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Blockchain-based Traceability System for Indonesian Coffee Digital Business Ecosystem

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ABSTRACT

Coffee is a crucial agricultural commodity in developing nations like Indonesia; so it is important to implement a trustworthy traceability system for the product. However, there are no established guidelines for developing a blockchain-based traceability system that the coffee industry can adopt. Therefore, this study aims to present a Digital Business Ecosystem (DBE) framework and a blockchain-based traceability system prototype for Indonesian coffee. The study process involved a literature review, field observations, and the creation of the proposed frameworks and prototypes using an integrated rapid prototyping method. The proposed DBE framework has three layers: business, digital, and infrastructure, while the prototype has use case diagrams and a model of functional, technological, and transaction flows. The system was validated through deployment tests such as recording-tracking coffee data using Ethereum smart contracts and interplanetary file system. The interconnectivity was verified through a mobile-based user interface design that includes registration and login pages, a main page, a transaction confirmation page, and a traceability page. It was discovered that the proposed framework and prototype have a high potential for real-world implementation due to their ability to effectively address the challenges and promote a positive business community culture while being supported by the mapped DBE layers. Further study is recommended to test and enhance the proposed framework and prototypes and examine the relationship between system development and technology adoption. Moreover, managerial insights were provided to the coffee business community, policymakers, and developers for the successful development of Indonesian coffee DBE with the blockchain-based traceability system.

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1. INTRODUCTION

Coffee is one of the essential commodities traded internationally. It is also the second primary commodity with the highest export value after oil in developing countries [1]. The quantity of coffee production in Indonesia is continuously increasing; thereby, making the country the fourth largest producer in the world as indicated in Figure 1. Moreover, several factors such as the species and cultivars of coffee, the presence of defective seeds, storage conditions, geographical origin, processing method, as well as roasting technique, all play a crucial role in determining the quality and taste of coffee [2]. It is also important to note that there are also concerns regarding adulteration and food mixing despite the increasing popularity of coffee [3]. Previous studies showed that despite the ability of physical, chemical, and biological analytical methods to detect the presence of adulteration in roasted and ground coffee [4-7]; they are not practical for the use in transactions between different factors within the coffee supply chain. Therefore, several traceability systems have been developed to record production activities associated with coffee starting from the plantation stage (tracing) to the movement of the product during the transaction process (tracking) [8].

Centralized-based systems experienced a wave of loss of trust due to several problems and scandals [9] such as hacking and alteration of client data by server admins

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to benefit certain parties [10]. Therefore, blockchain was introduced as a decentralized and Distributed Ledger Technology (DLT) which brings an entirely new idea to challenge the existence of a centralized system [11]. In the early decades of its launch [12], most studies were focused on its utilization in financial technology [13, 14] but the introduction of the second-generation blockchain [15] such as smart contracts & Ethereum led to the massive development of blockchain-based projects. This further contributes to a broader range of sectors such as supply chain management, finance, logistics, and security [16]. Several pilot projects observed to have been developed include land registration systems management [17, 18] and voting [19, 20] apart from the traceability system [21]. An example showed the increasing need for a reliable traceability system in the health sector to re-register the distribution of vaccines and drugs during Covid-19 outbreak [22–24]. It was also reported in the agricultural sector that blockchain has the potential to improve food integrity and safety [21, 25] through immutable production records and steps as well as product monitoring [26]. Several blockchain-based traceability systems have been developed but developing countries were observed to be facing a critical risk due to their slow movement in exploiting and adopting blockchain technology [27]. This means there is a need for a system development framework and fundamental traceability system model to resolve certain specific problems.

Therefore, a development framework that does not only focus on technology but emphasizes the solution to the problems and challenges of the business community in the coffee agroindustry is proposed in this study. It is pertinent to note that ecosystem metaphors usually describe the interactions and symbiosis between digital species and businesses [28, 29] to create new business habitats [30]. This led to the proposal of a novel Digital Business Ecosystem (DBE) framework that reduces technological complexity, is collaborative and integrated, and has never been developed before as a catalyst for a blockchain-based traceability system in the Indonesian coffee industry.

This article has 8 sections which start with the introduction followed by a literature review on blockchain coffee projects, the study gaps to be filled, an explanation on the sequence of methods applied to obtain results, and the presentation of the proposed DBE framework and blockchain-based traceability system in Indonesian coffee. The key findings and limitations are discussed, conclusions and recommendations for possible future study are provided, and the last part focuses on the managerial insights of the business community, policymakers, and system developers.

2. BLOCKCHAIN-BASED PROJECTS IN COFFEE

A reliable record system to support product traceability is one of the projects most frequently developed to address food safety and integrity issues [31]. In parallel with scientific study, several private companies have claimed to implement blockchain technology in their operations. The collected data on several blockchain coffee projects based on the acclaimed successful implementation process was used to highlight the advantages. These projects are presented in the following Table 1 based on the year they were launched.

In terms of development goals, the projects are generally expected to create a more efficient and secure system to provide real-time transaction data traceability results. It is important to note that most blockchain-based coffee traceability projects focus on increasing the transparency of transactions between actors in the supply chain. However, some projects also focus on providing economic scale-up opportunities to farmers by providing access to new capital and improving the social-environmental conditions of the coffee-producing countries.

