MODELING AN AUCTION SYSTEM BASED ON INTEGRATED BLOCKCHAIN AND ERP FOR CRUDE PALM OIL (CPO) COMMODITY

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AGROINDUSTRIAL ENGINEERING
GRADUATE SCHOOL
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Bogor, June 2023

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RINGKASAN

ARIES HARRY PRATAMA. Modeling an Auction System Based on Integrated Blockchain and ERP for Crude Palm Oil (CPO) Commodity. Dibimbing oleh TAUFIK DJATNA dan DWI SETYANINGSIH.

Penjualan Crude Palm Oil (CPO) di Indonesia biasanya melibatkan lelang tradisional. Mekanisme lelang unit tunggal tradisional untuk item multi-unit sering menyebabkan inefisiensi dalam alokasi sumber daya, karena kuantitas yang dilelang mungkin tidak sesuai dengan kebutuhan aktual pembeli. Selain itu, ketergantungan pada database terpusat dalam proses lelang menimbulkan masalah kepercayaan, karena bergantung pada otoritas tunggal untuk memelihara dan mengelola data. Selain itu, keterbukaan informasi yang terbatas menghambat daya saing dan keadilan lelang. Untuk menjawab tantangan tersebut, penelitian ini mengusulkan model Integrated Blockchain dan ERP-Based Auction (IBEA) untuk perdagangan Crude Palm Oil (CPO). Model IBEA menawarkan dua solusi inovatif untuk meningkatkan efisiensi, kepercayaan, dan keadilan sistem lelang. Pertama, ini menggabungkan mekanisme lelang multi-unit, memungkinkan pembeli untuk memilih jumlah CPO yang diinginkan dan mengoptimalkan alokasi sumber daya yang sesuai. Hal ini memastikan keselarasan yang lebih baik antara jumlah yang dilelang dan kebutuhan khusus pembeli. Kedua, model IBEA mengintegrasikan teknologi blockchain, menyediakan buku besar terdesentralisasi untuk mencatat dan memverifikasi transaksi lelang. Ini menghilangkan ketergantungan pada otoritas pusat, mengurangi risiko bias atau manipulasi dalam proses lelang. Transparansi yang ditawarkan oleh blockchain menumbuhkan kepercayaan di antara para peserta, memungkinkan mereka memverifikasi integritas lelang secara independen dan mencegah gangguan penawaran. Dengan menggabungkan manfaat teknologi blockchain dan sistem ERP, model IBEA yang diusulkan merevolusi perdagangan CPO dengan meningkatkan alokasi sumber daya, memastikan keadilan, dan menumbuhkan kepercayaan di antara peserta.

Kata kunci: CPO, lelang, blockchain, ERP

SUMMARY

ARIES HARRY PRATAMA. Modeling an Auction System Based on Integrated Blockchain and ERP for Crude Palm Oil (CPO) Commodity. Supervised by TAUFIK DJATNA and DWI SETYANINGSIH.

The sale of Crude Palm Oil (CPO) in Indonesia typically involves traditional auctions. The traditional single-unit auction mechanism for multi-unit items often leads to inefficiencies in resource allocation, as the auctioned quantity may not align with the buyer's actual needs. Moreover, the reliance on a centralized database in the auction process raises trust issues, as it depends on a single authority to maintain and manage the data. Additionally, limited information disclosure hampers the competitiveness and fairness of the auction. To address these challenges, this research proposes an Integrated Blockchain and ERP-Based Auction (IBEA) model for the trading of Crude Palm Oil (CPO). The IBEA model offers two innovative solutions to enhance the efficiency, trust, and fairness of the auction system. Firstly, it incorporates a multi-unit auction mechanism, allowing buyers to select their desired quantity of CPO and optimize resource allocation accordingly. This ensures a better alignment between the auctioned quantity and the buyer's specific needs. Secondly, the IBEA model integrates blockchain technology, providing a decentralized ledger for recording and verifying auction transactions. This eliminates the reliance on a central authority, reducing the risk of bias or manipulation in the auction process. The transparency offered by the blockchain fosters trust among participants, enabling them to independently verify the integrity of the auction and prevent bid tampering. By combining the benefits of blockchain technology and ERP systems, the proposed IBEA model revolutionizes the trading of CPO by improving resource allocation, ensuring fairness, and fostering trust among participants.

Keywords: CPO, auction, blockchain, ERP

MODELING AN AUCTION SYSTEM BASED ON INTEGRATED BLOCKCHAIN AND ERP FOR CRUDE PALM OIL (CPO) COMMODITY

ARIES HARRY PRATAMA

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PREFACE

Praise and gratitude are offered to Allah subhanaahu wa ta'ala for all His blessings, enabling the completion of this scientific work. The chosen theme of the research conducted from month February 2023 to June 2023 is Blockchain, with the title " Modeling an Auction System Based on Integrated Blockchain and ERP for Crude Palm Oil (CPO) Commodity ".

The author would like to express gratitude to the supervisors, Prof. Dr. Eng Taufik Djatna, STP., MSi, and Dr. Dwi Setyaningsih, STP, MSi, who have provided guidance and valuable suggestions. Thanks are also extended to the academic advisor, seminar moderator, and external examiners of the supervisory committee. Furthermore, the authors express their appreciation to PT Inacom for providing information on the requirements engineering process for this research. We would also like to thank my father, mother and all my family for their support and prayers while I was finishing this thesis. I would like to thank all of my friends from the Magister Program of Agroindustrial Engineering IPB, especially friends to study together and the Sensei Group.

May this scientific work be beneficial to those in need and contribute to the advancement of knowledge.

Bogor, June 2023

Aries Harry Pratama

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GLOSSARIES

Crude Palm Oil (CPO)	:	The raw oil extracted from the fruit of oil palm trees is widely used in various industries.
Traditional Auctions	:	Conventional methods of selling goods or commodities where potential buyers compete by offering bids, and the highest bidder wins.
Multi-unit Items	:	Goods or commodities sold in bulk or large quantities, rather than as individual units.
Resource Allocation	:	The process of distributing and assigning resources, such as goods, services, or funds, efficiently and effectively.
Centralized Database	:	A single, central authority is responsible for storing and managing data in a specific system or organization.
Trust Issues	:	Concerns related to the reliability, integrity, or security of a system that depends on a single authority to maintain and manage data.
Information Disclosure	:	Providing relevant and necessary information to participants in a transaction or process.
Competitiveness	:	The ability of participants or entities to effectively compete against each other in terms of price, quality, or other factors.
Fairness	:	The quality of being just, equitable, and unbiased in the treatment of individuals or entities.
Integrated Blockchain and ERP-Based Auction (IBEA) Model	:	A proposed model that combines blockchain technology and Enterprise Resource Planning (ERP) systems to enhance the efficiency, trust, and fairness of the auction system for trading Crude Palm Oil.
Multi-unit Auction Mechanism	:	An auction mechanism that allows buyers to specify the desired quantity of the commodity they want to purchase, enabling more flexible resource allocation.
Decentralized Ledger	:	A distributed ledger system that records and verifies transactions across multiple participants or nodes, eliminating the need for a central authority.
Bias or Manipulation	:	Unfair or dishonest practices that could influence the outcome of an auction, such as favoritism, insider trading, or bid tampering.
Transparency	:	The quality of being open, visible, and easily verifiable by all participants, ensures that the actions and transactions within the auction process are accessible and accountable.

Bid Tampering	:	Illegitimate alteration or interference with bids in an auction, aiming to manipulate the outcome in favor of a particular participant.
Blockchain Technology	:	A decentralized and transparent digital ledger that records and verifies transactions across a network of computers, providing security, immutability, and transparency.
ERP Systems	:	Enterprise Resource Planning systems are software solutions used by organizations to manage and integrate core business processes, including finance, procurement, inventory management, and sales.
Model-Based Systems Engineering (MBSE)	:	An approach to systems engineering that emphasizes the use of models, such as graphical representations or formal notations, to define and analyze system requirements, designs, and behavior throughout the entire lifecycle.
Revolutionizes	:	Significantly and positively transforms or changes the way something is done or perceived.
Trust	:	The confidence, belief, or reliance on the integrity, honesty, and fairness of a system or its participants.
Resource Allocation	:	The distribution and assignment of resources, such as goods, services, or funds, efficiently and effectively.

I INTRODUCTION

1.1 Background

Modeling an auction system involves creating a simplified representation of the complex processes and interactions involved in conducting auctions. The goal of modeling is to analyze and design the auction system effectively. The modeling process typically involves representing the requirements, behaviors, structures, and interactions of the auction system. This includes defining the roles and responsibilities of different parties involved, such as sellers, buyers, and auctioneers (Friedenthal *et al.* 2014; Qusa *et al.* 2020). Electronic auctions, also known as e-auctions or online auctions, involve buying and selling goods or services through an online platform using the internet and electronic communication to facilitate the bidding process. In contrast, traditional auctions involve physically attending the auction location in person (Chandra 2015). While centralized e-auctions that rely on a single platform can be perceived as lacking transparency and trustworthiness and posing security and privacy risks, they may also incur high costs (Shi *et al.* 2022).

Establishing trust between auction participants and creating a secure trading environment are crucial factors for successful online trading, and these concerns are particularly relevant for electronic auctions (El-Kenawy *et al.* 2014). Auction systems play a critical role in the sale of commodities, including crude palm oil (CPO), but the current mechanisms often suffer from a lack of transparency. This is primarily due to low auction visibility, which can lead to a high probability of no price discovery. In turn, this can negatively impact the auction success rate, causing a loss of potential revenue. There are also inefficiencies in the auction system, leading to an inefficient allocation of resources. One of the major reasons for these inefficiencies is the use of a single-unit auction mechanism in multi-unit items. This approach results in an auction unit volume that is not optimal, leading to an inefficient allocation of resources (Hong *et al.* 2016).

The low auction visibility in current systems is a major concern as it hinders the ability of market participants to accurately assess the value of the commodity being sold (Quiroga *et al.* 2021). This can result in an unreliable representation of market demand and supply, leading to a high probability of no price discovery. As a result, the auction success rate is often low, and the allocation of resources may not reflect the true market value of the commodity. The use of a single-unit auction mechanism in multi-unit items can result in a suboptimal distribution of resources. Market participants may not be able to purchase the optimal quantity of the commodity, leading to an inefficient allocation of resources. Furthermore, the auction unit volume may not accurately reflect the true market value of the commodity, leading to an unreliable representation of market demand and supply.

To overcome these challenges, an innovative approach is required that addresses the inefficiencies in resource allocation, fosters trust among participants and promotes competitiveness and fairness in the auction process. The proposed Integrated Blockchain and ERP-Based Auction (IBEA) model addresses the inefficiencies and trust issues inherent in traditional auction systems for multi-unit items. Solution 1 introduces a multi-unit auction mechanism, enabling buyers to select their desired quantity of CPO, optimizing resource allocation, and reducing wastage. This departure from the single-unit auction model aligns the auctioned quantity with buyer needs, improving overall resource allocation. Solution 2 integrates blockchain technology, utilizing a decentralized ledger to record and verify auction transactions transparently and immutably. By eliminating reliance on a central authority, the IBEA model enhances trust among participants, allowing for independent verification of the auction's integrity and preventing bid tampering. Through the combination of these solutions, the IBEA model presents a transformative approach that improves efficiency, fairness, and trust in the trading of CPO commodities.

1.2 Problem Statement

Low auction visibility & using a single-unit auction mechanism in multi-unit items tend to make lower mutual trust among stakeholders. So, the main problem statement in this study is: How to build a transparent and efficient auction system based on integrated blockchain and ERP for CPO commodity. These problems can be further broken down into:

1) How to identify and address the current challenges in the CPO auction system and how to understand the relationships between participants, to build a new auction system that improves the auction success rate and optimizes the auction unit volume?
2) How to develop functional, logical, and physical designs for the new auction system based on the system requirements?
3) How to effectively evaluate the design in a manner that is consistent with the requirements using appropriate evaluation?

1.3 Objective

Based on the problem statements presented, the objectives of this study are to:

1) To analyze the requirements of Blockchain and ERP-Based Auction (IBEA) Integration model.
2) To design the Blockchain and ERP-Based Auction (IBEA) Integration model.
3) To evaluate the Blockchain and ERP-Based Auction (IBEA) Integration model.

1.4 Benefit

This research is expected to provide benefits to stakeholders:

1) Input and consideration for palm oil supply chain actors in the context of improving and developing an auction system that is more equitable for all actors in the palm oil supply chain.
2) Contribution to the development and implementation of science related to the agroindustry supply chain auction system to support the sustainability of the agroindustry.
3) Scientific contribution for the community and business actors or investors who will invest in developing a sustainable supply chain contract system

1.5 Scope

1) This study uses the CPO as the object modeling auction system based on integrated Blockchain and ERP for crude palm oil (CPO) commodity.
2) Blockchain technology used in smart contract modeling is the Hyperledger Blockchain framework with programming language smart contracts with Javascript and Golang.
3) This study does not pay attention to supply chain product flow for export, only domestic supply chain product flow.

II LITERATURE REVIEW

2.1 E-Auction

In principle, electronic auctions (E-Auction) should transfer the actual offline auction scenario to the Internet. As such, it has the same basic components as auction participants, auction rules, and arbitration bodies. Traditional auction participants include bidders and sellers, as shown in Figure 1. His two main approaches to electronic auctions can be described as follows: In the first approach, a seller offers a product sought by multiple buyers who compete and raise their prices. The highest bidder wins and purchases the item. In contrast, in a reverse auction, the buyer controls the process. Unlike traditional auctions that take place in physical locations, reverse auctions are accessed online through a web browser and commercial software companies known as "market makers" (Qusa *et al.* 2020).

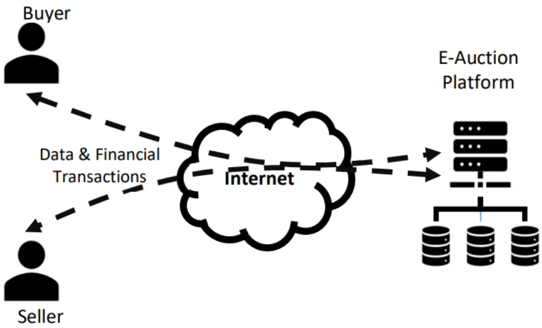

Figure 1 General E-Auction Framework

Like any information system, e-Auction faces a huge challenge - security requirements. The most serious security problem in electronic auction systems is the lack of trust between parties such as sellers, buyers, and auctioneers. The collaboration, anonymity, and link ability of the online environment can lead to fraudulent transactions. If the seller fails to deliver the property after the auction, if the buyer abandons the auction or refuses to pay the required price during the auction, or if a coalition is formed between groups of buyers, the actual buyer. brings a high price. Several online auction websites and platforms that have been developed and act as auctioneers suffer from these security issues. Building trust between auction participants sums up all the security issues of electronic auction systems and is seen as a major obstacle to the expansion of these online systems (El-Kenawy *et al.* 2014).

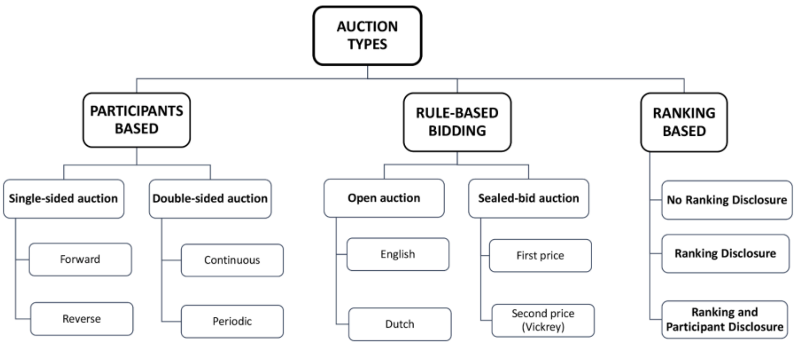

Figure 2 Auctions types

Auctions can be grouped into different categories based on the participants involved, the regulations, and the method for determining the winning bid. Figure 1 shows a classification of the various types of auctions that are commonly used. The type of auction that is chosen will determine whether information such as bids, bid history, participant list, and the announcement of the winning bid will be made public or kept confidential (Omar *et al.* 2021).

2.2 Model-Based System Engineering

The MBSE methodology (model-based system engineering) is an approach used in the field of system engineering. It can be defined as a set of interconnected processes, methods, and tools that support the discipline of system engineering within a model-based context. The methodology of MBSE can be applied to the design of agro-industrial systems, involving a series of processes to identify the functions and quality attributes of a product/system under development. These identified aspects are then prioritized to synthesize solutions to address the identified challenges (Fernandez dan Hernandez 2019).

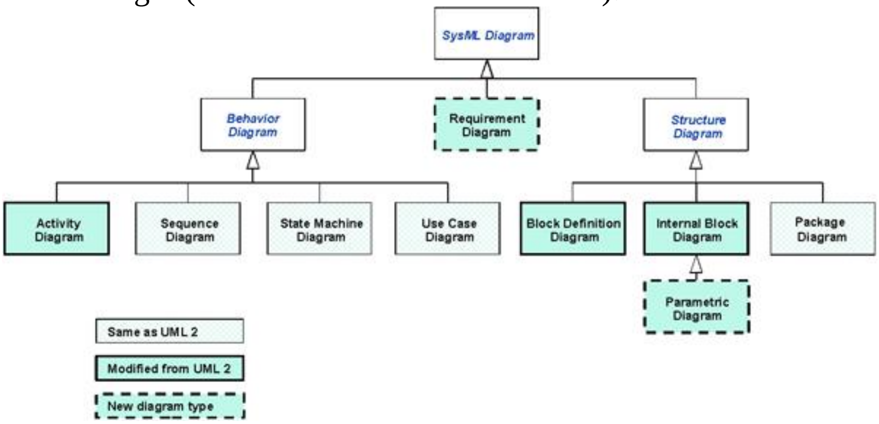

Figure 3 Tools of MBSE

In the context of agro-industrial systems, the application of the MBSE methodology offers numerous benefits. By employing a model-based approach, stakeholders can collaboratively capture and analyze the diverse aspects of the system, including its requirements, behavior, and interdependencies. The use of models allows for a visual representation of the system, enabling stakeholders to gain insights into the system's functionality, performance, and potential issues. Through this comprehensive understanding, the MBSE methodology aids in the synthesis of effective solutions that address the identified challenges in the agro-industrial domain.

Furthermore, the use of MBSE methodology in agro-industrial system design promotes traceability and ensures system integrity. With models serving as central artifacts, the relationships between various system elements, such as functional requirements, design components, and quality attributes, can be explicitly established and maintained. This traceability enables stakeholders to trace the impact of changes, manage requirements, and perform system-level verification and validation. Moreover, the MBSE methodology facilitates the integration of different engineering tools and environments, enabling seamless collaboration and information exchange between multiple disciplines involved in agro-industrial system development.

2.3 Analysis and Design of the System Development Life Cycle

Business processes refer to the series of steps involved in conducting business operations and achieving specific goals. These processes may be constantly modified and updated with new ideas and techniques to improve efficiency, speed, and cost-effectiveness. The involvement of stakeholders in business decision-making often stems from the introduction of innovations within the organization.

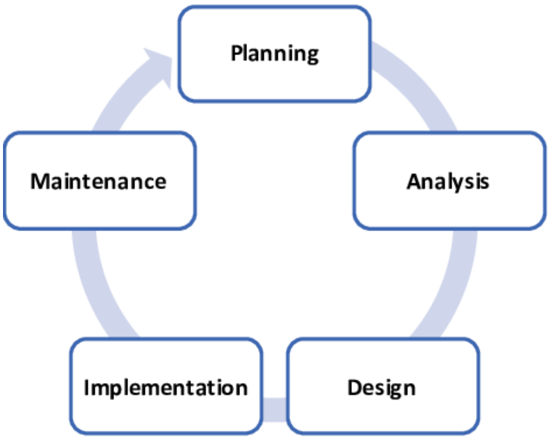

Figure 4 Steps of the System Development Life Cycle

The system development life cycle (SDLC) is a method for redesigning business processes, as illustrated in Figure 4. As defined by Valacich dan George (2020), the SDLC involves analyzing and designing systems and is an ongoing, iterative process. Input is transformed into output through the development of new versions of the current system, repeating until an acceptable system is achieved.

