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The Theoretical Framework and Application of Cross-Border Timber Traceability Based on Blockchain Technology

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Abstract: It is widely understood that the legal and sustainable supply of timber contributes to promoting the sustainable management of forests, addressing climate change and serving the poor in communities. The legality of origins of timber has continuously been an international concern for the past two decades. At present, timber traceability verification methods mainly rely on offline investigation including on-site audits, document verification, expert review, and have obvious disadvantages such as fraud, false claim, and "mixed products". Blockchain technology with the advantages of openness, tamper-proof, anonymity, and automated execution etc. can be a good method to solve the above-mentioned problems, and eventually to improve the transparency of timber supply chain, reduce the costs of legality certification, and improve the reliability of timber tracing methods. In this study, the blockchain technology is applied in the cross-border timber traceability. Based on the blockchain method, a cross-border timber tracing system is designed, including the application context, main participants, the traceability system and operation flowchart. It's found that a consortium chain formed by timber enterpirses, gorvenments and the third-party verification agencies is a feasible way to conduct the cross-border timber traceability when using the blockchain technology. The above-mentioned participants form a consortium chain and through the unified consensus and technical control, a cross-border timber traceability ecosystem with mutual trust, risk control, and credit-based circulation is established. Throughout the timber trade process, the forest owners, sawmills, exporters, importers, and processing plants input, in sequence, the data required for transactions and traceability. The forestry authorities, customs and other regulatory authorities in both the import and the export countries supervise cross-border timber trade, and strengthen the control of illegal timber. The third-party verification agencies view and verify the data reported by the timber enterprises. Meanwhile, four key issues in applying blockchain to cross-border timber traceability were identified, such as clarity of the implementing entities, need of the incentive mechanisms, balancing construction costs and small business burden, and forming the industry standards and regulatory practices. These methods and issues addressed provides theoretical and application basis for the development and operation of the traceability system. It is promising for the development of the blockchain-based traceability system to speed up its growth given the increasing demand for efficient and credible traceability for the wood industry.

Keywords: Blockchain Technology, Timber Traceability, Cross-Border Timber Trade

1. Introduction

The legality of origins of timber has continuously been an international concern for the past two decades. In recent years, many positive steps have been taken by the international community as well as individual countries towards regulating the supply chain of timber and its products. For example, the

European Union, the United States, Australia, Indonesia, Japan have introduced relevant regulations and methods to ensure that the imported timber and its products are coming from legal sources [1, 2]. In 2021, the 15th Conference of the Parties to the Convention on Biological Diversity and the 26th session of the UNFCCC Conference of the Parties (COP 26) adopted documents in support of eliminating deforestation, mitigating climate changing and protecting biodiversity. During the second China-EU High-Level Dialogue on Environment and Climate, China and EU have agreed upon strengthening the cooperation in forest protection and sustainable management, sustainable supply chain, combating illegal logging, and promoting bilateral trade.

At present, timber traceability relies on verifications by FSC-COC and other similar methods, through certifying the entire chain that covers logging, transportation, processing, and distribution to ensure the certified timber products are coming from reliable resource and not mixed with uncertified ones [3, 4]. These certifying processes have played an important and positive role in promoting the legal and sustainable utilization of timber. However, these methods mainly rely on offline investigation including on-site audits, document verification, expert review, and have obvious disadvantages such as fraud, false claim, and "mixed products". Therefore, in order to implement those regulations and requirements, new approaches as well as technologies are required for verification and traceability. If using traditional IT technology for timber tracing, it needs to establish a centralized traceability information system, and this would have two big challenges in constructing information infrastructure and model development as below:

The first one is that cross-border timber tracing involves a large amount of unstructured data (information that either does not have a pre-defined data model or is not organized in a pre-defined manner including pictures, videos, raw signaling data, etc.). Even if the centralized IT infrastructure uses cloud-based virtualization technology, the efficiency of data interaction such as calculation and query will encounter technical bottlenecks when the number of virtual nodes (namely the participants) passes a certain level. In this case, it would be difficult to break through and the cost would increase dramatically with the growth of nodes. Secondly, the traditional traceability system is based on the completion of the data interaction amongst interfaces of the information systems of all participants. This process has an obvious disadvantage in the lack of protection to data ownership and privacy, leading to the unwillingness and even resistance to provide accurate and complete data by the stakeholders [5]. In addition, the cost persists high in supply chain management and trust maintenance, which would hinder the popularization of cross-border timber traceability systems.

