Transformation Model of Smallholder Oil Palm Supply Chain Ecosystem using Blockchain-Smart Contract

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***Abstract*—The development of new technology has the potential to disrupt and transform an existing system as well as information technology. This study aims to build a proposed model in order to transform an old system into a Blockchain-based system. The smallholder oil palm supply chain currently uses a traditional information system and technology, hence its integrity, transparency, and security are vulnerable. To solve this problem, frontier technology is needed, such as a blockchain, which has trust, transparency, and traceable characteristics to improve performance and quality. The method used in this study was digital transformation in the context of operational processes and technology. In addition, the As-Is To-Be model was used as a mechanism to develop a transformation model for the smallholder oil palm supply chain system. Specifically, the As-Is model was implemented in identifying and analyzing the information system and technology in an already existing system, while the To-Be was used to determine the blockchain potential and characteristics. This becomes the proposed model for the transformation of the old system into a Blockchain technology-based. Also, a prospective and mechanism for system transformation were produced in the aspect of transactions, data, and architecture, as well as the flow of change strategies needed in the transformation of the blockchain-based smallholder oil palm supply chain system.**

Keywords—Transformation model; smallholder oil palm supply chain; blockchain; smart contract

I. Introduction

The oil palm industry is one of the leading sectors in Indonesia as indicated by its plantation area and productivity. Also, the oil palm supply chain, specifically the FFB management, has been extensively studied from different perspectives.

It has been observed that the smallholder oil palm agroindustry supply chain has a variety of chain models, with many actors and regulations [1]. The independent actors in the oil palm agroindustry supply chain, such as traders are more concerned with the profit element. Therefore, formal supply chain institutions, such as cooperatives need to improve their roles and functions in order to play an active role, which brings benefits and improves the welfare of an independent oil palm smallholder [2][3].

Currently, an information system is used for processing transactions in the smallholder oil palm supply chain environment. This developed system is still centralized, thereby allowing data vulnerability occurrence. Also, the role of users who still interact a lot with the system leads to input errors and other results that are not desired. This simply means data security is not guaranteed, and it is vulnerable to being exploited by other parties. Another problem with a centralized system is that it has a mechanism controlled only by one entity. This implies that the entity can fully control the activities and data contained in the system. Consequently, data are easily manipulated by system owners or hackers, thereby reducing the trust and data transparency in the operation of a product, as well as tracing an asset's provenance [4]. It has been discovered that the digital contract in the existing system was only an agreement between the oil palm mill and the cooperative but the contractual clauses contained therein are often not observed. This leads to manipulation and non-transparency in the running system. In addition, the centralized system poses a high operational challenge in securing the servers and data from hackers. It involves the cost of maintaining data authenticity due to a large amount of manual work and paperwork involved in the business processes [5].

These problems encourage the development of blockchain-based smart contract technology, as an alternative solution to eliminate and reduce challenges in data transactions and a centralized system. The smart contract's implementation reduces human intervention, supports transactions, and increases trust between entities [6]. Meanwhile, blockchain technology adoption targets several domains, such as supply chain, healthcare system, electronic voting, proof of location, distributed cloud storage, and even human resources management and recruitment [7]. According to [8]–[10] blockchain is managed by a distributed peer-to-peer system in a decentralized infrastructure secured by a cryptographic hashing mechanism and with the support of a smart contract and consensus system, which is effective in collaboration between organizations and individuals.

The transformation of a system becomes important when a new technology emerges and has the potential to improve the existing system's performance [11]. This study aims to develop a technological transformation model needed by an existing system to be blockchain technology-based. Subsequently, the following questions were answered

1) What model and technology is used in the current supply chain system for smallholder oil palm?

2) What is the desired model when blockchain is used for the proposed system?

3) Which system and technology transformation mechanisms are required?

Since the existing smallholder oil palm supply chain system is digital-based, the approach selected is a partial blockchain technology adoption mechanism model [12]. In this scenario, the transformation is performed by considering the presence of an information technology/information system existing previously and focusing on the transformation of technology and system architecture. This current study provides an overview of the system transformation mechanism from "traditional" digital solutions (As-Is) to model a system by applying "frontier" digital solutions (To-Be) technology - blockchain-based system.

This article is structured as follows, Section I discusses the problem background in the current system, potential solutions with blockchain technology, as well as the objectives and contributions. Section II entails the literature reviews, namely smallholder oil palm supply chain, blockchain technology, smart contract, and types of blockchain platforms. Furthermore, Section III describes the proposed methodology used in conducting the study phases. Section IV contains the results and discussion, starting with the existing system analysis, the proposed transformation model, and how it can be achieved, as well as discussions related to similar studies and future developments. Finally, the conclusions of the study results are presented in Section V.

II. Literature Review

A. Smallholder Oil Palm Supply Chain

The smallholder oil palm supply chain in Indonesia varies in different regions. However, one similarity between the many flows is that they always involve intermediaries, called middlemen. An example of an existing supply chain is shown in Fig. 1, in which the FFB is harvested from farmers' plantations and is then collected by cooperatives/farmer groups. Furthermore, the FFB is picked up by small agents, who distribute them to large agents, then to Delivery Order (DO) holders, before arriving at PKS. This supply chain is both long and also detrimental to farmers because every party takes profit along the process. This reduces the impact on prices and the profits that independent smallholders are able to earn [13].

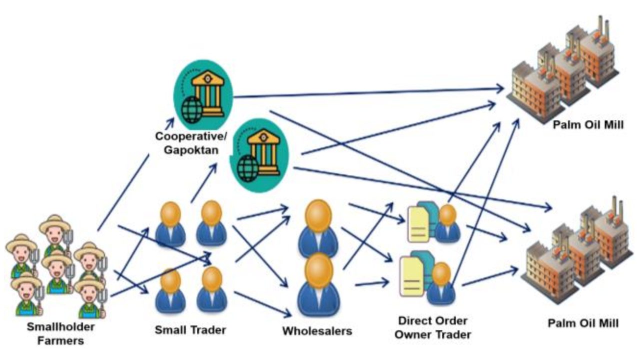

Fig. 1. Smallholder Oil Palm Supply Chain Flow.

Smallholder oil palm farmers do not have a great ability to obtain capital and assistance due to a lack of knowledge as well as access to information and capital that can ensure their sustainability [14]. To increase their prosperity and capacity, standardization and a good plantation management program need to be implemented [15]. Also, institutions capable of uniting smallholder oil palm farmers need to be developed. This can be encouraged through the existence of the farmers' groups (Gapoktan), as well as cooperatives that become facilitators in regulating and supporting smallholders [16]. As reported in [17][18], the ease of obtaining certification for smallholder oil palm farmers needs to be supported by the existing supply chain ecosystem in order to provide quality assurance and products produced.

B. Blockchain Technology

Blockchain is a ledger system, such as a master ledger, in which every transaction that has ever existed is recorded in the form of a decentralized database network. All existing transaction data are recorded in a block entity with each connected to a pre-existing block like a chain [19].

The use of blockchain technology is capable of transforming the conventional supply chain ecosystem with its benefits. In a Blockchain-based supply chain, there are several participants in the network working and interacting together. Each participant sends transactions specifically according to their task in the network [20][21]. In China, a traceability model for agricultural products was developed with blockchain technology and IoT using RFID [22]. As reported, this blockchain technology is capable of developing supply chain business models by reengineering the traditional supply chain to become blockchain-based [23]. Meanwhile, the implementation of blockchain-based logistics operations produces a system that provides a faster and more accurate traceability model [24].

Blockchain has an indelible data structure formed by a series of data blocks that are connected linearly in a time sequence [25]. Information is stored in each block and encrypted with asymmetric cryptographic algorithms to ensure the security of data access and transmission. In the system, each data block records and updates the node data as well as the transaction information according to the defined consensus algorithm of the distributed nodes. The validity of the data is verifiable for all blocks using a hash algorithm [26]. Fig. 2 shows a simple blockchain architecture consisting of a set of blocks containing transactions with a header, transaction, and hash component [27].