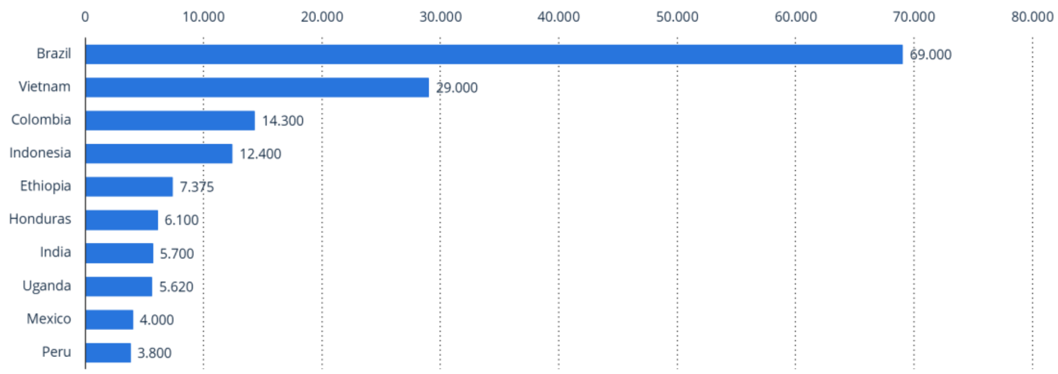

Figure 1. Coffee production worldwide in 2020 by leading country (in 1,000 60-kilogram bags)[1]

[1] www.statista.com/statistics/277137/world-coffee-production-by-leading-countries/

TABLE 1. Development Project of Coffee Traceability System Based on Blockchain Technology

Project and Initiator	**Public Launched**	**Descriptions**	**Highlighted Features**
Foodchain SpA[1] by *FoodChain*	2018	Provides the ultimate tool to follow the coffee product journey through the core engagement of the cooperative.	The company can choose the type of information to apply and share with users through a system of authorization and customized privacy.
Beyco[2] by *Progreso Foundation*	Oct 2018	Global independent coffee connection and trading platform on the blockchain. It uses a permissioned blockchain to verify the registration of all actors such as producers, exporters, importers, traders, and roasters playing a certain role in transporting coffee from the country of origin to the final consumer.	Signing smart contracts to provide connected access and chat with producers, traders, or roasters about their interests and public traceability as well as to apply for loans as a business continuity effort.
GrainChain[3] by *Medici Ventures*	May 2019	The platform includes a digital wallet enabling remote and unbanked farmers to apply for loans needed to improve their farming and crop standards. Smart contracts are used to improve traceability and logistics operations for vendors and buyers.	Product quality assurance is certified through sensors and stored using the Hyperledger-based blockchain. Payments use the dollar-backed stablecoin, GrainPay, to enable instant settlement of transactions between actors.
Yave[4] by *Yave*	May 2019	A coffee auction platform based on blockchain technology designed to remove intermediaries from the commodity or futures market and enable more transparent business between stakeholders in the coffee supply chain.	It uses Hyperledger to provide 5 excellent features which include digital ID, smart contract, direct payment, accessible record, and glass pipeline (transparency).
Farmer Connect[5], Thank My Farmer app by *IBM Blockchain*	Nov 2020	Food Trust Platform to enable a more efficient supply chain and create a better ecosystem for the global coffee farming community.	Ability to add taste profile (coffee type, acidity, sweetness, body, and intensity), filter based on taste characteristics and shareable reviews to product pages, and a fun Trivia quiz. The feature donates to local farming communities.
Angelique's Finest Goes Blockchain by *INA in Rwanda*	2020	Develop a transparent, open-source, and movable blockchain-based traceability solution that documents the path taken by coffee cherries from the planting stage to the finished product.	Development of an Open source blockchain solution to support Rwandan women farmers. Creating Digital IDs that can connect with markets and provide them with financial independence.
Emurgo Traceability Solution by *Emugo*	April 2021	Provide facilities to partner companies to track coffee products efficiently in a safe, transparent, and real-time manner. Display information such as source origin, processing date, shipping information, and other relevant data to each stakeholder at any time.	Provides a QR code for coffee products connected to the blockchain to ensure end customers have quick access to information about the origin of coffee by scanning with their smartphones.
FairChain Coffee[6] by *FairChain Foundation*	Nov 2021	It enables all stakeholders – growers, roasters, and consumers to access data across the supply chain and provides a fair-trading platform for coffee. Provide transparency to consumers regarding the origin and quality of the product.	Build a platform to radically improve the fair share of the deal, especially for farmers growing premium quality coffee, and to provide fair deals for their efforts.

From the regional perspective, it was discovered that most of these projects aim to solve the challenges in the coffee industries outside the Asian area. For example, the project initiated by Food-Chain[3] seeks to provide a recording system to secure the "distinctive ritual" of Italian espresso coffee. The blockchain-based system to support Rwandan women farmers created by INA project also focuses on encouraging Rwandan coffee production to meet the German market. Another point was that Rwandan coffee serves as a pilot project for the

[1] www.food-chain.it/public/case/san-Domenico
[2] www.beyco-nl.medium.com/the-different-forms-of-blockchain-284323b93ee2
[3] www.prnewswire.com/news-releases/grainchain-uses-blockchain-to-unite-honduras-coffee-industry-300923854.html
[4] www.gcrmag.com/yave-to-hold-worlds-first-blockchain-coffee-auction
[5] www.farmerconnect.com/traceability-solutions, www.ibm.com/thought-leadership/coffee
[6] www.fairchain.org/blockchain-info

traceability system designed by Starbucks in addition to the Colombian and Costa Rica coffee. Moreover, the pilot fair trade system was developed by FairChain for farmers of Moyee Coffee offering arabica beans from Ethiopia, Kenya, and Colombia. Emurgo also recently developed coffee traceability information services for Koerintji coffee in Southeast Asia but partnered with ALKO as an intermediate actor. This means the process required only passive input from the Koerintji coffee farmers and related communities.

Several companies have used platforms such as Food Trust designed by IBM which was applied directly by Sical[1] and Sucafina Specialty[2] to brand and provide added value to their products. However, it was discovered that there is no project designed to use a public blockchain-based traceability system for the coffee business community. There is also none developed to create and apply a DBE framework in the coffee industry. Therefore, this study seeks to fill this gap by providing alternative solutions while considering projects previously launched.

