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An Integrated Cloud-based Blockchain Model for Supply Chain Management

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Abstract. Effective and efficient supply chain management is a crucial issue for the success of involved interlinked companies in the modern business ecosystem which includes suppliers, manufacturers, distributors, and customers. This research proposes an integrated cloud-based blockchain model for supply chain management taking advantage of the technologies: IoT, cloud computing, and blockchain. The proposed model uses IoT systems to monitor and track the movement, transportation, and handling of shipments through the supply chain. Cloud data servers are used to host the blockchain system as a solution to its increasingly large size. The blockchain smart contract performs three main important functions: (i) Generate automated inventory replenishment and purchasing orders based on knowing exactly on-hand inventory in real-time to the highest ranked supplier (ii) Receive and inspect incoming shipments (iii) Generate and update real-time score for supply chain stakeholders. The implemented proposed integrated model was successfully able to record the shipments data to the cloud-based blockchain using IoT systems, present to the supply chain stakeholders the ability to generate automated inventory replenishment to the supplier with the highest rank based on real-time updated score for each supplier and make all these inventory replenishment transactions data available to all supply chain stakeholders. As a result, products quality increased, supply chain operations were more seamlessly executed, cost of inventory replenishment and total costs of the supply chain were reduced.

Keywords: Blockchain, Smart Contracts, IoT, Cloud Computing, Supply Chain Management.

1. Introduction

The supply chain gets started with the delivery of the raw material from supplier to manufacture and end with the consumer consuming that product. Managing the flow of the finished good from the origin to the point of destination is supply chain management (SCM). All successive actors involved in the SCM process must work harmoniously from the beginning of the supply chain from the producers to the final consumer, in order to achieve the greatest degree of consumer satisfaction at the lowest possible cost (Bechtel & Jayaram, 1997; Lambert & Cooper, 2000).

To maximize the profitability of supply chains, attention must be given to providing the best delivery performance through (inventory appropriate to requests, improving response to customer requests, reducing stock-outs, reliability of deliveries, high product quality) and increasing information availability through (future expectation of demand cycles, expecting future requests, real-time updating of orders and supplies) at the operational level and reducing time-to-market at the tactical and strategic levels. When applying SCM concepts, the supply chain must be optimized by reducing stagnant inventory (increasing inventory turnover, reducing overstocks), managing transportation costs in supply chains, reducing indirect and direct labor costs, and increasing sales and sales margins.

And due to the dynamism of the supply chain environment as a result of the large number of variables and factors influencing them, there was a need to digitize supply chains to increase competitiveness, and therefore many technological tools were merged into SCM process such as blockchain technology, Internet of Things (IoT), cloud computing, business analytics, and machine learning (Zantalis et al., 2019; Svorobej etal., 2019; Li, 2018).

The IoT depends on sensors that are classified into three main types: active, semi-active (or semi-passive), and passive. These sensors can perform a range of tasks such as movement, sensing activity, temperature, actuating and collecting. For example, food supply chains need certain environmental conditions during transportation, such as humidity, light, and temperature (Hsiao & Huang, 2016). Thus, the need to track the condition of food through sensors connected to a wireless sensor network (WSN) to avoid food spoilage or change its nature or quality. WSNs operate as a main system connected to the sensors through mobile networks such as 4G or GPRS (General Packet Radio Service) in order to transfer real-time data to all partners within the supply chains (Óskarsdóttir & Oddsson, 2019). Based on the received information through the sensors, the shipment can be accepted or rejected based on the conditions recorded in the smart contracts in the blockchain. if the shipment is accepted, payment is made automatically. The received information from the sensors is not only used to accept or reject the shipment but also enables the parties to the supply chain process to intervene quickly to take corrective actions to avoid damage to the shipment (Rejeb et al., 2018; Hofstede, 2003). Cloud computing technology is integrated with WSNs to facilitate the process of sharing sensor data and making it available to all parties in real-time through Internet networks (Flammini & Sisinni, 2014).

IoT applications help companies to monitor products, processes, and activities during each step-in supply chains, as they can monitor products during the manufacturing, storage, assembly, or transportation process. Cloud computing is the beating heart and fertile ground for the Internet of Things, as it provided the appropriate environment for IoT applications (Ray, 2016). On the other hand, the integration of blockchain technology with the IoT generates many application scenarios to enhance the trust, transparency, efficiency, and effectiveness of supply chains.

Securing supply chain networks is one of the main challenges, as it must be secured from external attacks in the perception layer, secure the data collection stage in the network layer, and give powers to users who are only authorized to enter the system in the application layer. Operations data can be secured through the use of blockchain technology to preserve and secure data from any attack (Tzounis et al., 2017).

Private or consortium blockchains are highly useful and effective in supply chain applications, as many parties deal with IoT systems securely, and it also gains scalability feature when it is integrated with cloud computing technology. Data received from IoT sensors can also be used to pass it on smart contracts in the blockchain to ensure the status of shipments (Wang et al., 2019; Kim, 2020).

Where the blockchain can be considered as a distributed digital ledger in which transactions are recorded in chronological order and all recorded transactions are secure, permanent, and not subject to tampering (Treiblmaier, 2018). Blockchain architecture provides a lot of benefits and features that are appropriate for supply chain management. These benefits are as follows (Golosova & Romanovs, 2018): [i] immutability, [ii] cryptography, [iii]decentralization, [iv] provenance [v] transparency, [vi] anonymity, [vii] reducing fraud or corruption, and [viii] removal of intermediates. All these advantages will increase transparency and trust between customers and sellers, vendors, or suppliers.

Due to the large amounts of IoT sensors, and blockchain generated data, the proposed model in this paper uses the cloud servers for saving the IoT sensors and the blockchain data to take benefit of the cloud computing technology also, which includes cost savings, high security, scalability, mobility, flexibility. On the other hand, the proposed model uses the blockchain to manage supply chain transactions and protect them from manipulation and distortion, and it also provides tracking of the status of products during supply chain operations.