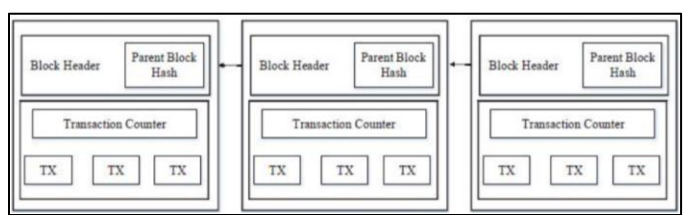

Fig. 2. Blockchain Architecture [27].

C. Smart Contract

It is believed that blockchain combined with smart contract technology has great potential to facilitate a business process [28]. A smart contract is considered a computerized transaction protocol that executes a series of contract clauses introduced in the nineties, while blockchain was the first technology to officially support its implementation [29]. In the literature, a smart contract and blockchain are inseparable terms that together form the second generation of blockchain technology [30][31]. The smart contract execution on the blockchain can be implemented in both public and private blockchain environments with conditioned functionality [32][33].

As described in [34], a smart contract is built with the specific purpose of executing a complete set of instructions on the blockchain. Furthermore, it is a computer program containing contractual agreements between entities generated by the user and extracted from the environment (blockchain) [35]. The purpose of a smart contract is to make the agreement efficient, secure, and increase trust between entities [36].

A smart contract is a working mechanism that involves digital assets and two or more parties. Some or all parties input assets, which are automatically redistributed among users according to a formula and on certain unknown data at the time of contract is initiated [37]. Based on the mechanism, a smart contract has five developmental stages, namely 1) negotiation, 2) development, 3) deployment, 4) maintenance, and 5) learning and self-destruction [38]. Also, a smart contract is capable of reducing human intervention in business process flows in the system environment [39], and can audit automatically in order to quickly and efficiently complete the work expected of users [40].

D. Types of Blockchain Platforms

In the development of a system, two types of blockchain platforms can be used. The first is a public blockchain, which emphasizes the importance of anonymity and decentralization, such as the Ethereum blockchain. The second is a private / consortium blockchain which has the characteristics of being more focused on efficiency and centralized to some extent, like the Hyperledger Fabric blockchain [41].

It is important to note that Ethereum was launched in 2015 with a programmable Blockchain. Due to this capability, Blockchain can be used to build decentralized applications according to user needs. As stated in [42], the characteristics of the Ethereum Blockchain are stateful and Turing Completeness, hence it is possible to store data other than transactions and create complex programs. In addition, the blockchain on Ethereum is a public ledger used to record transactions, which means all data from the initial launch of Ethereum are recorded in 23 Blockchains [43]. Since the ledger is publicly accessible, Ethereum connects each ledger block using a hash algorithm. Based on this mechanism, changing one transaction data requires replacing the hash of the next blocks. Ethereum is generally viewed as a transaction-based state machine [44][45] and a stateful Blockchain, as assets are stored in blocks, not just transactions. It was observed that there are three Merkle Patricia Trees, being a modification of the Merkle Tree on Bitcoin for transactions, accounts, and receipts, thereby leading to three roots stored in the block header. Another study found that there is more data on an Ethereum block than on Bitcoin, which supports the process of creating decentralized applications using the Ethereum Blockchain [46].

Meanwhile, Hyperledger Fabric is an open-source technology of a distributed ledger platform, which is blockchain-enabled [47]. Furthermore, it is a technology developed by the Linux Foundation which is modular for industrial use. Hyperledger Fabric has a smart contract called chain code [48], written with general-purpose programming languages such as Java, Go, and Node,js. It also uses a different approach to a smart contract in general, namely execute-order-validate [49]. Transactions are first executed on a smart contract, then it is ordered via a certain consensus protocol and finally validated with an endorsement policy before being written to the ledger [50]. Hyperledger Fabric has the following main components, such as assets, shared ledger, chain code, peer nodes, channels, organizations, membership service provider (MSP), and ordering services [51][52].

III. Proposed Methodology

This study aims to develop an existing system and transform it into a blockchain technology-based model. The approach used was the As-Is To-Be Model [53], in which the current system is the reference (As-*Is model*) for the development of a new blockchain-based model (*To-Be model*). This is achieved by developing a transformation model that bridges changes from the existing system to the new form. A limitation of digital transformation within the framework of technological transformation was provided, which includes network and communication, hardware and software, and data technologies [54]. Furthermore, the transformation vision approach is at the operational process level and relates to the study conducted by MIT and Capgemini Consulting [55] used to support technological change in the smallholder oil palm supply chain system. Fig. 3 shows the stages of the study performed.

In the first stage, analysis and evaluation of the existing system were conducted. It includes the activities for analyzing the transaction process contained in the existing system. It is important to mention that transaction includes activities or business processes performed by each actor in the current system. The existing system architecture as well as the data contained in the running system was then analyzed based on the model and database used. This architecture is a program structure or computer system consisting of software components, its externally visible characteristics, and its relationship.

In the second stage, a literature review discussing blockchain technology in relation to the transaction mechanism occurring in the blockchain environment, data processed and stored, as well as the architecture supporting the development of a Blockchain-based system was conducted. The final stage involves the development of a transformation model from the old system to a Blockchain technology-based model. This transformation model includes the transaction, the data, and the architecture.

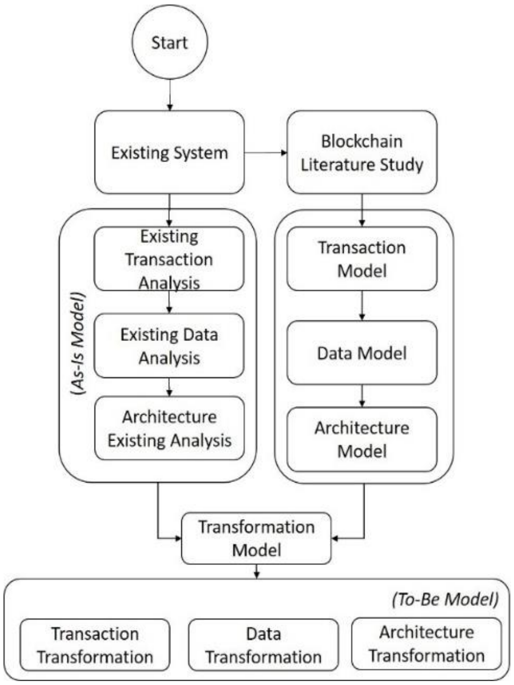

Fig. 3. Study Flow.

IV. Result and Discussion

This section entails the results of the study conducted, which include the discussion of the analysis and current system evaluation, the proposed transformation model, and its change strategy. Fig. 4 shows the discussion flow of the results, with the current system used as an As-Is model, which provides an overview of the operating conditions of transactions, as well as data and system architecture. Meanwhile, the To-Be model was proposed for a new system transformation using Blockchain technology. To produce the To-Be model, a transformation strategy is needed, which is described using a flowchart. Specifically, the transformation employed includes changes to the transaction mechanism, data, and technology architecture as part of the operational processes in the smallholder oil palm supply chain system to achieve the objectives.

A. Existing System of Smallholders Oil Palm Supply Chain

The current oil palm supply chain uses a compact mechanism, specifically for the smallholder, which includes only three actors, namely small farmers, cooperatives/farmer groups, and finally the oil palm mill. This aims to reduce the length of the existing supply chain, as well as to utilize institutions, such as cooperation and better welfare for smallholder oil palm farmers.

Fig. 5 shows the current smallholder supply chain work system, in which the flow of information in the system occurs in all supply chain actors, while the FFB products flow from upstream to downstream. In this supply chain, information system and technology was used to support operational transactions conducted by the actors, from procurement requests to FFB product fulfilment.