3. STUDY GAP

Taste, as a representation of coffee quality, is the most critical factor for consumers to make purchasing decisions [32]. This means improving the quality of Indonesian coffee can increase its global market but the process requires attention and good governance in collaboration with farmers [33]. Moreover, the integration of digitalization into the industry has a strong causal relationship with labor conditions, supply chain financing accessibility, and social responsibility [34]. This shows there is a need to adapt digital technology to the Indonesian coffee business community to solve environmental, economic, and social challenges [35].

Blockchain is an emerging technology with great potential to support sustainable agriculture and food security [36]. However, its implementation requires considering usability and flexibility before developing the applications in the business domain [37]. It has also been previously reported that integrity, decentralization, and tampering resistance are the characteristics of blockchain technology needed to meet the trust and transparency requirements of the system [25]. They serve as the principal features of applying blockchain technology as a reliable traceability system. Several studies have highlighted its great potential in the traceability of food and agricultural products but there is a need for the development of the system with due consideration for its properties, technology challenges, and specific case studies. Some of the properties requiring analysis before selection include the architecture, type, consensus, and platform [38]. Meanwhile, the technology challenges were related to the fundamental infrastructure, technical challenges, and data authenticity [39].

This study proposes a DBE framework for Indonesian coffee with a prototype of a blockchain-based traceability system as part of the digital layer. Previous studies have attempted to develop a coffee traceability system based on blockchain technology but none discussed the DBE framework encouraging the development of a blockchain-based traceability system with due consideration for the coffee business community. Therefore, this study is essential to describe the critical success factors to implement the proposed blockchain-based traceability system in the coffee industries through the framework and prototype proposed. The slices of the study gap discussed are presented in Figure 2.

4. METHOD

The first phase of this study focused on reviewing the literature on blockchain coffee projects, the condition of Indonesian coffee, and DBE development. Moreover, the problems of Indonesian coffee in the real world were explored through field observations and interviews conducted at the Kintamani coffee agroindustry in Bali. This was followed by the design of the proposed Indonesian coffee DBE framework based on work conducted by Nachira et al. [28], Corallo et al. [29] and the study gaps proposed by Senyo et al. [40].

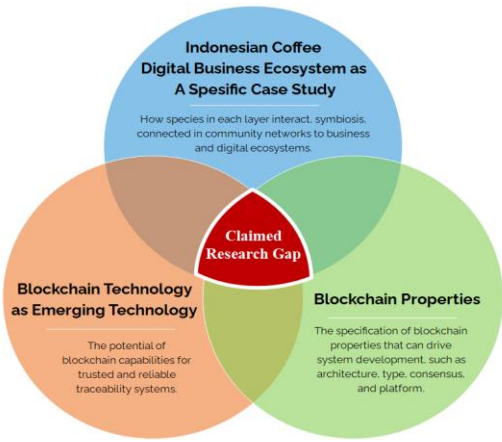

Figure 2. Claimed Study Gap

[1] www.esmmagazine.com/a-brands/sical-launches-limited-edition-coffee-with-blockchain-technology-225631, www.cointrust.com/market-news/sical-unveils-blockchain-certified-coffee-varieties

[2] www.sucafina.com/na/news/introducing-farmer-connect-coffee-transparency-through-blockchain-technology

The second phase was used to develop a prototype of a traceability system based on blockchain technology with due consideration for the blockchain coffee project previously analyzed. The proposed prototype was developed using the integrated rapid prototyping method [41, 42] including structuring system requirements [43] with the Unified Modeling Language (UML) [44], the development of the architectural layer and User Interface (UI) [45], and the consideration of the blockchain-traceability approach proposed by Betttin-Diaz et al. [46]. Finally, the prototype was validated through a deployment test process on the Ethereum network using two functions written into a smart contract and storing off-chain data on Interplanetary File System (IPFS).

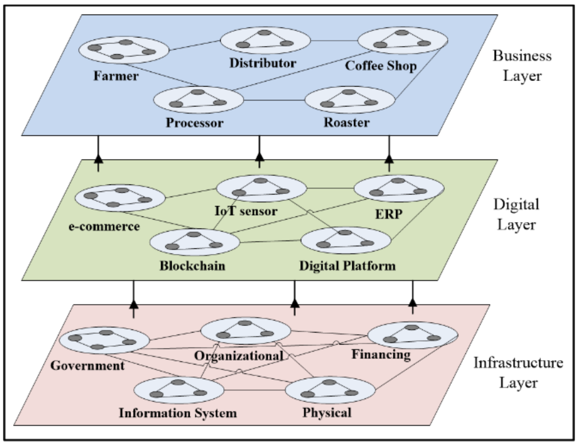

Figure 3. Proposed DBE for the Indonesian Coffee agroindustry

5. INDONESIAN COFFEE DBE

An in-depth analysis led to the proposition of a DBE framework for the Indonesian Coffee agroindustry with 3 main layers including business, digital, and architecture. At the business layer, the analysis showed that the Indonesian coffee industry currently has a good business ecosystem associated with production-consumption trends. The total coffee production over the past 5 years (2015-2019) in the country was observed to have an increasing linear trend [47] which strengthened its position as the fourth largest coffee-producing country after Columbia, Vietnam, and Brazil [48]. From the consumption perspective, Toffin [49] reported a threefold increase in coffee shops in Indonesia between 2016 and 2019. This was further confirmed by ICO data through the indication of a Compounded Annual Growth Rate (CAGR) value of 0.6% for coffee consumption which is higher than the average global value [50]. The increasing production and consumption (supply-demand) of coffee are good indicators of the development of the business ecosystem in Indonesia.