Compared to the traditional centralized traceability technology, blockchain technology with the advantages of openness, tamper-proof, anonymity, and automated execution etc. can effectively solve the above-mentioned problems, and plays a better role in facilitating comprehensive system of timber tracing and in empowering the entire industrial chain of timber products. Since the outbreak of COVID-19 pandemic, blockchain technology has been successfully applied in the fields of tracing virus, drugs and devices [6]. In this study, we analyze the technical advantages of blockchain technology in cross-border timber traceability. We also examine the scenarios, traceability systems, and key technical issues of applying this technology in the cross-border context. The overall objective is to propose concrete methods and pathways for applying blockchain technology in the timber traceability system. It is our hope to improve the transparency of timber supply chain, reduce the costs of legality certification, and improve the reliability of timber tracing methods.

2. Methodology

2.1. Blockchain and Its Technology Characteristics in Cross-Border Timber Tracing

Blockchain is a new technology combining P2P network, consensus algorithm, asymmetric encryption and etc [7]. In 2009, in the book *Bitcoin: A Peer-to-Peer Electronic Cash System*, Satoshi Nakamoto designed a peer-to-peer cash system and its basic protocol by using blockchain as the supporting technology, so that, billions of devices are able to exchange information securely without third-party intermediaries. This technology has sparked widespread attention and a research upsurge around the world. Specifically, blockchain is a distributed database system established by a number of nodes, and it is an open ledger system. It relies on technologies of distributed data storage in blocks, decentralized data transmission, and encryption algorithms, and links the blocks in a chain structure to form a distributed shared ledger [8]. In this ledger, the consensus algorithm determines the bookkeeper, and the tamper-proof of the transactions in the ledger is ensured by the cryptographic signatures and hash algorithms; the traceability of the information of the blockchain is ensured by the timestamps and hash functions: all these techniques provide a unique mechanism for credit creation. Applying blockchain technology in cross-border timber tracing has the following five advantages:

(1) Decentralization. Using blockchain technology in tracing origins of timber in a cross-border context enables each node to maintain and update the blockchain data and verify its effectiveness. This advantage is attributed to the distributed P2P network structure and equal right and obligation of each node at the same level. Because all node participants jointly maintain the data ledger, this effectively reduces the risks of overload to the server, single point of failure, and manager dereliction which happen frequently in traditional, centralized systems [9].

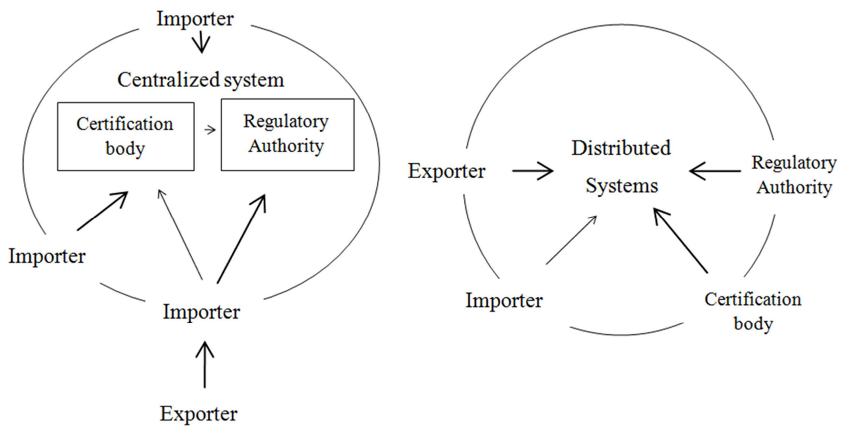

Figure 1. *Differences between traditional traceability systems and blockchain-based traceability system.*

(2) Traceability. Now we explain how it works using blockchain technology for timber tracing. Firstly, at any node, new transaction information is generated and immediately distributed to other nodes through the P2P network. Then, each node uploads the information into the block, and stamped with a timestamp. A blockchain is formed by linking this block with the previous block according to the hash value of the previous block, and reverse modification is impossible for each blockchain [10]. This whole process ensures the traceability of the data.

(3) Tamper-proof. Blockchain can be divided into public chain, consortium chain and private chain by the degree of openness [11]. The consortium chain is suitable for cross-border timber tracing due to accessibility and permission control: that is, participants need approval before they can participate in the preservation, updating and maintenance of the ledger [12]. At present, most of consortium chain uses BFT consensus algorithms, which ensures that the transaction cannot easily be tampered. A single node can tamper only if its 51% or higher computing power is controlled, and the cost of computing is usually much greater than the benefit, which could effectively prevent hacker attacks.

(4) Privacy. The hash function and asymmetric encryption and other cryptographic methods of blockchain techniques can make data "available and invisible" and ensures the privacy of any data [13]. At each node, the enterprise has a public and private key, based on which it converts the original data into a digital abstract by the hash algorithm, and then the digital abstract is encrypted and sent to any node with the private key; at any other nodes, the party who needs to verify traceability information can use the public key to decrypt and obtain the abstract value. In this process, the hash algorithm is again used to verify data authenticity. This entire tracing process does not retrieve any absolute data of the transaction information, and only verifies the authenticity of the encrypted data, thereby ensuring the privacy for each participant.

