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APPLIED RESEARCH

Blockchain-Based Process Quality Data Sharing Platform for Aviation Suppliers

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ABSTRACT Given the challenge of manufacturing data silos and information credibility issues in traditional aviation suppliers' result-oriented management approach, this paper proposes a blockchain-based aviation supplier manufacturing process quality data-sharing platform. Firstly, the paper introduces the possibility of integrating manufacturing supply chain quality management with blockchain technology. Secondly, the quality and data sharing platform architecture of the production process of new aviation suppliers is presented based on quality state and island kinds of aviation suppliers. Then, a detailed method for the implementation of quality and data security sharing is proposed to support the sharing platform's real-time and orderly operation. Build critical technologies such as manufacturing quality data block packaging models, data storage security sharing, and supplier assessment models on this foundation. Finally, depending on data collection of supplier product production processes to shared application practices based on a specific aircraft industrial park under the supervision of the platform architecture and technology. The application platform integrates the data supply and request components, providing practical and intelligent sharing solutions for airlines' product quality data.

INDEX TERMS Blockchain, supplier management, data sharing, evaluation mechanism, data information management.

I. INTRODUCTION

Aviation supplier process quality data refers to the characteristic values collected by suppliers during the manufacturing process, which are used to obtain the quality indicators of aviation products [1]. This data encompasses a wide range of topics, including manufacturing process planning, production batches, usage, and return maintenance. The timely and reliable collection of quality characteristic data, high-speed safe transmission, and stable traceability storage are essential for ensuring the comprehensive performance and service life of aviation goods. However, due to the involvement of aviation enterprises in a variety of product types, a large number of suppliers, and deep levels of the supply chain in the actual manufacturing process, the credibility sharing and security interoperability of quality data in the manufacturing process have always been a challenge in supplier quality management and control. This has also been a bottleneck for aviation enterprises seeking to improve their level of supplier quality management. A secure and reliable supply chain system is becoming a new need for both manufacturers and users [2]. Exploration of a new paradigm of deep integration of next-generation information technology and the aircraft manufacturing business is critical [3], [4]. The introduction of new data services and technologies, such as blockchain, has had a significant influence on the processing market and supply chain, generating new ideas for the study of aviation supplier intelligent governance [5], [6]. As a result, the blockchain-based process quality data-sharing platform for aviation suppliers is implemented in the paper.

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The blockchain is based on Bitcoin technology, and its decentralization, high-volume fault and security, and trustworthiness have piqued the interest of industrial manufacturing countries. According to the National Science and Technology Council's 2018 "U.S. Leadership Strategy in Advanced Manufacturing," it is employed as soon as possible to create or revise blockchain standards and guidelines in information and data security in the field of advanced manufacturing. In September 2019, the German government unveiled a blockchain policy to support industrial digital transformation. The Chinese government included blockchain technology in its "Fourteenth Five-Year Plan," which intends to improve technology integration and layout. The value of blockchain in enabling industrial intelligence innovation is growing [7].

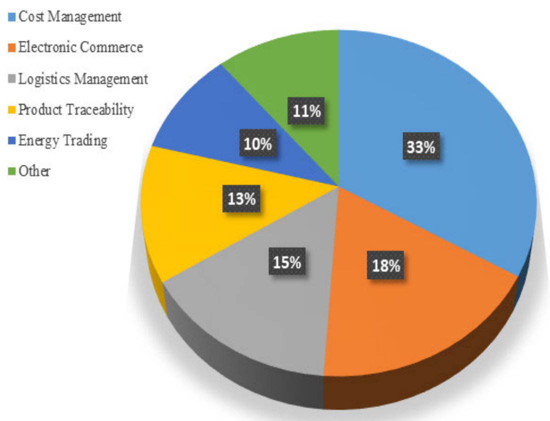

FIGURE 1. The proportion of document types is based on keywords.

Using the topic phrases "Manufacturing Supplier" and "Blockchain" as search terms, a total of 211 publications on blockchain research in industrial supply were published in the five years from 2018 to 2022, according to Web of Science. As seen in Figure 1, the majority of their research interests are in financial management [8], e-commerce [9], logistics management [10], and product traceability [11]. According to the examination of the preceding literature, deeper dimension management, such as the collection and distribution of industrial product quality data based on blockchain, is not extensively involved, and there is less research on aviation enterprises.

Currently, the academic community has produced some outcomes in the use of blockchain in the aviation supply chain. For example, Dmitry Ivanov investigated how blockchain technology might be used in the supply chain and how to realize its disruptive change in digital supply chains and networks [12]. G.T.S. Ho et al. concentrated on traceability research on aviation inventory management and suggested the blockchain aviation spare parts inventory management framework [13]. Based on blockchain research, this paper focuses on the exchange of quality and data from the supplier process. To be more specific, to create a blockchain-based data-sharing platform for airlines and suppliers. On this foundation, appropriate scenario applications are carried out to give new technical ideas for aviation firms to solve the process, distribution, and credible management of quality data of outsourced goods.

The remainder of the paper is structured as follows: Section II discusses supply chain quality management, fundamental blockchain principles, and the essential technological properties of the two. Section III proposes a blockchain-based aviation supplier process quality and data-sharing platform, and introduces the meaning and practical feasibility of each layer in detail. Section IV the whole process about process data sharing is proposed, and data storage and sharing strategy research is carried out based on the sharing process. Section V, based on the real demands of aviation companies, system design, and implementation from the standpoint of data suppliers and data request parties. Section VI concludes the paper and summary of further research.

II. RELATED OVERVIEW

In the information age, determining the validity of data information and the efficacy of data transmission interoperability, as well as confirming the credibility of information sharing, is critical to the survival and development of businesses. In this setting, blockchain technology is implemented, and its benefit is that it implies genuine data information sharing is done in an undesirable atmosphere. To better comprehend the quality and data management mechanisms of manufacturing suppliers under the blockchain, this chapter first covers supply chain quality management. The blockchain infrastructure and core technologies are then dug into. Finally, the blockchain is evolving in the industrial supply chain.

A. SUPPLY CHAIN QUALITY MANAGEMENT

Supply chain quality management combines and intersects supply chain management with quality management. Figure 2 depicts the link between the two. Cross-regional collaboration between international organizations is common in an atmosphere of economic globalization, and supply chain quality management has come to be valued by governments [14]. Scholars at home and abroad have summarized the research route of supply chain quality management from initial quality accident testing, process quality control, and statistical quality management to complete quality management since the end of the past century.

Quality management and control have traditionally prioritized "Quality dependence on data" [15]. Focusing on supplier quality studies and data exchange, some studies argued that the historical data left in production management is frequently huge yet quite valuable [16]. With the goal of mitigating quality risks in products, several strategies have been proposed, including the use of quality management tools, rapid product design, process design, and other approaches [17]. In addition, the American SAE Association has suggested the adoption of "Global Quality Management" and has published quality management guidelines for complex product categories. To support these efforts,

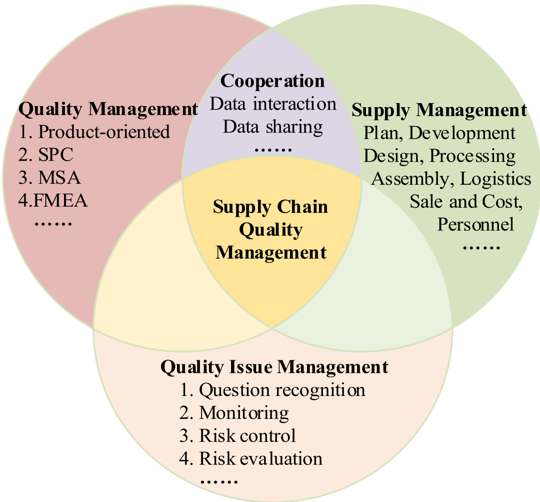

FIGURE 2. Supply chain quality management definition.

concepts for coordinating supply chain activities upstream and downstream have been put forward. It categorizes supply chain quality as the company's operation, supply chain information security, collaborative teamwork, and supply investment. Sahin suggested a supply chain-integrated information-sharing and decision-making coordination management methodology. This approach maintains the whole supply chain information in real-time and does not generally require artificial intervention, which may drastically cut the lead time and optimize freight and inventory management [18]. Wu et al. argued that information sharing has a positive influence on supply chain coordination [19]. The agility of the entire chain may be increased by information exchange and speedy interaction, and the link between suppliers and customers can be strengthened.

In summary, the data-sharing strategy is critical to improving the flexibility and interactivity of supply chain quality management. Exploring and combining new technologies and industrial supply chain data-sharing methods is an important trend in supply chain management research.