Key stakeholders in the Indonesian coffee agroindustry supply chain were also identified to form a business layer framework. The observation of the case study showed that the five main actors include the farmers, processors, distributors, roasters, and coffee shops with each playing specific roles in providing added value to coffee products followed by subsequent distribution to the next chain. At first, each actor is an individual species in the ecosystem but they come together to form a community interacting in the business ecosystem of the industry. The interactions are usually based on the principle of mutual benefit and adding value to the product. This business ecosystem is the top layer and this is the reason it is the most visible as indicated in Figure 3.

The second layer of the proposed Indonesian coffee DBE framework required mapping existing digital species and it was discovered several digital species are interacting in the industry such as blockchain, e-commerce, Internet of Things (IoT) technology devices, Enterprise Resource Planning (ERP) applications, and other digital platforms as presented in Figure 3. It is pertinent to note that the digital layer communities need to be developed using emerging technologies and encouraging interactions with other digital species to produce a trusted and reliable coffee traceability system. As a digital species, blockchain has excellent potential as the underlying technology for traceability systems. This is due to its ability to increase the flow of accurate information, reduce transaction costs, and encourage fair prices for all actors [51]. Moreover, the symbiosis between blockchain and other digital species existing in the Indonesian coffee industry was reported to have improved coffee market channels, reduced distribution intermediaries, assisted smallholder farmers to access the market, and provided new payment system options [52]. This means the blockchain-based traceability system needs to be developed within the Indonesian coffee DBE framework to address the challenges in the industry.

Finally, the identification results were used to propose an infrastructure layer that forms the basis for the two previous layers. This third layer consists of several main species including (1) the government and its regulations regarding coffee and traceability systems [53], (2) basic information systems such as population identity, (3) organizational structure and patterns of institutional development, (4) internet towers and other physical components, and (5) financing for the development of DBE as shown in Figure 3.

The Indonesian government issued regulations on Geographical Indication (GI) certification to guarantee the originality and quality of Indonesian coffee and strengthen its competitiveness. This certification shows the area of origin of an item or product which, due to geographical, environmental factors including natural, human, or a combination of the two, gives reputation, quality, and unique characteristics to the goods or products produced[1]. There are at least 32 types of Indonesian coffee that have received GI certification, starting with Bali Kintamani Coffee[2] (2008). The coffee stakeholders initiated by the government have also formed an organization known as the Society for the Protection of Geographical Indications (abbreviated as MPIG). MPIG is tasked with the responsibility of setting boundaries and providing guidelines to maintain coffee GIs such as the establishment of a traceability system.

The observation also showed that other species of infrastructure layer have fulfilled the minimum requirements to develop Indonesian coffee DBE. This is indicated by the availability of an electronic identity system for Indonesian residents, 5G, and almost the coverage of 4G networks in every area of the coffee industry, as well as the finance provided for system development in the department of agriculture. Therefore, blockchain is considered an emerging technology which is feasible to be developed as the underlying traceability system as well as to support the realization of DBE for Indonesian coffee.

6. DEVELOPMENT OF A BLOCKCHAIN-BASED TRACEABILITY SYSTEM

6. 1. Requirement Engineering

Stakeholders as users of the traceability system to be developed were successfully identified at the requirements determination stage. The information obtained was used to determine the interaction between the user and the proposed system as shown in the use case diagram presented in Figure 4. It is pertinent to note that each stakeholder in the coffee business community was identified as a user with the ability to log in (including register), confirm transactions, and track products. Moreover, the prototype used a permissioned system to ensure only the specified stakeholders can register as users by selecting the appropriate role during the process of accessing the system. The registration was also used to eliminate intermediary actors that usually disrupt the continuity of transactions between farmer-processors and processors-distributors.

Each actor is required to record the data related to its selected role. For example, the farmers are required to enter the data about cherry bean harvesting, information about the processing by the processor, packaging size and distribution route by the distributor, as well as the roasting and brewing data by the roasters and coffee shops. Finally, all the users and end customers can trace the coffee and store the data by entering the product ID code.

This study used three subsystems for the data recording and tracking process. First, the APIAuth subsystem processes each user's registration data to obtain an access code on the traceability system. Second, smart contracts are the core subsystem containing the agreement algorithms between users in the system and are applied to ensure a confirmation by the intended user before the transaction is successful and stored on the blockchain. Third, the IPFS subsystem was used for the distributed off-chain data storage.

The analysis also produced the minimum data required in addition to proposing system and user interactions as shown in Table 2. This was divided into internal and external records. The internal records include the activities of each user during a transaction

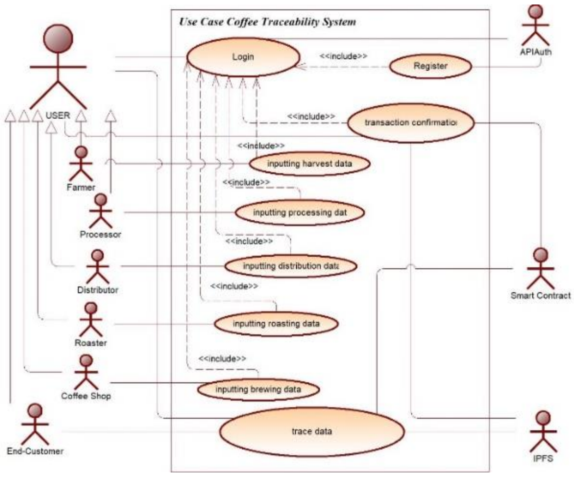

Figure 4. A proposed use case diagram

TABLE 2. Minimum data requirements

Variable	Contents
	Internal Record
Profile	Name, ID+, Business Location, Business Properties
Process	Cultivation, Production, Processing, and other Business activities
Additional Documents	Product Photos, Activity Documentation, SOP+, Standard compliance
	External Record
Origin	Varieties, Time, Timestamp, Location, Actor path
Link	The hyperlink to the shared additional document
Quality	GAP, GMP, GHP, SCAA, SNI+

+ID = Identity, SOP = Standar Operational Procedure, GAP = Good Agricultural Practices, GMP = Good Manufacturing Practices, GHP = Good Handling Practices,
SCAA = Specialty Coffee Association of America, SNI = Standar Nasional Indonesia (Indonesian National Standard)

[1] www.dgip.go.id/menu-utama/indikasi-geografis/pengenalan

[2] https://ig.dgip.go.id/

including the user profiles, product processing history according to their roles, and additional documents such as product photos and standardization documents. Meanwhile, the external records are data elicited from other sources such as seed variety certificates and quality standard documents as well as those recorded automatically by the system such as the timestamps and links to related documents.