2. Related Work

The topic of using the blockchain in business has sparked many researchers, as there are thousands of research papers covering different fields of business such as financial management (Li, 2022; Lu et al., 2022), marketing management (Lemos et al., 2022; Chukurna et al., 2023), sales management (Rakkini & Geetha, 2021), human resource management (Anaam et al., 2023), smart home management (Hassan & Eassa, 2022), production management (Balon et al., 2023), healthcare management (Salama & Eassa, 2022), and supply chain management (Van et al., 2023). Focusing on supply chains, we will find that many research has dealt with the importance of applying blockchain technology to supply chains such as Kshetri (2018) discussed the importance of the blockchain in managing supply chains and achieving its goals such as cost, quality, speed, dependability, risk reduction, sustainability, and flexibility. Longo et al. (2019) provided a simulation model using a software connector for integration between information systems within enterprises with a central blockchain to ensure that information data shares between enterprises while ensuring their accuracy. The results of the statistical analysis of the data that were recorded on the central blockchain appeared that there is an increase in the general performance of the supply chain and that blockchain technology overcame many problems related to confidence and cooperation between enterprises. There are many researches that contribute to solving many problems related to supply chain management. Therefore, we will focus on presenting related works that are closely related to the domain of our research through the following directions:

- Inventory management.
- Selecting and evaluating supplier.
- Demand forecasting.
- Inspecting incoming shipments.

In the first direction, many researchers have contributed to the area of inventory management using blockchain, such as Sunny et al. (2022) presented a simulation tool called "Blockchain-Enabled Beer Game" (BEBG), which is specifically concerned with inventory management and the research considered that the inventory management is one of the important basic elements in the supply chain management. The research considered that the provided tool is suitable for the purpose of teaching students to use blockchain in inventory management and training Industries employees to clarify the importance of blockchain in supply chain management. Kurdi et al. (2022) studied the empirical evidence of the impact of the blockchain and smart inventory management systems on the performance of retail supply chains in the United Arab Emirates. It used a sample of 303 respondents, and the data was analyzed using ANOVA. It was clear from the results of the analysis that there is a significant positive impact of the use of blockchain technology and smart inventory management systems in supply chains. Atyam et al. (2022) discussed the integration of IoT technology with blockchain technology, the research has used Internet of Things technology for monitoring the level of inventory and tracking moving of products through supply chains, and on the other hand blockchain technology has been used to achieve transparency of product data in supply chains. Hasan et al. (2020) discussed the importance of the reliability of original spare parts and ensuring their authenticity, through using smart contracts and blockchain technology, and tracking the movement of spare parts through supply chains. The research presented a decentralized system based on storage of interplanetary file systems (IPFS) to store and share spare parts data. Lakshmi et al. (2021) focused on inventory management using the Quick Response (QR) along with smart contracts and blockchain technology in order to track products accurately and also achieve transparency and reliability of inventory management. Govindasamy and Antonidoss (2022) presented a proposed model for inventory management and took into account some costs such as (transaction cost, shortage cost, inventory holding cost, time cost, transportation cost, backordering cost, setup cost, and quality improvement cost) and used an algorithm under the name Whale-based Multi-Verse Optimization (W-MVO) and the data of users and distributors are secured through the use of blockchain technology. Casino et al., 2019 presented an interaction mechanism between retailers and sellers that depends on the Vendor-managed inventory (VMI) strategy and its improvement through the use of blockchain technology and smart contracts.

On the second direction, many researchers have presented the use of the blockchain in supply chains, but their studies focused on the method of selecting and evaluating suppliers such as Luthra et al. (2017) presented a framework for evaluating and selecting suppliers using an integrated Analytical Hierarchy Process (AHP), and using 22 criteria through three different dimensions: environmental, economic, and social. According to the results of the analysis, the researcher found that there are five criteria with significant impact are environmental costs, quality of product, price of product, occupational health and safety systems, and environmental competencies. Xu et al. (2019) presented a scheme that uses the Ethereum blockchain to ensure that data related to supply chains are not tampered with. Also, the smart contracts of blockchain are used to evaluate the reputation of supply chain suppliers, thus choosing the best of them in the future. Yoon and Pishdad-Bozorgi (2022) highlighted the critical problems related to the construction supply chain (CSC), among which was the problem of evaluating suppliers in supply chains through some criteria such as claims auditing, forensic analysis and dispute resolution, and smart contract-based governance, with activation of the reward and punishment mechanism in the evaluation points for each supplier. Xu et al. (2022) proposed a system called SAS that relies on evaluating the reputation of suppliers in the supply chain using a neural network, thus ensuring quality of service and reducing product delivery time. Su et al. (2021) discussed his systematic scientific review of 9151 research and articles published in the period from 2017 to 2021. Among the results, the research found that the interest of the research community in emerging trends related to supply chains, including supplier evaluation and blockchain technology.

In the third direction, some researchers considered that demand forecasting is one of the essential elements in supply chains, and blockchain technology provides good solutions for demand forecasting (Dujak & Sajter, 2019). Farouk and Darwish (2020) discussed the importance of the blockchain in the reliability of data and ensuring its safety, and thus the ability to forecast demand by tracking supply chains. The research presented a proposed framework that integrates customer relationship management (CRM) with supplier relationship management (SRM) in an application suite by blockchain technology. Meghla, et al. (2021) presented an approach that uses blockchain technology and machine learning to forecast demand for the COVID-19 vaccine to ensure the success of its distribution in an ideal and timely manner. Peña et al. (2020) reviewed the importance of blockchain technology in food supply chain management (FSCM) in Ecuador, where the transported food may spoil if stored or transported improperly, and therefore the importance of blockchain technology in keeping all transactions and tracking them easily with the importance of predicting the required quantities. Shakhbulatov et al. (2020) presented a survey of some frameworks that discussed the use of blockchain technology to address some supply chain problems. Also, the survey study presents the advantages and disadvantages of each framework. The research discussed some of the frameworks that indicated the importance of forecasting demand as one of the main elements in the supply chain process.