The SDLC consists of two key stages: analysis and design. During the analysis phase, the current system is evaluated and the requirements for the new system are determined. This phase is divided into two sub-phases: determining the user's needs and organizing the information into a meaningful representation using tools such as UML diagrams and system entity diagrams, such as use case and BPMN diagrams. The design phase involves creating a plan for the new system based on the information gathered during the analysis phase (Valacich dan George 2020).

2.4 Enterprise Resource Planning (ERP)

An ERP system is a software system that can be used to standardize and streamline various sales structures, business processes, and IT infrastructure within a company using a suitable ERP strategy. It includes modules for various business functions such as procurement, production, sales, equipment management, finance, and accounting, which are connected through a shared database. This system is designed to support and optimize all business processes within a company. Incorporating business objectives into the planning for an ERP system leads to a more strategic approach to implementing it. Standardizing business processes beyond an organization's boundaries can result in significant synergies. An ERP system can be used to implement best practices and is viewed as a business tool rather than just an IT tool (Gronwald 2017).

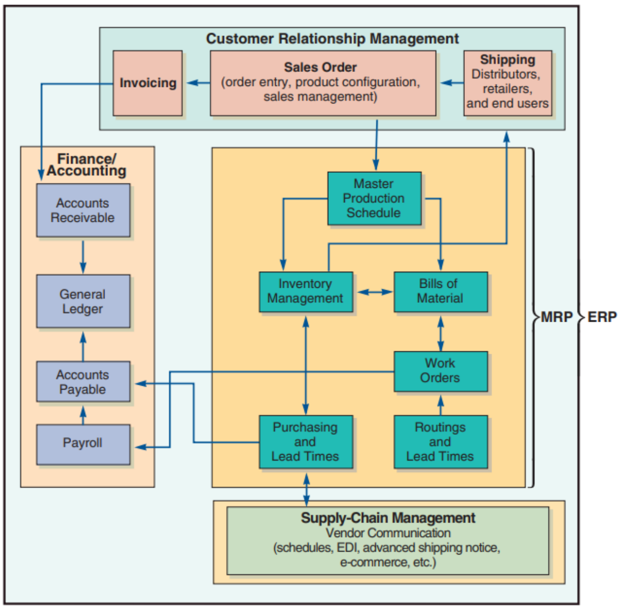

Figure 5 ERP Integration

The fundamental concept of an ERP system is a set of standardized business process modules that can be customized to fit almost any business process situation without the need for programming. This is achieved by configuring parameters and master data. These modules can be easily adjusted to meet the specific needs of a business (Heizer *et al.* 2017).

2.5 Blockchain Technology

Blockchain is a distributed ledger organized into a linked list of blocks. Each block contains an ordered set of transactions. A generic solution uses a cryptographic hash to secure the link from the block to its predecessor (Xu *et al.* 2019). Blockchain Technology (BCT) is the underlying technology that was originally used for digital currencies like Bitcoin (Nakamoto). Further developments were published by (Buterin 2013) in his white paper on Ethereum. In the whitepaper, Blockchain is introduced as a basic technology to which data and programming can be added, called smart contracts, thus enabling the creation of a decentralized application platform that is more than just a cryptocurrency exchange. Thus, the potential use of BCT has begun to penetrate several non-financial industries such as transportation, supply chains, pharmaceuticals, law, regulation, and agriculture.

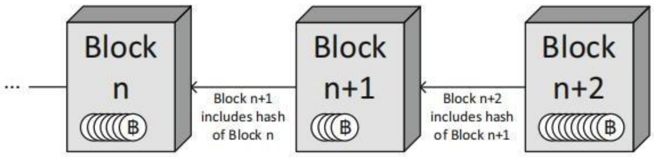

Figure 6 Blockchain Concept (Xu et al. 2019)

A graphical representation illustrating the Blockchain concept is shown in Figure 6. Hash cryptography ensures that the previous block is immutable. If the previous block is modified, the new hash will not match the previously recorded hash, so the link between the two blocks will be broken. Thus, Blockchain is a technology that cannot be manipulated. Organizations participating in SC benefit from high visibility through secure data-sharing mechanisms, enabling them to plan with greater certainty. Blockchains store data about the asset's current location, ownership or trusteeship of the asset, and its transactional status (Ølnes *et al.* 2017).

2.6 Smart Contract

Smart contracts a program that is used as data in a Blockchain ledger and executed in transactions on the Blockchain. Smart contracts can hold and transfer digital assets managed by the Blockchain and can request other smart contracts stored on the Blockchain. Smart contract code is deterministic and cannot be changed after use (Xu *et al.* 2019). While according to Dolgui et al. (2020) Smart contract is a set of digital agreements between companies in the SC process (eg shippers and carriers in the supply chain) represented in code and executed by the computer after certain conditions are met (eg conditions after the product is received by the buyer are met), the smart contract code is stored and replicated within the Blockchain network

Smart contracts monitor fulfillment operations as recorded in the Blockchain which allows for confirming the planned progress of the process and to identify deviations. Smart contracts usually store rules and policies for negotiating terms and actions between parties. Automatically verify that contract requirements have been met and execute transactions (Saberi *et al.* 2018). Regulatory processes (eg customs) can be accelerated using Blockchain by increasing trust in the documentation. This, in turn, can result in a reduction in wastage, risk, and insurance premiums. A list of all transactions is kept as a copy throughout the further development of many computers (networks even hundreds of computers). As a result, if an illegal or unauthorized modification occurs on any of the computers, it can be traced back for verification purposes (Nofer *et al.* 2017).

As shown in Figure 7, smart contracts are deployed on the Blockchain through contract creation transactions. The transaction data payload contains the smart contract object code. The signature of the sender of the transaction authorizes the transaction to create a smart contract on the Blockchain. After the creation transaction contract is successfully entered into the Blockchain, the smart contract is identified by the contract address.

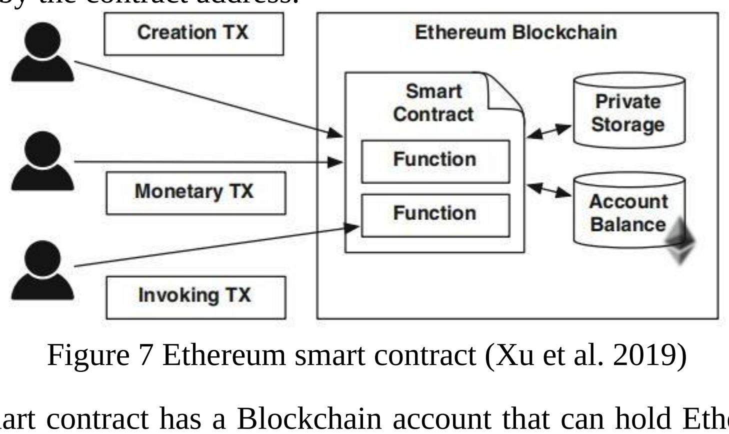

Figure 7 Ethereum smart contract (Xu et al. 2019)

Each smart contract has a Blockchain account that can hold Ether (Ethereum cryptocurrency) and an internal state. So, an Ethereum smart contract Account contains internal storage executable code to store its internal state and a certain amount of Ether, i.e. contract balance. Once the smart contract is successfully deployed on the Blockchain, Blockchain users can transfer Ether to the smart contract using basic monetary transactions.

2.7 Related research

The use of Blockchain to solve various fields continues to increase in various industries, including agriculture (Al-Jaroodi dan Mohamed 2019). Several studies have discussed how to use BCT to solve agricultural problems. Table 1 shows some of the concepts that have been offered to create Blockchain-based systems in agriculture.

Table 1 Related research

No	Author	Title	Method	Result
1	(Falgenti *et al.* 2021)	The design of fresh fruit bunch palm oil purchase system from independent smallholders to support Indonesia's biodiesel development program	Conceptual Model & Mockup	Conceptual Model Transparency Information System
2	(Duan *et al.* 2020)	A content-analysis-based literature review in Blockchain adoption within the food supply chain	Conceptual framework, pilot cases	Conceptual framework food traceability, food supply chain transparency and the efficiency
3	(Feng *et al.* 2020)	Applying Blockchain technology to improve agri-food traceability: A review of development methods, benefits and challenges	Study Literature	Conceptual Research food traceability concerns in terms of full information transparency
4	(Pournader *et al.* 2020)	Blockchain applications in supply chains, transport and logistics: A systematic review of the literature	Study Literature	Conceptual Research Traceability/ transparency, technology, trust and trade
5	(Astarita *et al.* 2020)	A review of Blockchain-based systems in transportation	Study Literature	Conceptual Research product traceability in food chains
6	(Wamba dan Queiroz 2020)	Blockchain in the operations and supply chain management: Benefits, challenges and future research opportunities	Study Literature	Conceptual Research traceability food supply chain in global trade

7	(Queiroz dan Wamba 2019)	Blockchain adoption challenges in the supply chain: An empirical investigation of the main drivers in India and the USA	Study Literature	Conceptual Research Traceability & transparency supply chain
8	(Wang *et al.* 2020)	Blockchain-based framework for improving supply chain traceability and information sharing in precast construction	Study Literature	Conceptual Research Visibility and product traceability
9	(Djatna *et al.* 2021)	A Conceptual Modelling of Digital Contract for Independent Palm Oil Supply Chain Systems	Conceptual Model	Conceptual Model Digital Contract Supply chain
10	(Chen *et al.* 2022)	SBRAC: Blockchain-based sealed-bid auction with bidding price privacy and public verifiability	Modeling and Simulation	Model of Blockchain-based sealed-bid auction contract

Auctions are a common mechanism for allocating resources and assigning values to goods and services in the supply chain. Blockchain-based sealed-bid auctions have the potential to enhance the transparency, fairness, and efficiency of the auction process, as they allow for secure, immutable, and verifiable record-keeping of bids and outcomes. However, the implementation of Blockchain-based auctions in the supply chain faces several challenges, such as the need to balance the trade-off between privacy and transparency, the difficulty of coordinating multiple parties with diverse interests and preferences, and the risk of collusion and manipulation. Therefore, further research is needed to understand how Blockchain-based auctions can be effectively designed and deployed in the supply chain, and how they can be used to address various issues such as trust, coordination, and efficiency.

III METHOD

3.1 Research Framework

This research consists of three phases to achieve three objectives. The first section is the analysis section which begins with a requirements analysis. It begins with the identification and requirements of stakeholders, creating system entities, and modeling business processes. The second stage is the development of the smart contract system design. At this stage, several sub-stages have their design results. In the first sub-stage, we start by translating the previous analysis results into functional/system operational architecture, and logical architecture, and the next sub-stage is developing the physical architecture using class diagrams and programming code. In the next stage, this research also conducted a prototype test and system evaluation. A graphic illustration of this work can be seen in figure below.

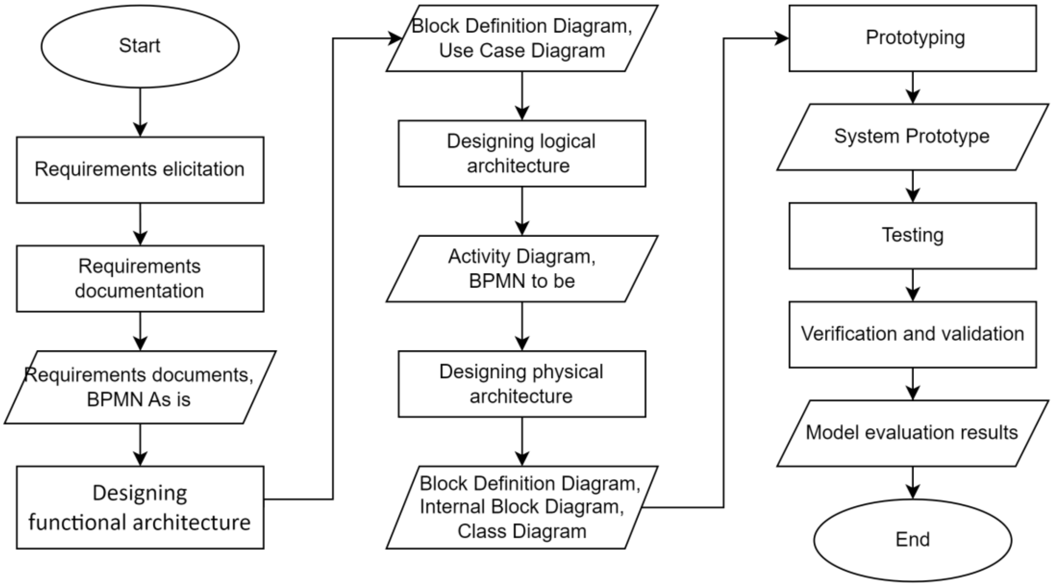

Figure 8 Research Framework

MBSE (Model-Based Systems Engineering) is a methodology used to develop complex systems using models and formal methods to ensure the correctness and completeness of the design. MBSE involves several layers, including operational analysis, functional and non-functional analysis, logical architecture, and physical architecture (Fernandez and Hernandez 2019).

Layer Operational Analysis, this layer is concerned with defining the system's operational context and identifying the requirements and constraints that must be met. It involves analyzing the system's intended use, its environment, and the stakeholders' needs and concerns.

Functional and Non-Functional Analysis, in this layer, the system's functions are defined, and the performance requirements are established. This layer is also concerned with identifying the non-functional requirements, such as reliability, safety, and maintainability, that the system must meet.

Functional architecture refers to the structural and organizational design of a system or software application that outlines the functional components and their interactions. It describes the system's high-level functionality, including its main modules, components, subsystems, and their relationships, and how they work together to achieve the system's intended purpose or functionality.

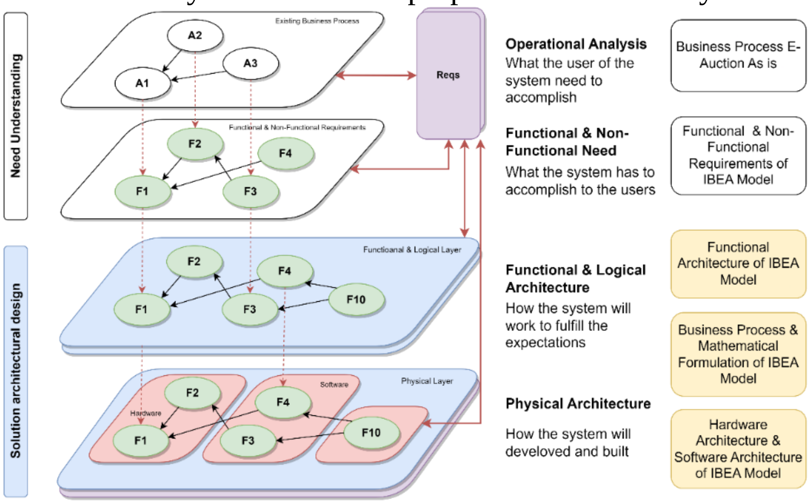

Figure 9 Layers MBSE

Logical Architecture, the logical architecture layer defines the system's components and how they interact with each other. It involves creating a high-level model that describes the system's structure and behavior, using various tools and techniques, such as block diagrams, state charts, and activity diagrams.

Physical Architecture, the physical architecture layer defines the system's physical components and their connections. It involves designing the system's hardware and software components and determining their physical characteristics, such as size, weight, and power consumption. This layer also includes the design of the system's interfaces and the allocation of functions to specific components.

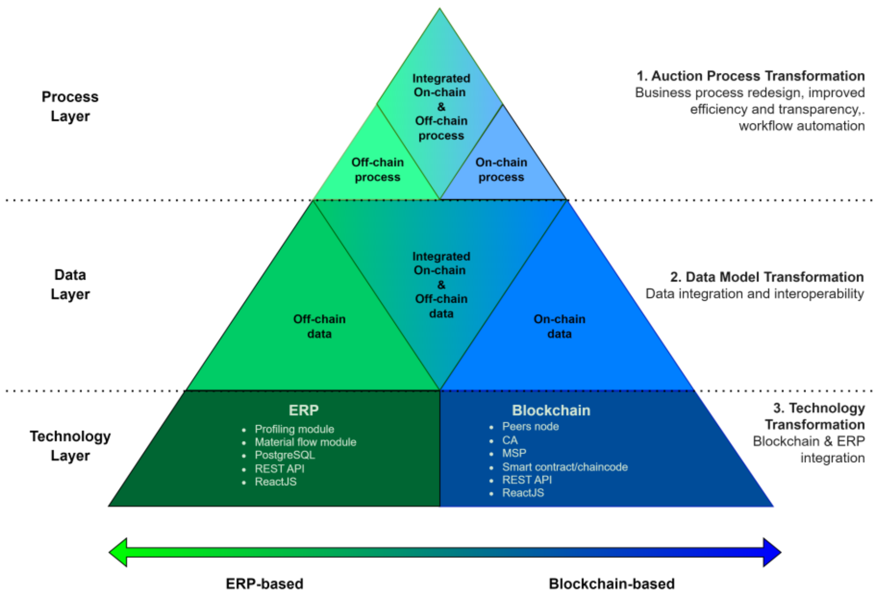

Figure 10 Digital Transfomation Pyramid

To transform the current auction system and establish an advanced integrated blockchain-ERP-based auction system, we adopt a transformative approach based on the digital transformation pyramid framework introduced by Adamczewski (2018). This framework consists of three key layers: the process layer, the data layer, and the technology layer, each contributing to the system's overall enhancement.

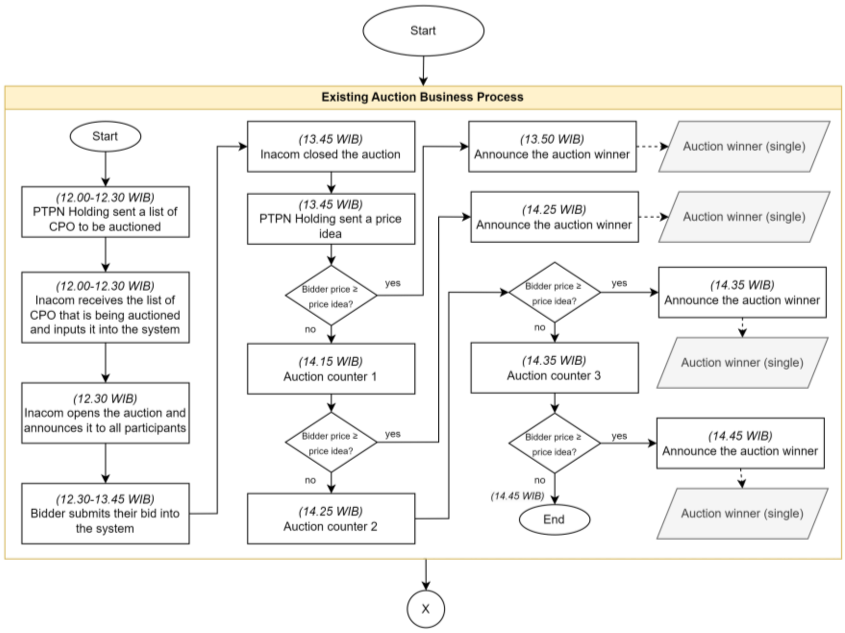

Figure 11 Existing Auction Process

In the process layer, we focus on streamlining the auction procedures through process transformation, business process redesign, improved efficiency, and enhanced transparency. We aim to automate workflows wherever possible. Within this layer, we must identify which processes should be executed on the blockchain (on-chain process), which processes are better suited for non-blockchain execution (off-chain process), and which processes require a combination of both (on-chain and off-chain process).

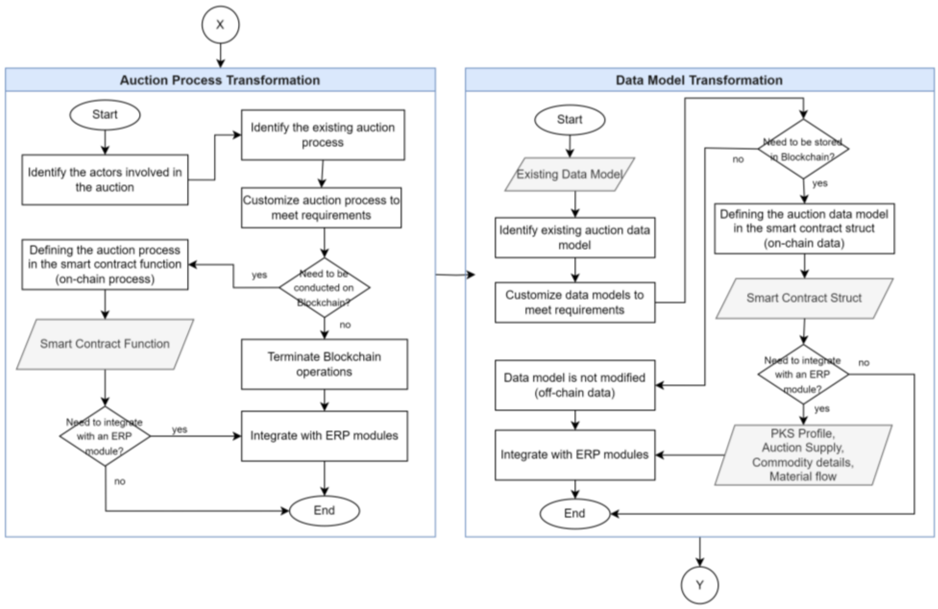

Figure 12 Auction Process Transformation & Data Model Transformation

Moving to the data layer, our goal is to transform the existing data into a comprehensive data model that ensures seamless integration and interoperability. Here, we must determine which data should be stored on the blockchain (on-chain data), which data is more suitable for off-chain storage (off-chain data), and which data necessitates a combination of both (on-chain and off-chain data).