6. 2. Modeling of The Proposed Prototype

6. 2. 1. Proposed Functional Model The system requirements analysis was used to propose a functional model of a traceability system with a focus on two main streams as presented in Figure 5 including (1) the flow of physical products and (2) the flow of information. These streams are required to be under the umbrella of the applicable regulations, certification, and food safety agreements set by the authority where the system is to be applied. Figure 5 shows the functional model proposed for the Indonesian coffee traceability system. It is important to note that each actor is expected to process coffee to ensure the products have added value in each of the streams. Moreover, the internal and external data recorded serve as a prerequisite for actors in the supply chain to make transactions. The transactions are subsequently stored on the blockchain network through a unique code embedded in each batch of products processed. The code for each product is formed into a QR code to make the tracking of the internal and external traceability processes easy.

6. 2. 2. Proposed Technological Architecture Model A model of technological architecture consisting of four layers was proposed to ensure the adequate development of the blockchain-based coffee traceability system. These include sensing, network, service, and application as shown in Figure 6. The QR code scanner has a sensor to obtain a unique code attached to coffee products for tracking purposes. Moreover, an internet connection and an Ethereum network are required at the network layer to perform transactions, record, and track. The interconnection between the blockchain network as a back-end and front-end display also requires services from the Web3 API. Furthermore, the data is large but there is a unified whole in transactions in the IPFS to ensure the blockchain stores the hash code of the file location. The application layer is the spearhead of the layer interacting with the user and this led to the application of a responsive web-based interface on mobile devices.

6. 2. 3. Proposed Transaction Flow Model This section was used to propose a transaction flow model consisting of 10 stages for one successful transaction cycle as shown in Figure 7. The transaction was designed to be initiated through the application UI when the registered user opens the system. The first transaction flow stores the large file in IFPS such as the product sample photo that can be used to check green bean defect standards. Furthermore, the hash address of IFPS can be obtained from the file stored and later displayed on the web application. The users are also allowed to enter the code containing the information on the coffee to be traded such as quantity and variety. The registered account is to be confirmed by the Ethereum or smart contract via the MetaMask wallet system. The response showing the account has connected to the network is then displayed to the user. It is also important to note that users are to receive notifications as a response from the system. Next, the system requests transactions to be stored on the blockchain network through a consensus algorithm on

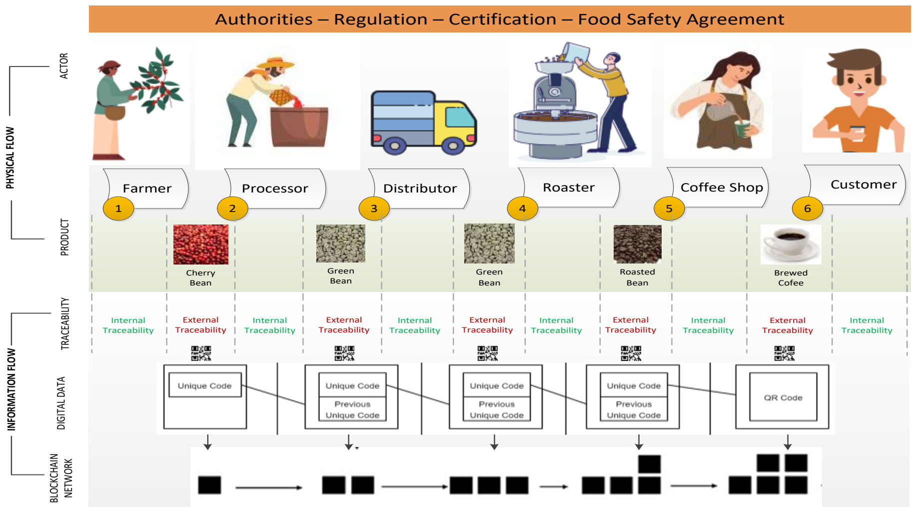

Figure 5. Proposed Functional Model of Indonesian Coffee Traceability System based on Blockchain Technology

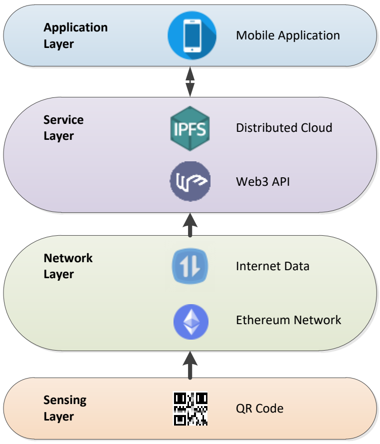

Figure 6. Proposed technological architecture model

the Ethereum network. In the end, the data stored in the traceability system is displayed as a successful transaction. The user gets a response as the final result of the transaction. The dotted line in Figure 7 separates the back-end and front-end environments of the proposed system, and the color differences indicate the different grouping of the system components.