(5) Low cost for each node. Compared to any traditional centralized information system, the biggest cost of the blockchain-based cross-border timber tracing system is system development and tailor-made chips. The increase in participating nodes does not affect the capacity. For example, if a new timber enterprise is added, the only addition would be to connect the dock of the enterprise to the current system. Even if the enterprise does not have an information system in place, the IT party can remotely deploy and build a corresponding system for it. In other words, each node operates independently in the blockchain-based tracing system, and any malfunction of one node does not affect the operation of the whole system. This guarantees the reliability of the tracing system. In contrast, the extra cost is substantial for higher requirements for hardware equipment in the cases of nodes increase under the traditional centralized traceability information system. This is not the case in the blockchain traceability system.

2.2. Basic Architecture of Blockchain System

Blockchain system can be divided into six layers, including data layer, network layer, consensus layer, incentive layer, contract layer and application layer [14]. The basic architecture is shown in Figure 2. The data layer mainly encapsulates the underlying data blocks, time stamps and related encrypted data, which are important to the security and privacy of information records. The network layer, which is the structural basis of decentralized storage, is responsible for the distributed networking mechanism, data dissemination mechanism and data verification mechanism. The consensus layer encapsulates various consensus mechanisms between network nodes, which is a guarantee of normal operation of the distributed network. The incentive layer is responsible for issuing mechanism and distribution mechanism of the economic incentives, which are necessary for blockchain to be applied to virtual currency scenarios, but it is not necessary in other application scenarios. The contract layer process different kinds of system scripts, algorithms and smart contracts, which are the entities of blockchain programmability. The application layer encapsulates the application scenarios and cases of blockchain.

