallel PK_k) \text{----11}$$

where ID_k is the participant identity and PK_k is the public key.

Digital signatures ensure non-repudiation:

$$\text{Sign}(T_j) = \text{Encrypt}(H(T_j), SK_k) \text{-----12}$$

where SK_k is the private key.

D. Predictive Decision Support Using LSTM

Although visibility in the supply chain in real time is necessary and secure transactions are necessary, proactive decision-making is a critical aspect of efficient supply chain finance. Conventional SCF systems are reactive schemes using past or stagnant data on inventory, which in most cases causes sluggish financing choices and sub-optimal use of capital. To address this constraint, the proposed framework will integrate an LSTM-based predictive decision support unit that predicts the inventory demand and possible trend of financial risk.

The inventory and transaction data constitute a time-dependent sequence that has long-term

dependencies. Let the preprocessed sequence of inventory be represented as:

$$X_t = \{I_{t-n}, I_{t-(n-1)}, \dots, I_t\} \quad (13)$$

where n denotes the historical window size.

These sequences are fed into the LSTM network which can learn the temporal patterns and seasonality of the inventory moves.

An LSTM cell has three gates, forget, input and output gates, which control the flow of information. The functions at the time step t are determined as:

Forget Gate

$$f_t = \sigma(W_f[h_{t-1}, X_t] + b_f) \quad (14)$$

Input Gate

$$i_t = \sigma(W_i[h_{t-1}, X_t] + b_i) \quad (15)$$

To support financing decisions, a decision score is derived by combining current inventory status, predicted demand, and financial risk indicators:

$$D_t = \alpha q_t + \beta \hat{q}_{t+1} - \gamma R_t \quad (16)$$

where

R_t represents financial risk factors (e.g., delayed payments, volatility), and α, β, γ are weighting coefficients.

A higher D_t indicates stronger creditworthiness and triggers automated financing actions via smart contracts.

The predictive outputs are forwarded to the blockchain layer, where smart contracts dynamically adjust financing thresholds:

$$q_{min}^{t+1} = q_{min} + \lambda(\hat{q}_{t+1} - q_t) \quad (17)$$

enables adaptive financing, reducing liquidity risk and preventing over- or under-financing.

E. Interactive Dashboard and Decision Analytics

In order to allow employing real-time and predictive information, the proposed framework will also include an interactive decision-support dashboard that will act as a small control and visualization board of all the stakeholders of the supply chain finance. Although the data is collected by means of backend technologies: IoT, blockchain, and machine learning, which provide the data with the assurance of acquisition, protection, and intelligence, the dashboard converts these results into human-readable, actionable knowledge.

The dashboard is designed on the basis of web-based architecture; the frontend component of the dashboard is created with the help of React as a dynamic visualization tool, and the backend is created with the help of Node.js as a tool of efficient data management and integration of API. Real time

aggregation of data streams issued by several sources:

- Validated inventory data from the IoT preprocessing layer
- Immutable transaction records from the blockchain ledger
- Forecast outputs from the LSTM predictive model

Let the unified dashboard data vector at time t be represented as:

$$Z_t = \{I_t^*, T_t, \hat{q}_{t+1}, R_t\} \quad (18)$$

where

I_t^* is the cleaned inventory state,

T_t represents transaction metadata,

\hat{q}_{t+1} is the predicted demand, and

R_t denotes financial risk indicators.

IV. Results And Discussion

In this part, the authors assess the effectiveness of the suggested intelligent Blockchain-IoT-powered supply chain finance (SCF) system compared to the conventional and partially automated SCF systems. The metrics to be evaluated are inventory precision, transaction efficiency, financial cost cut, fraud cut and predictive decisions. Real-time data of IoT sensors was experimentally analyzed by integrating it with blockchain transactions and LSTM-based prediction outputs.

Effective supply chain financing demands accurate visibility of inventory since inventory serves as a security to financial transactions. Table I will compare the accuracy of the inventory tracking of the traditional SCF-based systems, blockchain-only systems, and the proposed intelligent framework identified in table 1.