6. 3. Verification and Validation of the Proposed System

6. 3. 1. Deployment Test The deployment test was used as the verification and validation step to provide a reliable blockchain-based coffee traceability system. It was discovered from the analysis conducted on the needs of the Indonesian coffee business community that at least 2 main functions are needed in the traceability system, and these include adding transactions to record data and tracing transactions to track coffee products. The deployment tests were performed using the sample solidity code shown in Figure 8 to represent the smart contract. The agreement shows each user is allowed to

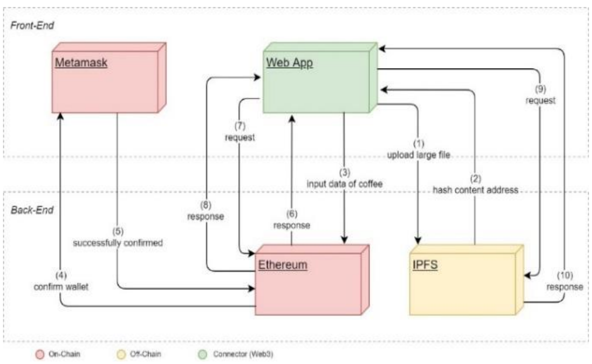

Figure 7. Proposed Transaction Flow Model of Blockchain-based Traceability System

```
pragma solidity 0.5.1;

contract traceability {
    uint256 public trxCount = 0;
    mapping(uint => transaction) public lihatTransaction;

    struct transaction{
        uint id;
        string varietas;
        int amount;

    }

    function addTransaction(string memory varietas, int amount) public {
        trxCount += 1;
        lihatTransaction[trxCount] = transaction(trxCount, varietas, amount);
    }
}
```

Figure 8. Example of solidity code for smart contract on Ethereum blockchain

enter the variety and quantity of each coffee product transacted. It is important to note that the application of different case studies can make smart contracts to be more complex and not limited to the management of multiple variables, functions, or data types. The deployment test validated that: (1) the addTransaction function stores variable and variable data on blocks on the Ethereum network and (2) lihatTransaction displays transactions made according to the hash record of the transaction.

In addition to testing the transaction process on the on-chain network (Ethereum), the off-chain data storage was also assessed in the form of green bean photos on the IPFS network. Figure 9(a) shows the process of inputting a file and the result of the hash address when submitted. It was discovered that the hash address used to identify the saved file is displayed in Figure 9(b) and later added as data stored in the on-chain. This test proves that additional files can be stored on IPFS and generate hash addresses as an alternative solution for the storage of large files when developing a proposed blockchain-based traceability system.

6. 3. 2. Designing UI A mobile-based UI prototype was designed to visualize the proposed

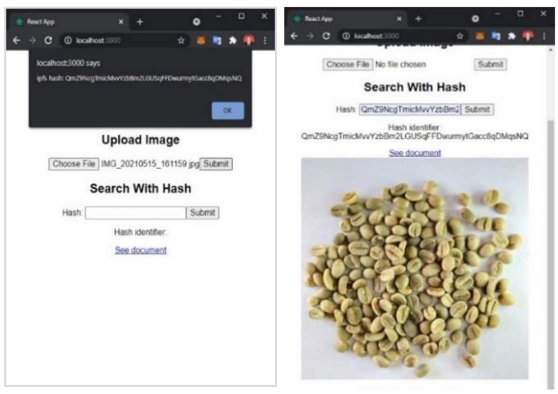

Figure 9. Deployment test on IPFS (a) Add green bean photos as an additional file (b) Result for the tracing of hash address

traceability system as shown in Figure 10. The four main components considered include the (a) login and register forms to select roles according to the use case of each actor in the supply chain, (b) the homepage which contains page information, profile information, action buttons to add and track transactions, as well as history and pending transaction information, (c) pages to confirm transactions, and (d) pages to trace the coffee products by end consumers. The register/login form validates the permissioned system requirements of each user while the addTransaction button and page to confirm transactions validate the user's need for reliable records. Finally, the traceability page verifies the success of the subsystem component and displays the time-based track of coffee products.

7. DISCUSSION AND CONCLUSION

7. 1. Blockchain-based Traceability System as Indonesia Coffee DBE Coupling

This study focuses on DBE conceptualization and technical issues to address the challenges of developing DBE frameworks and models [40]. It has been generally proven that the development of a model providing all information related to agricultural production such as varieties, cultivation and treatment methods, as well as other information attracts customers [54]. Moreover, previous studies have proposed a DBE framework in the agricultural sector [55, 56] with case studies to develop a responsive supply chain system for pineapple and frozen shrimp traceability systems. These studies confirmed the business community's lack of knowledge, entrepreneurship, and technology adoption capabilities [29]. Therefore, this study focused on developing the DBE model further to provide affordable ICT solutions for upstream actors (farmers) and Micro Small Medium Enterprises (MSMEs) considered to be members of the business ecosystem. The aim was also to provide a prototype to serve as a fundamental guideline to develop a blockchain-based traceability system that can be replicated easily by the coffee business community. To achieve this goal, there was consideration for robust, inexpensive, and easy-to-apply technology components with significant impact on the ecosystem.

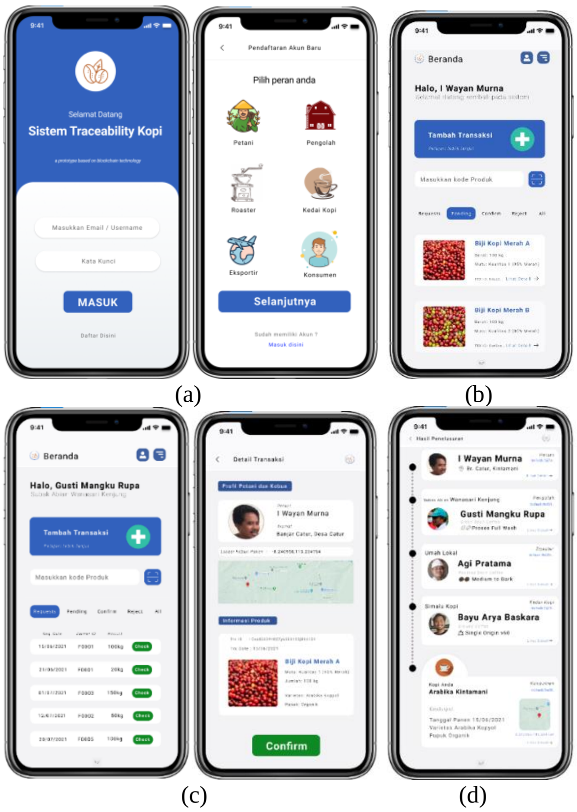

Figure 10. Proposed UI for (a) login and registration form, (b) homepage and addTransaction form, (c) transactions confirmation by the processor from farmers, and (d) time-based traceability page of coffee product