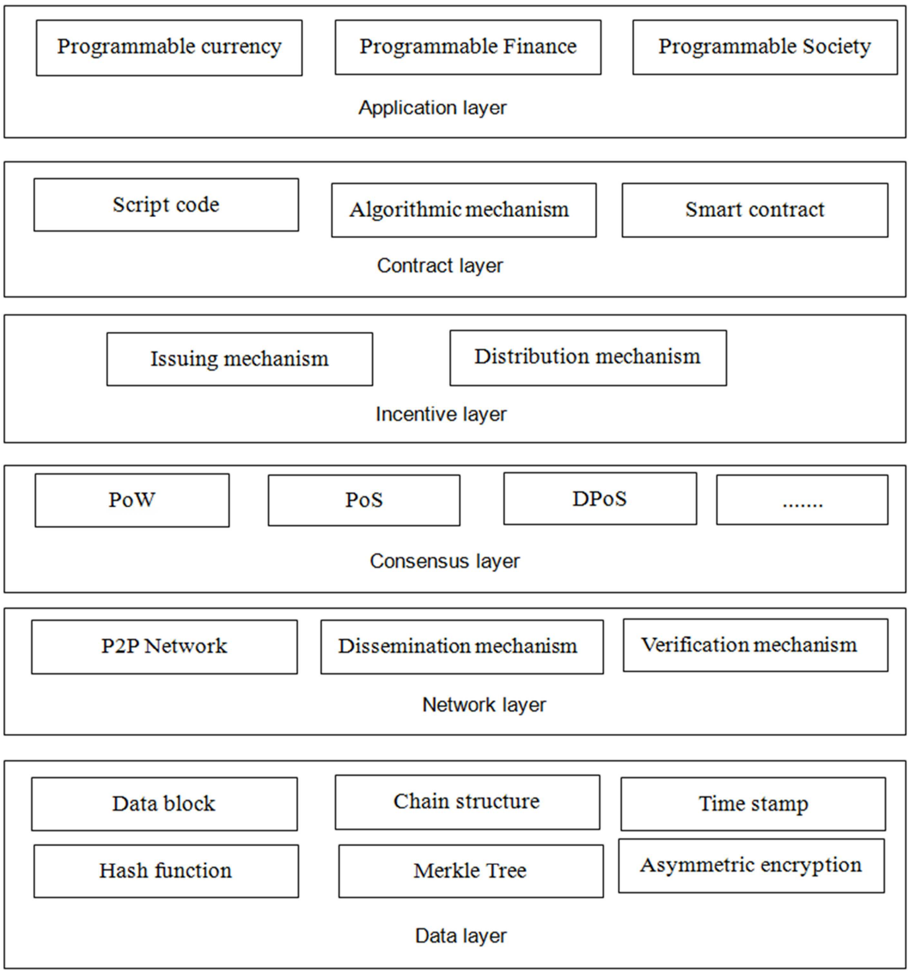

Figure 2. *The basic architecture of blockchain system.*

3. Results: Design of Blockchain Based Cross-Border Timber Tracing System

3.1. Application Context

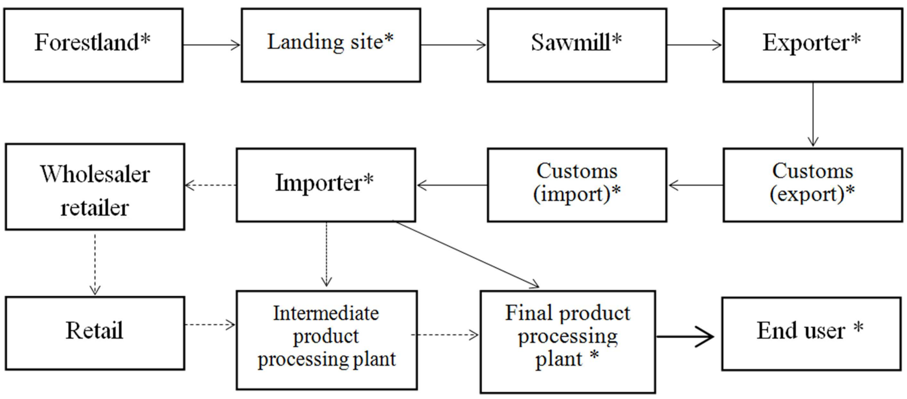

Figure 3. *The complete flow of timber supply chain.*

Note: "*" refers to the stage where data tracking is necessary in a cross-border timber traceability system; and the rest stages are optional by different end products.

A complete timber supply chain covers the entire process of timber from forestland to the end consumer, involving all the parties engaged in logging, processing, packaging, warehousing, transportation, export, commerce, and distribution (see Figure 3 for details). According to the rule of "one step forward, one step back" for commodity traceability, of which "one step forward" traces the raw material information from the supply chain of the product, and "one step back" acquires the whereabouts of the product. Theoretically, the cross-border timber traceability can access all the following original data: logging, processing, trade, production, delivering, distribution. For example, the origins and historical data can be traced for imported timber and wood products including the source and logistics trajectory, processing history, product details and current status, applications, and location.

Due to different purposes of timber tracing, the cross-border timber traceability can be divided into two types: the first is to trace the country of timber origin (especially for the tropical timber) in order to ensure the compliance with relevant forestry laws and regulations of the source country and importing country, which aims at improving the efficiency and transparency of timber trade and eliminating illegal timber [15]. The second is to trace the origin forest of the imported timber to verify the sustainability of the forest. The second type, based on the legitimacy of the source of timber, sets higher standard by requiring evidence of sustainable development of forests. In practice, the second type is based on standard setting and verification for sustainable forest management. However, currently, there does not exist an universal standard for sustainable forest management. The question on "how can wood/wood products importing and exporting countries reach a consensus on this issue" becomes the core of traceability.

3.2. Main Participants

Cross-border timber trade involves many entities, including the enterprises directly engaged in timber trade, the third-party service provider (such as the third-party certification agencies, customs brokers, freight forwarders, logistics companies, etc.) and the regulatory authorities [16]. Considering the demand for cross-border timber tracing, the core participants can be divided into three categories:

(1) The participants involved in timber production and operation, such as forest owner, sawmill, importer and exporter, and wood (wood products) processing enterprise. They are data providers, important users, and the main stakeholders of the timber traceability system, who are responsible for uploading the information needed for the trade transactions.

(2) The government departments that supervise timber legality, including forestry authorities, customs, etc., are important supervision authorities to ensure the effectiveness of cross-border timber traceability. Once illegal timber or unauthenticated/inauthentic data are identified, the regulatory authorities can locate the responsible unit through the blockchain traceability system in a timely manner, and reduce adverse impacts, impose penalties according to law.

(3) The third-party verification agencies that review and verify the reported data by the timber enterprises, are mainly responsible for auditing and verifying the authenticity and validity of the certificates of legal origins of timber provided by forest farm owners, sawmills and other enterprises in accordance with relevant laws and regulations, and in the end issuing corresponding certification documents. The third-party verification agencies are important service providers for blockchain-based cross-border timber traceability.