B. BLOCKCHAIN TECHNOLOGY

Blockchain is an overlay distributed ledger that packages important data into a chain structure using cryptography and consensus mechanisms. It is also decentralized, immutable, traceable, and maintained by numerous parties' distributed databases. The basic technology consists of encryption, hash algorithms, binomial structures, and a peer-to-peer network. Blockchain may be classified into three types based on the varying authority of nodes in the consensus mechanism: public chain, alliance chain, and private chain., and the difference between the three chain structures is the degree of de-naturalization. Buterin. V pointed out that the public chain is a permissionless blockchain, which means that anyone can read and send transactions, participate in the consensus process, and maintain data on the chain [16]. The blockchain, in theory, has none at the core, and the degree of de-neutralization is the greatest. Bitcoin and Ethereum apps symbolize it. A consortium chain means that when a node participates in a pre-selected blockchain, it needs to be authorized to join. It is suitable for a certain type of user group or secret-related enterprises with specific purposes, represented by R3 Blockchain Alliance and BigchainDB applications. The private chain is a blockchain deployment paradigm with a single center, and all activities need to be approved by the center and subject to its limits and restrictions. Participating nodes on the chain have only limited rights. For example, node A can only access data, node B can only regulate data rights writing, and so on [20]. At present, blockchain platforms are commonly used in the market. This section summarizes the characteristics of the three types of blockchain and the corresponding applicable scenarios, as shown in Table 1.

C. APPLICATION OF BLOCKCHAIN IN SUPPLIER MANAGEMENT

In a company's supply chain, stakeholders such as suppliers, raw material factories, operators, and transportation companies are involved. It includes procurement, manufacturing, testing, inventory control, logistics, and after-sales service [21], [22]. This paper focuses on supplier management as the research object. With the rapid development of economic globalization and the marketization of resource allocation, the number of participating members in aviation suppliers has increased dramatically. As a result, the relationship between businesses becomes highly complex, information is dynamic and scattered, the transparency of product quality information is not high, and the problem of information asymmetry among participants is increasingly prominent [23], [24]. To optimize product quality, reduce costs, and avoid information islands [25], this paper introduces blockchain technology to enterprise and supplier management. The key to potential mining and expanding applications of blockchain technology in supplier management lies in its ability to establish a connection with the physical world [26]. Kshetri proposed that blockchain can help supplier management achieve seven optimization goals of cost, quality, speed, dependency, risk reduction, sustainability, and flexibility [27]. Weber focused on solving the problem of distrust among suppliers through blockchain technology and found a protocol for sharing states through blockchain [28]. Francisco & Swanson used the concepts of blockchain and technological innovation to build a basic framework for supply chain traceability [29]. Lu, Yunlong, et al designed a blockchain-enabled secure data-sharing architecture for the security and privacy issues involved in supplier data sharing [30].

Compared with general enterprise suppliers, aviation suppliers have higher requirements in terms of knowledge, technical level, security, and privacy level. At the same time, aviation products have the characteristics of a highly complex process, customization, and a high degree of military-civilian

TABLE 1. Comparison of various blockchain platforms.

Platform name	Access type	Consensus algorithm	Database	Application Features
Bitcoin	public chain	PoW	LevelDB	Low access threshold and anonymity
Ethereum	public chain	PoW/PoS	LevelDB	
Corda	Alliance chain	Raft	MySQL	Low transaction speed, high reliability, and high security
TrustSQL	Alliance chain	BFT-Raft/PBFT	MySQL	
BigchainDB	Alliance chain	Quorum Voting	RethinkDB	
MultiChain	private chain	PoW	MultiChain Feeds	Low cost, strong security, and privacy

integration [31]. The application of blockchain technology seems promising to solve the above problems. This paper focuses on the application of blockchain technology in aerospace suppliers to reduce the overall risk of enterprises. Realize the whole process design of data collection, structuring, uploading, and information sharing.

III. DATA SHARING ARCHITECTURE FOR THE PROPOSAL PLATFORM

A blockchain-based aviation supplier process quality data-sharing platform is built using the core notion of blockchain and enterprise and supplier product management system integration, as illustrated in Figure 3. The platform is organized into five sections: the supplier manufacturing data collecting layer, the data collection, the storage layer, the blockchain data layer, the blockchain business layer, and the application layer. Based on aviation production management, transform, optimize, and extend to satisfy the engineering demands of aviation supplier data-gathering activities.

A. DATA ACQUISITION LAYER

The continuity and correctness of data collection are the keys to the monitoring and traceability management of aviation manufacturing suppliers. This layer is designed for two data collection methods involving manual sampling inspection and automatic full inspection in different measurement environments of the supplier's manufacturing workshop. Manual sampling is a key part of ensuring product quality and supporting factory administrative oversight. Quality inspectors can use measuring tools such as digital vernier calipers, digital micrometers, thickness gauges, and inclinometers to test the workpieces on the production line, and manually enter the data into the acquisition terminal. In the automatic full inspection, on the one hand, the built-in sensor of the machine tool identifies and detects the workpiece during product processing, and automatically fills the collected data into the present inspection sheet template in advance. On the other hand, automatic identification technology, such as RFID technology [32], is used to read and write process quality data at the manufacturing site.

B. DATA STRUCTURE LAYER

To handle the obtained process quality data, a structured procedure is devised in response to the huge scale, multiple types, and significant variability of quality data. This article divides product quality elements into six categories: human factors, equipment factors, raw material factors, process factors, environmental factors, and testing factors [33]. The aviation company's monitoring of the supplier's process quality data is fundamentally the process of overseeing and regulating these six criteria. The six-element management approach divides product quality characteristics into static characteristic data and dynamic characteristic data. Static feature data is used to describe product manufacturing duties, process requirements, preset geometric tolerances, and other quality data specifications such as process processing techniques, size variances, and so on. Dynamic feature data is derived from static features and is used to characterize the quality data of product and work quality status. Including processing status data, process evaluation data, process analysis data, etc. It is structured into a hierarchical data list according to different application requirements. The caching framework temporarily stores data information, including supplier process data sets and data sharing information received based on smart contracts. The manufacturing process data and management process data stored in the database are prepared for the chain.

C. BLOCK DATA LAYER

According to the classic block data structure, combined with the characteristics of data sharing between aviation companies and suppliers, the design is carried out. A blockchain is a chain-like structure composed of a series of blocks generated by a cryptographic algorithm, and each block generally consists of a block header and a block body. The block header includes the hash value of the previous block header, timestamp, Merkle root, SM2 national encryption algorithm, random number, etc [20]. The block body consists of a Merkle tree containing data-sharing information. In general, blockchain is mainly for retrieving and exchanging data, and real data is stored locally by its owner. When a supplier data provider participates in data sharing, its unique identification (ID) is recorded as a transaction on the blockchain, along with the provided data summary, data type, and data size. By merging the transaction data group information with the Hash algorithm, combined with the binary characteristics of the Merkle tree, the aggregated Merkle root value changes greatly, to achieve the purpose of data tamper-proof modification. The unique hierarchical structure of the Merkle