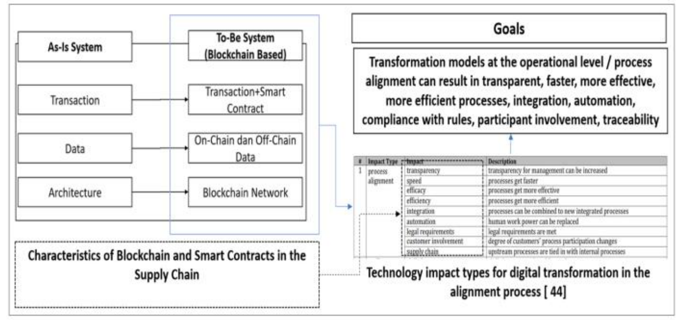

Fig. 4. Scope of Study Results.

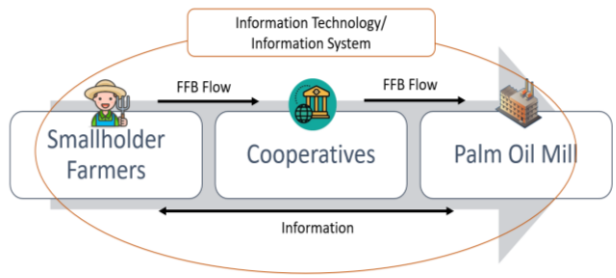

Fig. 5. Existing System Smallholder Oil Palm Supply Chain.

The current information system starts with a digital contract mechanism. Conceptually, a digital contract is a form of an agreement made electronically through the interaction between the offered party and the electronic system. In the current system, two digital contracts were used to initiate operations as well as the demand and supply transactions for fresh fruit bunches (FFB) from an oil palm mill to cooperatives, and also from cooperatives to smallholders. Fig. 6 shows the interaction of the digital contract in the current smallholder oil palm supply chain.

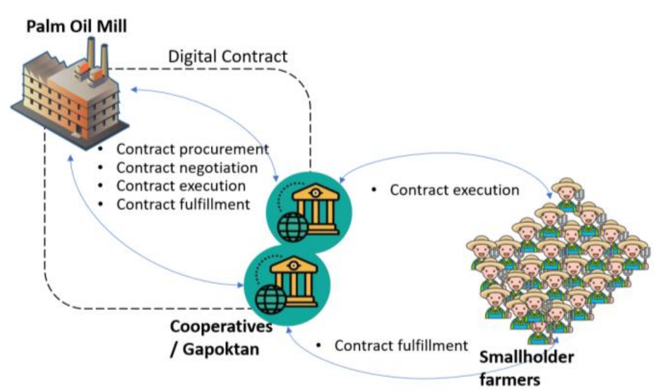

Fig. 6. Interaction of Digital Contract of Existing System Smallholder Oil Palm Supply Chain.

Meanwhile, Fig. 7 shows the current FFB business process. The activities occurring indicated that the contract initiation process was performed by an oil palm mill, offering the purchase of FFB to cooperatives. Furthermore, the cooperative party that gets a contract offer from the oil palm mill evaluates the approval. When there is a mutual agreement from the negotiations between the oil palm mill and the cooperatives, then a digital contract is created and stored in the system. The next stage is to provide a Direct Order (DO) as a work letter and implement the digital contract. The DO was given by oil palm mill to cooperatives, and cooperatives pass the DO on to smallholder oil palm farmers who are members. It is important to note that the smallholder oil palm farmers act as suppliers who are obliged to fulfill the DO by entering FFB production data simultaneously. Meanwhile, the cooperatives serve as 1) collectors, 2) distributors, and 3) sellers. This implies that the task of cooperatives is at the center of the current information system because the transactions they conducted are the most compared to other actors in the supply chain system. As a collector, the Cooperative monitors the FFB sent by independent smallholders and collects it into a large batch of FFB ready to be sent to the oil palm mill. Also, as a distributor, the Cooperative has a role to provide transportation tools to pick up and carry the FFB products, but as a seller, they are to ensure that the price obtained still meets the standard price and the mutually agreed contract. The Oil palm mill as a consumer is expected to check the suitability of the FFB products provided by the Cooperative and pay in accordance with the agreement.

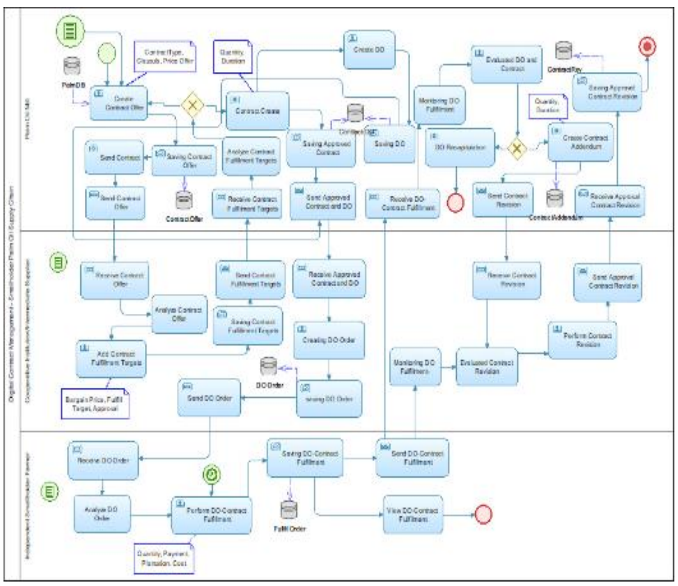

Fig. 7. Process Business of the Current Smallholder Oil Palm Supply Chain System.

Table I shows operational transactions performed by farmers which includes farmers' biodata, data on how their plantations and oil palm plantations are managed, and other supporting data. The next transaction is regarding the sale and purchase of FFB, including its fulfilment transaction based on the DO provided by the Cooperative, such as the sales process to the Cooperative as well as information on the farmers' performance level from profiles and the performed transaction records.

Meanwhile, Table II shows the transactions made by Cooperatives, being the intermediary that connects the oil palm farmers with coconut mills. The transaction starts with 1) the recording of the cooperative profile and supporting data in the system. 2) Contract creation and Direct Order (DO) for FFB request transactions. 3) Purchasing the FFB from farmers and selling it to an oil palm mill. The next operation is as a distributor that transports the FFB from a smallholder to oil palm mill. The process of receiving payments both from an oil palm mill and a farmer is performed by the cooperative. Based on the Cooperative’s transactions and profile results, their work performance is explained as follows.

TABLE I. SMALLHOLDER FARMER TRANSACTIONS

No	Actors	Identity Process	Transactions
1	Farmer	Profile	Member Data
2	Farmer	Profile	Farm
3	Farmer	Profile	Land Process
4	Farmer	Profile	Supporting data
5	Farmer	Operational	Transaction fulfillment
6	Farmer	Operational	Sales
7	Farmer	Operational	History DO
8	Farmer	Operational	Performance

TABLE II. COOPERATIVE TRANSACTIONS

No	Actors	Identity Process	Transactions
1	Cooperative	Profile	Member Data
2	Cooperative	Profile	Supporting data
3	Cooperative	Operational	Transactions History
4	Cooperative	Operational	procurement
5	Cooperative	Operational	fulfillment
6	Cooperative	Operational	Delivery
7	Cooperative	Operational	Transactions (procurement and fulfillment)
8	Cooperative	Operational	Payment
9	Cooperative	Operational	Contract History
10	Cooperative	Operational	History DO
11	Cooperative	Operational	Performance

The next operational transaction takes place at the oil palm mill as shown in Table III. It starts with the initiation of contracts between the oil palm mill and cooperatives, then continues with the making of DO and registration of FFB suppliers. The sale and purchase transaction was performed with the cooperative, a partner based on the agreed contract and DO. The FFB payment process was conducted by the oil palm mill at a mutually agreed time.

TABLE III. OIL PALM MILL TRANSACTIONS

No	Actors	Identity Process	Transactions
1	Oil Palm Mill	Profile	Member Data
2	Oil Palm Mill	Profile	Supporting data
3	Oil Palm Mill	Operational	procurement
4	Oil Palm Mill	Operational	Purchase
5	Oil Palm Mill	Operational	Payment
6	Oil Palm Mill	Operational	Contract History
7	Oil Palm Mill	Operational	DO History
8	Oil Palm Mill	Operational	Supplier
9	Oil Palm Mill	Operational	Performance

The government, such as the provincial or district plantation agency acts as an external actor that regulates, configures the system, processes the FFB reference price data, and monitors smallholder oil palm supply chain transactions in their area as shown in Table IV.