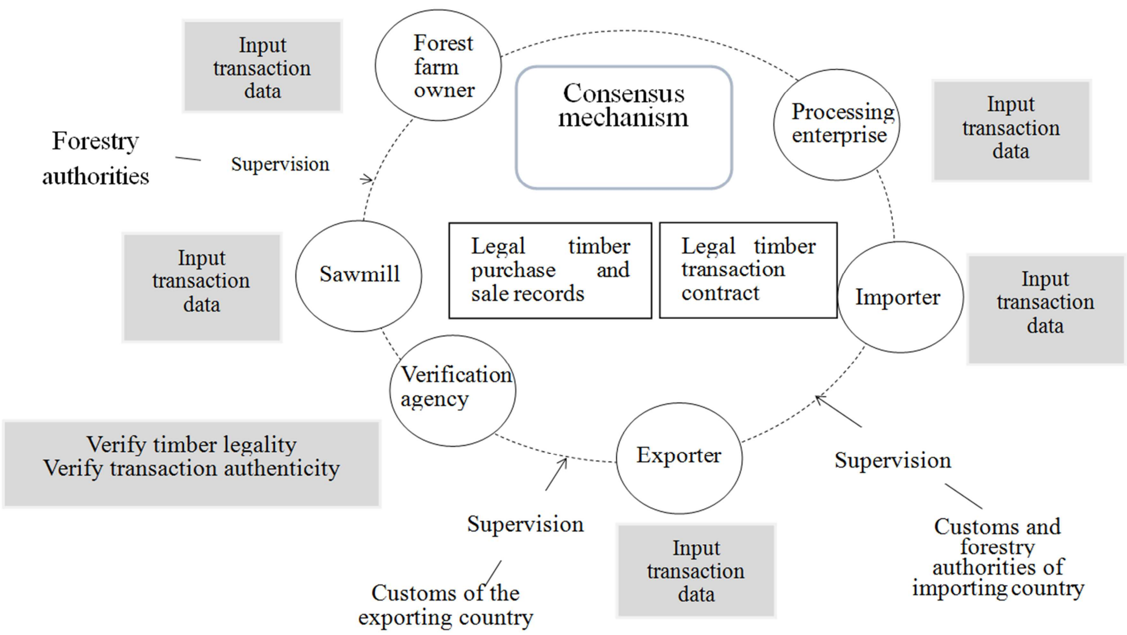

Figure 4. *Consortium chain of members of blockchain-based cross-border timber traceability.*

The above-mentioned participants form a consortium chain for cross-border timber traceability, and through the unified consensus and technical control, a cross-border timber traceability ecosystem with mutual trust, risk control, and credit-based circulation is established. Throughout the timber trade process, forest owners, sawmills, and exporters input, in sequence, the data required for transactions and traceability. Next, the third-party verification agency selects some samples and verifies the legality of origins of timber and the authenticity of transactions. Afterwards, timber importers, processing plants input the transaction data in turn to record the specific whereabouts of the wood. The forestry authorities, customs and other regulatory authorities in both the import and the export countries can link the system with their own existing information systems, they can retrieve any required data, supervise cross-border timber trade, and strengthen the control of illegal timber. In the circulation of wood product, each participant uses the private key to digitally sign and attach a timestamp to the blockchain. Once written, the data will be tamper-proof, and cannot be denied.

3.3. Design of the Blockchain-Based Cross-Border Timber Traceability System

According to the business scope of cross-border timber trade, the blockchain model for cross-border timber traceability is constructed according to the level of the blockchain (see Figure 5), which mainly includes three parts: the low-level blockchain layer, the middleware service layer, and application scenario service layer [17]. Based on the blockchain platform, it provides credible and secure data sharing across countries.

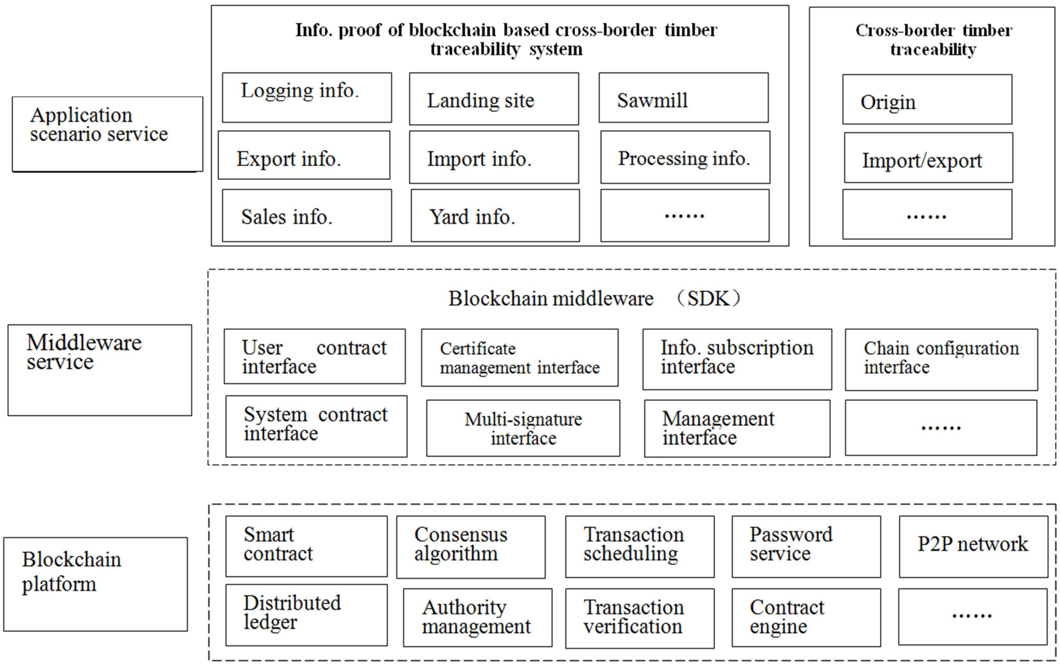

Figure 5. *Structure of blockchain-based cross-border timber traceability system.*