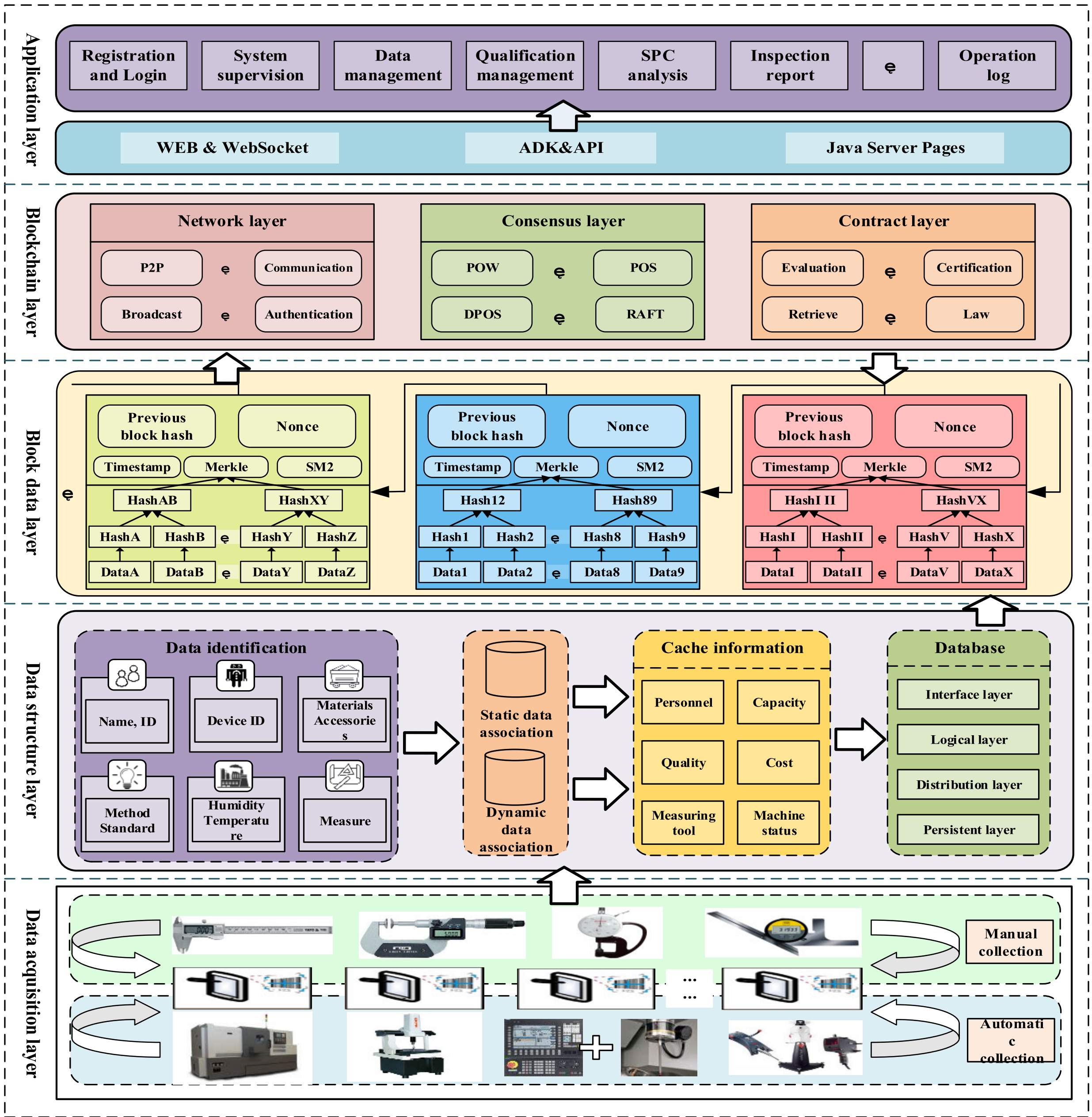

FIGURE 3. Blockchain-based intelligent sharing platform of process quality data for aviation suppliers.

tree also provides an important guarantee for the traceability of collected data. The timestamp in each block records the time when the block data is written, which provides the basis for the block authentication on the chain and further improves the credibility of the data. The recorded data cannot theoretically be modified by anyone in any way.

D. BLOCKCHAIN LAYER

The framework summarizes the key technologies required for blockchain on-chain. It covers the network layer, consensus layer, and contract layer in the basic architecture of the blockchain. The network layer uses the P2P network to transmit data. Compared with the traditional centralized networking technology, which may cause data security and privacy problems, peer-to-peer networking technology can not only effectively solve the above problems, but also reduce the damage to the entire network when the server has network delay [34]. Improve the fault tolerance of the system [35]. The consensus layer is an important part of blockchain technology. This layer is designed in this framework to ensure the consistency and validity of the data information published by all supplier nodes. By setting consensus algorithms and consensus mechanisms, data sharing distortion or node data fraud is prevented. Common consensus mechanisms mainly include PoW, PoS, DPoS, and PBFT [36], [37]. The contract framework includes contracts for evaluation, certification, and legal. It is a self-validating and self-executing computer interaction protocol that runs through the operation mechanism of slave node negotiation, development, deployment, execution, re-learning, and self-destruction. The blockchain completes the automatic processing of digital information through the invocation of smart contracts and the triggering of events. With this feature of automatically executing rules by contract, smart contracts are suitable for industrial engineering management.

E. APPLICATION LAYER

The functions of this layer are for the convenience of aviation companies to visually display and analyze the process quality data of suppliers through the platform, and support the acquisition of corresponding test reports on demand. The integration method adopts B/S architecture, and the process is shown in Figure 4.

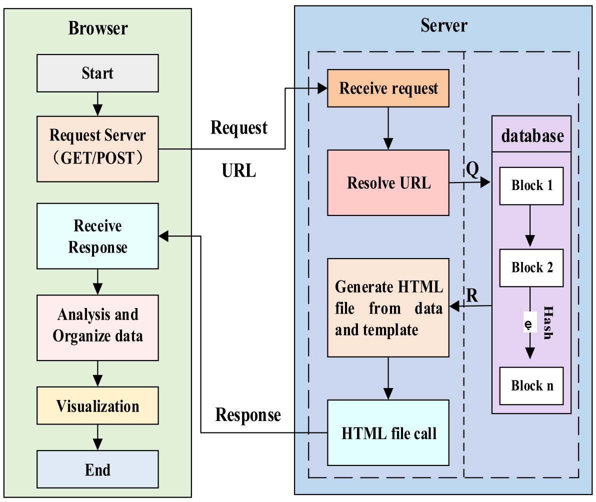

FIGURE 4. Brower/Server framework.

Framework operating mechanism:

1) Aviation companies can request data from the server through the protocol through the PC browser of the client.
2) After receiving the request, the server transfers the data from the block storage according to the screening conditions and according to the consensus mechanism and contract rules.
3) Through data transmission methods such as I\O streams, the browser receives and parses the data parameter values.

IV. BLOCKCHAIN-BASED QUALITY AND DATA SECURITY SHARING IMPLEMENTATION SOLUTION

The concept of distributed storage structure on the blockchain special chain is provided by the traditional centralized data storage method, when facing massive and confidential data processing, data query timely and secure sharing provides solutions. This advantage has made more and more industries introduce blockchain technology

At present, aviation manufacturing supply management has introduced blockchain technology, and problems in storage and security sharing, including:

1) How to manufacture quality data on the blockchain and how to implement step-by-step storage and safety sharing;
2) Facing the ever-increasing block data, the blockchain storage capacity scalability problem.
3) Interaction on the chain, as the number of data increases, the response delay problem.

This chapter responds to the above issues and proposes the full process of quality storage and safety sharing based on blockchain-based aviation manufacturing suppliers. Taking the data interaction between aviation companies and suppliers as an example, starting from solving the capacity of the block data, a combination of governance strategies on the chain is proposed. The design of the supplier of the blockchain intelligent contract layer provides support for optimizing the overall quality of the supplier.

A. THE FULL PROCESS OF QUALITY AND DATA SECURITY SHARING

There are three main parts in the data sharing stage, consisting of suppliers, aviation companies, and blockchain. The supplier office is responsible for the generation, collection, off-chain storage, and uploading of data, and the aviation enterprise mainly proposes and obtains data requirements. The blockchain is responsible for reviewing and storing summaries of quality data provided by suppliers and coordinating the exchange of information between suppliers and airlines. It is assumed that there are N aviation companies with the same product types and there is a competitive relationship. On the premise of data-based security, a data-sharing implementation framework is constructed, as shown in Figure 5.

1) Aviation companies conduct on-chain broadcasts on the blockchain network according to their product quality data requirements.
2) After each supplier receives the broadcast demand, take *Supplier A* as an example. A performs digital signature processing on the required data by using the private key and uploads the product summary to the chain according to the product requirements of the aviation enterprise. Before going to the chain, the blockchain needs to call the smart contract to verify the identity of the data digest signature, etc., and then store it on the chain and broadcast it on the supply alliance chain.
3) The aviation enterprise conducts preliminary verification of the data abstract shared by *Supplier A* through its private key (such as whether the data is the required product data, whether the accuracy meets the requirements, etc.). After this, signature identification is performed. If the preliminary verification is passed, under the action of the smart contract, the target *Supplier A* will be locked according to the supplier's data signature and the corresponding hash value.

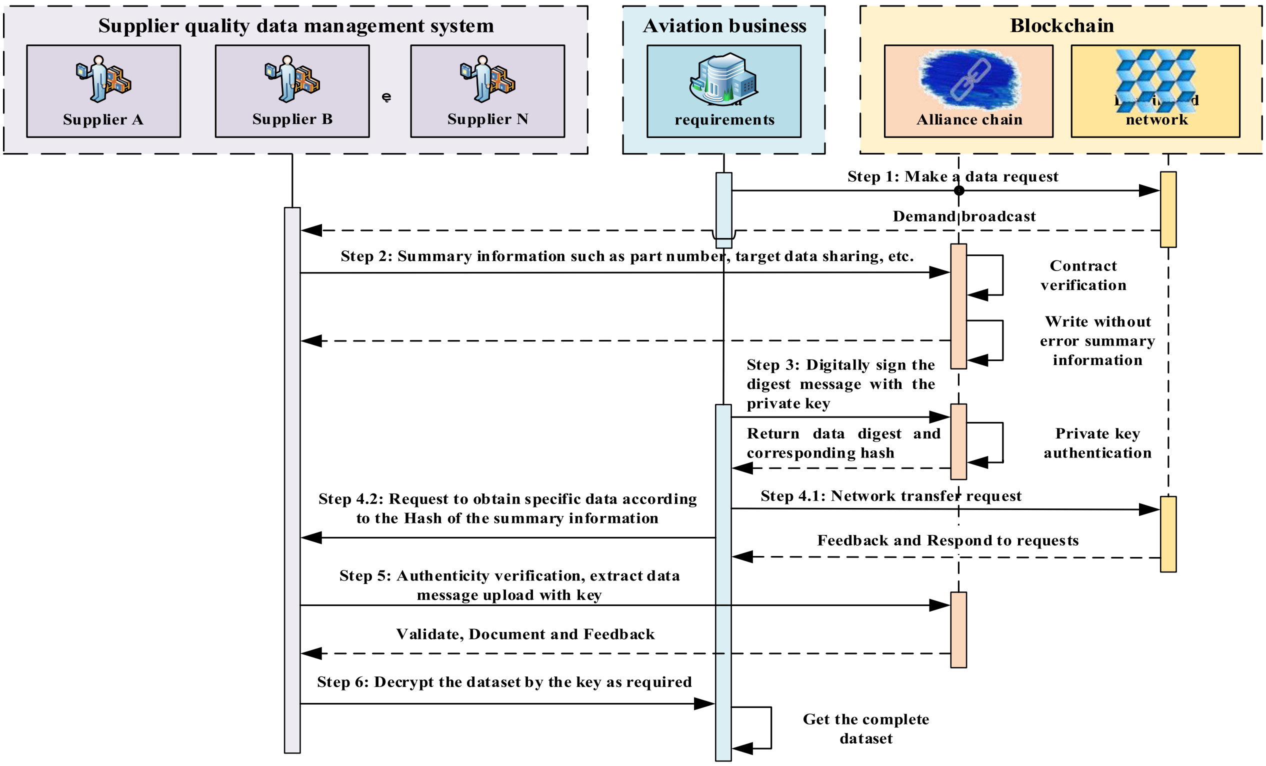

FIGURE 5. Real-time framework for supplier quality data sharing.