In the fourth direction, there are some researchers focused on inspecting incoming shipments to ensure that the shipment arrived at the right time, with the appropriate quality and the correct quantity, according to specific technical specifications. Consequently, supply chains will be affected, and there may be returns for shipments, and therefore additional costs for shipping returns. Hader et al. (2022) focused on the textile industry, as this industry faces many problems during supply chains such as tampering of products, poor traceability, delay, and lack of real-time information sharing, thus there are returns for shipments thus doubling the cost of transportation. The research proposed a framework for textile supply chain traceability based on blockchain to achieve full transparency and trust between the parties to the supply chain. Also, ElMessiry and ElMessiry (2018) focused on transparency in the textile industry and the importance of using blockchain technology in knowing the source of production and tracking shipments and their quality during supply chains. Singh and Raza (2023) presented a framework for IoT and Blockchain-based smart Food Chain Management System (IBFS) to measure the quality of foods throughout the food supply chains, by using the Internet of Things technology which broadcast all data collected to Message Queue Telemetry Transport (MQTT) (Message Queue Telemetry Transport) broker or server and a copy of it is passed on two types of smart contracts, the first smart contract deals with custody and the second smart contract focuses on monitoring food supply chain network. The proposed framework system was tested in different test conditions to ensure its effectiveness. Casino et al. (2021) presented a distributed architecture for tracking food supply chains and achieving traceability in supply chains through the use of blockchain technology. The feasibility of the proposed structure was assessed through an application of a case study in the dairy sector with the aim of ensuring the flow of dairy products through supply chains with high quality. Hong (2021) presented a detailed summary of multiple models that used blockchain technology with the Internet of Things in the supply chains of agricultural crops. The research focused on the grain inspection process that examines the quality of products during storage and during their transmission through supply chains. Kim (2023) used deep learning to detect fraud and predict the size of customers and applied the model to DataCo Global's data set. The data was processed using deep learning with eXtreme Gradient Boosting (XGBoost), and the results detected actual fraud operations and the proposed model can predict the sales volume using deep learning.

Based on the four main directions that were previously mentioned, each study mentioned previously focuses on one, two, or three directions at most. On the other hand, this research focuses on the four directions together. In the following section, the proposed model architecture, its components descriptions, functions, and the blockchain smart contracts algorithms are presented.

3. The Proposed IoT based Blockchain model for Supply Chain Management

The proposed integrated model for supply chain management consists of the main components shown in Figure 1. These main components are as follows: [i] Supply chain stakeholders. [ii] Wireless Sensors Networks (WSNs) IoT-based Systems. [iii] cloud-based consortium blockchain management system.
The three components are working together, as the stakeholders in the supply chain interact with each other through WSNs IoT-based Systems. Tracking products, orders, and inventory data are sent to the cloud-based consortium blockchain management system, so suppliers can be evaluated and select the best from them, incoming shipments inspected, to inventory management to forecast the demand.

3.1. Supply Chain Stakeholders

This component consists of all parties involved in the supply chain including suppliers, suppliers' suppliers, Original Equipment Manufacturer or OEM, distributors, and customers.

3.2. Wireless Sensors Networks (WSNs) IoT-based Systems

This component includes the wireless networks of sensors that represent IoT systems that monitor, and track the movement, transportation, and handling of raw materials, semi-finished goods, and finished goods throughout the supply chain starting from supplier1, supplier2, …., supplier n, OEM, distributor1, distributor2, … distributor n, and ending with customer. The used IoT sensors could be traditional and smart. Smart sensors are equipped with onboard technologies such as microprocessors, storage, diagnostics, and connectivity tools that transform traditional feedback signals into true digital insights that can in turn drive improvements in decreasing operating cost, performance, or customer experience. The used IoT sensors in the supply chain can be classified according to their physical properties they measure Temperature, Proximity, IR Sensor (Infrared), Pressure, Smoke, Gas, Touch, Color, Humidity, and Weight Sensors to measure light, heat, motion, moisture, pressure, or any one of several other environmental changes. In addition, IoT sensors provide real-time on-shelf and warehouse product stock levels, and location-tracking data regarding the location of the product and the transportation environment. The collected data by sensors are transmitted to the cloud-based consortium blockchain management system via different sensors-related transmission standards and technologies including Radio Frequency Identification (RFID) sensor tags, Wi-Fi, GPRS sensors, GPS satellites, and others.