TABLE IV. AGENCY TRANSACTIONS

No	Actors	Identity Process	Transactions
1	Agency	Operational	FFB-Province Reference Price Data
2	Agency	Operational	System Configuration

According to Fig. 8, a database was developed to store profile data, manage FFB transaction data, and calculate the performance of each actor in the smallholder oil palm supply chain. The model in the current system includes six interconnected table entities for storing the data used in the digital contract creation and the transaction executed by oil palm mill, cooperatives, and smallholders. Subsequently, the table entails oil palm mill, cooperatives, contracts, contract details, smallholders, and supporting data in the form of plantation profiles.

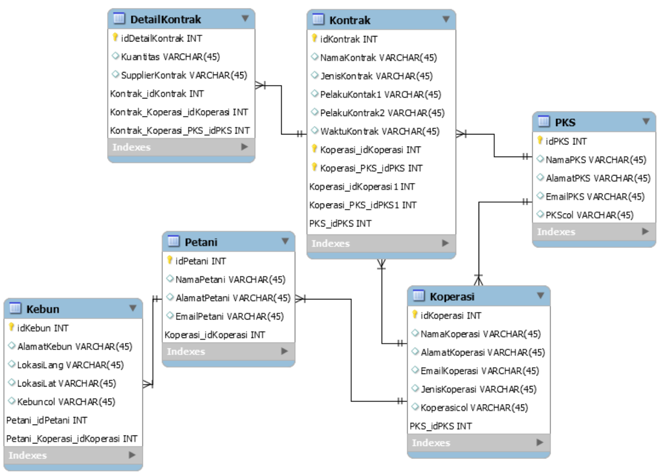

Fig. 8. Existing Database Scheme.

The web-based technology was employed in the current system architecture for it to be accessible by all supply chain actors. The system was developed using platform-based web technology with a centralized database model on a server. In accessing the system, supply chain actors were required to register in order to obtain access rights to perform transactions according to their privileges. Fig. 9 shows the current system architecture.

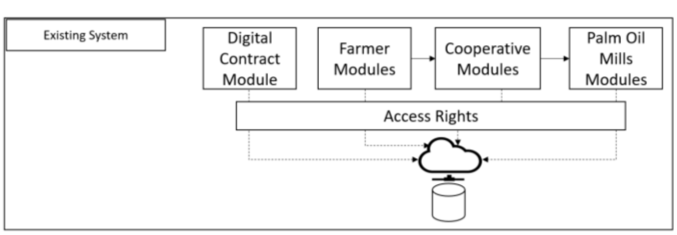

Fig. 9. Digital Contract Table Relation Schema.

B. *Proposed Blockchain-Based Smallholders Oil Palm Supply Chain System Transformation Model*

A blockchain technology-based system was the system model developed in the smallholder oil palm supply chain. Fig. 10 shows the logical changes made to the proposed system by adding smart contract technology and a blockchain network. A smart contract is generally used to automate manual work performed by users, as well as increase the accuracy and compliance with data entered in the system. Meanwhile, the use of the blockchain network serves as a data guarantor in a more secure, difficult-to-manipulate, and immutable environment.

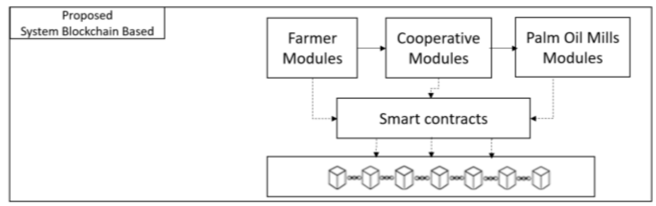

Fig. 10. Logic Model of Proposed System Smallholder Oil Palm Supply Chain.

Fig. 11 shows the differences between traditional application development and those that are blockchain-based. This difference affected the application development on the user side, the database model, and the network architecture used. Consequently, the changes caused a system transformation from a traditional model to one that is blockchain-based. The first transformation was the transformation of the designed application to manage transactions (transaction transformation) by changing the traditional concept into Decentralized applications (DApps) used to transact in the blockchain system. The second was the transformation of a traditional database system into a blockchain-based data model, both on-chain and off-chain data (data transformation). Meanwhile, the third was the blockchain network transformation used to store and disseminate transaction records to all nodes in a blockchain-based system (network/architecture transformation).

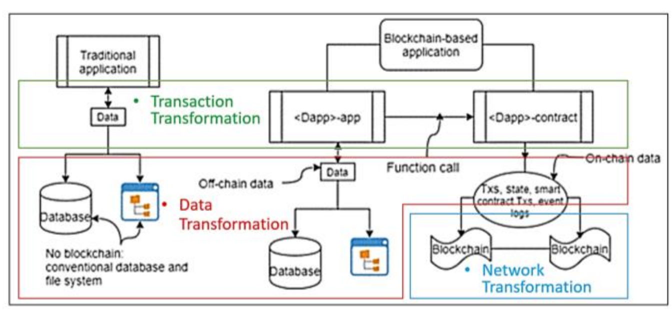

Fig. 11. Proposed Transformation Model of Smallholder Oil Palm Supply Chain Blockchain-based.

1) Transaction transformation model: It is important to reiterate that the first transformation conducted was to change the current system transactions into those executable in the blockchain environment. This mechanism is shown in Fig. 12 and it begins with identifying the transaction process for each supply chain actor, followed by determining whether the transaction needs to be stored on the blockchain environment or not. When the transaction requires a secure, transparent data environment, and traceability requirements, it was added/modified by adding a smart contract in the system development environment.

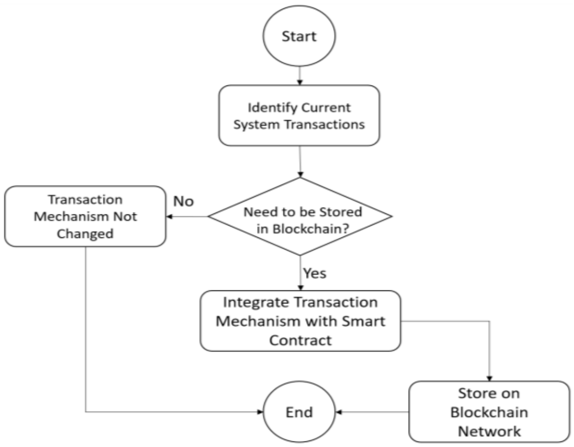

Fig. 12. Blockchain-based Smallholder Oil Palm Supply Chain Transaction Transformation Strategy.

The identification and analysis of transactions existing in the current system consist of actors in the supply chain, namely farmers, cooperatives, oil palm mill, and related agencies, such as admins. There are two process identities, namely the identity for storing profile data and that of operational data. Meanwhile, the business processes are operational data that can be executed by any user based on their access rights. Table V shows the results of the identification and analysis of actors, transactions, and recommendations for the proposed smart contract.

The proposed smart contract architecture model stores data related to the profile of each smallholder oil palm supply chain actor, such as farmer profiles, cooperatives, and oil palm mills. The profile data of supply chain actors are in the form of identity data of actors and other supporting data according to their roles. Meanwhile, smart contract transactions are designed to store transactional data occurring in smallholder oil palm supply chain activities, ranging from the main contract, DO manufacturing, FFB sourcing transactions, FFB fulfilment transactions, performance reviews, and payment mechanisms. The proposed smart contract architecture is shown in Fig. 13.

Fig. 14 shows a sequence diagram for the transaction of profiles of actors in the FFB supply chain, namely farmers, cooperatives, and oil palm mills. This helps in describing a scenario or a series of steps taken in response to an event to produce a certain output, including the changes that occurred.

It is important to reiterate that a smart contract is an executable code running on the blockchain to facilitate, execute, and enforce agreement terms. A smart contract's principal goal was to automatically execute the terms of the agreement once the specified conditions are met [56]. An illustration of the smart contract code is shown in Fig. 15, which described the transactions and actions performed.