4) The aviation enterprise sends relevant specific data requests to suppliers through the blockchain network and feeds back the request information and identity digital signature to *Supplier A* through the blockchain network.
5) The supplier confirms and verifies the request and identity sent by the blockchain network, and then sends the target data set key to the airline company. After the airline company receives the key and decrypts the data set, the data set is obtained and the data quality evaluate.

B. MANUFACTURING QUALITY DATA BLOCK PACKAGE MODEL

Aiming at the massive multi-source heterogeneous data generated during the product manufacturing process of various aviation suppliers, the product quality abstract framework of the universal model is constructed. The application of architecture has the characteristics of generalization, rich adaptation to resources, and good scalability, laying the foundation for quality data.

The construction of a unified model is carried out according to the evolution of various process elements during the product manufacturing process. The definition model is the direction $G = (N, E)$, where N is representing the processing process node on the graph, and E is a site that contains associated between nodes. On this basis, the processing processes of all suppliers' supply products are expanded. Set up the quality information collection of product nodes N_p, processing process node N_{pi}, and various process nodes $N_q = \{IP, S_N, ID, V_i, \ldots, VM\}$, N_q various information parameters mean as shown in Table 2.

For multi-level suppliers to conduct process quality information lump management, the implementation process can be mapped to increase, delete and modify the block in the above model. Taking the manufacturing of a certain part of the helicopter as an example, the implementation process is shown in Figure 6.

1) Before product processing, basic information such as supplier number IP, supplier name S_u, product number ID, node version number V_i, valid logo VM, and other basic information are created as the parent node as shown in figure "Product". Further build the processing process quality data under the modification node, as shown in Figure 6 the *Process A* node. Under normal circumstances, node storage includes quality data such as process number, node version number, inspector, valid logo, and theoretical value deviation, and connects through timestamp.
2) Add process quality information increase mode. When the actual processing needs appear, the process information is added after a certain process, and the *Process(A+1)* is added after *Process A* as an example. Create a new node N and edge E in the directed graph G, and the content of the process quality data increased through the C_q field records. The unique number ID

TABLE 2. Parameter definition in the block.

Parameter	Meaning
IP	As the main index, it is the only number of the supplier
S_N	Supplier name
ID	Each process number of the product
V_i	It is the node version number, such as V_0, V_1, and V_2. V_0 is the version number of the first-level node, and the unidentified node is 0. V_1 is the original version number of the node. V_2 is the version number of the current node
C_p	Node founder
C_q	The effective quality information of node storage, such as attribute characteristics data, actual measurement data, etc.
C_t	Node creation timestamp
U_p	Node deletion staff
U_t	Node delete time stamp
VM	Whether the node is effective

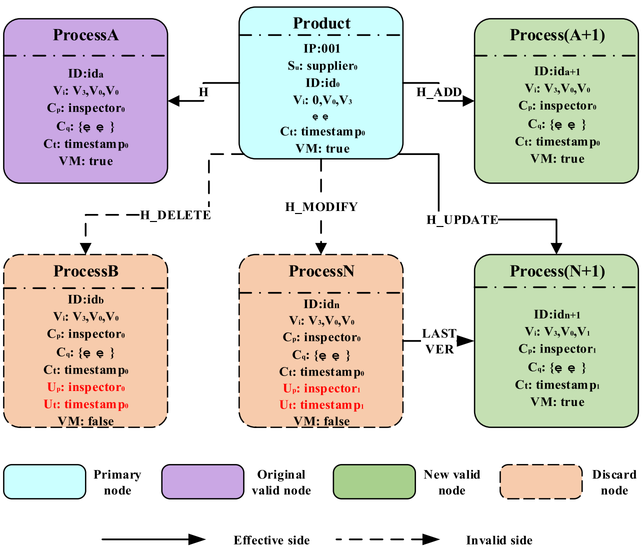

FIGURE 6. Process quality information module implementation process.

based on the supplier nodes is automatically generated by the database. For the node version number V_i, V_3 is the parent-level product version number, the first V_0 is the initial version of the node, determined according to the preset rules, the default value is 1, and the second V_0 record node is updated. For 1, the update changes with the number of updates. Effective label *VM* is "true". Through the construction of node mode, the normalization of computers can be identified and processed, and the quality information of the product processing process is completed.

3) Deletion of process quality information. To meet the requirement of quality data being callable and traceable, the design sets the validity mark *VM* of the error node to be deleted as "false" to complete the deletion of information in the model and avoid directly deleting the relevant process nodes or edges, as shown in the *Process B* node in Figure 6.

4) Process quality information modification mode. To realize the traceability and reading goals before and after the product quality information, the design decomposes the modification process to first add new information, and then delete the original information. Specific implementation steps include:

1) Create a new node to record new modification data according to step a).
2) If the node is involved in the sub-node, all the association nodes are redirected to the new node.
3) Set the validity of the original quality information to be set as "false".

Based on this, establish a connection between the original node and the marked node, and illustrate the process of modifying the information in Figure 6, which demonstrates the transformation from Process *N* node to *Process (N+1)* node.

Information encapsulation is formed by each supplier in response to a broadcast by the airline company. Its goal is to structure the broadcast requests in an agreed manner, laying the groundwork for enabling airline companies and other suppliers to receive data according to rules. Further data needs to be delivered and shared. The traditional blockchain data-sharing strategy for large amounts of process-quality data will result in increased consensus costs and challenges in terms of computing power, network transmission, and storage capacity. Therefore, a new data-sharing strategy needs to be proposed to alleviate the above challenges faced by blockchain.

C. ON-CHAIN AND OFF-CHAIN FUSION DATA GOVERNANCE STRATEGY

Design on-chain and off-chain storage methods, extract information from large data sets and confidential data, and store only summary information on the chain, while the complete information is still held by each data source node. Implementing this in this way can not only reduce the storage burden on the chain but also ensure the privacy of each

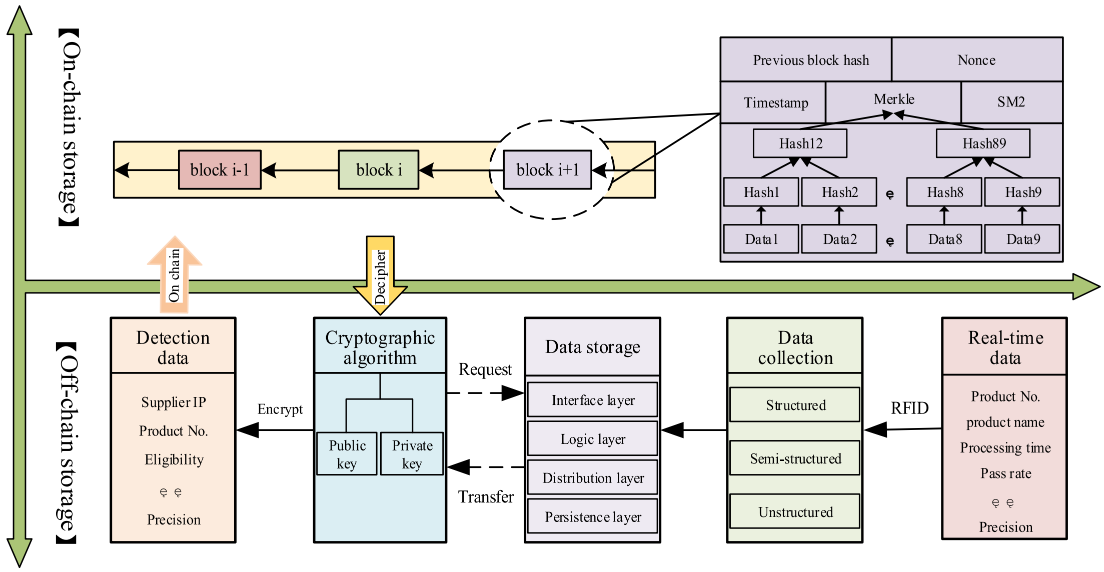

FIGURE 7. Process quality information module implementation process.

data source. At the same time, it can also ensure effective information sharing during the operation process, that is, ensure the consistency of the information of each block node. The specific process is shown in Figure 7.