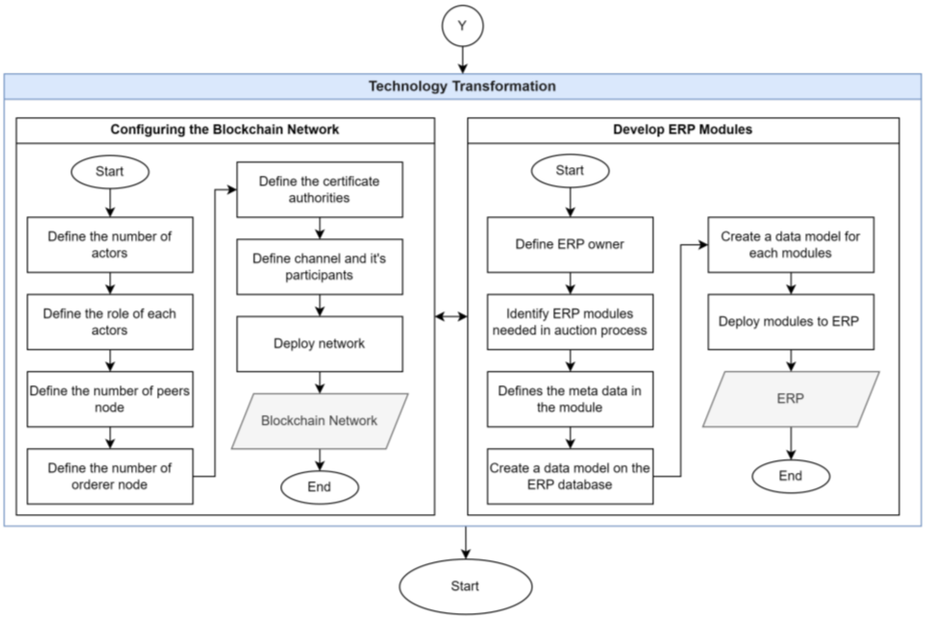

Figure 13 Technology Transformation

The technology layer is where the integration of Blockchain and ERP takes place. This layer serves as the foundation for the system, supporting the layers above. By integrating Blockchain technology with the existing ERP system, the auction system can leverage the benefits offered by blockchain, such as decentralized and immutable record-keeping, enhanced security, and smart contract functionality. This integration empowers the auction system with a robust and reliable infrastructure.

3.2 Data Collection

This research consists of primary data collected through interviews with individuals involved in the CPO auction and secondary data from literature and previous research reports. The data used in this study includes both qualitative and quantitative sources, with the qualitative data comprising profile information about the actors involved in the CPO auction and the quantitative data including data such as costs, time, capacity, and other relevant details related to the CPO auction. The interviews are being conducted to gain insight into the user and system requirements, as this information is crucial for establishing and implementing effective agreements within the system. By understanding the needs and requirements of both the users and the system, we can ensure that the CPO auction process is efficient and effective.

3.3 Requirements Engineering

According to Soares et al. (2007), a requirement is a statement that describes the desired behavior of a product or system. There are various types of requirements, including user requirements which are high-level summaries of what the user needs, and system requirements which provide more detailed descriptions of what the system is expected to do. Requirements analysis is a crucial step in the development of a system, and in this study, it was conducted through interviews and analysis of existing system documents to gather the system requirements. To structure these requirements, the researchers analyzed the business processes typically involved in the CPO auction. The collected data was then organized and grouped based on their relevance to the components that need to be developed in the system. Successful requirements engineering is based on including the right stakeholders as well as embedding the four core activities of requirements engineering (elicitation, documentation, validation and negotiation, and management) into the system development process (Pohl dan Rupp 2015).

3.4 Architecture Modeling

This study conducted a thorough design process by working on four different levels of the system. These design levels are mutually reinforcing and will be used as input in the subsequent stages of the system development cycle. Figure 11 illustrates a reduction in abstraction from the design stage, which will be further explained in the following sections. Overall, the goal of this design development was to create a comprehensive design that takes into account all aspects of the system.

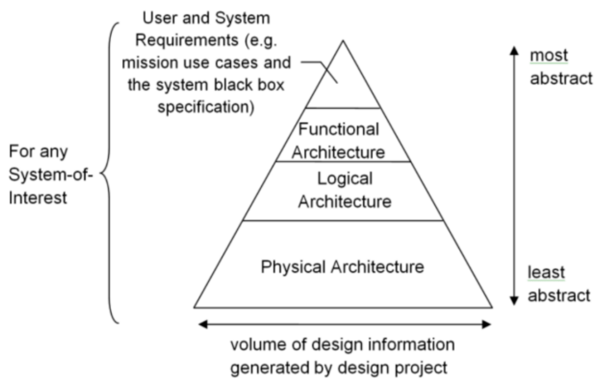

Figure 14 System design abstraction stage (Pearce dan Friedenthal 2013)

3.4.1 Functional Architecture

The functional architecture of the system enables the evaluation of functionality and performance of operational requirements, the division and assignment of sub-functions to physical components of the system architecture, and the identification and operation of interfaces. This functional architecture, which represents the problem space (what the system should do), is at the highest (abstract) hierarchical level and is not tied to a specific technical solution. These characteristics make the functional architecture of the system more enduring than the physical architecture, which is more influenced by technological advancement (Fernandez dan Hernandez 2019).

In this research, the functional architecture of a CPO (commodity product offering) auction system is outlined using a business process modeling approach. The goal is to create a smart contract that can facilitate CPO auctions. The conceptual model for this smart contract is based on the functional architecture of the CPO auction system. The aim is to provide the necessary functions for conducting auctions of CPOs.

3.4.2 Logical Architecture

Logical architecture serves as a bridge between functional architecture and physical architecture. It involves the abstraction of physical components into logical ones, which are defined by their functions, properties, and interfaces. Logical architecture is relatively technology-agnostic and supplier-independent, providing a stable foundation for the development of physical architecture (Fernandez dan Hernandez 2019).

3.4.3 Phicycal Architecture

Physical architecture is the counterpart to logical architecture. While logical architecture is concerned with business requirements but is independent of any specific technical solution, physical architecture represents a specific technical implementation. In the process of designing technology-based systems, there are several stages involved in the development of physical architecture: (1) database specification design, (2) physical business processes and software specifications, and (3) user interface and system specifications (Whitten dan Bentley 2015).

3.4.4 Prototype Development

A prototype is a form or example of an original product that serves as a basis or standard for other items of the same category. The prototype contains attributes that are representative of a category and can be used as examples (Chua *et al.* 2003). Moreover, IEEE defines Prototyping as a type of development where emphasis is placed on developing prototypes early in the development process to allow early feedback and analysis to support the development process.

In prototype-based engineering, only a part of the complete system is applied to represent the whole system. This allows system developers to quickly and inexpensively test the parts of the system that are most likely to experience problems. Once the problems in the prototype are solved, the complete product can be built following the prototype design (Hilton 2000). A rapid prototype is a rapidly implemented version of the target software delivered to the client. This prototype was created to verify and validate the requirements of users. Conventionally, there are two approaches to reusing rapid prototypes: discard and conversion.

3.5 Evaluation Modelling

The relationship between validation and model verification is shown in the following figure. Validation of the conceptual model involves checking that the underlying theory and assumptions are correct, and that the model accurately represents the problem it is intended to address. Verification of the computerized model ensures that the programming and implementation of the conceptual model are correct. Operational validation involves determining that the model produces accurate output behavior over the intended application domain. Data validity involves ensuring that the data used to build, evaluate, test, and experiment with models is accurate and sufficient (Sargent 2011).

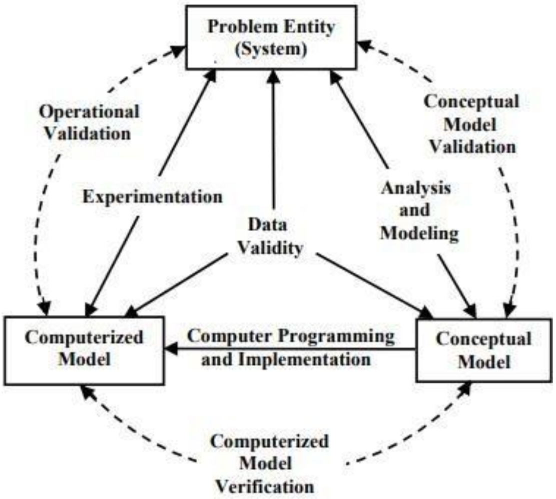

Figure 15 Simplified version of the modeling process (Sargent 2011)

Verification involves proving that a system meets its requirements, while validation focuses on whether the requirements and the resulting system are acceptable solutions for the stakeholders. There are various methods that system developers can use to determine the value of meeting these requirements and meeting the needs of users. Based on Debbabi et al. (2010), There are four main types of techniques for verifying and validating a model: informal, static, dynamic, and formal.

V RESULTS AND DISCUSSION

5.1 Existing E-Auction Business Process

The BPMN diagram represents an existing e-auction system for a crude palm oil commodity. The three main actors in the system are the Supplier, Customer, and System Administrator.

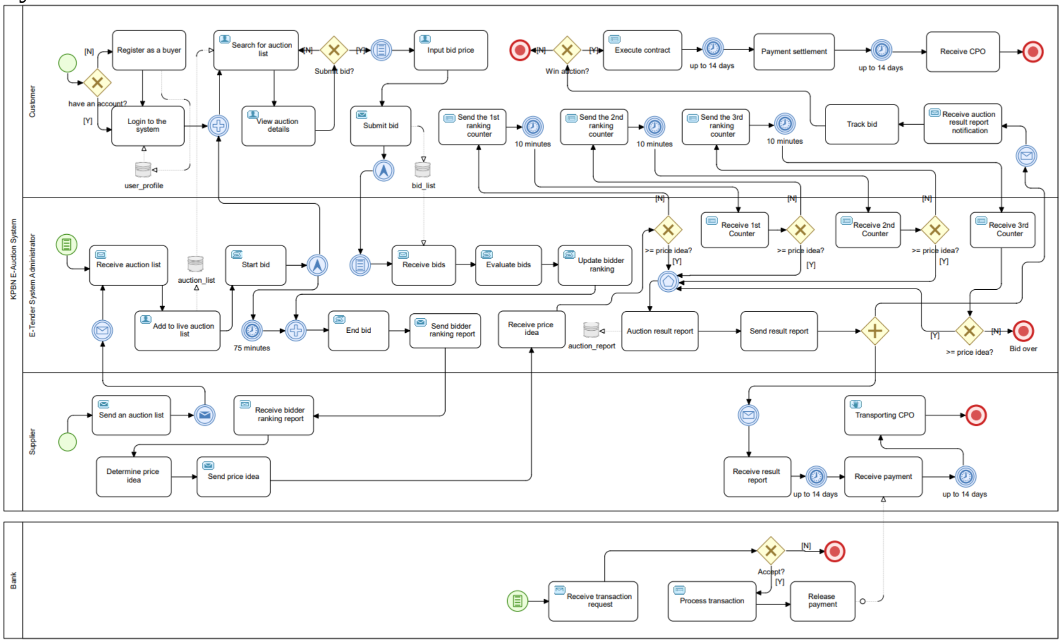

Figure 16 Existing E-Tender Business Process

Access to the system is granted to the Suppliers and Customers through a registration and login process. Once logged in, Suppliers can create an auction, specifying the details and terms of the auction. Customers can search for auctions and view the auction details, then participate in the bidding process by inputting a bid price and submitting their bid.

The bidding process involves multiple rounds of bidding, with a counter process for each round. The first counter is for the first-ranking bid and takes place between 14:15 WIB and 14:25 WIB. The second counter is for the second-ranking bid and takes place between 14:25 WIB and 14:35 WIB. The third counter is for the third-ranking bid and takes place between 14:35 WIB and 14:45 WIB.

Once the bidding process is complete, the auction/tender result report is generated, detailing the winner of the auction and the final bid prices. The winning bidder is then required to execute the contract and settle payment, which must be done within 14 days, either through a bank transfer or another agreed-upon method. Finally, the crude palm oil is transported, with options for FOB Destination or FOB Shipping Point and a maximum timeframe of 14 days.

If a bid is unsuccessful, the tender continues the following day, or the option to make a Bid Offer (BO) may be given. The BPMN diagram captures these various stages of the e-auction process, providing a visual representation of the activities and interactions between the Suppliers, Customers, and System Administrator.

Table 2 BPMN Description

Business Process ID	Actor	Task	Description
BP.I-01	Customer	Register as a buyer	Registers as a buyer by providing their personal and contact information, such as name, address, email, phone number, etc to the system.
BP.I-02	Customer	Log in to the system	Logs into the system using their registered username and password.
BP.I-03	Customer	Search for the auction list	Searches for available auctions for crude palm oil commodities using various search criteria, such as auction date, commodity type, and location.
BP.I-04	Customer	View auction details	Views detailed information of the selected auction, including specifications and bidding rules, auction start and end time, price idea, etc.
BP.I-05	Customer	Input bid price	Inputs a bid price for the desired quantity of crude palm oil based on their evaluation and market research.
BP.I-06	Customer	Submit bid	Submits the bid to the system, which will then validate the bid against the auction rules.
BP.I-07	Customer	Send the 1st ranking counter	An opportunity is given to first-ranking buyers counterbid for 10 minutes
BP.I-08	Customer	Send the 2nd ranking counter	An opportunity is given to second-ranking buyers to counter-bid for 10 minutes
BP.I-09	Customer	Send the 3rd ranking counter	An opportunity is given to third-ranking buyers to counter bid for 10 minutes
BP.I-10	Customer	Receive closed auction result report	Receives notifications of auction closure and bid results. The notification includes the final auction price and the status of their bid (accepted/rejected).
BP.I-11	Customer	Track bid	Tracks the status of their bid and auction results through the system's dashboard.
BP.I-12	Customer	Execute contract	Executes the contract if their bid is accepted by signing the electronic contract and providing any required documentation.

BP. I-13	Customer	Payment settlement	Settles payment for the contracted crude palm oil commodity by making a bank transfer or using other payment methods as agreed upon, a maximum of 14 days since auction closed.
BP. I-14	Customer	Receive CPO	Receives delivery of the purchased crude palm oil commodity as specified in the contract.
BP. I-15	E-Tender System Administrator	Add to live auction list	Adds a new auction to the live auction list by setting the auction details, such as commodity type, quantity, location, and bidding rules.
BP. I-16	E-Tender System Administrator	Receive bids	Receives bids from buyers and validates the bids against the auction rules.
BP. I-17	E-Tender System Administrator	Evaluate bids	Evaluates bids based on the predetermined criteria, such as bid price, bidding time.
BP. I-18	E-Tender System Administrator	Update auction details	Updates auction details, such as the highest bid price and the number of bidders, in real-time to the buyers.
BP. I-19	E-Tender System Administrator	Receive the 1st ranking counter	The system receives a counter and evaluates whether it is equal to or exceeds the price idea or not for 1st ranking
BP. I-20	E-Tender System Administrator	Receive the 2nd ranking counter	The system receives a counter and evaluates whether it is equal to or exceeds the price idea or not for 2nd ranking
BP. I-21	E-Tender System Administrator	Receive the 3rd ranking counter	The system receives a counter and evaluates whether it is equal to or exceeds the price idea or not
BP. I-22	E-Tender System Administrator	Receive price idea	Admin receives price ideas from suppliers
BP. I-23	E-Tender System Administrator	Auction result report	Generates an auction result report, which includes the final auction price, the winner, and the status of all bids.
BP. I-24	E-Tender System Administrator	Send bidder ranking report	Sends notifications to all buyers, informing them of the auction result and the status of their bid. The notification may also include ranking up to 3rd rank based on bidding price.
BP. I-25	Supplier	Send an auction list	At this stage, PTPN Holding as a supplier will send a list of CPO quantities and areas to be tendered to the KPBN.

BP. I-26	Supplier	Receive bidder ranking report	Receives report of auction closure and auction result. The report includes the ranking of buyer based on their bidding price
BP. I-27	Supplier	Determine price idea	Supplier determines the price idea based on market analysis
BP. I-28	Supplier	Send price ide	The supplier sends the price idea to the tender admin
BP. I-29	Supplier	Receive payment	Receives payment from the winning buyer as specified in the contract.
BP. I-30	Supplier	Transporting CPO	Transports the crude palm oil commodity to the buyer as agreed upon in the contract.
BP. I-31	Bank	Receive transaction request	Receives transaction requests from the buyer and seller for payment settlement related to the crude palm oil commodity auction.
BP. I-32	Bank	Process transaction	Processes the transaction by verifying the transaction details and ensuring sufficient funds are available.
BP. I-33	Bank	Release payment	Releases payment to the seller if the transaction is approved, either through a direct bank transfer or other payment methods agreed upon by the parties involved.

5.2 Requirements Engineering

Requirements engineering is a disciplined approach to identifying and managing requirements with the goal of achieving a consensus among stakeholders, documenting them according to standards, and minimizing the risk of delivering a system that fails to meet stakeholder needs and desires (Pohl dan Rupp 2015). During elicitation requirements, different techniques are used to obtain requirements from stakeholders and other sources and to refine requirements in more detail such as discussions with stakeholders, observing the existing system, and reading related documents and reference sources such as book journals and related standard documents. In the initial process, an analysis of the existing CPO auction business process was carried out at Inacom, by discussing directly with Inacom to find out the existing business processes of the CPO auction system.

The Integrated Blockchain & ERP-based Auction system involves several actors, including Supplier, Customer, Administrator, ERP Odoo, and Blockchain Network. Each of these actors has different use cases that they can perform within the system. Requirements engineering is a disciplined approach to identifying and managing requirements with the goal of achieving a consensus among stakeholders, documenting them according to standards, and minimizing the risk of delivering a system that fails to meet stakeholder needs and desires (Pohl dan Rupp 2015). During elicitation requirements, different techniques are used to obtain requirements from stakeholders and other sources and to refine requirements in more detail such as discussions with stakeholders, observing the existing system, and reading related documents and reference sources such as book journals and related standard documents. In the initial process, an analysis of the existing CPO auction business process was carried out at Inacom, by discussing directly with Inacom to find out the existing business processes of the CPO auction system. In short, the CPO auction business process at Inacom consists of the user registration process, auction initiation by Inacom based on a request from PTPN, the bidding process by prospective CPO buyers, determining the auction winner and price and the last process is reporting. The business process details can be seen in Figure 3

Table 3 Functional & Non-Functional Requirements

Req ID	**Functional Req**	**Non-Functional Req**
FR-01	The system must allow users to create an account	Response Time < 5s, Concurrent processes > 30, Generate digital certificate from Hyperledger fabric
FR-02	The system must allow users to log in to their account	Response Time < 2s, Concurrent processes > 30, Login with digital certificate
FR-03	The system must allow users to browse CPO lots available for auction	Response Time < 5s Concurrent processes > 30
FR-04	The system must allow users to place bids on CPO lots	Response Time < 5s, Concurrent processes > 30
FR-05	The system must allow users to create a new auction	Response Time < 5s, Concurrent processes > 30
FR-06	The system must calculate the clearing price and determine the winning bid for each CPO lot	Response Time < 5s, Handling of multi-unit auctions, Concurrent processes > 30
FR-07	The system can generate a report of the CPO lots won in the auction	Response Time < 5s, Concurrent processes > 30,
FR-08	The system can store and display PKS Profile	Response Time < 2s, Concurrent processes > 30
FR-09	The system can store and display Material Flow	Response Time < 5s, Concurrent processes > 30

The auction system includes several use cases that allow actors to interact with the platform. The first step for actors is to log in, which grants them access to the system by entering their credentials. If an actor is new to the system, they can register and create an account by providing the necessary information. The Suppliers can create an auction by providing the required information about the commodity, such as the type of CPO, the quantity, and the starting bid price. Customers can submit their bids by providing the bid price they are willing to pay for the CPO. Actors can search for active auctions by using relevant keywords or filters and view the details of a specific auction, such as the commodity information, bid history, and other relevant information. The final report of an auction, including the winning bid and other relevant information, can be generated by the Administrators. The Payment Settlement use case allows actors to make payments for the CPO, which are processed and recorded in the ERP Odoo and Blockchain Network. Actors can view their transaction history and the history of auctions they have participated in. Finally, the system can determine the winner of an auction based on the highest bid submitted.