(1) The base technology platform provides basic functional modules such as consensus algorithms, smart contracts, transaction scheduling, cryptographic services, multi-chain ledger storage, and contract engines. The overall objective for this platform is to provide a universal technical support for the upper business applications. The most important functions are smart contracts and consensus algorithms. The smart contract incorporates relevant laws and regulations, policies, standards, and action plans from both the import and the export countries into the blockchain and compiles them into computer programs. All the nodes are obliged to abide by them, which not only improves the standardization of timber transactions, but also reduces intervention and ensures the verification of legal timber. Meanwhile, the smart contract stipulates that, in case the status of timber changes in any stage of the supply chain, logging, production, transportation, trading, processing, and selling, the digital signature of each participant can be used for judgement and to ensure the coherence and integrity of the timber supply chain. The traceability platform adopts BFT consensus algorithm, and this can ensure that the ledgers of honest nodes remain consistent unless the number of malicious nodes exceeds one-third. The platform also avoids excessive energy consumption by "proof-of-work" (PoW) protocol and Po* algorithms due to the use of token incentives.

(2) Blockchain middleware encapsulates the capabilities of the low-level blockchain into different forms of application programming interfaces (API) such as Go and Java, for fetching and interacting with upper application systems. Throughout the middleware layer, the system can be docked with the interface among timber companies, regulatory authorities, third-party verification agencies and international organizations. Information can be retrieved for verification, while the privacy of the participant can be well protected.

(3) The application service layer provides core services to

node users of the traceability system. It stores documents and certificates related to timber logging, piling, import and export, processing, selling, and also provides service support including information inquiry and verification, with trackable information to the origins. In addition, each batch or each piece of timber can be marked with a quantum cloud code, and users can scan the code and quickly access the timber traceability information.

3.4. Operation Flowchart

The key of the blockchain-based cross-border timber traceability system is that all participants achieve a consensus and form a consortium chain, to which they upload the timber production and circulation information in turn, and the corresponding information is digitized in the blockchain system (including the identity and parameter information), and the participants maintain/update the timber flow information. In addition, timber traceability information can be recorded in quantum cloud code by the "one-object-one-code" carrier-tracing technology. Due to the complexity of timber supply chain, there are a number of branches in the transaction process. In this paper, we focus on the key operation procedures as shown in Figure 6.

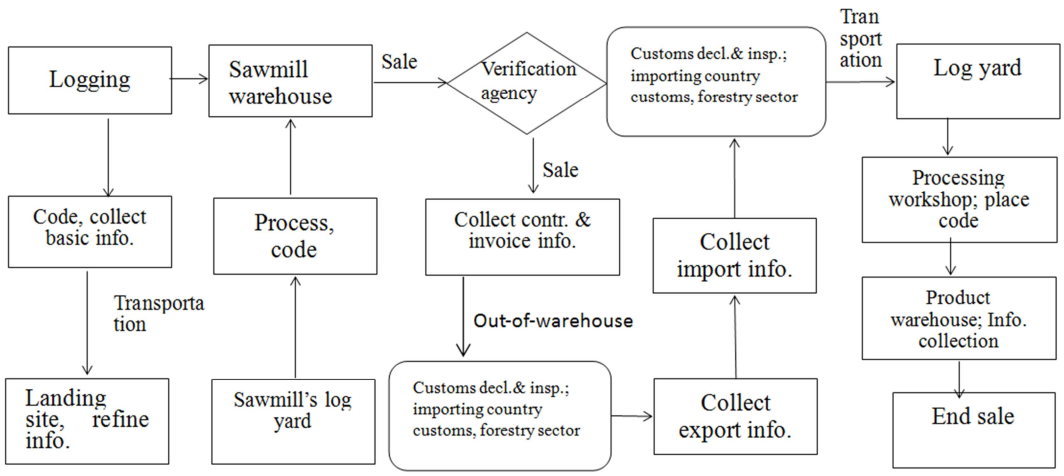

Figure 6. *Operation flowchart of the blockchain-based cross-border timber traceability system.*

Logging: The main entity in this stage is the forest farm owner. Monitoring and video surveillance equipment can be installed on the forestland to collect real-time data on timber growth and the environment, in order to document the wood information. Each piece of timber is marked with a quantum cloud code (namely, "data fingerprint") after harvesting. In the cases where local network is bad, a location chip can be embedded in the quantum cloud code to record and store the real-time displacement change of the timber. Considering the forestland conditions, the following basic information can be entered after logging – i.e., tree species, harvester, and harvesting time. Next, the information such as tree species, and licenses of sustainable forest management and harvesting permit can be added after transporting to the wood landing site. If the timber is sold from forest farm owners to sawmills, the sales information should be uploaded to the blockchain, by means of electronic scanning on the contracts, invoices and other documents. This process reduces human intervention and improves operational efficiency. All the on-chain data are immediately time stamped once entered the blockchain traceability system. When the timber is sold to the next stage, the forest farm owner makes a transaction request, encrypts the digital abstract using the private key and sends it to the sawmill, followed by the real-time updates of the timber transaction.