1) Suppliers collect real-time quality data of workshop products to lay the foundation for subsequent self-use or other use.
2) The quality data is collected and processed through six elements of manufacturing resources such as 'man-machine material method environmental measurement', which is convenient for storage and recall.
3) Save structured or unstructured data sets to the supplier's local database.
4) Encrypt data through cryptographic algorithms such as asymmetric encryption, and extract key data digests from the encrypted data;
5) According to the broadcast content of the aviation enterprise, the data digest is packaged and uploaded to the chain in a chain structure;
6) The consensus algorithm drives the suppliers in the alliance chain to verify and store the data of the new block, ensuring that each supplier node stores a copy of the data of the new block.

D. AVIATION SUPPLIER EVALUATION MODEL

The quantification of supplier quality is reflected in how to ensure the quality of manufacturing data of supplied products. In actual production, most of the quality data of outsourced products of aviation companies are provided by suppliers, so how to judge the quality of multi-suppliers through the obtained massive data is particularly critical. This section proposes a supplier quality evaluation model based on data application. It aims to screen the best suppliers from massive data by evaluating process quality data.

Set each supplier as each data sharing node y_{N}, and the total node-set is $Y = \{y_1, y_2, y_3, \ldots, y_{\mathrm{N}}\}$. f_t is the number of times data collection of node y_N. Since there is a slight difference node for each feature data collection, we set the feature data set of the jth process collected at the y_{N} node to be $X_j = \left\{x_{j,1}^N, x_{j,2}^N, x_{j,3}^N, \ldots, x_{j,t}^N\right\}$. The characteristic standard data here is x_t, where $x_{j,t}^N$ represents the t data collected for the jth process under the node y_{N}. Fotouhi, A means that the theoretical sample value set X_t forms a cluster around the x_t value, and the standard data x_t is equivalent to the centroid. In the actual data collection, the data is affected by the difference between product materials and the external environment, and the actual center of mass x_t^* often formed is deviated from the x_t position. Judging the coherency between the data cluster and the actual value according to the distance between the actual centroid x_t^* and the theoretical centroid x_t. The smaller the definition distance, the greater the coherence, the better the data quality, and the more reliable the supplier's product.

The optimal node model to predict the product is designed as Eq. 1.

$$d = \arg\min \left[dist^2\left(x_t^*, x_t\right) A_j\right] \tag{1}$$

where $dist^2\left(x_t^*, x_t\right)$ represents the distance between x_t^* and x_t, and use the Euclidean distance to calculate the absolute distance between the two centroids. The calculation of the actual centroid x_t^* is a calculation process of performing continuous minimum distance iterations on each data in the data set X_t, which can be expressed as Eq. 2.

$$x_t^* = \min \sum_{t=1}^{n} \sum_{\tilde{x} \in x_i} dist^2\left(x_{j,t}^N, \tilde{x}_i\right) \tag{2}$$

At the beginning of the iteration, take any point value $\tilde{x}_i$ in the data cluster as the initial actual centroid. The actual distance between $x_{j,1}^N$ and $\tilde{x}_i$ performing cluster analysis are calculated. Update the position of the centroid based on the results of the clustering and define this value as the centroid for the next iteration. Iterate sequentially until the centroid position no longer changes. Thereby, the optimal estimation of the data quality of the supplier node is obtained. By comparing the estimated values, the optimal supplier can be obtained.

Applying the above evaluation algorithm, according to the current situation of aviation supplier informatization and the actual information flow demand, build the aviation supplier evaluation and data transfer model on the chain. As shown in Figure 8.

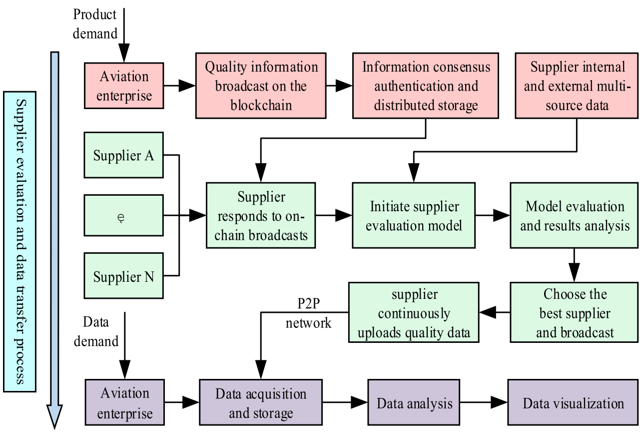

FIGURE 8. Blockchain-based supplier evaluation and data transfer model.

In Figure 8, according to the product requirements of the aviation enterprise, each supplier only has the authority to store the production process quality data in a distributed manner. Supplier business subject data is encrypted before storage. The encryption keys of each supplier are stored and managed by a third party (such as the relevant product quality supervision bureau) to ensure the immutability of the keys and fair competition among the suppliers. When aviation companies select product suppliers, they will send out their needs through on-chain broadcast and conduct consensus authentication and distributed storage of relevant information. Each supplier responds to the broadcast on the chain according to its situation and provides its key to participating in the competition. Aviation companies access the quality data of each corresponding product through the key of each supplier and use the evaluation model of supplier data to obtain the optimal supplier that suits them. Aviation companies and optimal suppliers continue to cooperate, and continuously obtain supplier product process quality data. Ensure product quality through the collection, aggregation, storage, and visual analysis of quality data from suppliers.

V. DEVELOPMENT AND IMPLEMENTATION OF SHARING PLATFORM

The acquisition of data is the prerequisite for industrial interconnection, and data application is the key to industrial interconnection. For the large amount of data generated during the production process, on the one hand, the data supply side is how to collect, store and secure sharing of the data supply side, and on the other hand, the data request side is effective analysis and application of the collected data. This chapter is based on the platform framework and combined with methodologies. The implementation process framework of the design system is shown in Figure 9. In the figure, the data supply side is designed for the dynamic collection, secure storage, and sharing of multi-detection module quality data in the manufacturing process. The data request side is an application for receiving, aggregating, and visualizing process quality data obtained from suppliers by aviation companies.

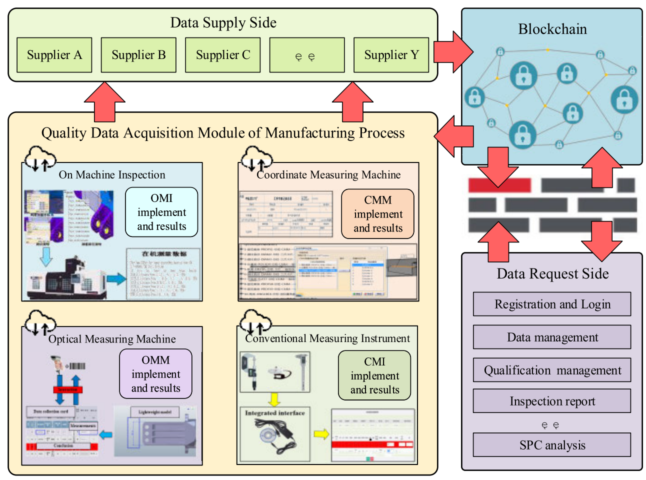

FIGURE 9. System implementation process.

A. PLATFORM CONFIGURATION

The construction of the aviation supplier process quality data-sharing platform involves hardware and software. In terms of hardware, multiple mobile terminals are used to collect process data. Two intranet PC servers, configured with Intel Core i7 processors, 8GB memory, and 80G hard drives. As a collection and analysis workstation for testing data, it is used to collect and analyze product quality data on the supplier's production site. In terms of software, the platform adopts the Windows 10 operating system. Based on the JAVA environment, the platform is developed through the spring-boot framework combined with the bootstrap & HTML front end.

B. REGISTRATION AND LOGIN VERIFICATION

Our platform provides supplier node application registration and authentication login functions, as shown in Figures 10 and 11. Suppliers to be certified fill in the application through the registration interface. After verification by

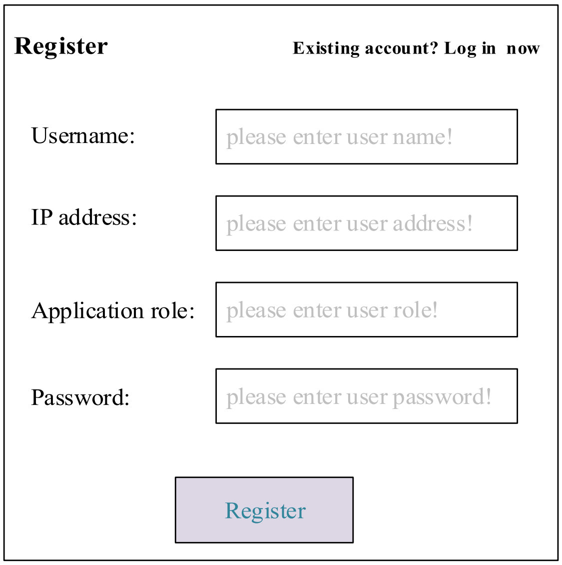

FIGURE 10. Registration interface.