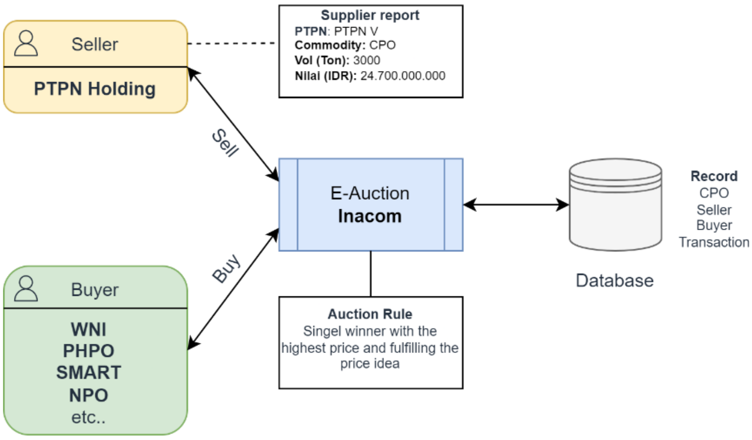

Figure 17 Existing auction model (Inacom 2023)

The existing system has two main issues. Firstly, it relies on a central database that is controlled by a single authority, which poses a dependency problem. It is crucial for online trading, especially in electronic auctions, to establish trust among participants and create a secure trading environment. These concerns were highlighted in a study by El-Kenawy *et al.* (2014). Auction systems, such as those used for the sale of commodities like crude palm oil (CPO), often lack transparency, primarily due to limited auction visibility. This lack of transparency increases the likelihood of insufficient price discovery, negatively impacting the success rate of auctions and resulting in potential revenue loss. The second problem lies in the inefficiencies of the auction system, leading to suboptimal allocation of resources. One major reason for these inefficiencies is the use of a single-unit auction mechanism for multi-unit items. This approach does not optimize the auction unit volume, ultimately resulting in inefficient allocation of resources (Hong *et al.* 2016).

The CPO auction mechanism uses a single item auction method, while CPO is an item with a large quantity, causing an inefficient allocation of resources. That is why, we need an auction mechanism for multi-unit items. To address the inefficiencies caused by using a single item auction method for multi-unit items like CPO, a multi-unit auction mechanism can be implemented. This type of auction method allows bidders to bid on multiple units of the item, rather than just one, which enables a more efficient allocation of resources. In a multi-unit auction, bidders can place bids on any number of units they desire, and the auction is then conducted in rounds, with the highest bidder for each round being allocated the desired number of units until all units have been allocated. This allows for a more competitive bidding process and a more efficient allocation of resources. Implementing a multi-unit auction mechanism can help to maximize the revenue generated from the auction of multi-unit items like CPO, while also ensuring that the units are allocated to the bidders who value them the most(Hailu dan Thoyer 2006; Ausubel *et al.* 2014; Kasberger *et al.* 2021).

The auction mechanism employs various clearing price mechanisms, such as uniform prices and price discriminatory. However, when evaluating these mechanisms based on their potential to generate the highest revenue, price discriminatory is considered more favorable. Price discriminatory mechanism allows the auctioneer to charge different prices to different bidders based on their willingness to pay. This means that the highest bidder pays more than the second-highest bidder and so on, maximizing the revenue generated from the auction. In contrast, uniform prices mechanism charges the same price to all bidders, regardless of their willingness to pay, which can lead to a lower revenue compared to price discriminatory. Therefore, for this auction mechanism, utilizing price discriminatory as the clearing price mechanism can potentially result in the highest revenue outcome (Monostori 2014).

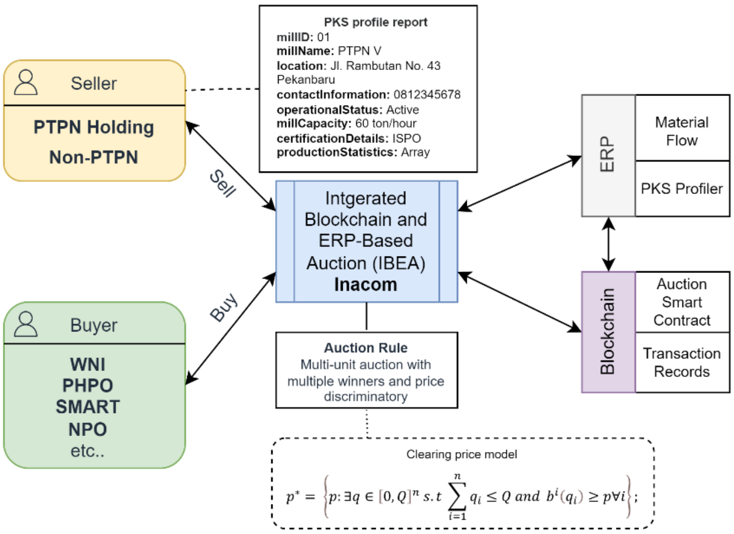

Figure 18 Proposed IBEA model

Transparency in the supply chain involves sharing information with trading partners, shareholders, customers, consumers, and regulatory bodies. This information includes high-level details such as product components, supplier names, locations involved, and certificates (Hellani *et al.* 2021). To achieve transparency, traceability is a prerequisite, as it allows individuals and companies to trace their products back to their origin, building trust in the supply chain. Distributed Ledger Technology, such as Blockchain, can enable full transparency of data records, making it a promising solution for overcoming trust-related issues. To design an efficient and transparent auction system, a thorough requirements analysis was conducted, resulting in a requirements matrix as shown in Table 1. This matrix provides a comprehensive overview of the key requirements, ensuring that the new system meets the needs of stakeholders and addresses the challenges of the current system.

5.3 Functional Architecture

The functional architecture provides a clear and concise view of the system's capabilities and functions, which can be used to guide the development process and ensure that the system meets its requirements and objectives. By focusing on the functions and their relationships, functional architecture can help identify potential design flaws, optimize system performance, and improve system reliability and maintainability.

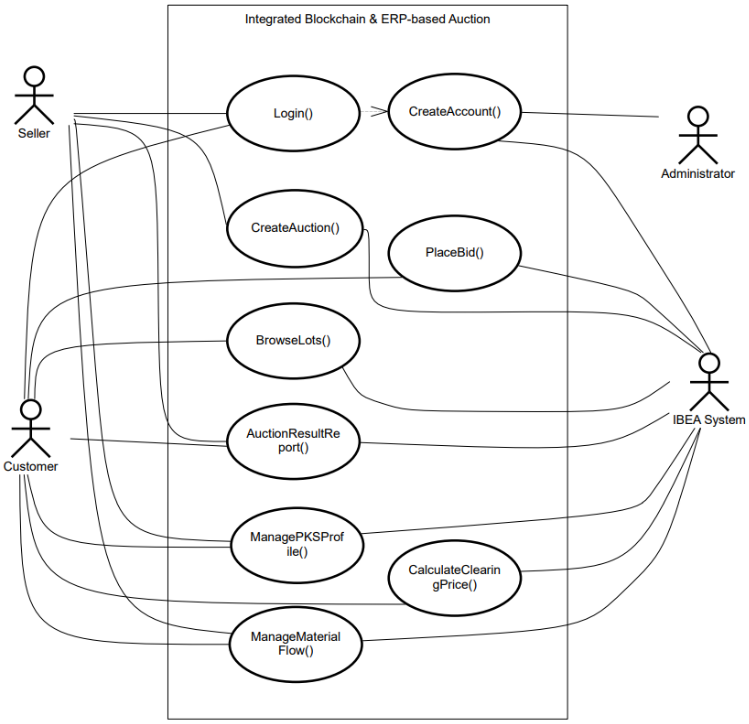

Figure 19 Use case Diagram of IBEA Model

The Integrated Blockchain-ERP-Based Auction System (IBEA) for crude palm oil (CPO) commodity involves several actors, each with their specific roles and interactions. The first actor is the Seller, which can be represented by entities like PTPN 1, PTPN 2, PTPN 3, and so on. Sellers have the capability to create their accounts in the IBEA system, allowing them to participate in the auction process. They can also manage their profiles, including information about their palm oil mills (PKS), and the system provides them with the ability to manage the material flow of the crude palm oil commodity.

On the other hand, the Customer actor, exemplified by companies like Wilmar and PHPO Sinarmas, represents the potential buyers interested in purchasing the CPO. Customers can create their accounts in the IBEA system as well, enabling them to log in and browse through the available lots of crude palm oil up for auction. Once they find a lot they are interested in, they can place bids on it.

The IBEA System itself is a crucial actor in this scenario. It acts as the central platform that facilitates the entire auction process. It allows Sellers and Customers to create accounts and login to access their respective functionalities. The system provides Customers with the ability to browse available lots and place bids. It also enables Sellers to create new auctions, calculate the clearing price, and generate reports containing the auction results. The IBEA System plays a vital role in ensuring transparency and efficiency throughout the auction process.

Lastly, the Administrator actor represents the system administrator responsible for managing the IBEA System. The Administrator oversees the overall functioning of the system, ensures its stability and security, and performs administrative tasks such as user management, system maintenance, and monitoring.

The use cases in this system illustrate the interactions between the actors and the IBEA System. The Seller and Customer actors utilize the Create Account and Login use cases to access their respective accounts. Customers can then utilize the Browse Lots use case to search for available lots, while the Place Bid use case allows them to participate actively in the auction. Sellers, on the other hand, can use the Create Auction use case to initiate new auctions and the Manage Palm Oil Mills (PKS) Profile and Manage Material Flow use cases to manage relevant information.

Additionally, the IBEA System utilizes the Calculate Clearing Price use case to determine the final price for the auction and generates an Auction Result Report to communicate the outcome. The Administrator actor oversees the entire system, ensuring its smooth operation and addressing any administrative needs that arise. Overall, these interactions between the actors and the use cases demonstrate how the IBEA System facilitates the auction process for the crude palm oil commodity, promoting transparency and efficiency for both sellers and customers.

5.4 Logical Architecture

Based on the functional architecture, the logical architecture takes a broader view and addresses how the system will be organized to achieve the desired functionality. It focuses on defining the major components, their responsibilities, and how they interact with each other. The logical architecture provides an abstract representation of the system, highlighting the key concepts, interfaces, and relationships between components.

CreateAccount (FR-01) allows users to create an account within the IBEA System. Users provide necessary information to establish their unique identities. The system generates a digital identity using a public-private key pair, where the private key is securely stored and the public key is recorded on the blockchain. This decentralized approach ensures secure storage and tamper-resistance. Users can log in, participate in auctions, and perform authorized actions using their digital identity, en- hancing trust and integrity in the auction process.

$$CR = \text{account report} \;;$$
$$O = \text{table of account\_profile} \;;$$
$$o = \text{attributes of O} \;;$$

$$CR = \{(o) \mid o \in O\}$$

Login (FR-02) enables users to authenticate themselves and access their accounts within the Blockchain- based Auction System. Users provide their credentials, which are verified by the system. Upon suc- cessful authentication, users gain access to their account and can participate in auctions and perform authorized actions.

$$LR = \text{login report} \;;$$
$$O = \text{table of account\_profile} \;;$$
$$o = \text{attributes of O} \;;$$

$$LR = \{(o) \mid o \in O\}$$

BrowseLots (FR-03) allows users to explore and view the available CPO (Crude Palm Oil) lots within the Blockchain-based Auction System. Users can access detailed information about each lot, including relevant details such as quantity, quality, starting price, and auction duration.

$$BR = \text{ browsing result report };$$
$$L = \text{ table of list\_auction };$$
$$l = \text{ attributes of L };$$

$$BR = \{(l) \mid l \in L\}$$

PlaceBid (FR-04) permits users to submit their bids for CPO lots in the Blockchain-based Auction System. Users specify the lot they want to bid on and enter their bid amount. The system validates the bid and records it on the blockchain. Users can monitor the status of their bids and adjust them as desired.

$$IR = \text{ bid report };$$
$$B = \text{ table of bid };$$
$$b = \text{ attributes of B};$$

$$IR = \{(b) \mid b \in B\}$$

CreateAuction (FR-05) enables authorized users to initiate a new auction for CPO lots in the Blockchain- based Auction System. Users provide the necessary details for the auction, such as lot specifications, starting price, and duration. The system creates a new auction record on the blockchain, making it accessible to participants.

$$OR = \text{ open auction report };$$
$$A = \text{ table of auction };$$
$$a = \text{ attributes of A};$$

$$OR = \{(a) \mid a \in A\}$$

CalculateClearingPrice (FR-06) involves the system determining the clearing price and the winning bid for each CPO lot in the Blockchain-based Auction System. Using predefined algorithms and auction rules, the system calculates the highest bid that clears the market and identifies the corresponding winning bidder. In this case, we used price discriminatory for the clearing price method.

Price discriminatory is a pricing strategy employed by businesses or auctioneers to maximize their profits by charging different prices to different customers or bidders based on their willingness to pay. The concept behind price discrimination is to capture as much consumer surplus as possible, which refers to the difference between what a customer is willing to pay for a product or service and what they actually pay.

In the context of an auction, a price discriminatory mechanism allows the auctioneer to set different prices for different bidders based on their individual valuations or willingness to pay for the item being auctioned. This mechanism enables the auctioneer to extract the maximum value from each bidder by charging them an amount close to their personal valuation.

$$p^* = \text{clearing price};$$
$$Q = \text{total CPO supply};$$
$$b^i(q_i) = \text{bidder price};$$
$$p^* = \left\{ p : \exists q \in [0, Q]^n \; s.t \sum_{i=1}^{n} q_i \leq Q \; and \; b^i(q_i) \geq p \forall i \right\}$$

AuctionResultReport (FR-07) allows the system to generate reports of the CPO lots won in the auc- tion within the Blockchain-based Auction System. The reports provide details about the winning bids, lot quantities, winning bidders, and other relevant information. These reports aid in transparency and provide a record of auction outcomes.

$$OR = \{(a) \mid a \in A\};$$
$$A = \text{table of auction};$$
$$a = \text{attributes of A};$$

$$OR = \{(a) \mid a \in A\}$$

ManagePKSProfile (FR-08) facilitates the storage and retrieval of PKS (Pabrik Kelapa Sawit, or Palm Oil Mills) profiles in the Blockchain-based Auction System. It securely stores information about PKS, including their identities, capacities, and potential. This function ensures transparency and reliability in the auction system by providing participants with accurate and verified PKS profile data.

$$PR = \text{PKS profile report};$$
$$P = \text{table of pks\_profile};$$
$$S = \text{table of sales\_history};$$
$$p = \text{attributes of P};$$
$$s = \text{attributes of S};$$

$$PR = \{(p, s) \mid p \in P, s \in S\}$$

ManageMaterialFlow (FR-09) is responsible for tracking and managing the movement of CPO within the IBEA Model. It ensures transparent and secure recording of PKS transactions, including origin, quantity, and movement. By leveraging blockchain technology, this function enhances trust, reduces fraud, and provides reliable records for PKS flow management.

$$MR = \text{material flow report};$$
$$C = \text{table of commodity};$$

$$M = \text{ table of material\_flow ;}$$
$$c = \text{ attributes of C ;}$$
$$m = \text{ attributes of M}$$
$$MR = \{(c, m) \mid c \in C, m \in M\}$$

The Business Process of IBEA Model includes several key actors, including the Supplier, Customer, and IBEA System. The diagram also outlines the key processes involved in the auction system, including profiling, bidding, material flow, and reporting processes. The Authentication Process has been replaced with a blockchain-based authentication system using Hyperledger Fabric and a digital certificate method. This process involves the use of public and private keys to ensure that only authorized entities can participate in the auction. This provides increased security and transparency to the auction process.

The Bidding Process has been changed to efficient resource allocation. This process involves multiple stages of bidding until the resources are allocated optimally. The use of a blockchain-based system ensures that all bids are accurately recorded and cannot be altered, providing increased transparency to the bidding process. Finally, the Payment Process can occur immediately following the successful allocation of resources. This process involves the use of blockchain transactions to ensure that payment is secure and transparent.

In summary, the BPMN diagram of the Integrated Blockchain-ERP-based Auction System provides a visual representation of the key actors and processes involved in the auction system. The use of blockchain technology and a digital certificate method ensures that the auction process is secure and transparent, while the open bidding process and efficient resource allocation ensure that the auction is conducted in an efficient and optimal manner. The immediate payment process, facilitated by blockchain transactions, ensures that payment is secure and transparent.

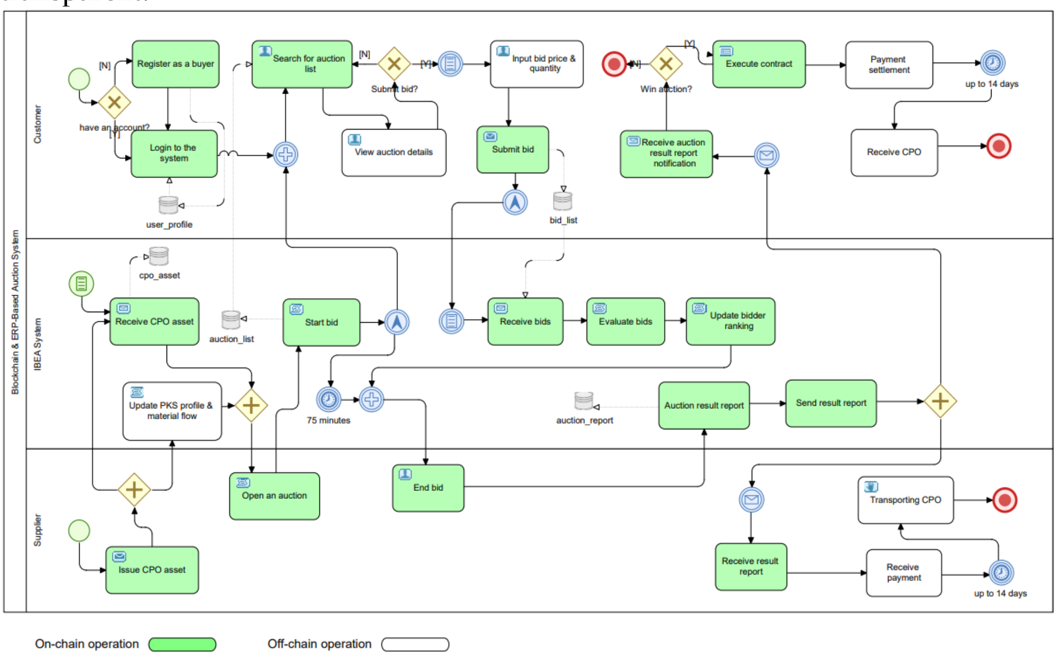

Figure 20 BPMN of IBEA Model

The BPMN diagram illustrates a process flow involving a customer, the IBEA System, and a supplier. The diagram represents the steps involved in purchasing Crude Palm Oil (CPO) through the auction system. The process begins with the customer registering as a buyer in the IBEA System. The customer provides their details, such as name, contact information, and any required certifications. This information is stored in the user table within the system.

Once registered, the customer can log in to the IBEA System using their credentials. The login process verifies the entered information against the user table for authentication purposes. Upon successful login, the customer gains access to the system's features.

The customer can then search for CPO auction listings within the system. This task involves querying the auction_list table, which contains information about available CPO auctions, including details such as quantity, quality, and delivery terms. The search results are displayed to the customer, enabling them to view and evaluate the available CPO options. After selecting a specific CPO auction, the customer can view the auction details. The auction table holds relevant information about the auction, such as the current highest bid, auction status, and additional details about the CPO being auctioned.