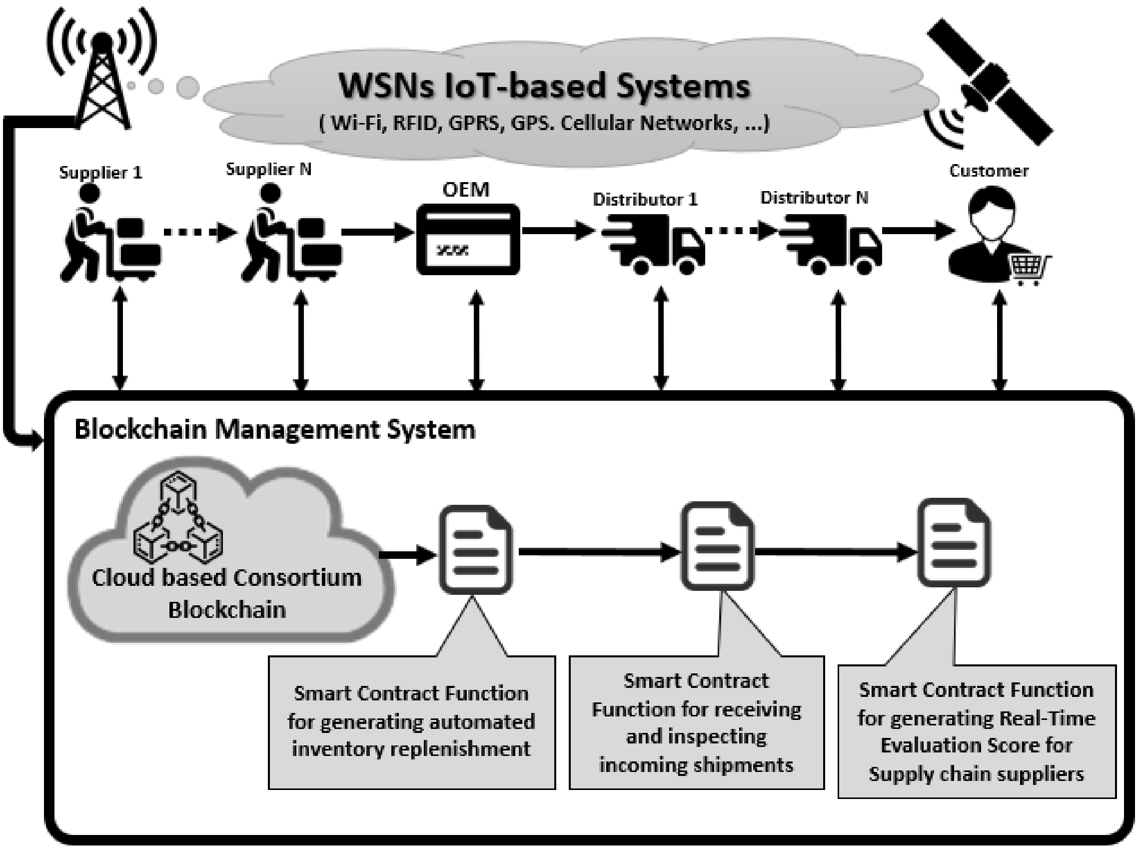

Fig. 1: Integrated IoT based Blockchain Model for Supply Chain Management

3.3. Cloud-based Consortium Blockchain Management System

The cloud-based consortium blockchain management system is responsible for executing the smart contract rules, recording and retrieval of data from the blockchain. This paper focuses on proposing a blockchain-based system that uses a smart contract that includes several functions, three main important functions of them are: First, generating automated inventory replenishment based on the real-time recorded products updated stock levels in the blockchain. Second, receiving and inspecting incoming shipments, and finally generating real-time supply evaluation scores for the supply chain suppliers.

The smart contract contains several functions that are responsible for adding new suppliers' data to the blockchain or removing their data, selecting the highest rank score suppliers, and generating purchasing orders for them automatically by executing Generating Automated Inventory Replenishment Function, recording details of each implemented inventory replenishment transaction including the supplier evaluation criteria values required to calculate his evaluation score by executing Receiving and Inspecting Incoming Shipments Function, calculating real-time evaluation score for suppliers who made any shipments by executing Generating Real-Time Evaluation Scores for Suppliers Function that calculates and updates suppliers score in blockchain. In addition, other smart contract functions can trace the evaluation score progress of each supplier by executing Trace Supplier Function, and finding suppliers that have specific scores, or supplying certain goods.

The supplier evaluation score can be a reliable indicator for selecting the appropriate supplier for procurement as more shipments are made. The transparency feature of the blockchain will motivate supply chain parties to maintain a good reputation that is represented by as high evaluation score and help build trust among the supply chain stakeholders.

3.3.1. Generating Automated Inventory Replenishment Function

This function is used to manage inventory for supply chain stakeholders including supplier(s), OEM, distributors, and retailers giving them real-time inventory and replenishment information at the items stock levels on the department or store level. The function selects the appropriate supplier with the highest evaluation score for inventory replenishment. After that, a purchasing order is generated for the selected supplier and the order details are recorded in the blockchain as shown in the next algorithm.

Generating Automated Inventory Replenishment Algorithm

1. With every deduction from each item stock level:
    - 1.1 IF current updated item stock level < item stock reorder point Then
        - 1.1.1 Retrieve list of all item suppliers
        - 1.1.2 Select item supplier(s) with the largest supplier evaluation score and has/have the required quantities
        - 1.1.3 Create purchasing order with the regular item stock level or specific order quantity
        - 1.1.4 Let supplier in purchasing order equals to selected supplier
        - 1.1.5 Record purchasing order details to blockchain
        - 1.1.6 Notify selected supplier with purchasing order
        - 1.1.7 Make records available to supply chain stakeholders
    - 1.2 Else Do Nothing
2. End

3.3.2. Receiving and Inspecting Incoming Shipments Function

This function is responsible for receiving and inspecting incoming shipments against the shipment inspection criteria variables, calculating, and updating the supplier rank evaluation score by calling Generate Real-Time Supplier Updated Evaluation Score, and recording any shipment problems to the blockchain as shown in the next algorithm. Proposed criteria variables for incoming shipment inspection include:

- Shipment Delay time. (In days)
- Shipment components arrangement status. (Accepted/Rejected)
- Shipment Packaging. (Accepted/Rejected)
- Shipment quality. (Accepted/Rejected)
- Shipment items count. (Accepted/Rejected)
- Shipment defected items check. (Pass/ Not Pass)

Receiving and inspecting incoming shipments Algorithm

1. Initialize order incoming shipment inspection criteria variables with their desired values.
2. Record shipment dispatch details to blockchain.
3. Record Shipment arrival details to blockchain.
4. Compare the received shipment details against the accepted values of shipment inspection criteria variables using smart contract
   - 4.1 IF (Checking = Ok) then
     - 4.1.1 Update shipment status = “Accepted”
     - 4.1.2 Execute payment in tokens for the accepted shipment
   - 4.2 Else
     - 4.2.1 Update shipment status = “Rejected”
     - 4.2.2 Record an alert with the shipment problems to blockchain
5. Calculate real time supplier rank evaluation score
6. Make records available to supply chain stakeholders.
7. End

3.3.3. Generating Real-Time Evaluation Scores for Suppliers Function

This function is responsible for calculating and updating real-time supplier rank evaluation scores. The most important supplier evaluation score criteria that are considered for each supplier are as follows:

- Previously listed 6 incoming shipment inspection criteria variables in section 3.3.2
- Supplier price rate. (High/Moderate/Low)
- Supplier service level. (High/Moderate/Low)

The supplier price rate and service level evaluation are added by each consumer in the supply chain to the blockchain. Table (1) presents proposed weights for the 8 supplier evaluation criteria. To maintain an open database of information, all parties in the supply chain are required to record their details on the blockchain.