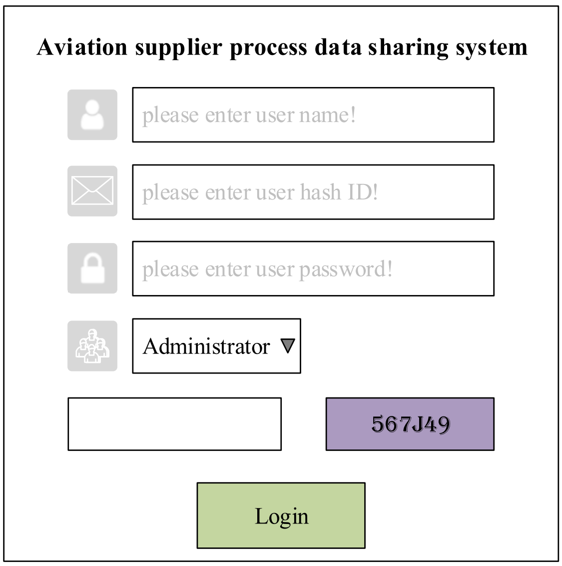

FIGURE 11. Login verification interface.

the system administrator, the key information is generated based on the IP of the supply node as its unique identifier. The registration and login interface is designed with the authority of administrators, airline companies, affairs, and various service providers. Each participant has a fixed IP number. The system administrator has the highest authority and can assign roles to other participants and be the person in charge of system maintenance. Other participants can access some resources of the system by default.

The login access and data acquisition management process are shown in Figure 12, Access control policies are defined through the Java ACL permission control language. Aviation companies send data requests to suppliers and use the on-chain review process to determine whether the company's attributes and IP are correct. Through auditing, it can conduct

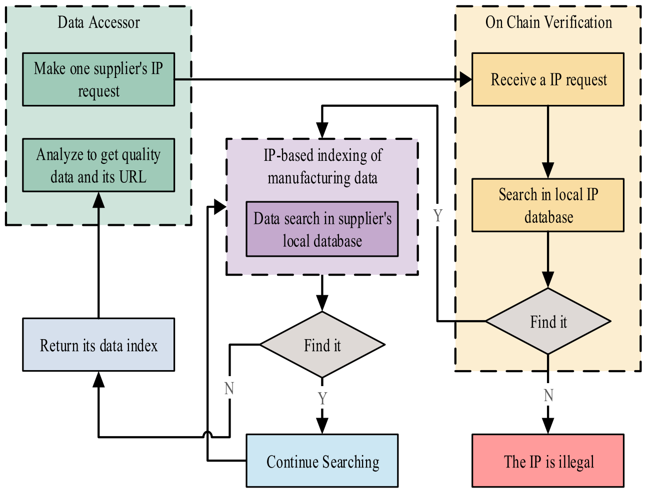

FIGURE 12. Decentralized IP access and data acquisition process.

trusted access and continuous sharing of required data with suppliers, and at the same time realize the privacy protection control of supplier node information by the system.

C. SUPPLIER DATA COLLECTION AND MANAGEMENT

1) DYNAMIC PERCEPTION SCHEME OF MANUFACTURING QUALITY DATA

Introduce Radio Frequency Identification (RFID) technology, which aims to promote the automatic collection of data manufacturing data. RFID is a technology that is a technology that is automatically recognized and read through a wireless radio frequency signal [38]. The classic RFID configuration consists of three parts: reader, electronic label, and signal transmission medium. Under the ideal state, in the smart workshop, the RFID label is attached to all quality manufacturing resources, such as operators, production equipment, transportation equipment, measurement tools, inspectors, etc., through manufacturing resources and labels to realize the production process data Automatic association and dynamic tracking.

This paper proposes a data reading and writing configuration solution based on FRID technology, as shown in Figure 13, which is designed to be effective for the discrete data generation process. This figure not only reflects the full process of processing of manufacturing typical processes, but also clearly explains what data, how to collect, and how to use the data collected in the production process flow.

In Figure 13 (a), the flow of the discrete manufacturing process is shown, including the processing of the rough according to the production tasks.

In Figure 13 (b), the RFID read and write configuration processing for the work unit at J is shown. The work unit status is divided into three types: the inlet cache area, the processing area, and the induction area. By analyzing the differences in quality and data among the three states, the changes in process data are recorded.

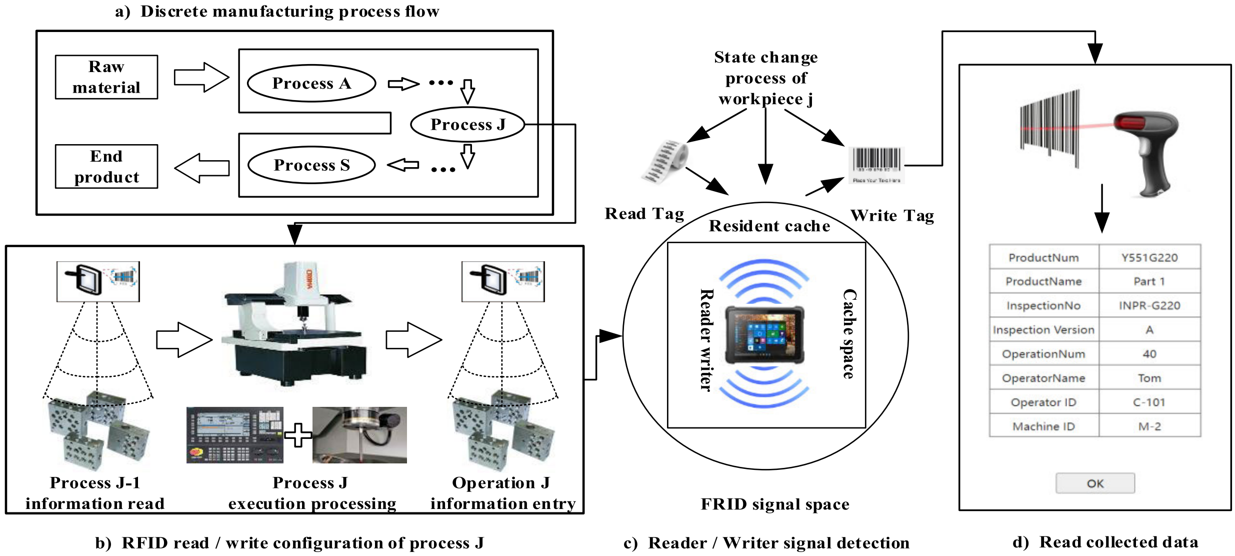

FIGURE 13. RFID -based dynamic perception configuration solution.

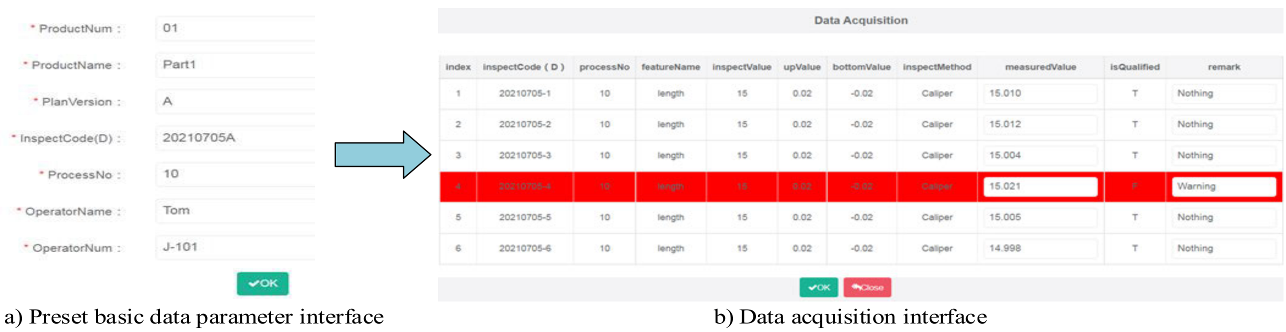

FIGURE 14. Data collection and entry interface.