TABLE V. PROPOSED SMART CONTRACT ON BLOCKCHAIN-BASED SMALLHOLDER OIL PALM SUPPLY CHAIN SYSTEM

No	Actors	Identity Process	Business Process	Proposed Smart Contract
1	Farmer	Profile	Member Data	Profile Smart Contract
2	Farmer	Profile	Farm	
3	Farmer	Profile	Land Process	
4	Farmer	Profile	Supporting data	
5	Farmer	Operational	Transaction (fulfillment)	Transaction Smart Contract
6	Farmer	Operational	Sales system	
7	Farmer	Operational	History DO	
8	Farmer	Operational	Performance	
9	Cooperative	Profile	Member Data	Profile Smart Contract
10	Cooperative	Profile	Supporting data	
11	Cooperative	Operational	Transaction History	Transaction Smart Contract
12	Cooperative	Operational	Transactions (procurement and fulfillment)	
13	Cooperative	Operational	Payment system	
14	Cooperative	Operational	Contract History	
	Cooperative	Operational	History DO	
15	Cooperative	Operational	Performance	
16	Oil Palm Mill	Profile	Member Data	Profile Smart Contract
17	Oil Palm Mill	Profile	Supporting data	
18	Oil Palm Mill	Operational	Transaction (procurement)	Transaction Smart Contract
19	Oil Palm Mill	Operational	Purchase	
20	Oil Palm Mill	Operational	Payment system	
21	Oil Palm Mill	Operational	Contract History	
	Oil Palm Mill	Operational	History DO	
22	Oil Palm Mill	Operational	Supplier	
23	Oil Palm Mill	Operational	Performance	
24	Admin (Agencies)	Operational	FFB/Province Reference Price Data	Transaction Smart Contract
25	Admin (Agencies)	Operational	System Configuration	

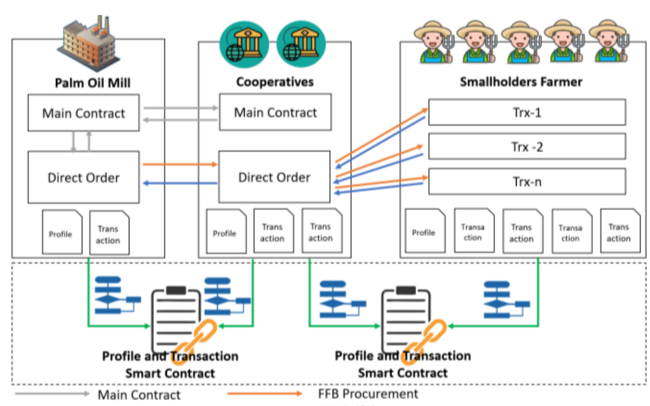

Fig. 13. Proposed Smart Contract Architecture Smallholder Oil Palm Supply Chain.

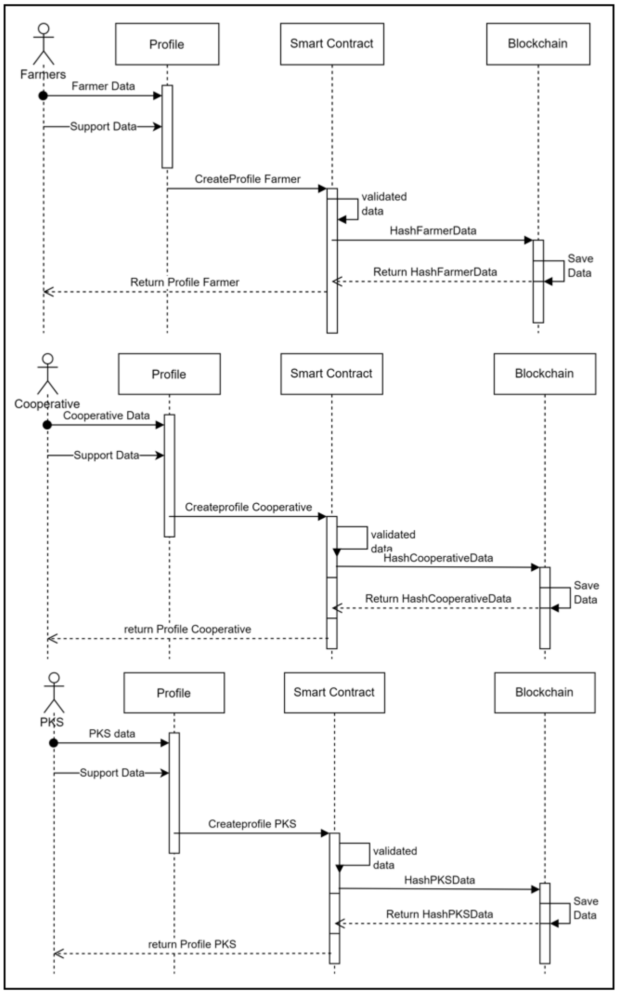

Fig. 14. Sequence Diagram Proposed Smart Contract on Smallholder Oil Palm Supply Chain.

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Algorithm 1. Simplified structure of a transaction script in
Hyperledger

transaction tx(inputs)
if contract terms are fulfilled then
...
  return Transaction Accepted        ← create/ update blockchain object(s)
                                     ← if network consensus achieved
Else
     return Transaction Rejected
end if                               ← do nothing if contract terms  not met
end transaction
```

Fig. 15. Structure of Smart Contract on Smallholder Oil Palm Supply Chain.

2) Data transformation model: Data transformation is part of the development of the current system into a blockchain-based model. Also, data changes and adjustments are needed in determining the data to be stored in the internal database environment and those to be stored on the blockchain network. Fig. 16 shows the mechanism for adapting the existing data in the current system into a blockchain-based model.

The databases managed by centralized authorities typically store multiple copies of data for secure server management. A copy of the data is very important because those stored are prone to corruption. The decentralized nature of blockchain has a major influence on the changes in how each industry implement digital transaction system. Furthermore, blockchain allows anyone who accesses it to work independently and eliminates any need for centralized control. For example, a server-based database acts as a centralized processing unit, thereby allowing the database to work dynamically from small to large scale. The client and server communicate with each other over a secure connection. It was observed that blockchain is based on distributed ledger technology and the network is enabled with a secure, peer-to-peer cryptographic protocol. Meanwhile, it shows another way of working, in which the accessor can only read and write. It is important to note that the data stored on a blockchain cannot be deleted or replaced. This is because its nature is fixed and it supports immutability, hence the inputted data is not disturbed or manipulated.

Fig. 17 shows the transformation of the proposed data model from a centralized to a decentralized database. The decentralized data model on the blockchain network is facilitated by the existence of an on-chain transaction mechanism stored in the blockchain network environment. It also involves an off-chain transaction mechanism, which is a data model stored outside the blockchain network. The proposed model uses a NoSQL database type to facilitate the development of a blockchain-based system, as shown in Fig. 18.

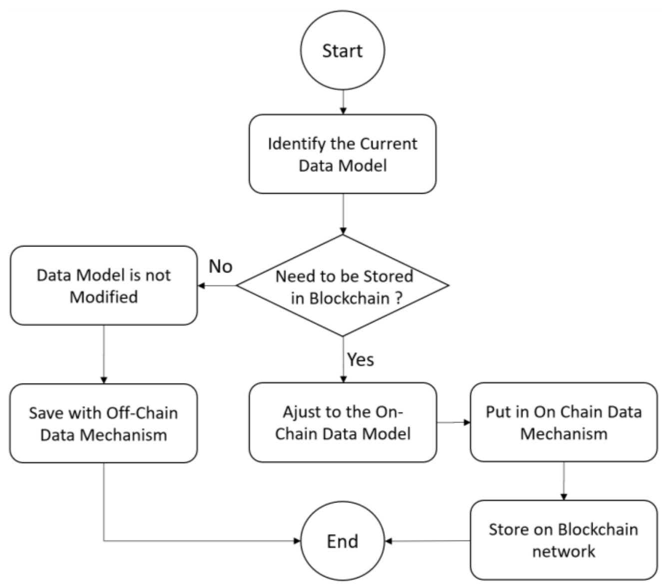

Fig. 16. Blockchain-based Smallholder Oil Palm Supply Chain Data Transformation Strategy.

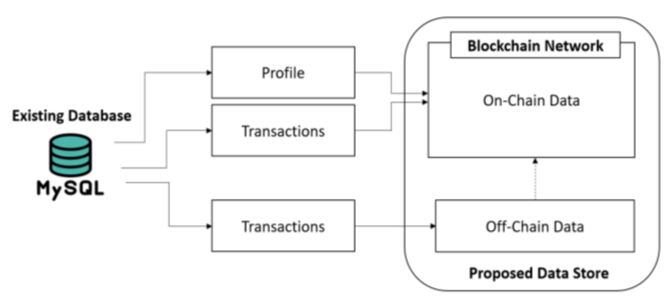

Fig. 17. Proposed Decentralized Data Model Transformation.

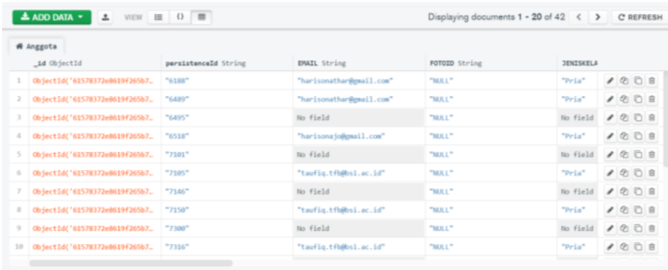

Fig. 18. Example of a NoSQL-based Data Model.

The data format used in database development, which is stored in a No-SQL and the process of sending it to the blockchain network with json formatted APIs is shown in Fig. 19.