Table 1. Proposed Supplier Evaluation Criteria Weights

No	Supplier Evaluation Criterion	Proposed Weight
1	Supplier price rate (High 0, Moderate 1, Low 2)	20%
2	Quality level (Low 0, Moderate 1, High 2)	20%
3	Delivery Time (Ontime 1, Delayed 0)	10%
4	Shipment components arrangement status (good 1, bad 0)	10%
5	Shipment Packaging (good 1, bad 0)	10%
6	Shipment Service Level (good 1, bad 0)	10%
7	Shipment items count (Correct 1, Incorrect 0)	10%
8	Shipment defected items check (no effected exist 1, defected exist 0)	10%
	Total	**100%**

A supplier rank score is updated in real-time with each executed inventory replenishment transaction. A simple way to determine the updated supplier rank score of each supplier is to calculate his new score as an average of his calculated supplier rank score in the last inventory replenishment transaction and his stored supplier rank score in the blockchain as illustrated in Generating Real-Time Supplier Updated Evaluation Score function algorithm.

Generate Real-Time Supplier Updated Evaluation Score Algorithm

Inputs: current shipment eight evaluation criteria values

1. Calculate equivalent weight w_i for each supplier evaluation criterion value $c_i v_i$ where i = 1 → 8 evaluation criterion, weight of criterion i: w_i, supplier evaluation criterion: c_i, criterion value: v_i.
2. Calculate current supplier total score (css) $= \sum_{i=1}^{8} w_i$
3. Retrieve stored old supplier score in blockchain (oss).
4. Calculate new supplier evaluation score (nss) = (oss + css)/2
5. Update stored supplier evaluation score in blockchain

6. Make it accessible to supply chain stakeholders.
7. End

4. Experiments and Results

Solidity is a programming language used for implementing smart contracts, and in this paper, it was used through the Remix platform. Remix is a browser-based solidity compiler and integrated development environment (IDE) (Modi, 2018), was used to provide a preliminary validation of the proof-of-concept. It simulates the EVM, containing all the tools necessary to create, compile, deploy, and test smart contracts as they would be done on the actual Ethereum network, but does not actually connect to the live network. The implemented smart contract was based on four main structures, which are suppliers, items, orders, and supplier evaluation. Each structure contains a set of its own characteristics, as shown in Figure 2.

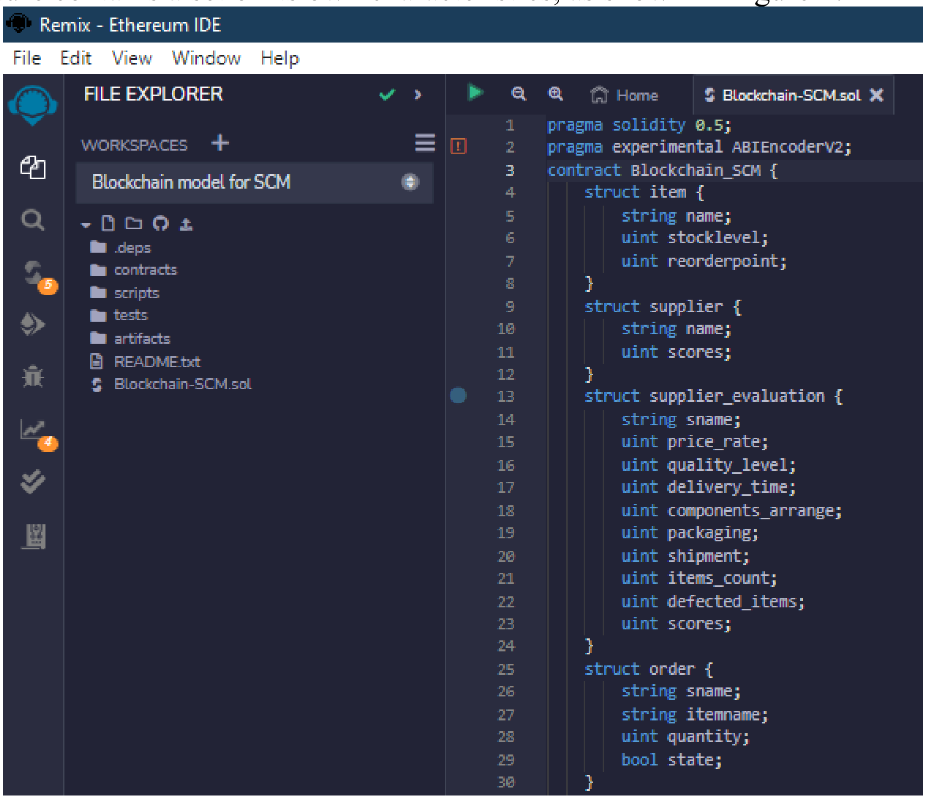

Fig. 2: The main four structures (suppliers, items, orders, and supplier evaluation)

The four structures are mapped to associate a unique Ethereum address to access the values within each structure. Figure 3 illustrates the mapping process.

```
mapping (bytes32 => item) items;
mapping (bytes32 => supplier) suppliers;
mapping (bytes32 => supplier_evaluation) suppliereval;
mapping (bytes32 => order) orders;
```
Fig. 3: The mapping process for the main four structures

The "supplierevaluation" function evaluates each supplier according to the values of each of the previously defined variables in Table 1, and the evaluation of each supplier is updated continuously after the completion of the supply of each order, as shown in Figure 4.

```
function supplierevaluation (supplier_evaluation[] memory _suppliereval,string memory suppliername) public view returns (supplier_evaluation[] memory) {

    _suppliereval[0].sname=suppliername;
    _suppliereval[0].scores=(_suppliereval[0].price_rate*10)+(_suppliereval[0].quality_level*10)+(_suppliereval[0].delivery_time*10)+(_suppliereval[0].
    return _suppliereval;
}
```
Fig. 4: Supplier Evaluation Function

Assuming that there is a supplier who has completed a specific order and the values of the variables are as in Table 2.