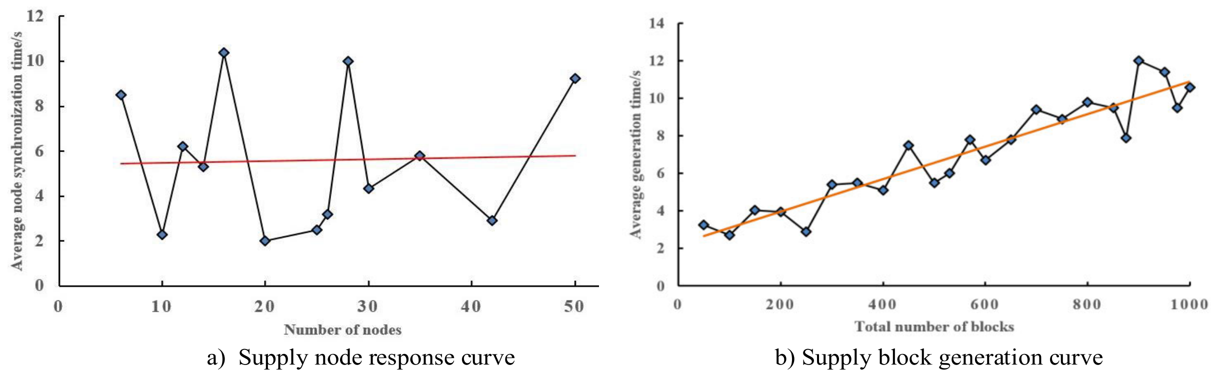

FIGURE 15. Data request node response performance curve.

In Figure 13 (c), the abstract FRID data reading and writing process is represented by assigning and writing the ERC tags. By adjusting the power of the reader, the signal coverage area for reading and writing can be increased to enhance the efficiency of these processes.

In Figure 13 (d), the read data collection information is presented. When the label is read through the RFID reader, the dynamic data generated by the process J processing is associated with the label. Using this association, the dynamic data of the process flow can be obtained for the production tasks.

2) DATA COLLECTION AND ENTRY

Supplier manufacturing plant to ensure one-to-one correspondence of discrete information of processes during data collection and traceability of data after collection. Before

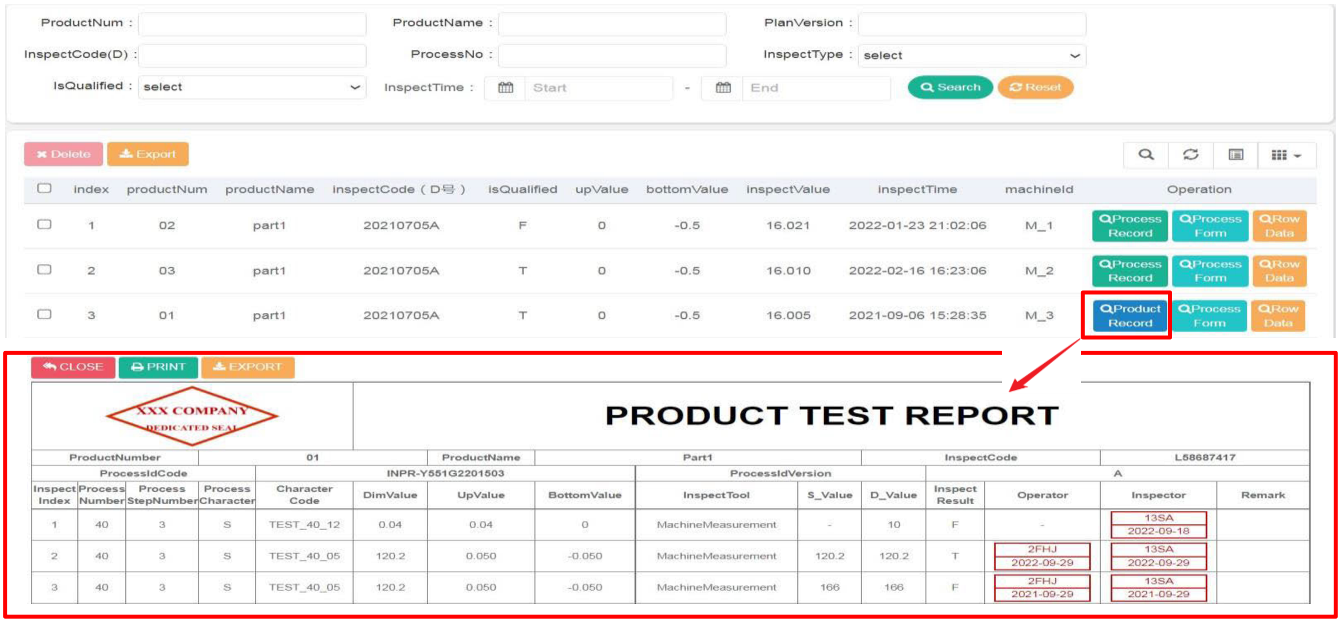

FIGURE 16. Data collection interface.

TABLE 3. Summary of calculation data of each group.

Number of groups		1	2	3	4	5	6	7
Sample value	1	15.002	14.985	14.998	15.002	15.000	15.008	14.998
	2	15.000	15.000	15.018	15.001	15.001	15.005	15.000
	3	14.998	15.000	15.000	15.000	15.002	15.001	15.005
	4	15.005	15.002	15.010	15.008	15.000	15.002	14.999
	5	15.001	15.000	15.000	15.001	15.001	14.998	15.002
	6	15.010	14.997	14.995	15.002	15.001	14.995	15.005
ΣX		90.016	89.984	90.021	90.014	90.005	90.009	90.009
$\bar{X}$		15.0027	14.9973	15.0035	15.0023	15.0008	15.0015	15.0015
R		0.0120	0.0170	0.0230	0.0080	0.0020	0.0130	0.0070

data collection, the system designs the basic data transfer interface. By scanning the code label of the *(J-1)*th process, confirm some basic information on the production line, such as product drawing number, name, and operator information. The advantage of this interface design is that it can provide data link information support for the Jth process processing, and further realize the monitoring and tracking of all aspects of product production. As shown in Figure 14a), the interface provides two types of data transmission methods: manual input and automatic scanning. Click "OK" to complete the input of relevant parameters before the Jth data collection.

In the data collection interface, with the preset basic parameters as the screening conditions, the platform retrieves the data collection results of the manufacturing process from the supplier, as shown in Figure 14b). The platform supports the logical judgment of whether the process quality data inspection is qualified or not. Automatically compare the measured value scanned or manually input with the theoretical value, and the platform judges whether the measured value is within the theoretical value tolerance band, and verifies the qualified processing of the process. Take part 1 for example, part 1 is processed in length according to process number 10, the theoretical value is 15 mm, and the deviation is ±0.02 mm. When the measured value is 15.010 mm after analysis, "T" will be displayed in the "isQualified" field, indicating that the current processing procedure is qualified. On the contrary, the automatically resolved value is 15.021 mm, and the "Quality" field displays "F". At this time, the data collection box is displayed abnormally in red, indicating that the process is processed incorrectly. The relevant detection results will be used as a quality abnormal record, and the abnormal conclusion will be fed back to the aviation enterprise interface.