```
const mongoose = require("mongoose");
const AnggotaSchema = new
mongoose.Schema({
  nama: {
    type: String,
  },
  nomorHP: {
    type: String,
  },
  ttl: {
    type: String,
  },
  noKTP: {
    type: Number,
  },
  JenisKelamin: {
    type: Number,
  },
});
module.exports =
mongoose.model("Anggota", userSchema);
```

```
Type Anggota struct {
  ID          string 'json:"id"'
  nama        string 'json:"nama"'
  nomorHP     string 'json:"NoHP"'
  ttl         string 'json:"ttl"'
  noKTP       int64  'json:"noKTP"'
  JenisKelamin string json:"jk"'
}
```

Fig. 19. On-chain and off-chain Data Models in Smallholder Oil Palm Supply Chain.

3) Network architecture transformation model: Network transformation is the evolution of the current model to a blockchain-based system. Specifically, the current system works with a centralized network, while the blockchain network is decentralized and distributed.

Fig. 20 shows the mechanism for developing a blockchain network architecture on a smallholder oil palm supply chain system. In addition, the stages of change include 1) an analysis of the web platform technology used in the current system, 2) the development towards a web platform that supports blockchain, namely by building a blockchain network, 3) the deployment of a smart contract on a blockchain network, and 4) end-user application development.

The network architecture in the smallholder oil palm supply chain is shown in Fig. 21. Starting from an end-user, applications interact with a smart contract to perform operations on the blockchain network. Consequently, the blockchain stores these records immutably and return the changes in response to the client application.

A smart contract works by updating the ledger in the blockchain network, which represents the immutable data on all transactions and manages a world state denoting the current data state. Furthermore, it is capable of executing the state stored in the state DB and requesting transaction records contained in the blockchain. Client applications interact with a smart contract to perform operations on the blockchain network. This causes the blockchain to store these records immutably and return the changes in response to the client application.

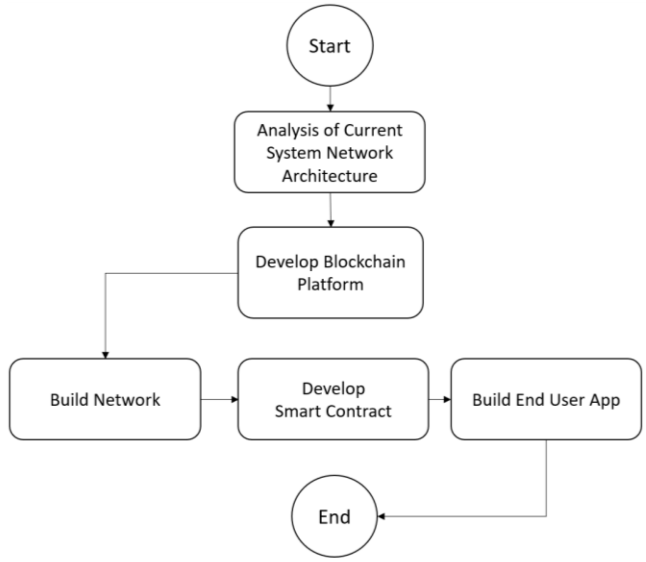

Fig. 20. Blockchain-based Smallholder Oil Palm Supply Chain Network Architecture Transformation Strategy.

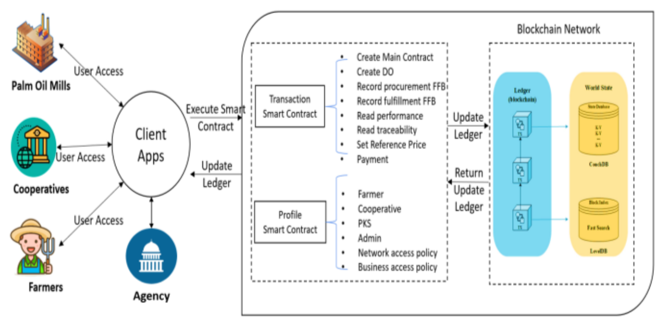

Fig. 21. Proposed Network Architecture in Smallholder Oil Palm Supply Chain.

This is consistent with the study in [57], that the development of a smart contract started from the re-engineering of existing business processes. According to [58], the smart contract's function is applied as an automation mechanism and data integrity guard. This means the smart contract has the ability as a secure data storage mechanism, particularly for access to a smallholder oil palm supply chain [59]. However, this study was only completed at the transformation model stage, hence it is necessary to conduct a maturity assessment of the digital transformation model [60]. It also needs to be developed towards a physical model in the form of developing a prototype system, in which the data, transactions, APIs used, and the blockchain platform was tested [61].

V. Conclusion

This study has led to a transformation model from the current smallholder oil palm supply chain to a blockchain-smart contract-based system. The system transformation produced consisted of elements of transaction, data, and network architecture transformations. The results were obtained by taking a digital transformation approach, particularly at the technological level, and focusing on the operational processes. The proposed system model was derived from the partial integration mechanism for the adoption of blockchain technology. This is because the current system uses an information technology/information system in its working process. The results represented the As-Is To-Be model in developing the system transformation. Specifically, the current system was used as an As-Is model, which was analyzed and evaluated, while the To-Be was the result of analysis and collaboration with blockchain technology, serving as the solution. Furthermore, a flow of transformation strategies in transactions, data, and network architecture was produced. The transaction transformation was based on business processes and those occurring within the smallholder oil palm supply chain. This transaction is analyzed in order to get a picture of the parts that are still being conducted manually by the user, have low accuracy, and lack integrity. Based on the investigation results, a form of change and adjustment of transactions was obtained using the smart contract mechanism. Regarding the data transformation, the results were achieved through the analysis performed on the current system model, which was developed with data in accordance with blockchain technology. The evaluation results showed that some data in the smallholder oil palm supply chain need to be included in the blockchain in order to maintain its security, integrity, and transparency. Consequently, the direction in this section was to apply on-chain and off-chain data storage mechanisms. The last transformation was the network architecture, in which the current system employs an architectural model and the network used was centralized, while blockchain technology was distributed and decentralized. This indicates the need to develop a network that is able to distribute records/ledgers to all nodes and user applications. It is important to mention that these applications are developed based on Dapps capable of working in a blockchain environment with smart contract by utilizing APIs as a medium for connecting data to be stored in the network. This study's results were practically useful as a guide, direction, and strategy for developing the existing model for it to be transformed into a new system based on blockchain-smart contract technology. In the future, studies have to be directed toward the development of physical models and prototypes of the blockchain-smart contract-based smallholder oil palm supply chain system. This can be implemented using a suitable platform with a smart contract model and executed on a blockchain-based prototype environment.

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REFERENCES