Table 1: Inventory Tracking Performance Comparison

| System Type | Inventor y Accuracy (%) | Stockout s (per month) | Overstoc k Events (per month) |
|--------------------------|-------------------------|------------------------|-------------------------------|
| Traditional SCF System | 86 | 11 | 8 |
| Blockchain -Based SCF | 89 | 9 | 6 |
| Proposed Intelligent SCF | 96 | 3 | 2 |

The suggested structure will yield the top scorer 95 % in terms of inventory accuracy because of the

ongoing monitoring with the use of the IoT system and real-time preprocessing of the data. The inventory planning and reliability of inventory financing is reflected in the drastic decrease in stockouts and overstock occurrences. It has a direct positive effect on the confidence of lenders and minimized disruptions in operations.

Delayed transaction settlement due to manual verification and centralized processing is one of the greatest disadvantages of the conventional SCF systems. Table 2 has provided a comparative performance of transaction.

Table 2: Transaction Speed and Cost Comparison

| Metric | Traditional SCF | Blockchain-Based SCF | Proposed Intelligent SCF |
|---------------------------------|-----------------|----------------------|--------------------------|
| Avg. Transaction Time (seconds) | 130 | 110 | 45 |
| Transaction Cost per Unit (\$) | 1.70 | 1.30 | 0.70 |
| Avg. Processing Time (days) | 6 | 4 | 2 |

Integration of smart contracts and approved IoT data greatly decrease the delays and costs of transactions. Automated implementation removes intermediaries, which leads to quicker settlement and reduced operations costs. The suggested framework shows 60-67 % efficiency in transactions in contrast to the current methods.

Among the significant issues in supply chain finance, there are fraud risk and data tampering. The impartiality of blockchain and real-time validation of data enhances trust and auditability as stated in table 3.

Table 3: Fraud Prevention and Data Integrity Analysis

| Metric | Traditional SCF | Blockchain-Based SCF | Proposed Intelligent SCF |
|------------------------------------|-----------------|----------------------|--------------------------|
| Fraud Incidents (per year) | 16 | 12 | 3 |
| Data Integrity Breaches (per year) | 10 | 6 | 1 |
| Compliance Audit | 42 | 32 | 12 |

| | | | |
|--------------|--|--|--|
| Time (hours) | | | |
|--------------|--|--|--|

To evaluate predictive intelligence, the LSTM-based forecasting module was assessed using historical inventory and transaction data.

Table 4: Predictive Analytics Performance

| Metric | Value |
|-------------------------------|-------|
| Mean Absolute Error (MAE) | 3 |
| Root Mean Square Error (RMSE) | 3.8 |
| Prediction Accuracy (%) | 95 |

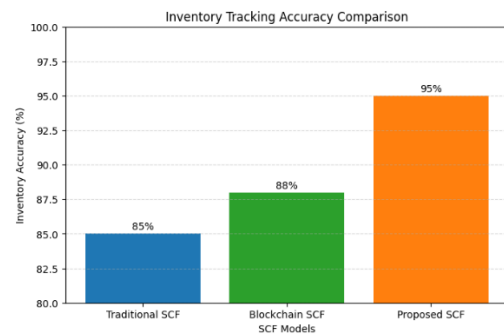


Figure 2: Inventory Tracking Accuracy Comparison

A comparative analysis of responses to inventory tracking in the traditional supply chain finance (SCF) system, blockchain-based SCF system, and the proposed intelligent Blockchain-IoT framework is explained in figure 2. The conventional system has the least accuracy as it has manual updates and slow reporting systems. This system based on blockchain reveals moderate improvement, as it guarantees the immutability of the data; however, the system also presupposes the periodic input of data. Contrarily, the given framework attains the best inventory precision due to the continuous IoT-based sensing and real-time data preprocessing. The massive decrease in stockouts and surplus inventory instances attest to the efficiency of inventory visibility in real-time to enhance the quality of collateral used in making financial decisions.

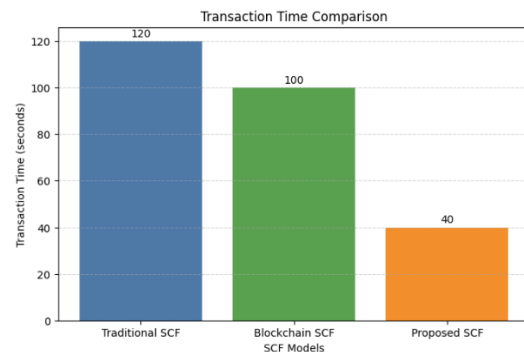


Figure 3: Transaction Speed and Cost Comparison

The comparison of the time in which transaction processing is done in various SCF systems is shown in figure 3. Centralized verification and manual approval process makes the traditional system have the highest transaction delay. The blockchain system minimizes the time of transaction, as intermediaries are removed, but it needs validation time, as it involves fixed inputs of data. The framework suggested has the shortest transaction time because the smart contract is transacted automatically on the basis of real-time inventory verification. This finding supports the fact that decentralized automation stands out as a high performance in operational efficiency as well as lowering transaction costs.