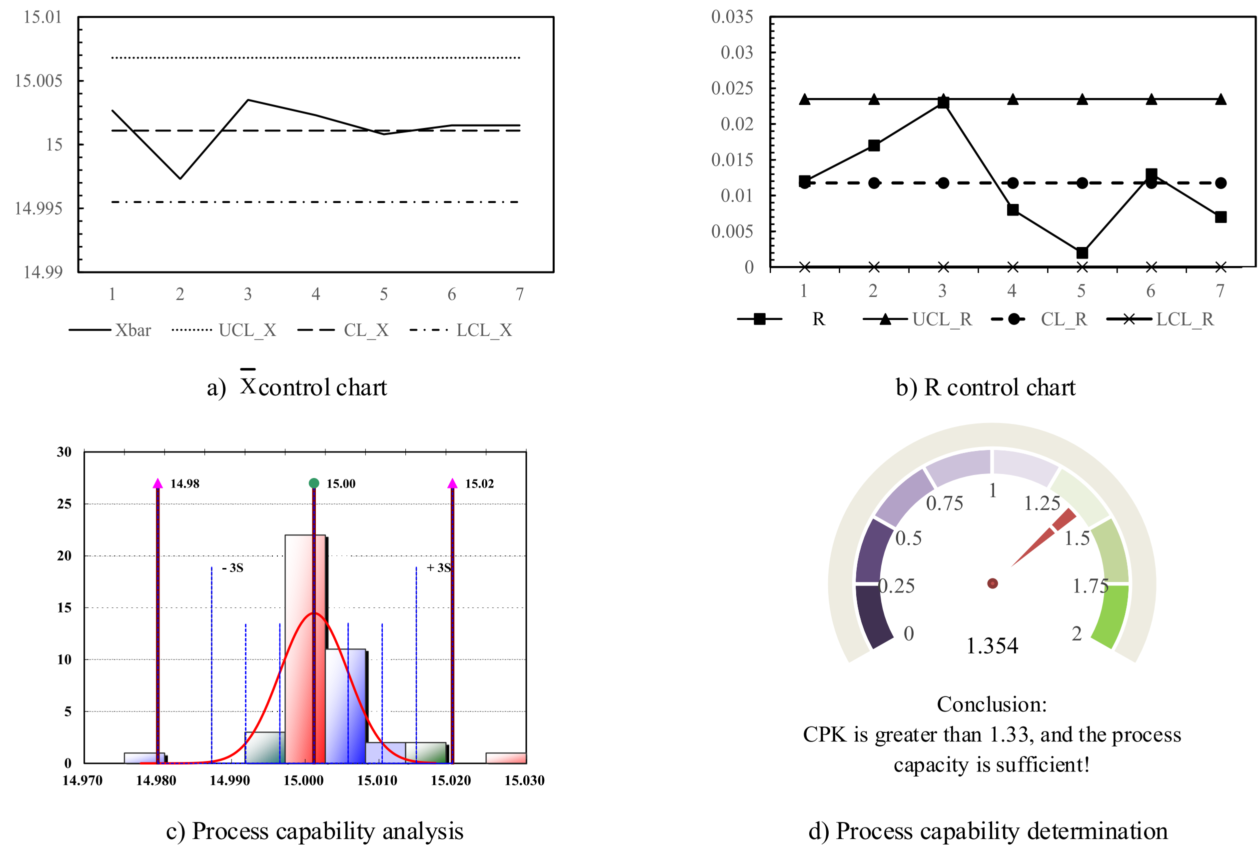

FIGURE 17. **SPC control diagram interface.**

D. AVIATION CORPORATE DATA ACQUISITION AND MANAGEMENT

1) THE RESPONSE AND GENERATION OF SUPPLY DATA BLOCK

Product quality information is uploaded to the data requesting party of aviation companies through the authorization method on the blockchain. The response of the block node of the test system is shown in Figure 15a). The graph depicts the relationship between the time it takes an airline to request and receive quality data from suppliers and the number of blocks requested. The curve shows that with the increase of the requesting product data nodes, the time of synchronization of node data is stable. It shows that the system adopts the effectiveness and feasibility of the data sharing mentioned.

In terms of block encapsulation generation rate, it is shown in Figure 15b). As the total number of blocks increases, the average time used shows an increasing trend. This is because each block in the blockchain needs to be synchronized across the chain members by the consensus algorithm, resulting in a longer update time due to the increase in the total number of blocks, which is in line with the actual situation and the average time is within the manageable range.

2) INSPECTION DATA REPORT INTERFACE

After data collection, aviation companies need to classify and structure the data to better understand the quality of outsourced products. Therefore, the platform designs the detection data report generation interface, as shown in Figure 16. Aviation companies can retrieve the required quality information of the workpiece, such as product drawing number, production number, etc., to achieve the staged quality information acquisition of the product. The data set can be exported on the interface according to the requirements, and the relevant inspection reports can also be generated for the parts according to different inspection types.

Taking the product test report under the "01" figure, click the "Product Recond" button to jump the interface, as shown in Figure 16. The quality characteristics of each process are listed in the product "Part 1". The report automatically matches the inspector and test time seal to provide a basis for the traceability of quality and data.

3) DATA VISUALIZATION ANALYSIS INTERFACE

Statistical Process Control (SPC) is a tool that applies statistical analysis techniques to realize real-time monitoring of production processes. The platform can scientifically distinguish random or abnormal fluctuations in-process quality through visual statistics of key measurement parameters. Further, aviation enterprises can predict the occurrence of abnormal product process quality and achieve the goal of reducing product defect rate and ensuring product quality.

The research on the SPC algorithm has a long history and will not be repeated in this article. Drawing on Sanchez-Marquez, R's introduction of control charts and process capabilities in Statistical Process Control, this section implements a sample application at the platform application level [39].

• *CONTROL CHART CALCULATION*

The system platform design adopts the visual analysis of the quality data of the production process (mean-polar) control diagram.

The control limit formula for the $\bar{X}$ control chart is computed by Eq. 3.

$$\begin{cases} U_{CL\_X} = \bar{\bar{X}} + A_2\bar{R} \\ L_{CL\_X} = \bar{\bar{X}} - A_2\bar{R} \\ \bar{\bar{X}} = \left(\bar{X}_1 + \bar{X}_2 + \cdots + \bar{X}_n\right)/n \end{cases} \tag{3}$$

where $\bar{\bar{X}}$ represents the expected value of the mean $\bar{X}$ of n groups. U_{CL_X} is the upper limit of the $\bar{X}$ control chart. L_{CL_X} is the lower limit of the $\bar{X}$ control chart. A_2 is a constant related to the number of samples.

The control limit formula for the R control chart is computed by Eq. 4.

$$\begin{cases} U_{CL\_R} = B_4\bar{R} \\ L_{CL\_R} = B_3\bar{R} \\ \bar{R} = (R_1 + R_2 + \cdots + R_n)/n \end{cases} \tag{4}$$

where $\bar{R}$ represents the mean of the range of n groups. U_{CL_R} is the upper limit of the R control chart, L_{CL_R} is the lower limit of the R control chart, and B_3 and B_4 are constants related to the number of samples, which can be obtained by Aslam et.al. [40].

• *PROCESS CAPABILITY CALCULATION*

Process capability refers to the actual process capability exhibited when the product manufacturing process is in a steady state. Process capability index C_{pk} is computed by Eq. 5:

$$\begin{cases} C_{pk,U} = \frac{U_{SL}-\bar{X}}{3\hat{\sigma}} \\ C_{pk,L} = \frac{\bar{X}-L_{SL}}{3\hat{\sigma}} \\ C_{pk} = \min\left(C_{pk,U}, C_{pk,L}\right) \\ \hat{\sigma} = \frac{\bar{R}}{d_2} \end{cases} \tag{5}$$

Where U_{SL} and L_{SL} represent the upper and lower limits of the process size of qualified products, respectively. $C_{pk,U}$ and $C_{pk,L}$ represent the upper and lower process capability indices of the product, respectively. $\hat{\sigma}$ is the standard deviation of the estimated process, which can be obtained from the ratio of the average range $\bar{R}$ to the estimated divisor d_2 of the standard deviation.

• *CASE ANALYSIS*

Taking aviation ''Part1'' as an example, its theoretical design size is 15 mm, and the allowable error is ±0.02 mm. Visual analysis of production process quality data using $\bar{X} - R$ (mean-range) control charts.

The platform conducts process inspection data collection, sampling, and grouping for a random continuous period of parts in the manufacturing process. The number of groups is 7, and the sample size of each group is 6. The data in Table 3 are calculated by Eq. (3-5).

The platform processes the process data according to the statistical method and generates the $\bar{X} - R$ control chart, as shown in Figure 17.

From Figure 17a, it can be concluded that the average size of part 1 is 15.0012 mm, the upper limit of the average control U_{CL_X} is 15.0068 mm, the middle limit of the average control CL_X is 15.0011 mm, and the lower limit of the average control L_{CL_X} is 14.9956 mm. The subgroup mean of all data points collected is within the specified range of the process, and the mean value is less than 50% within the upper and lower control limits of the allowable error. It can be concluded from Figure 17b that the average range $\bar{R}$ is 0.0117 mm, the upper limit U_{CL_R} of range control is 0.0234 mm, the middle limit L_{CL_R} of range control is 0.0117 mm, and the lower limit L_{CL_R} of range control is 0. Consecutive data points have no increasing or decreasing trend, and the process is in a relatively steady state. The platform concluded that there is no abnormality and further passed the process capability verification conclusion.

From the normal distribution diagram of process capability analysis in Figure 17c, the approximate relationship between the test data set and the error band required by the part can be intuitively obtained. As reflected in the mean value of the sampled data set deviates from the theoretical value by 15 mm, which is in the positive tolerance range. Another example is the shape of the normal curve, the distribution of the sample population (discrete or concentrated) can be judged. It can be seen from the process capability judgment diagram in Figure 17d that the C_{pk} value of the sample data set used in this experiment is 1.354. The platform concludes that the process capability quantified by the data collected at this stage performs well and meets the requirements for product qualification prediction.

VI. CONCLUSION

This paper focuses on the management and application of aviation supplier product quality data sharing. Committed to using blockchain technology to solve the problems of information opacity and interaction difficulties in the traditional supplier system. Avoid the phenomenon of ''island of information'' in supplier supervision, and achieve more effective process data information sharing and collaboration between upstream and downstream product supply.

Specific contributions include:

1) A quality data-sharing platform that integrates data collection and tracking, storage, up-linking, and visual presentation is proposed.

2) A new data security storage and sharing strategy are proposed, through the data storage method of on-chain and off-chain convergence.
3) A supplier evaluation algorithm based on information sharing is constructed.
4) Build supply-side system process data collection blocks and request-side system block data reception and structured report generation, etc. in conjunction with real-world cases. Further, statistical analysis and visualization display based on supply-side data, etc.

In the future, this study can be extended and improved from the perspectives of practical application and organizational management. The research presented in this paper mainly focuses on the aviation and aerospace industries. Given the complexity and customization of the supplied products, the overall design of the supplier management system needs to be combined with the specific business requirements of each supplier. In terms of organizational management, as the technology proposed in this paper becomes more widely adopted, a variety of data processing modules related to supplier product logistics, costs, energy consumption, and other factors can be integrated to further enrich the digital aviation supply quality management system.

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