Sawing: The main entity in this stage is the sawmill. Transported from the wood landing site to a sawmill, the logs are usually piled in the stockyard, and then cut into sawn timber with standard length. In this process, the quantum cloud code attached to the log could be damaged, and it is necessary to attach a new label to the minimum unit of sawn timber manually and record the segment data once the log becomes several sawn timbers. In order to prevent fraud in this process, the following two approaches could be applied: The first is to install video surveillance equipment in the sawmill to monitor the whole process of log stacking, sawing, and selling. The second is to apply a cap for the total amount of output sawn timber based on the volume and other relevant data of the harvested logs, with the aim of avoiding excessive processing.

Verification: The main entity of this stage is the third-party verification agency. In the exporting country, the authoritative organizations with experience in forest management and timber certification are selected, who will verify the timber data of the forest farms and sawmills to ensure the legality of timber and the authenticity of transactions. The third-party verification agency needs to have a relatively complete database and connect to the cross-border timber traceability system, and to verify the legality of timber without retrieving private data. In the cases of abnormality, on-site verification will be conducted by the blockchain administrator.

Trade: The main entities in this stage are importers and exporters, while customs and forestry authorities can join to strengthen the supervision of timber trade. The import and export traders upload the data of the enterprise, the purchase, the inbound and outbound details, the port details of the import and the export. These data is uploaded by means of electronic scanning to the cross-border timber traceability system via the quantum cloud code. The customs and forestry authorities of both the importing and exporting countries can build their own management system and connect to the cross-border timber traceability system, so as to access data on timber harvesting, processing, certification and amount value. They can certify the legality of timber trade by signing with their private key, which effectively speeds up the customs clearance.

Processing: The main entity in this stage is the wood or wood product processing and manufacturing plant. Timber can be purchased through the domestic importer or from the wood market, or, the processing plant can directly import timber from other countries. The quantum cloud code carried by timber records any status change in the past. In a processing plant, timber could experience several key nodes including the log stockyards, processing workshops, finished product warehouses, and sales sites. Take the processing workshop, sawn timber may be processed into boards or furniture products, involving complex timber status changes. Once the original quantum cloud code is damaged, a new label needs to be attached. The control method in this process is consistent with that in the stage of sawn timber, where the "video surveillance + cap control" method is adopted to reduce the risk of any intervention in the traceability process. The processing plant retrieves the information in the cross-border traceability system, attaches a new quantum cloud code to the smallest unit of wood products, and sells it to consumers.

Sales: The main entity in this stage is the consumer of wood or wood products. Consumers do not need to upload any data but can scan the code and obtain the traceability information for their consumption rights. Generally, the consumer rights are limited to the basic information such as the origin, logistic information and tree species. In the cases of re-exporting the wood product to another country who requires the verification of legality, greater rights of authorization can be given to the customs of the importing country.

4. Discussion

Blockchain technology has been largely applied in commodity traceability including agricultural products, medicine, cold chain transportation, and so on [18-20]. However, it is still in its initial stage in the wood sector. Timber and wood products are unique due to the economic value and ecological value, and thus having higher level of requirements in forest resource protection and sustainable use. Using blockchain technology for cross-border timber traceability requires thorough knowledge from an objective perspective, covering the following four aspects.

4.1. Clarity of the Implementing Entities

As mentioned above, cross-border timber traceability aims at two issues: "legality" and "sustainability", and the implementing entities are different by purposes. Aiming at the verification for the legitimacy of timber, the tracing system inherently takes the role as public goods, and it is best that government departments or international intergovernmental organizations take the lead. If an enterprise or enterprises alliance takes the role, without approval by the competent authorities such as customs and forestry authorities, such legitimacy verification would be difficult to be recognized due to lack of authority. Customs and forestry authorities should be aware of the advantages of using blockchain technology for cross-border timber traceability in promoting data sharing, improving supervision methods and reducing enterprise costs, also actively promote the use of blockchain technology beyond the traditional model. With respect to the aim of sustainability, the third-party certification agencies, the timber alliances or associations, and the timber enterprises can establish a platform corresponding to their own needs. In other words, the blockchain-based system for tracing timber cross-border is essentially a centralized platform in this sense, because for each single institution, the cost using the traditional tracing system is much higher and less effective than that of using the blockchain-based technology.