To participate in the auction, the customer must input their bid price and quantity for the desired CPO. This bid information is recorded in the bid table, which tracks each customer's bids for a particular CPO auction. As the CPO auction concludes, the IBEA System generates a closed auction result report. This report contains the final results, including the winning bid and the identity of the winning bidder. The report is associated with the auction table.

Following the contract execution, the winning bidder initiates the payment settlement process. This task involves the financial transactions between the winning bidder and the supplier. The payment settlement process interacts with the asset_commodity table to ensure accurate recording of financial transactions and ownership transfer.

Table 4 The data involved in each task on the Customer swim line

Actor	Task	Table
Customer	Register as a buyer	user
	Login to the system	user
	Search for auction list	auction_list
	View auction details	auction
	Input bid price & quantity	bid
	Submit bid	bid
	Receive closed auction result report	auction asset_commodity
	Execute contract	auction
	Payment settlement	asset_commodity
	Receive CPO	asset_commodity

Within the IBEA System, there are several tasks and tables involved in the process. The system's functionality extends beyond customer interactions to include various operations related to managing the CPO (Crude Palm Oil) assets and conducting the auction process. Firstly, the IBEA System is responsible for receiving the CPO assets from the supplier. This task involves updating the asset_commodity table to reflect the new inventory of CPO within the system. This ensures accurate tracking of available CPO assets for future auctions or transactions.

Additionally, the IBEA System is responsible for updating the PKS profile and material flow information. This task involves modifying the pks_profile table to reflect changes in PKS availability, recording relevant transaction details in the sales_history table, adjusting the commodity table to reflect the current PKS market conditions, and updating the material_flow table to track the movement of PKS within the system. These updates enable efficient management of PKS resources and facilitate informed decision-making in the auction process.

When it comes to conducting the auction, the IBEA System plays a crucial role. It initiates the bidding process by starting a new auction in the auction table. This task signifies the commencement of the auction, allowing bidders to participate and place their bids for the CPO assets.

As the bidding progresses, the IBEA System receives the bids from the bidders and stores the bid information in the bid table. It then proceeds to evaluate the received bids based on predefined criteria, determining the highest-ranking bids. This evaluation process ensures fairness and transparency in the auction process. Throughout the auction, the IBEA System updates the auction details in the auction table, providing real-time information to bidders regarding the current status and progress of the auction Once the auction concludes, the IBEA System generates an auction result report, summarizing the final results of the auction. This report, associated with the auction table, contains essential details such as the winning bid and the identity of the winning bidder.

Table 5 The data involved in each task on the IBEA System swim line

Actor	Task	Table
IBEA System	Receive CPO asset	asset_commodity
	Update PKS profile & material flow	pks_profile sales_history commodity material_flow
	Start bid	auction
	Receive bids	bid
	Evaluate bids	auction
	Update auction details	auction
	Auction result report	auction
	Send bidder ranking report	auction

The supplier plays a crucial role in the auction process and is involved in various tasks that are essential for managing the CPO (Crude Palm Oil) assets and ensuring a smooth transaction flow. Firstly, the supplier is responsible for issuing the CPO asset to the buyer. This task involves updating the asset_commodity table to reflect the transfer of ownership and the decrease in the available CPO quantity.

In addition to issuing CPO assets, the supplier has the authority to open an auction. This task involves updating the asset_commodity table to reflect the availability of CPO for auction and creating a new entry in the auction table. By opening an auction, the supplier invites potential buyers to participate in bidding for the available CPO assets.

Once the auction is completed, the supplier receives the bidder ranking report from the IBEA (Integrated Blockchain-ERP-Based Auction) System. This report, associated with the auction and bid tables, provides the supplier with information about the positions of bidders and their respective bid amounts. The supplier can use this report to assess the bids and determine the winning bidder.

To assist in the auction process, the supplier also determines a price idea for the CPO. This task involves analyzing market conditions, demand, and supply factors to arrive at a reasonable price. The price idea is associated with the auction and bid tables, providing guidance to bidders during the auction.

Once the price idea is determined, the supplier sends the price idea to the IBEA System. This task involves updating the auction and bid tables with the supplier's suggested price for the CPO. The price idea serves as valuable information for bidders, helping them make informed bidding decisions. Upon successful completion of the auction, the supplier receives the payment from the buyer. This task involves updating the asset_commodity table to reflect the financial transaction and recording the details of the payment received.

Finally, the supplier is responsible for the transportation of the CPO to the buyer. This task involves managing the logistics and arranging for the physical delivery of the CPO. The asset_commodity table is updated to track the transportation process and ensure accurate record-keeping.

Table 6 The data involved in each task on the Supplier swim line

Actor	Task	Table
Supplier	Issue CPO asset	asset_commodity
	Open an auction	asset_commodity auction
	Receive bidder ranking report	auction bid bid
	Receive payment	asset_commodity
	Transporting CPO	asset_commodity

5.5 Physical Architecture

The Integrated Blockchain & ERP-based Auction System is composed of three main components: the back-end, the front-end, and the web browser. The back-end of the system consists of two key components: blockchain and ERP (Odoo). The blockchain component provides a secure and transparent platform for recording transactions. This ensures that all transactions are accurately recorded and cannot be altered, providing increased security and transparency to the auction process. The ERP component (Odoo) is responsible for managing and organizing

PKS profile and material flow. This component ensures that the auction mechanism is efficient and that the auction unit volume is optimized.

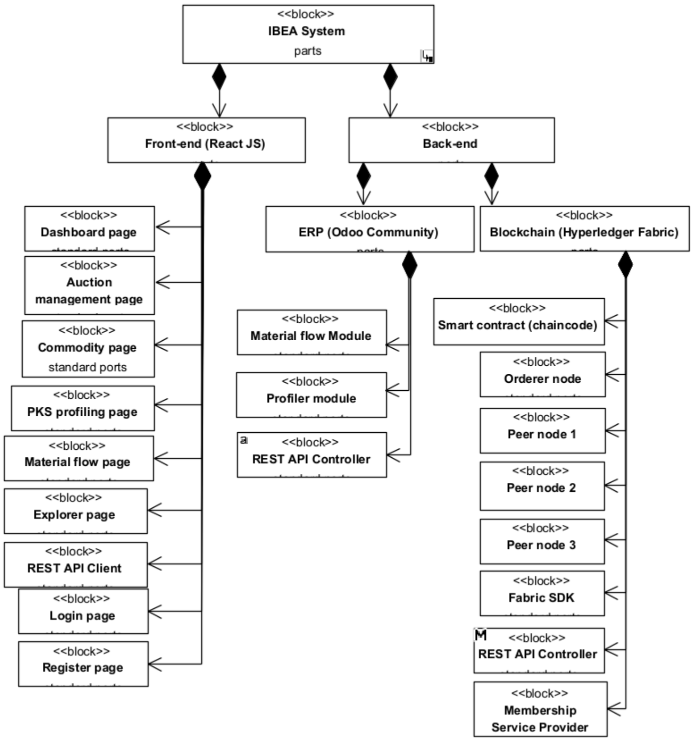

Figure 21 Hierarchy of Physical Architecture

In this research, to establish a connection or bridge between the Hyperledger blockchain and Odoo ERP systems is to utilize the REST API as an intermediary or middle ware component. This REST API acts as a communication channel between the blockchain network, the ERP system, and the front-end interface built with React. Hyperledger Fabric, the specific blockchain framework being used in this context, provides a fabric SDK (Software Development Kit) that enables communication with clients. While it is possible to communicate directly through the fabric SDK, it is deemed more convenient and efficient to employ the REST API for interoperability purposes.

By leveraging the REST API, the integration between the blockchain network and the ERP system can be facilitated, ensuring smooth communication and data exchange between these components. This approach simplifies the overall process of connecting and interacting with the blockchain from within the Odoo ERP system.

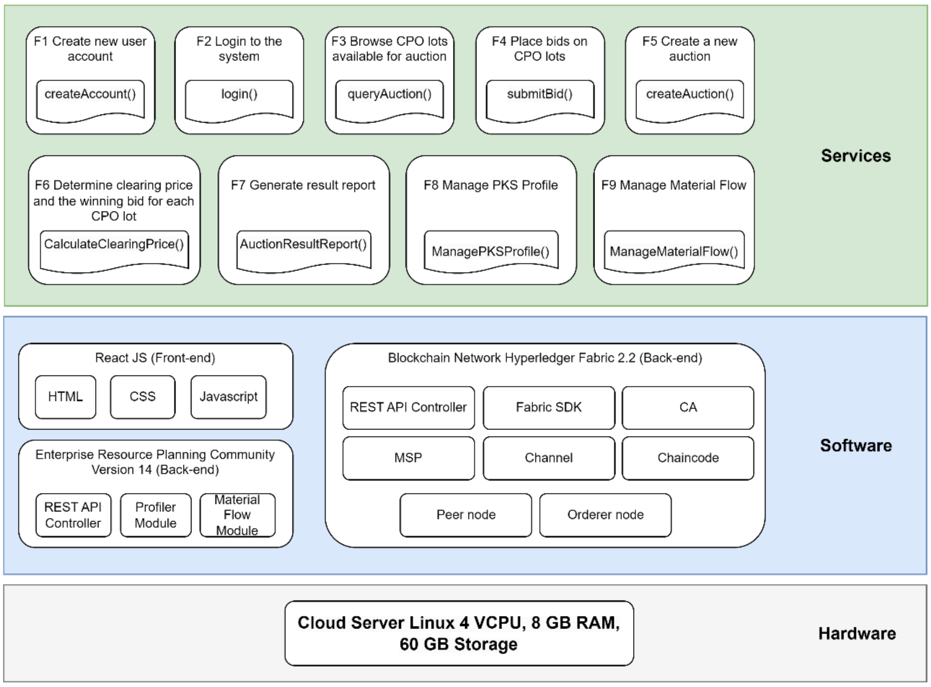

Figure 22 Physical architecture allocation to logical architecture

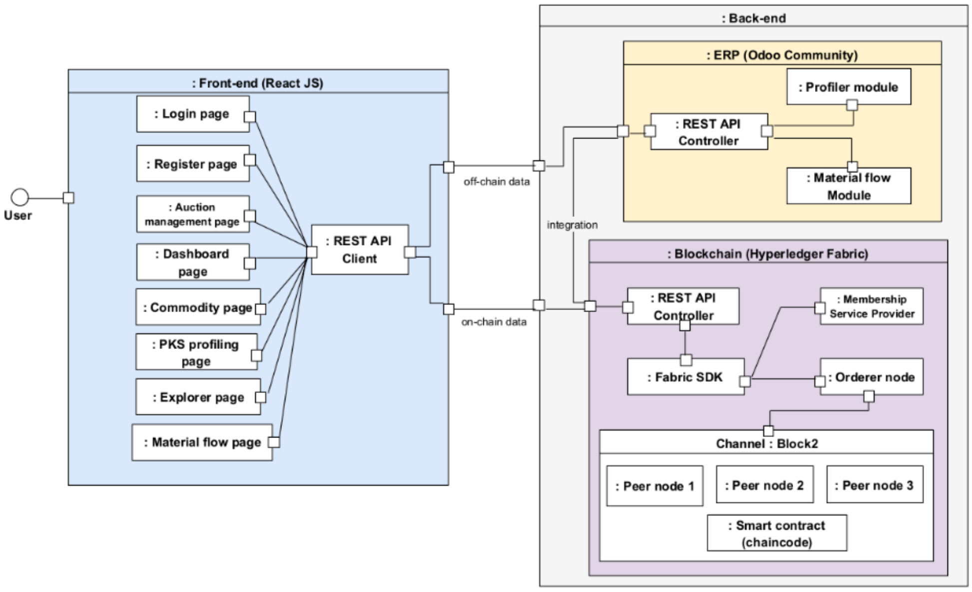

Figure 23 Internal Block Diagram System

The front-end of the system is developed using the React framework. This component provides a user-friendly interface for participants to interact with the auction system. The front-end is responsible for presenting the relevant information to the user and allowing them to participate in the auction process. Finally, the web browser component provides access to the auction system. Participants can access the system through a web browser, where they can view relevant information and participate in the auction process.

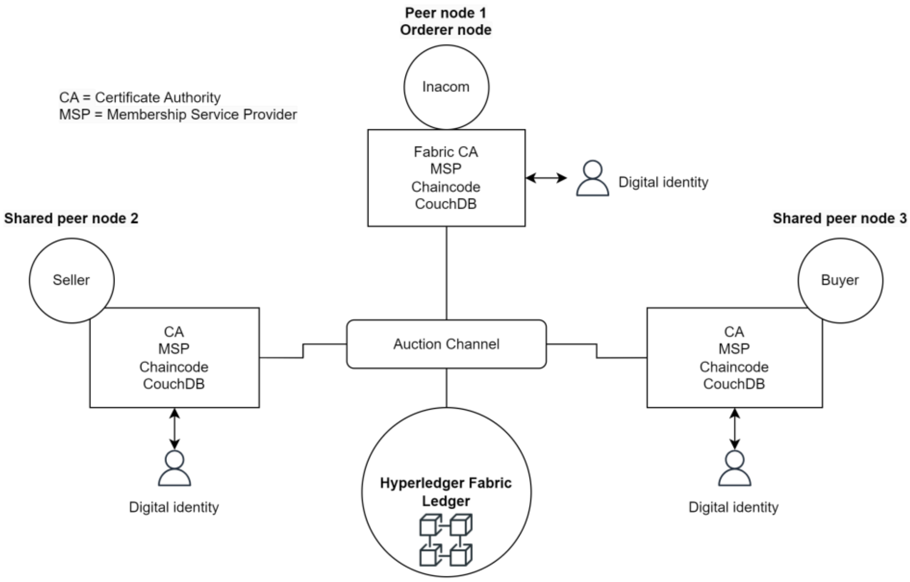

Figure 24 Hyperledger Fabric Configuration

In Hyperledger Fabric Configuration, each organization involved in the Crude Palm Oil (CPO) auction system has its own Certificate Authority (CA) and Membership Service Provider (MSP) to issue and manage user identities. These identities are represented in the form of digital certificates following the X.509 standard. The digital certificates serve as the identity for each participant in the blockchain network. They contain information such as the participant's public key, organization details, and other relevant metadata. By having separate CAs and MSPs for each organization, you ensure that the identities are managed independently and securely within their respective organizations.

These identities play a crucial role in the blockchain network as they are used to authenticate and authorize users. Authentication ensures that only valid and authorized users can access the network and participate in transactions. Authorization controls the ownership and rights of users to modify data within the blockchain. When a user wants to interact with the blockchain network, they present their digital certificate to establish their identity. The certificate is verified against the CA's root certificate to ensure its authenticity. Once the user's identity is verified, they are granted access to the network and can perform authorized actions based on their permissions.

Each peer node in the network is responsible for running the smart contracts, which are implemented using chaincode. Chaincode contains the business logic and rules that govern the behavior of the blockchain network. Peer nodes execute transactions and validate them against the rules defined in the chaincode. In addition to the chaincode, each peer node also utilizes CouchDB, a database technology, to store the records. CouchDB provides a distributed and replicated storage solution, ensuring that the data is consistently available across the network. The data stored in CouchDB represents the current state of the blockchain, including the transaction history and other relevant information.

In summary, the IBEA System is a highly secure and efficient mechanism for the sale of commodities, such as crude palm oil (CPO). The combination of blockchain technology and ERP ensures that the auction process is transparent, efficient, and optimized for the equitable distribution of resources. The front-end provides a user-friendly interface for participants to interact with the system, and the web browser provides access to the auction system from anywhere with an internet connection.

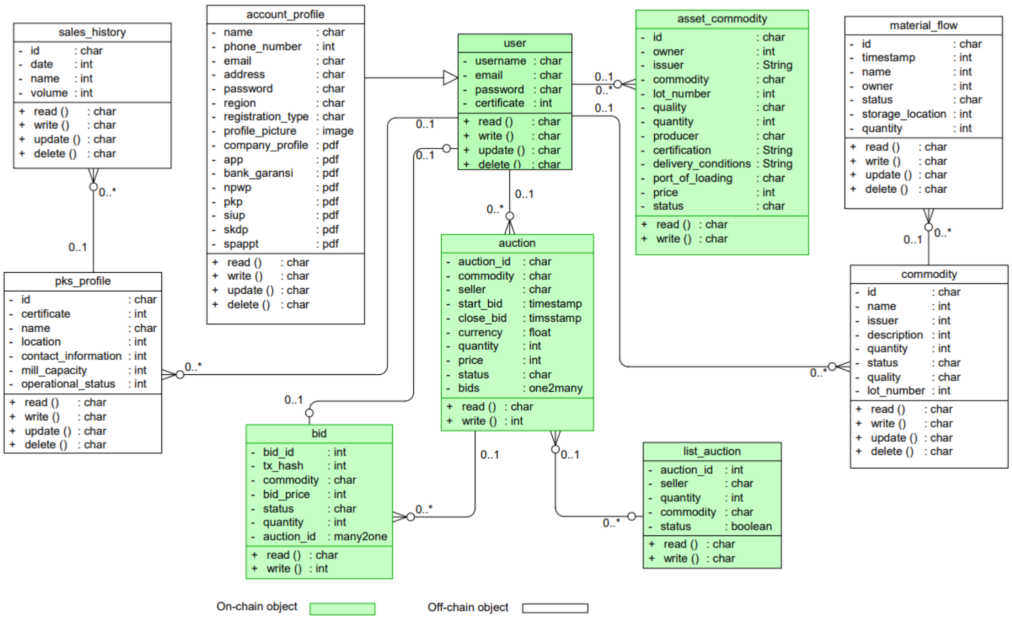

Figure 25 Class Diagram

In summary, the class diagram of the Integrated Blockchain-ERP-based Auction System provides a clear representation of the entities involved in the auction process, as well as the information about each entity and the relationships between them. The classes work together to provide a secure and transparent platform for the sale of commodities, such as crude palm oil (CPO), ensuring an efficient and optimized auction process.

5.6 Model Evaluation

5.6.1 Back-end Testing

Backend testing for a blockchain-based auction system in Hyperledger Fabric involves verifying the functionality and performance of the software that runs on the server-side of the application. The goal of backend testing is to ensure that the blockchain-based auction system performs as expected, is secure, and can handle high transaction volumes.

In Hyperledger Fabric, the backend consists of smart contracts, also known as chaincode, that are deployed on the blockchain network. These smart contracts define the rules and logic for the auction system, such as the bidding process and the auction winner selection. Hyperledger Fabric is an open-source blockchain framework that allows organizations to create their own blockchain networks for various use cases. In this particular system, Fabric Version 2.2 is being used, which is the latest stable version as of the knowledge cutoff date of this model.

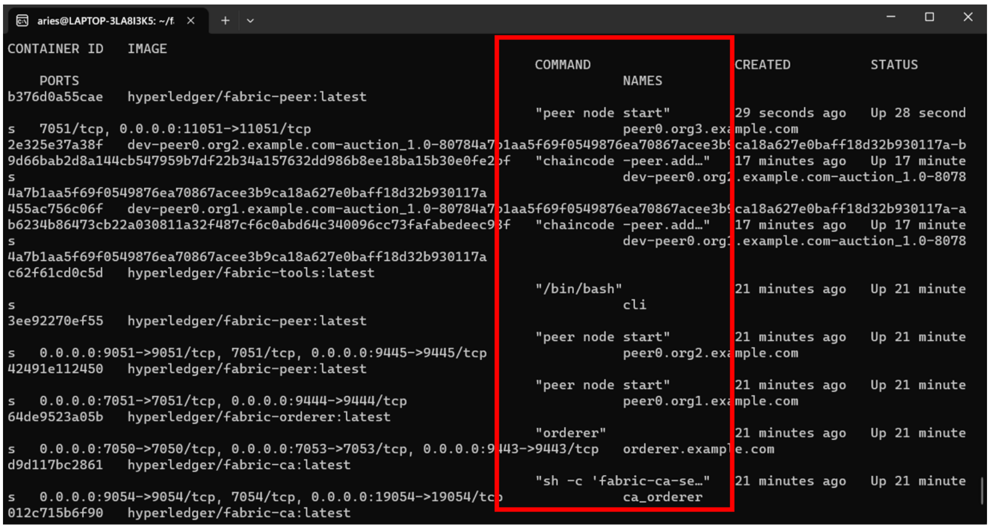

Figure 26 Fabric Network Configuration

The system consists of 3 peer nodes, which are responsible for executing transactions and maintaining the distributed ledger. These peer nodes contain the smart contracts, also known as chaincode, that define the rules and logic for the auction system. The peer nodes also communicate with each other to reach consensus on the state of the ledger.