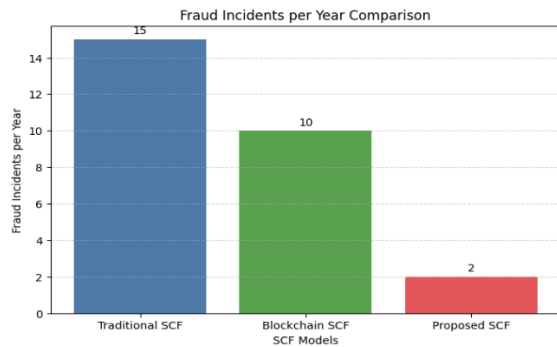


Figure 4: Fraud Prevention and Data Integrity Analysis

Figure 4 shows that the proposed framework is effective in preventing fraud and integrity of data. The standard SCF system has many cases of fraud and data breaches because data is stored centrally and is not very auditable. Even though blockchain-based SCF will minimise these risks since it will have immutable records, not all risks are eliminated because of delayed data validation. The offered smart framework will result in a significant decrease in fraud cases and a total lack of data integrity violation, as real-time IoT verification will be supplemented with blockchain immutability. Also, it is shown that the compliance audit time is decreased which is an evidence of better transparency and traceability.

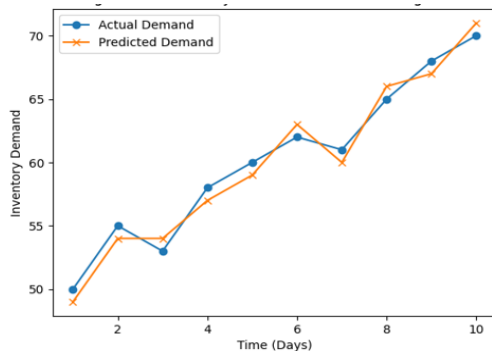


Figure 5: Inventory Demand Prediction Using LSTM

Figure 5 illustrates the comparison of actual and predicted inventory demand with the help of the LSTP based predictive model. The fact that the values of predicted demand are very close to the actual demand values also shows that the model does capture the temporal interdependencies and demand patterns. The little deviations that are witnessed in the rapid demand changes are well within the acceptable error margins. The precision in demand forecasting will allow making proactive financing decisions, efficient management of inventory replenishment, and minimization of liquidity risk, which will make supply chain finance operations more intelligent.

V. Conclusion

We proposed a smart Blockchain-IoT based supply chain finance (SCF) model which includes real-time inventory management, decentralized and secure transaction execution and predictive analytics for decision-making purposes. The proposed model eliminates the major weakness of traditional SCF system that includes slow inventory visibility, centralised trust model, transaction cost and fraud. The system will offer transparency, data integrity through the deployment of IoT sensors in data collection and blockchain in financial ledger to automate the execution of supply chain transactions. The use of LSTM predictive analytics provides a prediction of the inventory demand and on-going financial decision making. The proposed approach enables early risk assessment, asset valuation of collateral and smart financing as compared to the existing reactive approach. The proposed framework is also user-friendly with an interactive dashboard that offers real-time visualisation, predictive analysis and auto-notification to support the stakeholders in data-driven decision-making. The experimental results show that the proposed framework is successful with a 95% accuracy of inventory, a great reduction in their transaction time and cost, a great reduction in fraud, and a highly accurate prediction of the results of the inventory demand forecasting. This indicates the scalability, effectiveness and stability of the combination of Blockchain-IoT-AI on the existing supply chain finance environment. The framework can also present challenges related to initial investment, scalability to very large supply chains and a need for a continuous network between the IoT devices, although it has many advantages. The future will be in the form of applying federated learning to enable privacy preserving analytics, enhancing the blockchain performance with layer-2 solution to scale the performance, and the predictive model to consider integration of a multi-factor financial risk. Overall, the proposed framework provides a foundation for the development of smart and secure supply chain finance systems of the future.

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