[1] T. Djatna, M. Asrol, and T. Baidawi, "SCOR-Based Information Modeling for Managing Supply Chain Performance of Palm Oil Industry at Riau and Jambi Provinces, Indonesia," Int. J. Supply Chain Manag., vol. 9, no. 5, pp. 75–89, 2020.

[2] S. Raharja et al., "Institutional strengthening model of oil palm independent smallholder in Riau and Jambi Provinces, Indonesia," Heliyon, vol. 6, no. 5, p. e03875, 2020, doi: 10.1016/j.heliyon.2020.e03875.

[3] H. Heryani et al., "Institutional Development in the Supply Chain System of Oil Palm Agroindustry in South Kalimantan," Int. J. Technol., vol. 13, no. 3, pp. 643–654, 2022, doi: 10.14716/ijtech.v13i3.4754.

[4] H. Halaburda, "Blockchain revolution without the blockchain?," Commun. ACM, vol. 61, no. 7, pp. 27–29, 2018.

[5] I. Önder and H. Treiblmaier, "Blockchain and tourism: Three research propositions," Ann. Tour. Res., vol. 72, pp. 180–182, 2018, doi: https://doi.org/10.1016/j.annals.2018.03.005.

[6] F. Idelberger, G. Governatori, R. Riveret, and G. Sartor, "Evaluation of logic-based smart contracts for blockchain systems," in International symposium on rules and rule markup languages for the semantic web, 2016, pp. 167–183.

[7] M. M. H. Onik, M. H. Miraz, and C.-S. Kim, "A recruitment and human resource management technique using blockchain technology for industry 4.0," in Smart Cities Symposium 2018, 2018, pp. 1–6.

[8] M. Conoscenti, A. Vetro, and J. C. De Martin, "Blockchain for the Internet of Things: A systematic literature review," in 2016 IEEE/ACS 13th International Conference of Computer Systems and Applications (AICCSA), 2016, pp. 1–6.

[9] O. Bermeo-Almeida, M. Cardenas-Rodriguez, T. Samaniego-Cobo, E. Ferruzola-Gómez, R. Cabezas-Cabezas, and W. Bazán-Vera, "Blockchain in agriculture: A systematic literature review," in International Conference on Technologies and Innovation, 2018, pp. 44–56.

[10] A. Gorkhali, L. Li, and A. Shrestha, "Blockchain: A literature review," J. Manag. Anal., vol. 7, no. 3, pp. 321–343, 2020.

[11] F. Zaoui and N. Souissi, "Roadmap for digital transformation: A literature review," Procedia Comput. Sci., vol. 175, pp. 621–628, 2020, doi: 10.1016/j.procs.2020.07.090.

[12] I. Afrianto, T. Djatna, Y. Arkeman, I. S. Sitanggang, and I. Hermadi, "Disrupting Agro-industry Supply Chain in Indonesia With Blockchain Technology: Current and Future Challenges," in 2020 8th International Conference on Cyber and IT Service Management (CITSM), 2020, pp. 1–6.

[13] Marimin et al., "Supply chain performance measurement and improvement of palm oil agroindustry: A case study at Riau and Jambi Province," IOP Conf. Ser. Earth Environ. Sci., vol. 443, no. 1, 2020, doi: 10.1088/1755-1315/443/1/012056.

[14] N. S. Rahayu, A. A. Nugroho, and R. R. Yusuf, "Exclusion of Smallholders in the Indonesia Palm Oil Industry," KnE Soc. Sci., vol. 2022, pp. 1158–1182, 2022, doi: 10.18502/kss.v7i9.11010.

[15] H. Bakhtary, F. Haupt, C. Luttrell, D. Landholm, and I. Jelsma, "Promoting sustainable oil palm production by independent smallholders in Indonesia," Clim. Focus Meridian Inst., no. February, pp. 1–12, 2021, doi: 10.13140/RG.2.2.35216.74242.

[16] K. Anwar, D. Tampubolon, and T. Handoko, "Institutional Strategy of Palm Oil Independent Smallholders: A Case Study in Indonesia," J. Asian Financ. Econ. Bus., vol. 8, no. 4, pp. 229–238, 2021, doi: 10.13106/jafeb.2021.vol8.no4.0529.

[17] J. D. Watts et al., "Challenges faced by smallholders in achieving sustainable palm oil certification in Indonesia," World Dev., vol. 146, p. 105565, 2021, doi: 10.1016/j.worlddev.2021.105565.

[18] E. P. Pramudya et al., "Incentives for Palm Oil Smallholders in Mandatory Certification in Indonesia," Land, vol. 11, no. 4, pp. 1–28, 2022, doi: 10.3390/land11040576.

[19] A. Pieroni, N. Scarpato, L. Di Nunzio, F. Fallucchi, and M. Raso, "Smarter City: Smart energy grid based on Blockchain technology," Int. J. Adv. Sci. Eng. Inf. Technol., vol. 8, no. 1, pp. 298–306, 2018, doi: 10.18517/ijaseit.8.1.4954.

[20] A. Litke, D. Anagnostopoulos, and T. Varvarigou, "Blockchains for Supply Chain Management: Architectural Elements and Challenges

Towards a Global Scale Deployment," Logistics, vol. 3, no. 1, p. 5, 2019, doi: 10.3390/logistics3010005.

[21] I. Afrianto, T. Djatna, Y. Arkeman, I. Sukaesih Sitanggang, and I. Hermadi, "Disrupting Agro-industry Supply Chain in Indonesia with Blockchain Technology: Current and Future Challenges," 2020, doi: 10.1109/CITSM50537.2020.9268872.

[22] F. Tian, "An agri-food supply chain traceability system for China based on RFID & blockchain technology," 2016 13th Int. Conf. Serv. Syst. Serv. Manag. ICSSSM 2016, 2016, doi: 10.1109/ICSSSM.2016.7538424.

[23] L. Cheng, J. Liu, C. Su, K. Liang, G. Xu, and W. Wang, "Polynomial-based modifiable blockchain structure for removing fraud transactions," Futur. Gener. Comput. Syst., vol. 99, pp. 154–163, 2019, doi: https://doi.org/10.1016/j.future.2019.04.028.

[24] P. Helo and Y. Hao, "Blockchains in operations and supply chains: A model and reference implementation," Comput. Ind. Eng., vol. 136, no. July, pp. 242–251, 2019, doi: 10.1016/j.cie.2019.07.023.

[25] I. Afrianto and Y. Heryanto, "Design and Implementation of Work Training Certificate Verification Based On Public Blockchain Platform," in 2020 Fifth International Conference on Informatics and Computing (ICIC), 2020, pp. 1–8.

[26] Y. Xinyi, Z. Yi, and Y. He, "Technical Characteristics and Model of Blockchain," pp. 562–566, 2018, doi: 10.1109/controlo.2018.8439793.

[27] Z. Zheng, S. Xie, H. Dai, X. Chen, and H. Wang, "An Overview of Blockchain Technology: Architecture, Consensus, and Future Trends," Proc. - 2017 IEEE 6th Int. Congr. Big Data, BigData Congr. 2017, no. October, pp. 557–564, 2017, doi: 10.1109/BigDataCongress.2017.85.

[28] J.-C. Cheng, N.-Y. Lee, C. Chi, and Y.-H. Chen, "Blockchain and smart contract for digital certificate," in 2018 IEEE international conference on applied system invention (ICASI), 2018, pp. 1046–1051.

[29] B. K. Mohanta, S. S. Panda, and D. Jena, "An overview of smart contract and use cases in blockchain technology," in 2018 9th International Conference on Computing, Communication and Networking Technologies (ICCCNT), 2018, pp. 1–4.