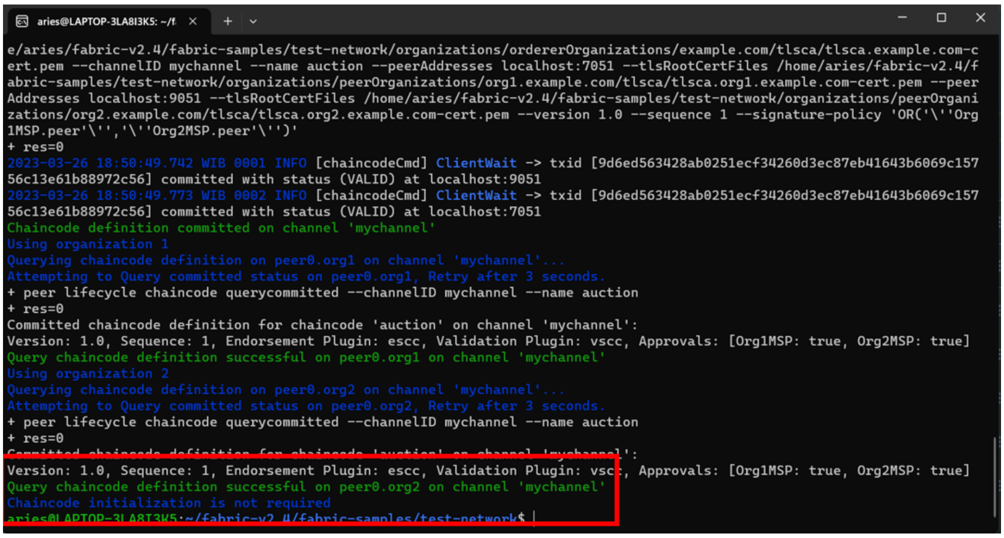

Figure 27 Deploy Chaincode

There are also 2 orderer nodes in the system, which are responsible for ordering and validating transactions before they are added to the ledger. The orderer nodes use a consensus algorithm to ensure that all transactions are ordered correctly and that the ledger remains consistent across all nodes.

To ensure the security of the system, a Certificate Authority (CA) is being used. The CA is responsible for managing digital certificates and public key infrastructure (PKI) for the blockchain network. Each node and participant in the network has a unique digital certificate that is verified by the CA, ensuring that only authorized participants can access and interact with the network.

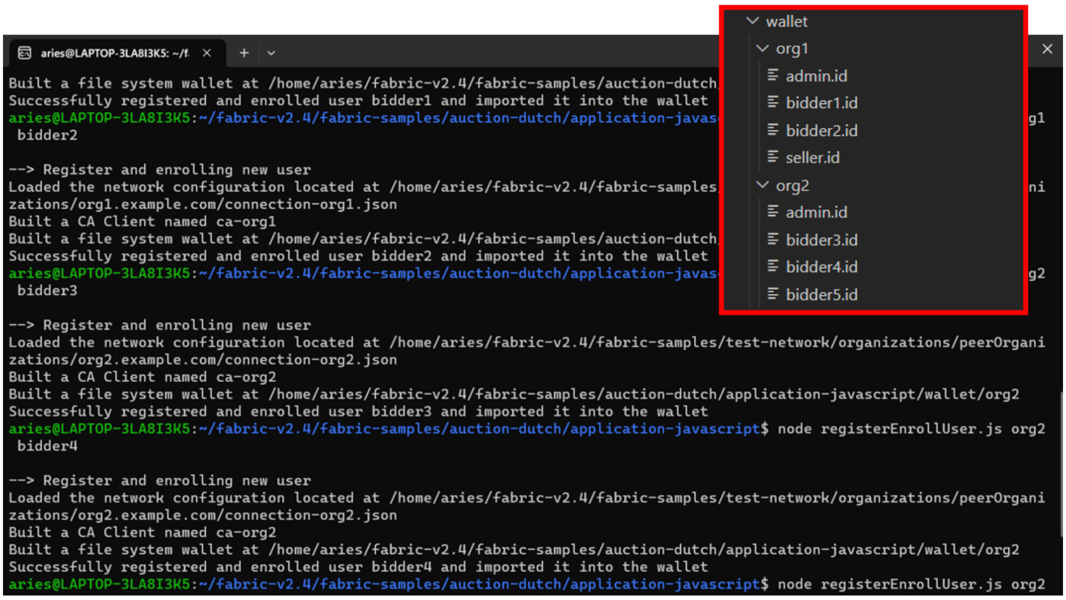

Figure 28 Make user identity

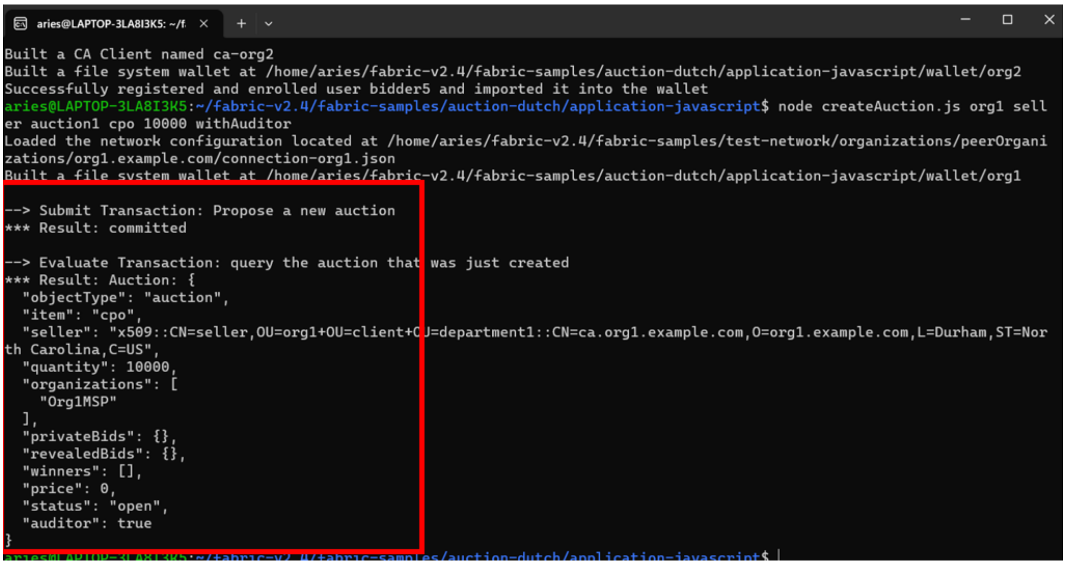

Figure 29 Make new auction

Testing the chaincode for a multi-unit auction involves verifying the functionality and performance of the smart contracts that define the rules and logic for the auction system. In this particular case, the auction system is designed for selling crude palm oil (CPO) and involves one seller and five bidders.

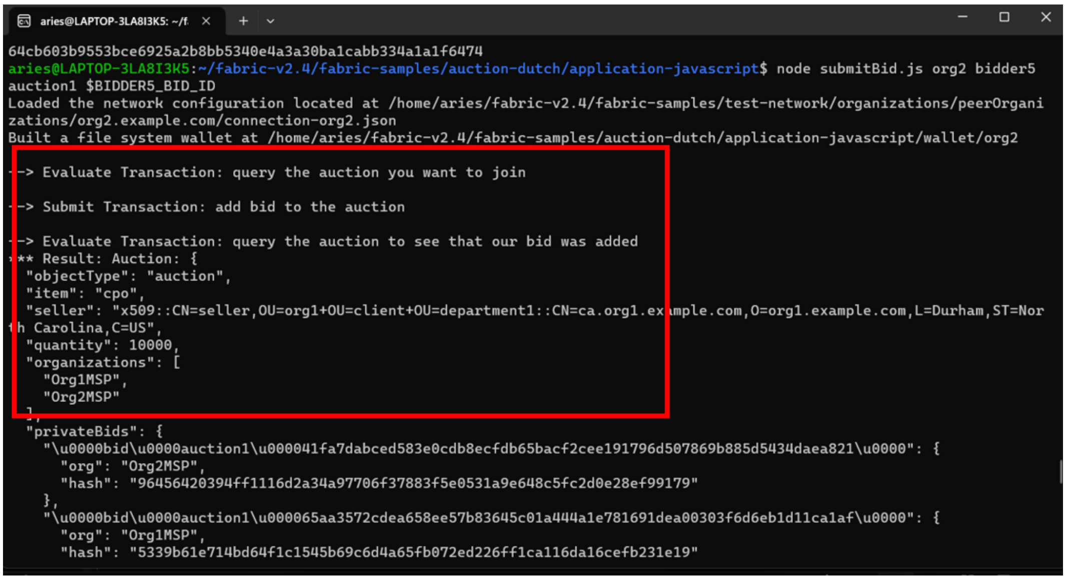

Figure 30 Submit bid

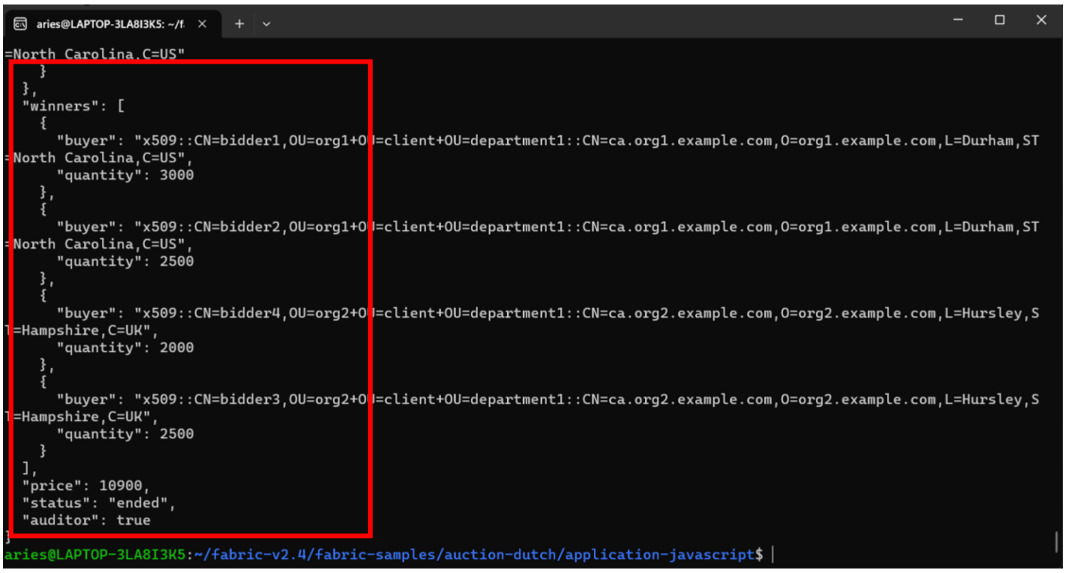

Figure 31 End auction and determine the winner

The testing process for this auction system can be as follows:

1. Seller creates a new auction with a total quantity of 10000 tons of CPO.
2. Bidders make their bids, with the following quantities:
   Bidder 1: 3000 tons
   Bidder 2: 2500 tons
   Bidder 3: 2500 tons
   Bidder 4: 2000 tons
   Bidder 5: 2000 tons
3. The system ends the auction and selects the winners based on the highest bids. The winners and their respective bid quantities are as follows:
   Bidder 1: 3000 tons
   Bidder 2: 2500 tons
   Bidder 3: 2500 tons

Bidder 4: 2000 tons

With this testing process, we can verify that the smart contracts are functioning correctly and that the auction system is able to handle multiple units of a commodity. By maximizing the allocation of the total supply of CPO among the winning bidders, the auction system ensures that the seller receives the best possible price for their commodity, while the bidders receive a fair and equitable distribution of the CPO.

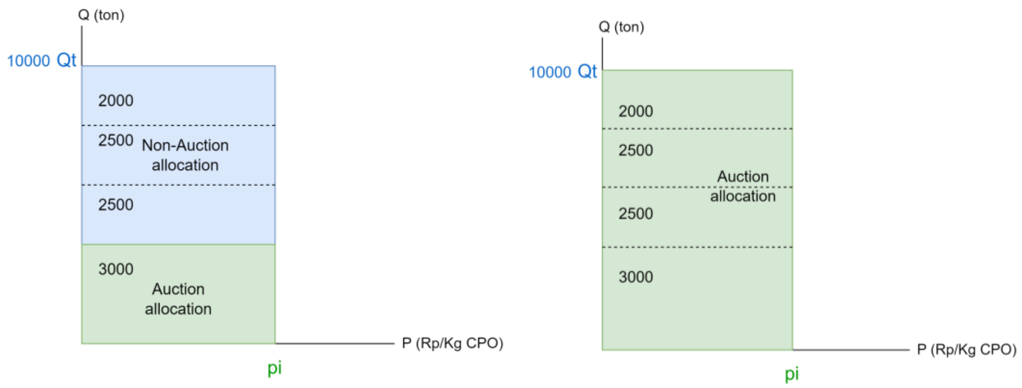

Figure 32 Comparison single auction with multi-unit auction

5.6.2 Front-end Testing

Front-end testing involves evaluating and validating the functionality, performance, and user experience of the GUI or front-end components of a software application. It encompasses various aspects, including functionality testing to ensure the correctness of features and interactions, UI testing to validate visual aspects and aesthetics, and cross-browser and cross-device testing to ensure compatibility across different platforms.

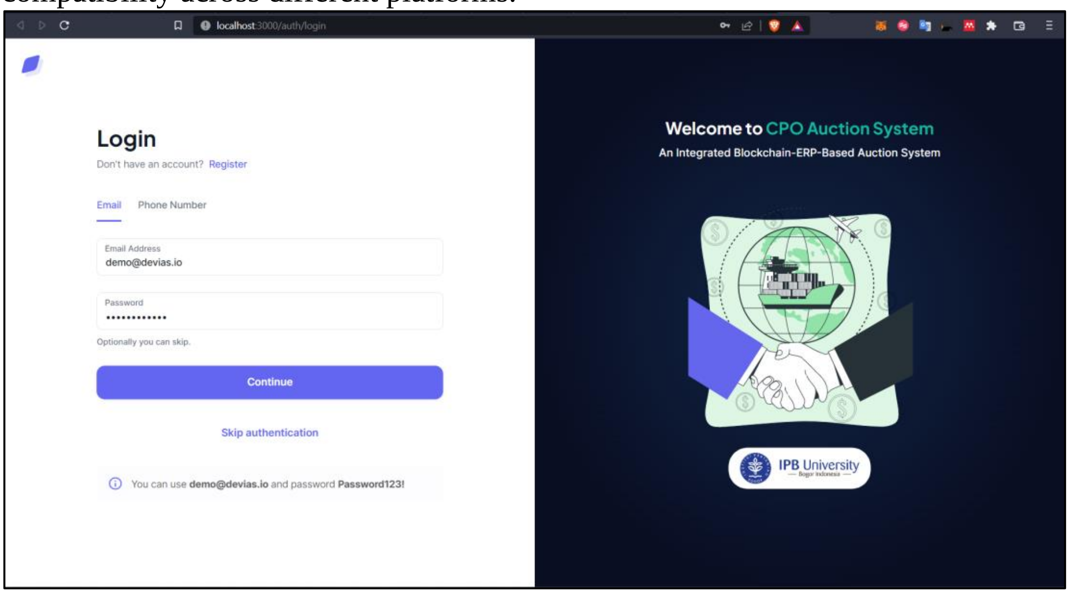

Figure 33 Login page

Additionally, responsiveness and mobile testing are essential to verify how the application adapts to various screen sizes and orientations, particularly with the increasing use of mobile devices. Conducting thorough front-end testing ensures that the application meets requirements, behaves as expected, and delivers a seamless user interface experience.

The dashboard is a front-end component designed to provide an overview of relevant information in a visually appealing manner. In the context mentioned, the dashboard would display live auction data, including ongoing auctions and relevant details. Additionally, it would include a graphical representation of the Crude Palm Oil (CPO) price over time, allowing users to visualize the price trends. Furthermore, the dashboard would present the total supply of CPO over time, showcasing the supply dynamics in a graphical format.

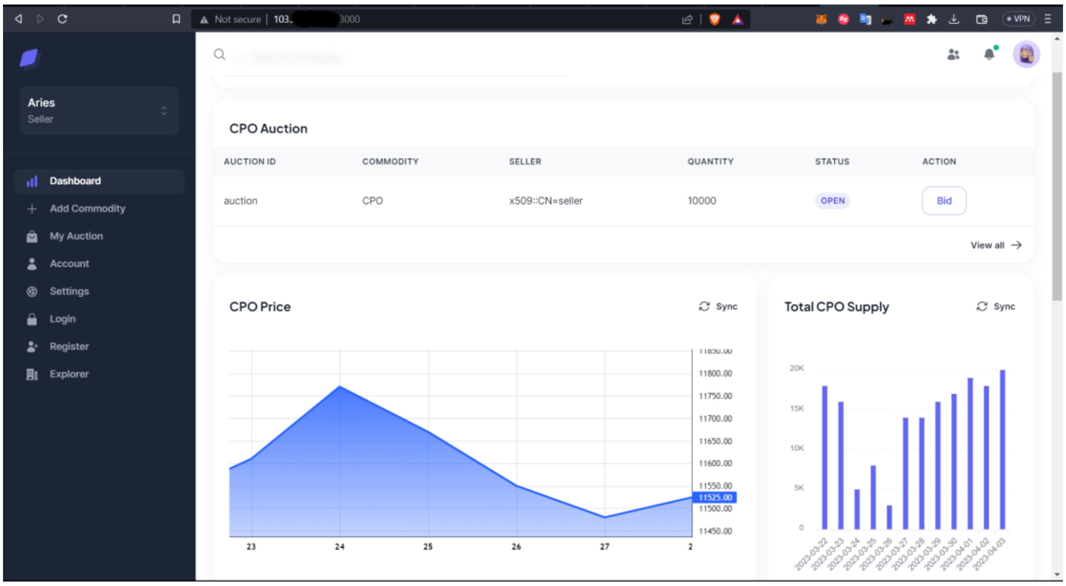

Figure 34 Dashboard

Add Commodity page is front-end component serves as a dedicated page for users to add a commodity, specifically Crude Palm Oil, to the blockchain network as an asset. It provides a user-friendly interface where users can input relevant information and initiate the process of registering the commodity on the blockchain. This page would typically include form fields for capturing details such as commodity type, quantity, origin, quality parameters, and any other pertinent information required to establish the commodity as a blockchain asset.

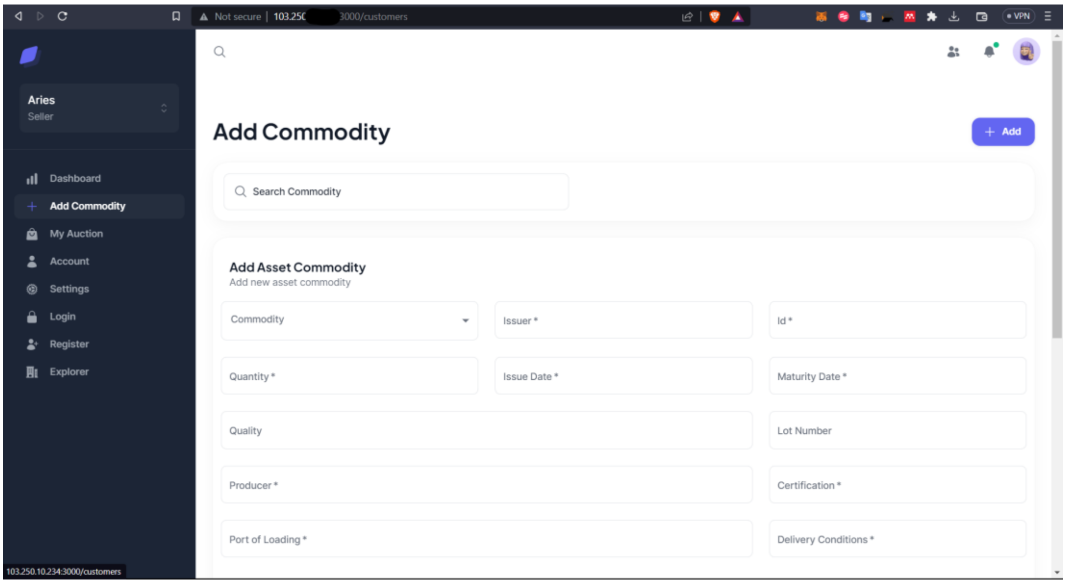

Figure 35 Add Commodity page.