A blockchain-based coffee traceability system prototype was proposed using the configurations applied in several previous studies [57–60]. The process involved the application of Ethereum and IPFS networks with other supporting architectures and tools presented in Figure 6 to address the industry's usability, reliability, and scalability issues [37, 61–63]. It is pertinent to note that the IPFS is a technology enabler allowing a "decentralized database+blockchain" dual storage system structure through on-chain and off-chain mechanisms as indicated in Figure 7. It has been noted in previous studies that the proposed system has the ability to effectively reduce chain load pressure and realize efficient information queries [64, 65]. Moreover, the public-permissioned blockchain network was proposed by requiring a user registration process and transaction confirmation for each record made as indicated in Figure 4. This is to ensure privacy data security [66], a reduction in data entry errors, and a decrease in the risk of tampering [67], thereby, leading to an increase in the trust of the users in the system. It is pertinent to note that the public-permissioned network was selected because it is the most promising platform for a digital traceability system in the food industry [68]. Furthermore, a mechanism was designed to input and trace data by using QR Codes to mark each coffee product life cycle in the supply chain flows. The application of the QR Code is due to the convenience and simplicity provided for users in identifying products and inputting new data in subsequent transaction processes with minimal cost [69]. Lastly, several UIs were proposed to address the challenges associated with recording the data by supply chain actors and to provide immutable and traceable data benefits [70]. A time-based UI design was also proposed as indicated in Figure 10 due to the preference of the product origin traceability by end consumers [71].

A functional or operational system mechanism was also proposed as shown in Figure 5 to create internal and external traceability processes using the minimum input data presented in Table 2. Moreover, the standards of compliance with external data were proposed to include the components of local wisdom at each location of the Indonesian coffee GIs to encourage the sustainability of the coffee industry [72]. For example, there is an agricultural organization called Subak (a member of MPIG) in the Kintamani Coffee agroindustry, Bali with a philosophy of Tri Hita Karana (three causes of prosperity). This philosophy encourages a work culture in the business community such as good governance [73], adoption of innovation, farmer's welfare [74], sustainability [75], and fraud prevention [76]. It was discovered that the guidelines developed by Subak support food security programs, water distribution and allocation management, mobilization of resources for operations and maintenance, and facilitation of fund raising and conflict management [77]. This means the Tri Hita Karana philosophy set as the compliance standard for blockchain-based traceability systems influences the work culture of human resources in the Kintamani coffee supply chain. The phenomenon is ultimately expected to create a favorable ecosystem in the interconnection between coffee business species.

The proposed blockchain-based traceability system is expected to technically encourage digital layer interconnection with the supporting digital components integrated into immutable-decentralized storage. This means the proposed system is acting as a coupling to create the DBE of the Indonesian coffee industry. It was discovered to have a better sensitivity to real-world demands because it is based on capturing and analyzing the problems of the coffee business community at the business layer. Moreover, it provides an integrated digital platform and accommodates business processes. This simply means the proposed system has a higher success rate for implementation in the real world because it answers real challenges, encourages the good business community's culture, and is supported by a mapped infrastructure layer.

7. 2. Findings, Limitations, and Recommendations

This study has several significant findings. First, eight blockchain-coffee projects publicly launched were mapped with the core highlight features published in each considered in developing other coffee industry projects. Second, the DBE framework was developed for Indonesian coffee with three essential layers including business, digital, and infrastructure. Third, a prototype of a coffee traceability system was successfully proposed based on blockchain technology using properties that match the challenge and community needs in the Indonesian coffee industry. As an integral part of the proposed DBE framework, the prototype proved to have a better success rate for implementation and can be used as a basic model to develop traceability systems in several Indonesian coffee industrial areas.

The subjectivity of studies in translating observations and interviews is one of the weaknesses of this study and can affect the final results in several sections. Moreover, there is a need for a more in-depth verification and validation process to increase the reliability of the results. The proposed system configurations were based on the perspective of the authors that participated as users and this means there is a possibility of different decisions when a model is developed based on other views such as the government's perspective. Furthermore, the focus was only on one species at the digital layer, blockchain, which was argued to be an emerging core technology with the potential to serve as the underlying technology to design a traceability system in the DBE of the Indonesian coffee industry. The stages of field observation and case study interviews were also limited to the Kintamani coffee agroindustry in Bali and this reduces the generalizability of the findings.

The results can be used by scholars and practitioners to develop a blockchain-based traceability system for the Indonesian coffee agroindustry or coffee agroindustry in general. For academics, it is recommended that future studies are focused on (1) further development or testing of the model proposed with due consideration for the required novelty gaps in blockchain projects on coffee as described in section 2 and recommendations made by Senyo et al. [40] to fill DBE gaps in theories, methodologies, and themes. (2) The proposed DBE model requires a performance evaluation using the method proposed by Sadri et al. [78] based on the layer components or those considered to be sensitive to the system.