[30] M. Swan, "Chapter Five - Blockchain for Business: Next-Generation Enterprise Artificial Intelligence Systems," in Blockchain Technology: Platforms, Tools and Use Cases, vol. 111, P. Raj and G. C. B. T.-A. in C. Deka, Eds. Elsevier, 2018, pp. 121–162.

[31] I. Afrianto, C. R. Moa, S. Atin, and I. Rosyidin, "Prototype Blockchain Based Smart Contract For Freelance Marketplace System," in 2021 Sixth International Conference on Informatics and Computing (ICIC), 2021, pp. 1–8.

[32] D. Macrinici, C. Cartofeanu, and S. Gao, "Smart contract applications within blockchain technology: A systematic mapping study," Telemat. Informatics, vol. 35, no. 8, pp. 2337–2354, 2018, doi: https://doi.org/10.1016/j.tele.2018.10.004.

[33] R. Yuan, Y.-B. Xia, H.-B. Chen, B.-Y. Zang, and J. Xie, "Shadoweth: Private smart contract on public blockchain," J. Comput. Sci. Technol., vol. 33, no. 3, pp. 542–556, 2018.

[34] D. Tapscott and A. Tapscott, Blockchain revolution: how the technology behind bitcoin is changing money, business, and the world. Penguin, 2016.

[35] F. Idelberger and G. Governatori, "Rule Technologies. Research, Tools, and Applications," vol. 9718, no. November 2017, pp. 167–183, 2016, doi: 10.1007/978-3-319-42019-6.

[36] I. Afrianto, T. Djatna, Y. Arkeman, I. Hermadi, and I. S. Sitanggang, "Block Chain Technology Architecture For Supply Chain Traceability Of Fisheries Products In Indonesia: Future Challenge," J. Eng. Sci. Technol. Spec. Issue INCITEST2020, pp. 41–49, 2020.

[37] W. Reijers, F. O'Brolcháin, and P. Haynes, "Governance in Blockchain Technologies & Social Contract Theories," Ledger, vol. 1, pp. 134–151, 2016, doi: 10.5195/ledger.2016.62.

[38] L. Wang, X. Shen, J. Li, J. Shao, and Y. Yang, "Cryptographic primitives in blockchains," J. Netw. Comput. Appl., vol. 127, pp. 43–58, 2019, doi: https://doi.org/10.1016/j.jnca.2018.11.003.

[39] Y. Cao, "3 - Energy Internet blockchain technology," W. Su and A. Q. B. T.-T. E. I. Huang, Eds. Woodhead Publishing, 2019, pp. 45–64.

[40] Y. Zhao, X. Meng, S. Wang, and T. C. Edwin Cheng, Contract Analysis and Design for Supply Chains with Stochastic Demand, vol. 234. 2015.

[41] M. N. M. Bhutta et al., "A Survey on Blockchain Technology: Evolution, Architecture and Security," IEEE Access, vol. 9, pp. 61048–61073, 2021, doi: 10.1109/ACCESS.2021.3072849.

[42] R. A. Canessane, N. Srinivasan, A. Beuria, A. Singh, and B. M. Kumar, "Decentralised applications using ethereum blockchain," in 2019 Fifth International Conference on Science Technology Engineering and Mathematics (ICONSTEM), 2019, vol. 1, pp. 75–79.

[43] C. Rupa, D. Midhunchakkaravarthy, M. K. Hasan, H. Alhumyani, and R. A. Saeed, "Industry 5.0: Ethereum blockchain technology based DApp smart contract," Math. Biosci. Eng., vol. 18, no. 5, pp. 7010–7027, 2021.

[44] M. S. Abhijith, A. T. M. Achuthan, M. Alan Babu, and K. Shyam Krishna, "Enhanced Pharmaceutical Supply Chain Management Using Ethereum Blockchain," Int. J. Innov. Sci. Res. Technol. ISSN, no. 2456–2165, 2021.

[45] S. K. Panda and S. C. Satapathy, "An investigation into smart contract deployment on ethereum platform using Web3. js and solidity using blockchain," in Data Engineering and Intelligent Computing, Springer, 2021, pp. 549–561.

[46] P. Kamboj, S. Khare, and S. Pal, "User authentication using Blockchain based smart contract in role-based access control," Peer-to-Peer Netw. Appl., vol. 14, no. 5, pp. 2961–2976, 2021.

[47] D. Li, W. E. Wong, and J. Guo, "A survey on blockchain for enterprise using hyperledger fabric and composer," in 2019 6th International Conference on Dependable Systems and Their Applications (DSA), 2020, pp. 71–80.

[48] H. Mukne, P. Pai, S. Raut, and D. Ambawade, "Land record management using hyperledger fabric and IPFS," in 2019 10th International Conference on Computing, Communication and Networking Technologies (ICCCNT), 2019, pp. 1–8.

[49] Q. Nasir, I. A. Qasse, M. Abu Talib, and A. B. Nassif, "Performance analysis of hyperledger fabric platforms," Secur. Commun. Networks, vol. 2018, 2018.

[50] D. Ravi, S. Ramachandran, R. Vignesh, V. R. Falmari, and M. Brindha, "Privacy preserving transparent supply chain management through Hyperledger Fabric," Blockchain Res. Appl., vol. 3, no. 2, p. 100072, 2022.

[51] H. Sukhwani, N. Wang, K. S. Trivedi, and A. Rindos, "Performance modeling of hyperledger fabric (permissioned blockchain network)," in 2018 IEEE 17th International Symposium on Network Computing and Applications (NCA), 2018, pp. 1–8.

[52] "Peers — Tài liệu hyperledger-fabricdocs main." https://hyperledger-fabric.readthedocs.io/vi/latest/peers/peers.html (accessed Sep. 05, 2022).

[53] E. Gonçalves and I. Monteiro, "Reporting the Usage of iStar in a Model-Based Industrial Project to Evolve an e-Commerce Application," CEUR Workshop Proc., vol. 2983, pp. 8–14, 2021.

[54] K. Pousttchi, A. Gleiss, B. Buzzi, and M. Kohlhagen, "Technology impact types for digital transformation," Proc. - 21st IEEE Conf. Bus. Informatics, CBI 2019, vol. 1, pp. 487–494, 2019, doi: 10.1109/CBI.2019.00063.

[55] Capgemini Consulting, "Accelerating Digital Transformation," Digit. Transform. Rev., no. May, p. 62, 2013.

[56] M. Alharby and A. van Moorsel, "Blockchain Based Smart Contracts : A Systematic Mapping Study," pp. 125–140, 2017, doi: 10.5121/csit.2017.71011.

[57] I. Sarker and B. Datta, "Re-designing the pension business processes for achieving technology-driven reforms through blockchain adoption: A proposed architecture," Technol. Forecast. Soc. Change, vol. 174, no. May 2020, p. 121059, 2022, doi: 10.1016/j.techfore.2021.121059.

[58] I. A. Omar, R. Jayaraman, M. S. Debe, K. Salah, I. Yaqoob, and M. Omar, "Automating Procurement Contracts in the Healthcare Supply Chain Using Blockchain Smart Contracts," IEEE Access, vol. 9, pp. 37397–37409, 2021, doi: 10.1109/ACCESS.2021.3062471.

[59] Z. Sun, D. Han, D. Li, X. Wang, C.-C. Chang, and Z. Wu, "A blockchain-based secure storage scheme for medical information," EURASIP J. Wirel. Commun. Netw., vol. 2022, no. 1, pp. 1–25, 2022.

[60] E. Gökalp and V. Martinez, "Digital transformation maturity assessment: development of the digital transformation capability maturity model," Int. J. Prod. Res., 2021, doi: 10.1080/00207543.2021.1991020.

[61] L. Hang, I. Ullah, and D.-H. Kim, "A secure fish farm platform based on blockchain for agriculture data integrity," Comput. Electron. Agric., vol. 170, p. 105251, 2020, doi: https://doi.org/10.1016/j.compag.2020.105251.