Table 2. Supplier Evaluation Example

Supplier Evaluation Element	Value	Proposed Weight
Supplier price rate	Low 2	20%
Quality level	High 2	20%
Delivery Time	Delayed 0	0%
Shipment components arrangement status	Good 1	10%
Shipment Packaging	Good 1	10%
Shipment Service Level	Good 1	10%
Shipment items count	Correct 1	10%
Shipment defected items check	No effected exist 1	10%
Total		**90%**

Therefore, according to the evaluation rules that were specified in Table 1, the evaluation result is 90, and Figure 5 shows the result of applying these rules.

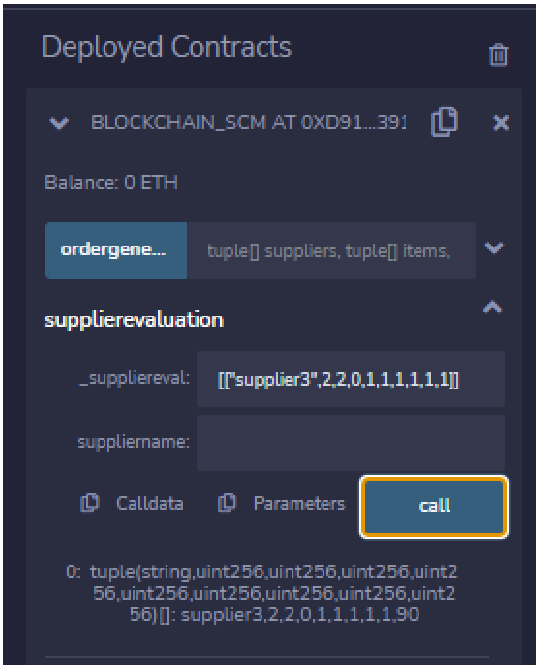

Fig. 5: Supplier Evaluation Example

We will present the following example to illustrate the selection process of the best supplier for supplying items whose inventory level has reached the reorder point, assuming the following suppliers and items data as in Tables 3 and 4.

Table 3. Suppliers Example

Supplier Name	Supplier Evaluation
supplier 1	40
supplier 2	70
supplier 3	90

Table 4. Items Example

Item Name	Current Stock Level	Reorder Point
item1	40	84
item2	50	9
item3	50	70
item4	20	70

The "ordergenerator" function in the presented smart contract is responsible for generating orders according to suppliers' evaluation and items reorder points. The function "supplierevaluation" is called after completing each order to update the score for each supplier, the following code explains that as shown in Figure 6.

```
function ordergenerator(supplier[] memory suppliers,item[] memory items,order[] memory _orders) public view returns
    uint max_score= 0;
    uint i;
    uint j;
    uint p;
    uint k=0;
    for (j = 0; j < items.length; j++) {
       if(items[j].stocklevel<=items[j].reorderpoint){
       for (i = 0; i < suppliers.length; i++) {
          if(max_score<suppliers[i].scores){
              max_score = suppliers[i].scores;
              p=i;
          }
        }
       _orders[k].sname=suppliers[p].name;
       _orders[k].itemname=items[j].name;
       _orders[k].quantity=items[j].reorderpoint-items[j].stocklevel+1;
       _orders[k].state=true;
       k=k+1;
       supplierevaluation(supplier_evaluation[p],suppliers[p].name);
       }
    }
   return _orders;
}
```

Fig. 6: Order Generator Function

Therefore, based on the previously assumed data, the following becomes clear:

- The highest rated supplier is "supplier 3.
- The items that need to be ordered, where the current stock level is less than the reorder point level, are "item 1, item 3, item 4".

Accordingly, orders will be generated depending on "supplier 3" and for items "item 1, item 3, item 4" and in quantities that cover the reorder point for each item as shown in Figure 7.

Based on the testing results and examples in this section, the proposed model can improve the quality of inventory management and predict future orders and quantities. It also processes orders automatically, facilitates the process of tracking products, tracking the transportation and storage environment, and transportation, thus better quality of products and reducing product damage. Based on the data received during supply chains, the proposed model can evaluate suppliers and thus assign new orders to the best of them in evaluation.