4.2. Incentive Mechanisms

The blockchain-based cross-border timber traceability system requires the participation of all the upstream and downstream enterprises. Any missing enterprise may lead to the interruption of the supply chain information. Therefore, the success of the establishment and long-run operation of a cross-border timber traceability system rely on the degree of recognition by the timber enterprises. Led by customs and forestry authorities, enterprises covered by the chain need to purchase hardware facilities in the initial stage, including the equipment of monitoring, scanning, and tracing code generating, as well as adjust and optimize the management process; they also need to deploy specific personnel responsible for data upload: all these are extra workload in the initial stage of the establishment of the traceability system. Therefore, the system should have an incentive mechanism for the enterprises. For instance, timber traceability can be combined with financial module with financial support to the participating enterprises [21]. Alternatively, synergies could be enhanced among the transaction and custom systems through data sharing, which could improve the efficiency of customs clearance and reduce port time. Or, the timber transaction payment sections could be incorporated into the traceability system, so that the blockchain completes the automatic payment or cross-border payment among enterprises, which largely improve the efficiency of funds flow and reduce the costs of capital settlement.

4.3. Balancing Construction Costs and Small Business Costs

The cost of establishing a blockchain-based cross-border timber traceability platform involves development, operation and maintenance for the developer, and purchases of equipment, hardware and software as well as management. It is estimated that the total investment cost for the developer reaches tens of million Chinese Yuan in the cases with good network infrastructure in the host country. It is highly recommended that the government departments lead the construction due to the high cost for a single enterprise. In the cases where the network condition is not good, like in some African countries, tracing timber back to the forestland requires the installation of GPS chips or the lease of commercial satellites, imposing additional cost. Speaking for a single enterprise, the more participating nodes in the traceability platform, the lower marginal cost for a new node. If the enterprise already has its own information system, it can simply connect to the traceability system without any big cost. For those enterprises without an information system, the technical personnel must remotely deploy one and it costs about tens of thousands of Chinese Yuan, which is usually a one-time investment. Such an investment puts little pressure on large and medium-sized timber enterprises, but it is too much for small and micro enterprises. Thus, it is recommended to provide one-time financial subsidies for small and micro enterprises to participate the blockchain. In the meantime, training could be provided for small and medium-sized wood enterprises to minimize the hidden costs in the switch to the new information system.

4.4. Industry Standards and Regulatory Practices

The core of the requirements by the traceability system is the credibility of the data, and it should be traceable and easily accessible for timber with reliable origins [22]. Inevitably, there exist a number of stages that require manual inputs, such as rotary cutting, sawing, manufacturing, and so on. And this has been challenged by some people on the reliability of blockchain technology for tracing timber. Indeed, there does not exist any technology that can guarantee data authenticity unless any human intervention is excluded. However, this means that it is necessary to have the supporting standards and regulations for the application of blockchain technology in tracing the timber in a cross-border context. On the one hand, industrial standards could focus on the participation mechanism, technical standards, operating procedures, safety specifications, etc., and the guidance using a unified code of conduct and norms with the aim to minimize the deviation in implementation caused by human interventions. On the other hand, supervision can devote to the clarification of rights and responsibilities of the implementing and participating entities, the standardization of the code of conduct for all parties, and the establishment of an effective investigation and punishment mechanism [23]. For example, building up an integrity file for each of the timber enterprises in the cross-border timber traceability platform, any fraud or illegal activity would be notified, with penalties, by the regulatory authorities through the blockchain platform, which raises the costs of fraud. In the end, the trustworthy enterprises will be given green light all through the system, whilst the untrustworthy ones being removed from the supply chain.

5. Conclusions

Due to the characteristics of multiple participants, lack of centralized organization, and lack of universal standards for implantation, using traditional technology in timber tracing would be subject to problems being opaque, incredible, difficult for management, and too costly. However, the blockchain technology, adopting a distributed ledger, meets the requirements of cross-border timber traceability and has the technical advantages on decentralization, traceability, tramper-proof and privacy protecting, etc. Based on these advantages, this study analyzes the application context and the main participants of blockchain in the cross-border timber traceability system. The study also proposes designs of the structure of the traceability system, simulates business operation processes, and discusses four important issues in the implementation process, and finally forms a framework for the blockchain-based cross-border timber traceability system. It provides theoretical basis for the development and operation of the system. It is promising for the development of the blockchain-based traceability system to speed up its growth given the increasing demand for efficient and credible traceability for the wood industry. The overall contribution will largely be to the development of timber legality verification system towards digitalization and sustainable use of timber resources.

Declaration

This study is based on two projects:

a. Nation Forestry and Grassland Administration. Research on the application of blockchain in cross-border timber traceability.
b. International Tropical Timber Organization. Study of the Blockchain-based Global Timber Tracking System: Building Sustainable Wood Supply Chains.

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