The auction page is designed to facilitate the process of adding a CPO asset to an auction. It allows users to create auction listings for CPO assets, specifying key details such as starting price, auction duration, and any additional terms and conditions. This front-end component enables users to interact with the auction functionality, such as placing bids, monitoring ongoing auctions, and managing auction-related activities.

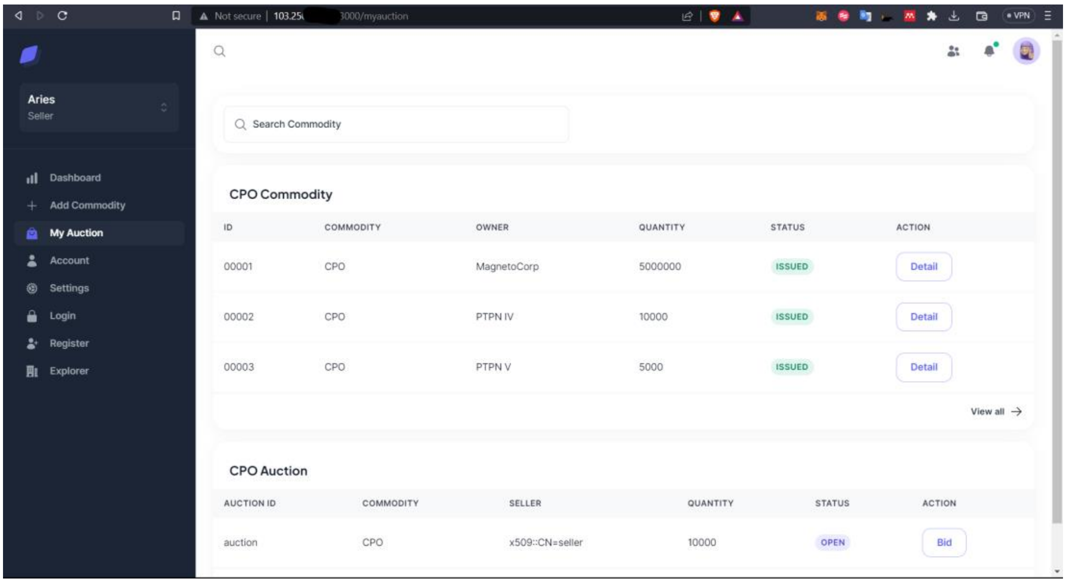

Figure 36 Auction page

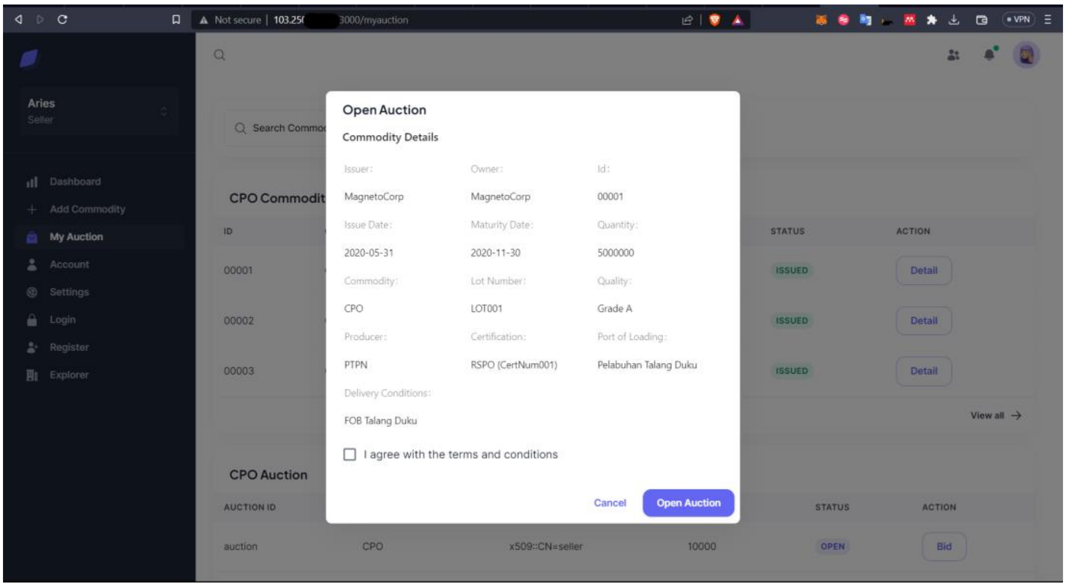

Figure 37 Pop-up to open auction

PKS Profile Page is page serves as a front-end component that integrates with the PKS Profiling module in the ERP system, specifically Odoo. It provides a dedicated area where users can access and view profiles and potential information of PKS (Pabrik Kelapa Sawit or Palm Oil Mills). The page displays essential details related to each PKS, such as its location, production capacity, certifications, operational history, and other relevant data. This integration enhances the overall functionality of the ERP system by providing seamless access to PKS-related information.

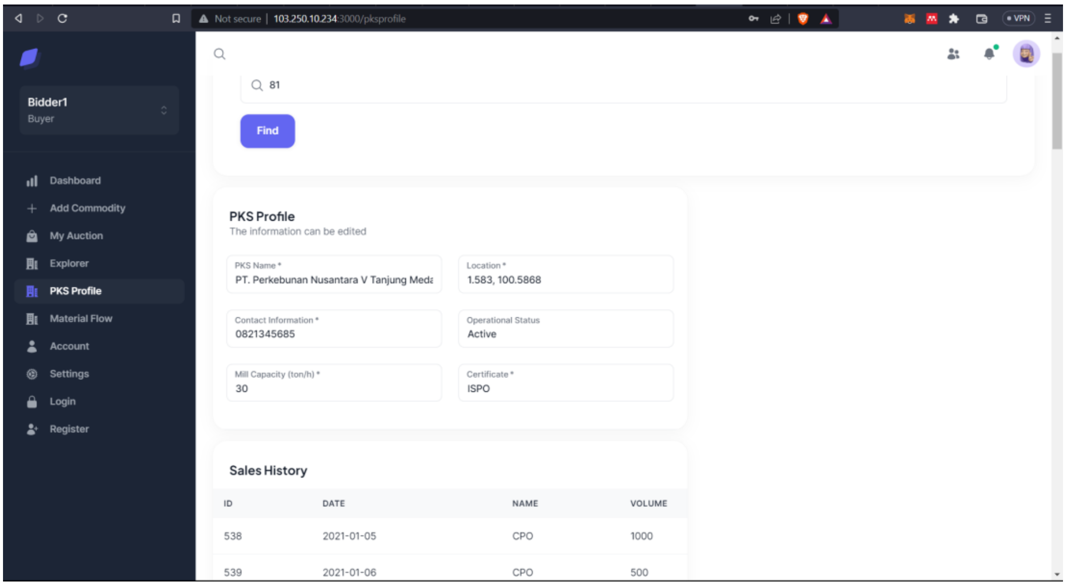

Figure 38 PKS Profiling page

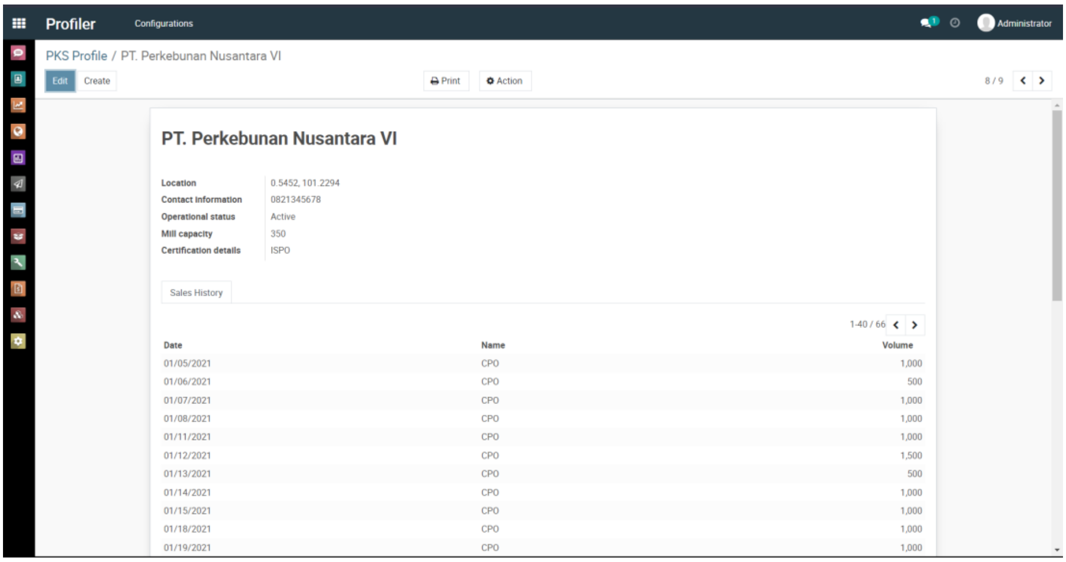

Figure 39 Module ERP PKS Profiling

Material Flow Page component is integrated with the material flow module in the ERP system, specifically Odoo. Its purpose is to present a visual representation of the flow of materials within the organization. The page displays information about the movement of materials, including their source, destination, quantities, and any associated processes or operations. By utilizing this front-end component, users can gain insights into the material flow within the organization, facilitating better planning, tracking, and optimization of resources.

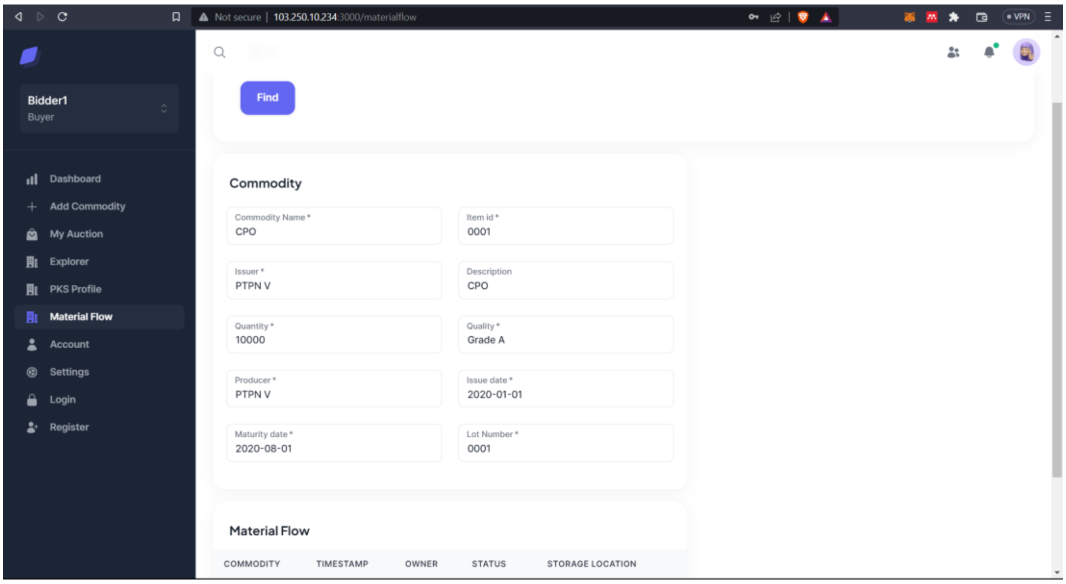

Figure 40 Material Flow page

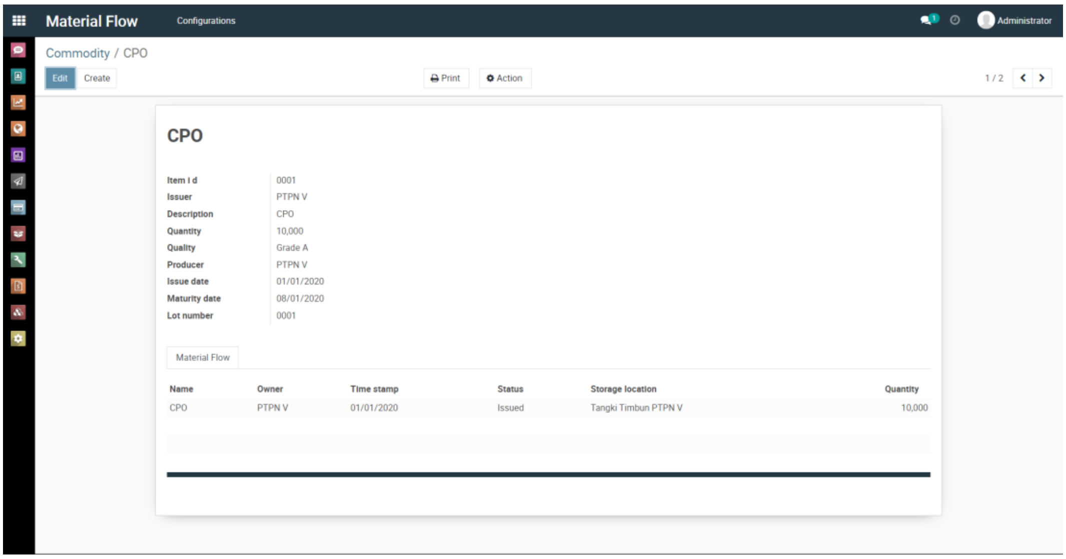

Figure 41 Module ERP Material Flow

The Hyperledger Fabric Explorer is a comprehensive tool designed to simplify the management and monitoring of Hyperledger Fabric blockchain networks. Its primary function is to provide users with a user-friendly interface for exploring and analyzing various components and activities within the network. One of its key features is network visualization, which offers a graphical representation of the blockchain network, including peer organizations, channels, and smart contracts. This visualization helps users understand the network's structure and relationships between different components.

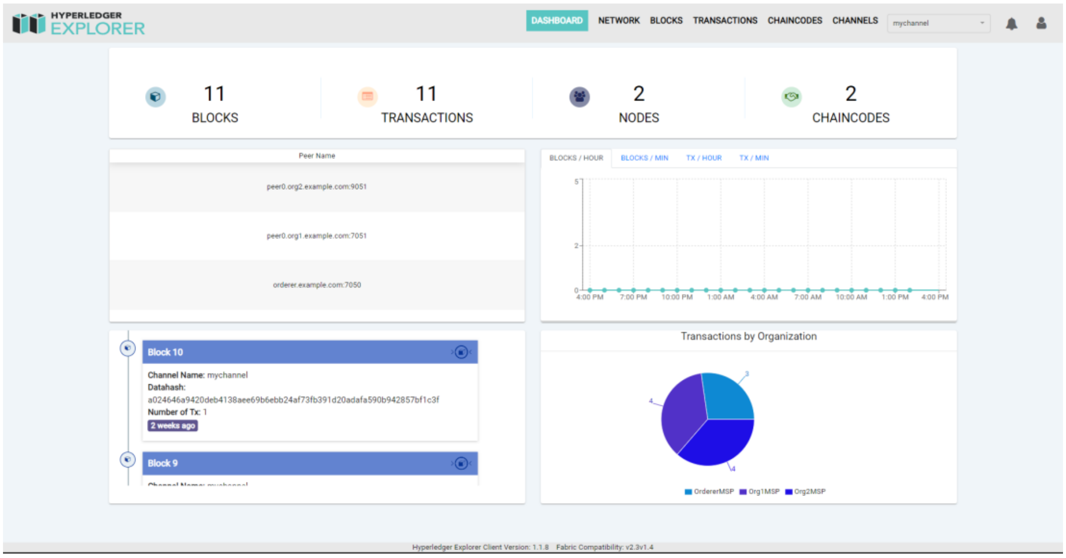

Figure 42 Fabric Explorer for monitoring all transaction in Blockchain.

The Explorer also allows users to track individual transactions within the network, providing details such as sender and recipient information, timestamps, input/output data, and endorsements. This transaction tracking capability is valuable for auditing and monitoring the flow of transactions.

Additionally, the Explorer enables users to analyze blocks and the underlying ledger data. Users can explore block details, including height and hash, and gain insights into the ledger state. Historical data can be queried, allowing users to track changes made to the blockchain over time.

Table 7 Auction Methods Comparison

Auction Version	**Bid Submission Method**	**Technology**	**Key Features**	**Advantages**
Auction v1	Letter	Traditional mail	N/A	- Nonelectronic process
Auction v2	Fax	Fax machines	N/A	- Faster bid submission compared to postal mail
Auction v3	Digital platform	Dedicated auction platform	Digital bid submission and management	- Enhanced convenience and efficiency through digital processes
Auction v4	Digital platform with Blockchain	Blockchain-integrated platform	Multi-unit auction, Blockchain integration, ERP	- Improved transparency and security through blockchain - Streamlined auction process with Smart contract/chaincode - Optimal resource allocation through multi-unit auction format

Auction v1 involves the submission of bids via traditional mail using letters. As a non-electronic process, it lacks the convenience and efficiency provided by digital platforms. However, it may still be used in situations where digital means are not readily available or preferred.

Auction v2 introduces fax machines as a bid submission method, offering faster bid submission compared to traditional mail. While this improves the speed of communication, it still does not utilize advanced digital platforms. Fax machines can be a viable option when transitioning from purely non-electronic processes to more modern methods.

Auction v3 represents a significant advancement as it leverages a dedicated digital platform designed specifically for auctions. Bidders can conveniently submit their bids and manage the entire auction process digitally. This approach enhances efficiency, reduces paperwork, and allows for seamless bid management and tracking. It provides enhanced convenience and accessibility for bidders, enabling them to participate from any location with an internet connection.

Auction v4 marks the most advanced version by integrating a digital platform with blockchain technology. This integration brings numerous benefits to the auction process. Blockchain ensures improved transparency and security, as all bid transactions and auction data are stored on an immutable and decentralized ledger. This fosters trust among participants and reduces the risk of tampering or fraud. Additionally, the auction system can leverage smart contracts or chaincode, which streamline the auction process by automating key steps and ensuring adherence to predefined rules. This enhances the efficiency, accuracy, and reliability of the auction.

Table 8 Verification and validation

Exiting Auction	**Time**	**Duration (min)**	**IBEA System**	**Time**	**Duration (min)**
Auction initiation	12.00-12.30	30	Create Auction	12.00-12.30	30
Open auction	12.30	0	Open Auction	12.30	0
Bidding	12.30-13.45	75	Bidding	12.30-13.45	75
Close auction	13.45	0	Close Auction	13.45	0
Announcing the results of the auction	13.45-14.15	30	Announcing the results of the auction	13.45	0
Counter 1	14.15-14.25	10			
Counter 2	14.25-14.35	10			
Counter 3	14.35-14.45	10			
Total Duration		165			105

Based on the table, it can be concluded that the IBEA model has a shorter duration compared to the existing auction model. This means that the IBEA model is capable of completing tasks more quickly than the existing auction model. The advantage of a shorter duration in the IBEA model may indicate better efficiency or performance. The IBEA model may utilize a more efficient approach or algorithm to optimize its processes, allowing it to achieve the desired results in a shorter amount of time.