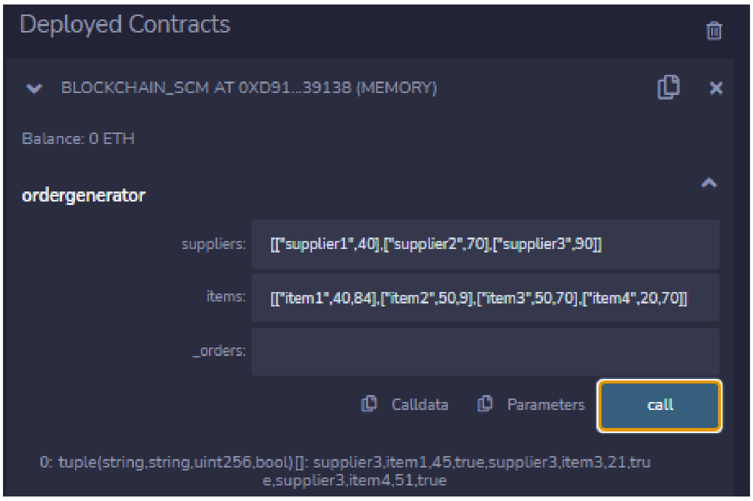

Fig. 7: Order Generator Example

5. Conclusions

An integrated cloud-based blockchain model for supply chain management is proposed in this paper. This model is based on three main components [i] Supply chain stakeholders. [ii] Wireless Sensors Networks (WSNs) IoT-based Systems. [iii] cloud-based consortium blockchain management system. The proposed model uses IoT systems to monitor and track the movement, transportation, and handling of shipments through the supply chain. The blockchain smart contract performs several functions, mainly three important functions: generating automated inventory replenishment and purchasing orders based on knowing exactly on-hand inventory in real-time to the highest ranked supplier, receiving and inspecting incoming shipments, and generating and updating real-time scores for supply chain stakeholders. Cloud data servers are used to host the blockchain system as a solution to its increasingly large size. The implemented proposed integrated model was tested on many inventories' replenishment cases. The testing results proved that the system was successfully able to record the shipments data to the cloud-based blockchain using IoT systems, generate automated inventory replenishment to the supplier with the highest rank based on the real-time updated score for each supplier and make all these inventory replenishment transactions data available to all supply chain stakeholders. As a result, the proposed model caused indirectly higher product quality, more seamlessly executed supply chain operations, lower cost of inventory replenishment specifically, and lower total costs of the supply chain generally.

References

Anaam, E., Ghazal, T. M., Haw, S. C., Alzoubi, H. M., Alshurideh, M. T., & Al Mamun, A. (2023). Utilization of Blockchain Technology In Human Resource Management. *In 2023 IEEE 2nd International Conference on AI in Cybersecurity (ICAIC)*, IEEE, 1-5.

Atyam, N. R., Ponmurugan, P., Senthamil, L. S., Augustine, P. J., & Govindarajan, A. (2022). Integrated Internet of Things with Blockchains for Vendor-Management Inventory System. *In 2022 6th International Conference on Computing Methodologies and Communication (ICCMC)*, IEEE, 86-99.

Balon, B., Kalinowski, K., & Paprocka, I. (2023). Production Planning Using a Shared Resource Register Organized According to the Assumptions of Blockchain Technology. *Sensors*, 23(4), 2308.

Bechtel, C., & Jayaram, J. (1997). Supply chain management: a strategic perspective. *The international journal of logistics management*, 8(1), 15-34.

Casino, F., Dasaklis, T. K., & Patsakis, C. (2019). Enhanced vendor-managed inventory through blockchain. *In 2019 4th South-East Europe Design Automation, Computer Engineering, Computer Networks and Social Media Conference (SEEDA-CECNSM)*, IEEE, 1-8.

Casino, F., Kanakaris, V., Dasaklis, T. K., Moschuris, S., Stachtiaris, S., Pagoni, M., & Rachaniotis, N. P. (2021). Blockchain-based food supply chain traceability: a case study in the dairy sector. *International journal of production research*, 59(19), 5758-5770.

Chukurna, O., Zamlynskyi, V., & Dankevych, A. (2023). Modern trends in digital transformation of marketing & management.

Dujak, D., & Sajter, D. (2019). Blockchain applications in supply chain. SMART supply network, 21-46.

ElMessiry, M., & ElMessiry, A. (2018). Blockchain framework for textile supply chain management: Improving transparency, traceability, and quality. *In International conference on blockchain*, Cham: Springer International Publishing, 213-227.

Farouk, M., & Darwish, S. M. (2020). Reverse Logistics Solution in e-Supply Chain Management by Blockchain Technology. *Egyptian Computer Science Journal*, 44(1).

Flammini, A., & Sisinni, E. (2014). Wireless sensor networking in the internet of things and cloud computing era. *Procedia Engineering*, 87, 672-679.

Golosova, J., & Romanovs, A. (2018). The advantages and disadvantages of the blockchain technology. *In 2018 IEEE 6th workshop on advances in information, electronic and electrical engineering (AIEEE)*,IEEE,1-6.

Govindasamy, C., & Antonidoss, A. (2022). Enhanced inventory management using blockchain technology under cloud sector enabled by hybrid multi-verse with whale optimization algorithm. *International Journal of Information Technology & Decision Making*, 21(02), 577-614.

Hader, M., Tchoffa, D., El Mhamedi, A., Ghodous, P., Dolgui, A., & Abouabdellah, A. (2022). Applying integrated Blockchain and Big Data technologies to improve supply chain traceability and information sharing in the textile sector. *Journal of Industrial Information Integration*, 28, 100345.

Hasan, H. R., Salah, K., Jayaraman, R., Ahmad, R. W., Yaqoob, I., & Omar, M. (2020). Blockchain-based solution for the traceability of spare parts in manufacturing. *IEEE Access*, 8, 100308-100322.

Hassan, S. A., & Eassa, A. M. (2022). A Proposed Architecture for Smart Home Systems Based on IoT, Context-awareness and Cloud Computing. *International Journal of Advanced Computer Science and Applications*, 13(6).

Hofstede, G. J. (2003). Trust and transparency in netchains: a contradiction?. *In 8ème Colloque AIM Grenoble*,1-9.

Hong, Y. (2021). New model of food supply chain finance based on the Internet of Things and blockchain. *Mobile Information Systems*, 2021, 1-8.

Hsiao, H. I., & Huang, K. L. (2016). Time-temperature transparency in the cold chain. *Food Control*, 64, 181-188.

Jeyasheela Rakkini, M. J., & Geetha, K. (2021). Blockchain-enabled microfinance model with decentralized autonomous organizations. *In Computer Networks and Inventive Communication Technologies: Proceedings of Third ICCNCT 2020*, Springer Singapore, 417-430.

Kim, B. (2023). Development of Online Fraud Detection and Sales Prediction Model using Supply Chain Dataset. *Journal of System and Management Sciences*, 13(20), 501-514.

Kim, J. W. (2020). Blockchain technology and its applications: Case studies. *Journal of System and Management Sciences*, 10(1), 83-93.

Kshetri, N. (2018). 1 Blockchain's roles in meeting key supply chain management objectives. *International Journal of information management*, 39, 80-89.

Kurdi, B., Alzoubi, H., Akour, I., & Alshurideh, M. (2022). The effect of blockchain and smart inventory system on supply chain performance: Empirical evidence from retail industry. *Uncertain Supply Chain Management,* 10(4), 1111-1116.