At the infrastructure layer, (3) it is recommended that the development of the physical architecture using Radio Frequency Identification (RFID) [69] has been studied for more efficient product detection and IoT integration [79, 80]. In the software development process, there is a need to (4) consider the Blockchain Development Life Cycle (BDLC) framework proposed by Takyar[1] and iFour[2] as the method to develop a coffee traceability system in the future. It is also necessary to add monitoring and evaluation stages to the application model generated using valid verification and validation methods. Another important suggestion is that (5) several technical developments need to be conducted on the digital layer of the Indonesian coffee ecosystem to increase the capability and automation of the blockchain-

[1] www.leewayhertz.com/guide-to-blockchain-development-process

[2] www.ifourtechnolab.com/blog/blockchain-project-development-life-cycle

based traceability system. Furthermore, studies on adding machine learning techniques to classify the quality and adulteration of coffee [81, 82] or clustering as an approach to detect product mixing [83] need to be conducted. Some essential features such as notifications on product demand forecasting to provide production plans [84] are also suggested to be added. Moreover, there is a need to consider a broader scope of technology such as artificial intelligence, IoT, and cyber-physical systems. (6) It is also important to develop a copy traceability system in the future using the Hyperledger platform due to the ever-evolving blockchain technology as well as to use smart contracts with due consideration for the usage cases and requirements of the business community [85–88].

It was assumed that the components outside the developed model ideally support the proposed Indonesian Coffee DBE. Therefore, the recommendation for future study is to (7) measure the requirements and readiness value of implementing the proposed model [89]. Moreover, previous studies have reported a lack of understanding and limited application of blockchain technology in MSMEs in Indonesia [90, 91]. This led to the need to evaluate the acceptance and adoption of blockchain technology, especially in the coffee agroindustry, in future studies [92]. Finally, (8) there is also the need to study the closed-loop supply chain domain of agroindustry [93, 94] to support a sustainable environment and circular economy [95, 96].

8. MANAGERIAL INSIGHT/ACUMEN

The results from the field analysis, literature, and model development were used to present a comprehensive reference for decision-making in relation to the development of Indonesian coffee DBE. Moreover, the increasing trend of system development based on blockchain technology, especially for coffee traceability, led to some insights recommended to be adopted by the community, policymakers, and developers.

- The coffee business community first needs to pay attention to the success of forming a business community network with positive and cooperative interactions or mutualism between the species. For example, some fundamental things need to be regulated and determined such as the interaction patterns, transaction rules, and boundaries between each community. Furthermore, the business community needs to agree on the properties of the digital technology used and encourage the development of fundamental infrastructure by relevant stakeholders. The digital properties agreed upon should become the guidelines and proposals to develop the digital ecosystem layer.
- Regulators and government can play a more active role in developing the DBE of the Indonesian coffee industry. This is due to the fact that infrastructure development is an enabler for the development of the digital and business layer and this means it requires the attention of policymakers. Regulations are also needed to ensure the availability of fundamental infrastructure to develop the DBE. Furthermore, the government needs to be open to input from the business community, consider digital layer development proposals, and conducted development analysis with developers. Using a third-person point of view, the government can also develop alternative models such as systems based on Hyperledger. However, the implementation of such development requires the government, as a system request, to define its authority in the system to avoid destabilizing the trusted decentralization database system.
- Developers also need to ensure the model is not limited to software development but involves hardware and human components of the business community. The use of physical components such as IoT sensors, RFID, and other needs to be considered to increase system efficiency and the effectiveness of interactions among the Indonesian coffee business community. Finally, this insight is not limited to the development of Indonesian coffee DBE but extended to similar business ecosystems with several configurations tailored to the specific case studies to be completed.

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Persian Abstract

چکیده

قهوه یک کالای مهم کشاورزی در کشورهای در حال توسعه مانند اندونزی است. بنابراین اجرای یک سیستم قابل ردیابی قابل اعتماد برای محصول بسیار مهم است. با این حال، هیچ دستورالعمل مشخصی برای توسعه یک سیستم ردیابی مبتنی بر بلاک چین وجود ندارد که صنعت قهوه بتواند آن را اتخاذ کند. بنابراین، این مطالعه با هدف ارائه یک چارچوب اکوسیستم کسب و کار دیجیتال (DBE)و یک نمونه اولیه سیستم ردیابی مبتنی بر بلاک چین برای قهوه اندونزی است. فرآیند مطالعه شامل بررسی ادبیات، مشاهدات میدانی، و ایجاد چارچوب‌ها و نمونه‌های اولیه با استفاده از روش نمونه‌سازی سریع یکپارچه بود. چارچوب DBE پیشنهادی دارای سه لایه است: تجاری، دیجیتال و زیرساخت، در حالی که نمونه اولیه دارای نمودارهای مورد استفاده و مدلی از جریان های عملکردی، تکنولوژیکی و تراکنش است. این سیستم از طریق آزمایش‌های استقرار مانند ضبط و ردیابی داده‌های قهوه با استفاده از قراردادهای هوشمند اتریوم و سیستم فایل بین سیاره‌ای تأیید شد. اتصال متقابل از طریق طراحی رابط کاربری مبتنی بر تلفن همراه که شامل صفحات ثبت نام و ورود به سیستم، صفحه اصلی، صفحه تایید تراکنش و صفحه قابلیت ردیابی است، تأیید شد. مشخص شد که چارچوب و نمونه اولیه پیشنهادی به دلیل توانایی آنها در مقابله موثر با چالش‌ها و ترویج فرهنگ مثبت جامعه تجاری در حالی که توسط لایه‌های DBE نقشه‌برداری شده پشتیبانی می‌شوند، پتانسیل بالایی برای پیاده‌سازی در دنیای واقعی دارند. مطالعه بیشتر برای آزمایش و تقویت چارچوب و نمونه های اولیه پیشنهادی و بررسی رابطه بین توسعه سیستم و پذیرش فناوری توصیه می شود. علاوه بر این، بینش های مدیریتی برای توسعه موفقیت آمیز DBE قهوه اندونزی با سیستم ردیابی مبتنی بر بلاک چین به جامعه کسب و کار قهوه، سیاست گذاران و توسعه دهندگان ارائه شد.