Lakshmi, G. V., Gogulamudi, S., Nagaeswari, B., & Reehana, S. (2021). BlockChain based inventory management by QR code using open CV. *In 2021 International Conference on Computer Communication and Informatics (ICCCI)*, IEEE, 1-6.

Lambert, D. M., & Cooper, M. C. (2000). Issues in supply chain management. *Industrial marketing management*, 29(1), 65-83.

Lemos, C., Ramos, R. F., Moro, S., & Oliveira, P. M. (2022). Stick or twist—the rise of blockchain applications in marketing management. *Sustainability*, 14(7), 4172.

Li, F. (2022). Research on the Design of Financial Management System Based on Blockchain. *In 2022 2nd International Conference on Management Science and Software Engineering (ICMSSE 2022),* Atlantis Press, 528-532.

Li, Y. (2018). An integrated platform for the internet of things based on an open source ecosystem. *Future Internet*, 10(11), 105.

Longo, F., Nicoletti, L., Padovano, A., d'Atri, G., & Forte, M. (2019). Blockchain-enabled supply chain: An experimental study. *Computers & Industrial Engineering*, 136, 57-69.

Lu, Y., Wang, Y., & Chen, R. (2022). Design of enterprise financial information management system based on blockchain technology. *Security and Communication Networks*.

Luthra, S., Govindan, K., Kannan, D., Mangla, S. K., & Garg, C. P. (2017). An integrated framework for sustainable supplier selection and evaluation in supply chains. *Journal of cleaner production*, 140, 1686-1698.

Meghla, T. I., Rahman, M. M., Biswas, A. A., Hossain, J. T., & Khatun, T. (2021). Supply chain management with demand forecasting of covid-19 vaccine using blockchain and machine learning. *In 2021 12th International Conference on Computing Communication and Networking Technologies (ICCCNT)*, IEEE, 1-7.

Modi, R. (2018). Solidity Programming Essentials: A beginner's guide to build smart contracts for Ethereum and blockchain. Packt Publishing Ltd.

Óskarsdóttir, K., & Oddsson, G. V. (2019). Towards a decision support framework for technologies used in cold supply chain traceability. *Journal of Food Engineering*, 240, 153-159.

Peña, M., Llivisaca, J., & Siguenza-Guzman, L. (2020). Blockchain and its potential applications in food supply chain management in Ecuador. *In Advances in Emerging Trends and Technologies: Volume 1*, Springer International Publishing, 101-112.

Ray, P. P. (2016). A survey of IoT cloud platforms. *Future Computing and Informatics Journal*, 1(1-2), 35-46.

Rejeb, A., Sűle, E., & G Keogh, J. (2018). Exploring new technologies in procurement. *Transport & Logistics: the International Journal*,18(45), 76-86.

Salama, A. S., & Eassa, A. M. (2022). IOT and cloud based blockchain model for COVID-19 infection spread control. *Journal of Theoretical and Applied Information Technology*, 100(1), 113-126.

Shakhbulatov, D., Medina, J., Dong, Z., & Rojas-Cessa, R. (2020). How blockchain enhances supply chain management: A survey. *IEEE Open Journal of the Computer Society*, 1, 230-249.

Singh, A. K., & Raza, Z. (2023). A framework for IoT and blockchain based smart food chain management system. *Concurrency and Computation: Practice and Experience*, 35(4), e7526.

Su, Z., Zhang, M., & Wu, W. (2021). Visualizing sustainable supply chain management: a systematic scientometric review. Sustainability, 13(8), 4409.

Sunny, J., Pillai, V. M., Nath, H. V., Shah, K., Ghoradkar, P. P., Philip, M. J., & Shirswar, M. (2022). Blockchain-enabled beer game: a software tool for familiarizing the application of blockchain in supply chain management. *Industrial Management & Data Systems*, 122(4), 1025-1055.

Svorobej, S., Takako Endo, P., Bendechache, M., Filelis-Papadopoulos, C., Giannoutakis, K. M., Gravvanis, G. A., & Lynn, T. (2019). Simulating fog and edge computing scenarios: An overview and research challenges. *Future Internet*, 11(3), 55.

Treiblmaier, H. (2018). The impact of the blockchain on the supply chain: a theory-based research framework and a call for action. *Supply chain management: an international journal*, 23(6), 545-559.

Tzounis, A., Katsoulas, N., Bartzanas, T., & Kittas, C. (2017). Internet of Things in agriculture, recent advances and future challenges. *Biosystems engineering*, 164, 31-48.

Van Nguyen, T., Cong Pham, H., Nhat Nguyen, M., Zhou, L., & Akbari, M. (2023). Data-driven review of blockchain applications in supply chain management: key research themes and future directions. *International Journal of Production Research*, 1-23.

Wang, X., Zha, X., Ni, W., Liu, R. P., Guo, Y. J., Niu, X., & Zheng, K. (2019). Survey on blockchain for Internet of Things. *Computer Communications*, 136, 10-29.

Xu, X., Gu, J., Yan, H., Liu, W., Qi, L., & Zhou, X. (2022). Reputation-aware supplier assessment for blockchain-enabled supply chain in industry 4.0. *IEEE Transactions on Industrial Informatics*, 19(4), 5485-5494.

Xu, Z., Liu, Y., Zhang, J., Song, Z., Li, J., & Zhou, J. (2019). Manufacturing industry supply chain management based on the ethereum blockchain. *In 2019 IEEE International Conferences on Ubiquitous Computing & Communications (IUCC) and Data Science and Computational Intelligence (DSCI) and Smart Computing, Networking and Services (SmartCNS)*, IEEE, 592-596.

Yoon, J. H., & Pishdad-Bozorgi, P. (2022). State-of-the-art review of blockchain-enabled construction supply chain. *Journal of construction engineering and management*, 148(2), 03121008.

Zantalis, F., Koulouras, G., Karabetsos, S., & Kandris, D. (2019). A review of machine learning and IoT in smart transportation. *Future Internet*, 11(4), 94.