Table 9 Verification and validation

Req. ID	**Functional Req**	**Non-Functional Req**	**Status**	**Status Description**	**Performance**
FR-01	The system must allow users to create an account	Response Time < 5s, Concurrent processes > 30, Generate digital certificate from Hyperledger fabric	success	The system successfully allows the user to create an account. Membership Service Providers (MSP) on each peer can create on chain accounts with digital certificates	Concurrent processes = 163, Successfully generate digital certificate from Hyperledger fabric
FR-02	The system must allow users to log	Response Time < 2s, Concurrent processes >	success	The system manages to allow users to log in to their account with the	Concurrent processes = 163, Successfully

	in to their account	30, Login with digital certificate		private key obtained from the MSP	login with digital certificate
FR-03	The system must allow users to browse CPO lots available for auction	Response Time < 5s Concurrent processes > 30,	success	The system successfully allows users to browse CPO lots available for auction by using the Auction ID to list available auctions	Response Time = 304 Ms, Concurrent processes = 163
FR-04	The system must allow users to place bids on CPO lots	Response Time < 5s, Concurrent processes > 30,	success	The system successfully allows users to bid on CPO lots by inputting the quantity and price to submit bids in a smart contract	Response Time = 4,98 s, Concurrent processes = 163
FR-05	The system must allow users to create a new auction	Response Time < 5s, Concurrent processes > 30,	success	The system manages to allow users to create new auctions by inputting auction information such as product name, quantity, manufacturer etc	Response Time 5,15 s, Concurrent processes = 163
FR-06	The system must calculate the clearing price and determine the winning bid for each CPO lot	Response Time < 5s, Handling of multi-unit auctions, Concurrent processes > 30,	success	The system succeeded in calculating the clearing price and determining the winning bidder for each CPO lot based on a multi-unit auction mechanism automatically by a smart contract	Successfully handled multi-unit auctions, Response Time = 8,16 s, Concurrent processes = 163
FR-07	The system can generate a report of the CPO lots won in the auction	Response Time < 2s, Concurrent processes > 30	success	The system successfully generates a report of the CPO lots won in the auction	Response Time = 304 Ms, Concurrent processes = 163
FR-08	The system can store and display PKS Profile	Response Time < 5s, Concurrent processes > 30,	success	The system successfully generates a report of the CPO lots won in the auction	Response Time = 304 Ms, Concurrent processes = 163
FR-09	The system can store and display Material Flow	Response Time < 2s, Concurrent processes > 30, Generate pdf file	success	The system successfully allows the user to see the current bid amount on the CPO lot by inputting the bid id	Response Time = 258 Ms, Concurrent processes = 163,

CONCLUSION

In this study, an auction system for the crude palm oil commodity was developed by integrating blockchain and ERP systems. The development process consisted of three phases, which were analyzing the system requirements, designing the auction system, and evaluating its performance. To identify the necessary features and functions of the auction system, a comprehensive understanding of the crude palm oil auction process was conducted. The system requirements were determined based on the needs of the stakeholders. To ensure the auction process's security, transparency, and efficiency, the system design employed an integrated blockchain and ERP system. A smart contract was developed to automate the auction process and guarantee that the auction's terms and conditions were fulfilled. The performance of the system was evaluated based on its functional and non-functional. The evaluation focused on how well the system met the requirements. The results of this study have the potential to increase transparency and reliability of the auction process for crude palm oil commodities and also to optimize resource allocation.

RECOMMEDATION

Real-world Implementation: Implement the developed auction system in a real-world setting, such as a pilot study or a limited-scale deployment. Monitor and evaluate the system's performance, reliability, and user acceptance in a practical environment. Gather feedback from users and stakeholders to identify any challenges, limitations, or additional requirements that arise during the implementation phase.

Economic and Business Impact Analysis: Assess the economic and business impact of integrating blockchain and ERP systems in the crude palm oil auction process. Analyze factors such as cost-effectiveness, resource optimization, and the potential for reducing fraud or inefficiencies. Quantify the benefits and drawbacks of the integrated system and provide recommendations for decision-makers in the palm oil industry.

Security and Privacy Analysis: Conduct a comprehensive analysis of the security and privacy aspects of the integrated blockchain and ERP system. Evaluate potential vulnerabilities, threats, and risks associated with the system, and propose solutions or enhancements to mitigate them. Consider factors such as data encryption, access controls, and secure communication protocols.

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APPENDIX

Appendix 1. Smart Contract Pseudocode

Table 10 Pseudocode for CreateAuction Function

```
Algorithm 1: CreateAuction
  Data: itemSold, seller, quantity, orgs, user
  Result: Auction object
  if UserAuthentication(user) is not valid then
  |  return "User authentication failed";
  end
  if UserPermissions(user) do not allow auction creation then
  |  return "User does not have permission to create auction";
  end
  Create a new Auction object;
  Set Auction.ItemSold to itemSold;
  Set Auction.Seller to seller;
  Set Auction.Quantity to quantity;
  Set Auction.Orgs to orgs;
  Set Auction.Status to "Open";
  Initialize Auction.Bids as an empty dictionary;
  Initialize Auction.Winners as an empty list;
  Set Auction.Price to 0;
  Set Auction.Auditor to false;
  return Auction;
```

Table 11 Pseudocode for SubmitBid Function

```
Algorithm 2: SubmitBid
  Data: auction, quantity, price, org, buyer, user
  if UserAuthentication(user) is not valid then
  |  return "User authentication failed";
  end
  if UserPermissions(user) do not allow bid submission then
  |  return "User does not have permission to submit bid";
  end
  if auction.Status is not "Open" then
  |  return "Auction is not Open";
  end
  Create a new FullBid object;
  Set FullBid.Quantity to quantity;
  Set FullBid.Price to price;
  Set FullBid.Org to org;
  Set FullBid.Buyer to buyer;
  Add FullBid to auction.Bids dictionary;
```

Table 12 Pseudocode for EndAuction Function

```
Algorithm 3: EndAuction
  Data: auction, user
  if UserAuthentication(user) is not valid then
  |  return "User authentication failed";
  end
  if UserPermissions(user) do not allow auction ending then
  |  return "User does not have permission to end auction";
  end
  if auction.Status is not "Open" then
  |  return "Auction is not Open";
  end
  Set auction.Status to "Ended";
  Call CalculateClearingPrice(auction);
```

Table 13 Pseudocode for CalculateClearingPrice Function

```
Algorithm 4: CalculateClearingPrice
  Data: auction
  Sort the bids in auction.Bids by descending order of price;
  Set remainingQuantity to auction.Quantity;
  foreach bid in the sorted bids do
  |  if remainingQuantity ≤ 0 then
  |  |  Break the loop;
  |  end
  |  if bid.Quantity ≤ remainingQuantity then
  |  |  Add bid to auction.Winners list;
  |  |  Set remainingQuantity to remainingQuantity - bid.Quantity;
  |  end
  |  else
  |  |  Create a new FullBid object;
  |  |  Set FullBid.Quantity to remainingQuantity;
  |  |  Set FullBid.Price to bid.Price;
  |  |  Set FullBid.Org to bid.Org;
  |  |  Set FullBid.Buyer to bid.Buyer;
  |  |  Add FullBid to auction.Winners list;
  |  |  Set remainingQuantity to 0;
  |  end
  end
  Set auction.Price to the price of the last bid in the auction.Winners list;
```

Table 14 Pseudocode for QueryAuction Function

```
Algorithm 5: QueryAuction
  Data: auction, user
  if UserAuthentication(user) is not valid then
  |  return "User authentication failed";
  end
  if UserPermissions(user) do not allow auction query then
  |  return "User does not have permission to query auction";
  end
  return auction;
```

Table 15 Pseudocode for addCommodity Function

```
Algorithm 6: addCommodity
  Data: user, issuer, id, issueDateTime, maturityDateTime, quantity, commodity,
        lotNumber, quality, producer, certification, portOfLoading, deliveryConditions
  Result: Message indicating success or failure
  if authenticateUser(user) is not valid then
  |  return "User authentication failed";
  end
  if authorizeUser(user, "addCommodity") is false then
  |  return "User not authorized to add commodities";
  end
  Create a new commodity object;
  Set commodity.issuer to issuer;
  Set commodity.id to id;
  Set commodity.issueDateTime to issueDateTime;
  Set commodity.maturityDateTime to maturityDateTime;
  Set commodity.quantity to quantity;
  Set commodity.commodity to commodity;
  Set commodity.lotNumber to lotNumber;
  Set commodity.quality to quality;
  Set commodity.producer to producer;
  Set commodity.certification to certification;
  Set commodity.portOfLoading to portOfLoading;
  Set commodity.deliveryConditions to deliveryConditions;
  Set commodity.status to "Issued";
  Add commodity to the ledger;
  return "Commodity added successfully";
```

Table 16 Pseudocode for QueryCommodity Function

```
Algorithm 7: queryCommodity
  Data: user, commodityId
  Result: Commodity object or error message
  if authenticateUser(user) is not valid then
  |  return "User authentication failed";
  end
  if authorizeUser(user, "queryCommodity") is false then
  |  return "User not authorized to query commodities";
  end
  for each commodity in ledger do
  |  if commodity.id is equal to commodityId then
  |  |  return commodity;
  |  end
  end
  return "Commodity not found";
```

Appendix 2. Activity Diagram for Each Function

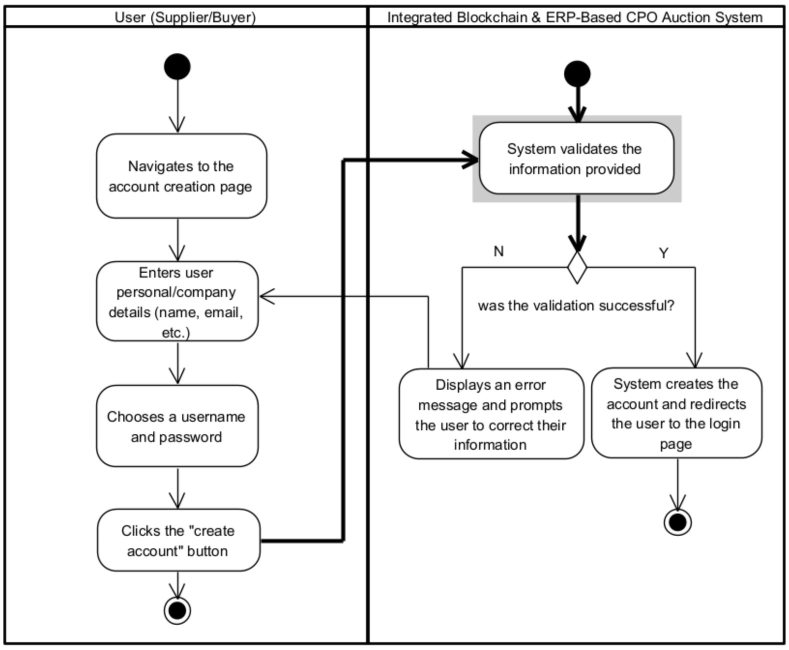

Figure 43 Create new user account (F1)

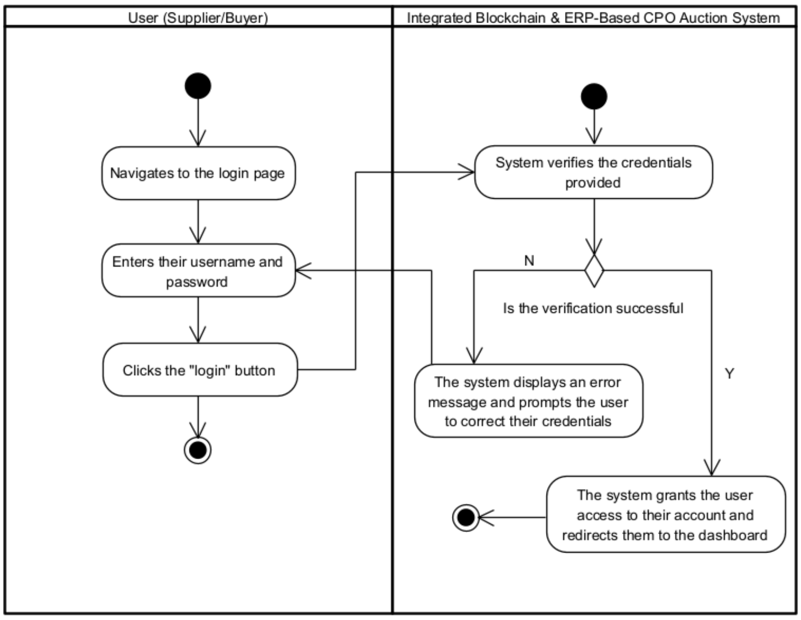

Figure 44 Login to the system (F2)

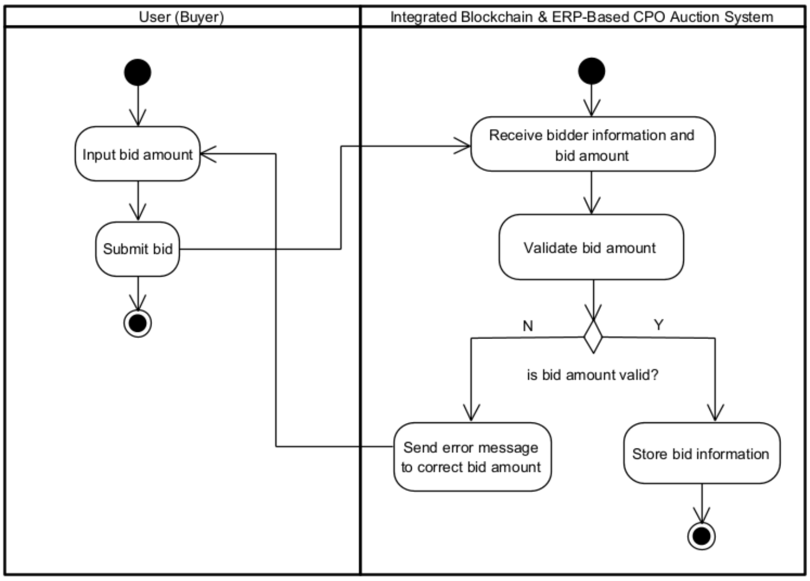

Figure 45 Place bids on CPO lots (F3)

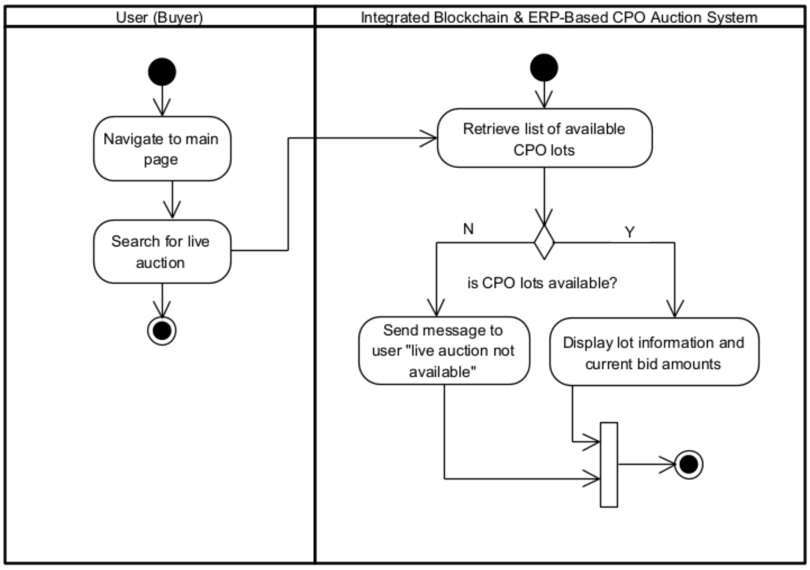

Figure 46 Browse CPO lots available for auction (F4)

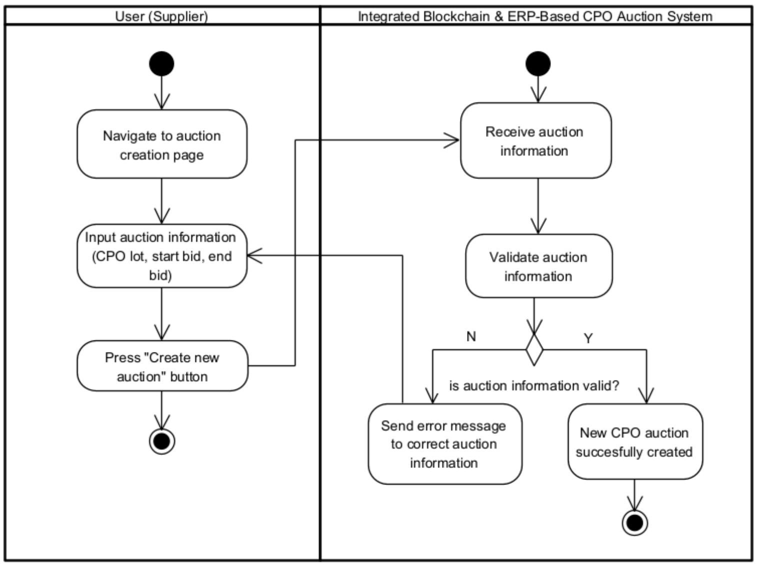

Figure 47 Create a new auction (F3)

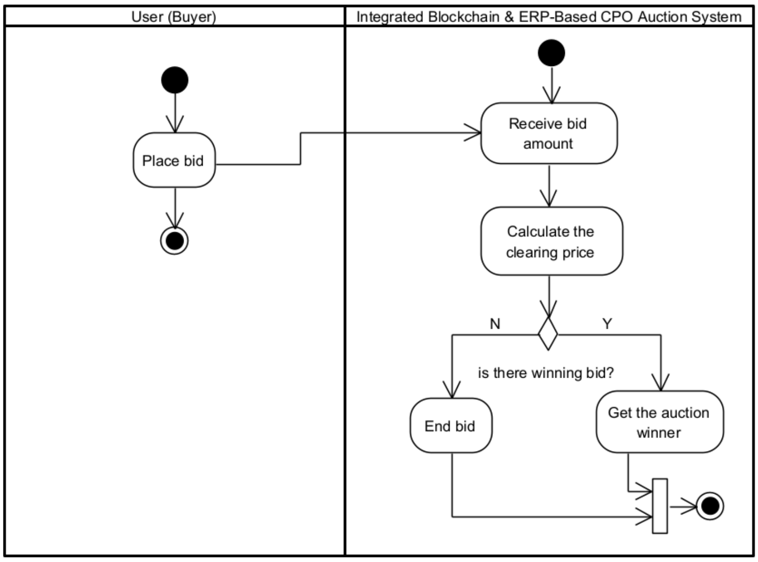

Figure 48 Determine clearing price and the winning bid (F6)

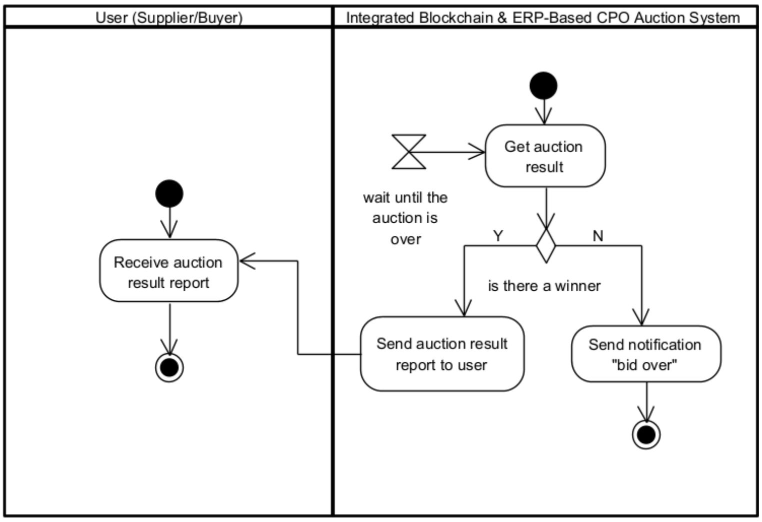

Figure 49 Notify the auction result report (F7)

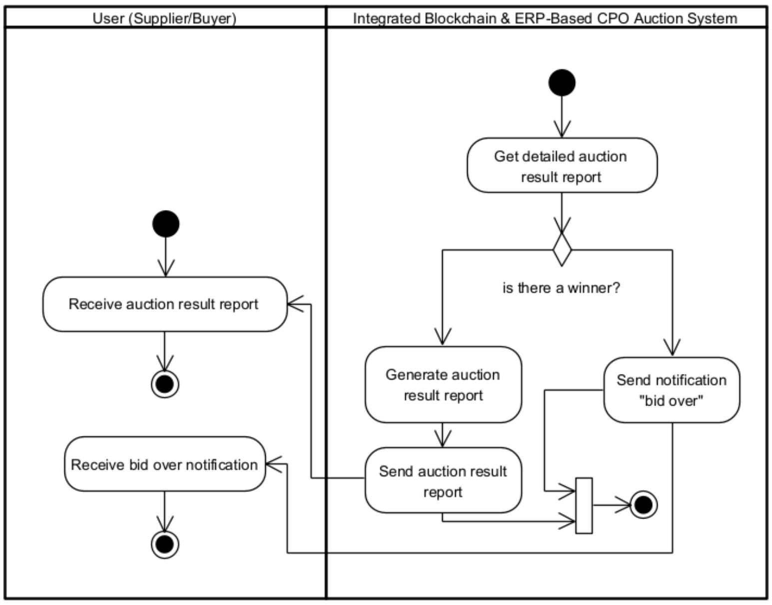

Figure 50 Generate a report of the CPO lots won in the auction (F8)

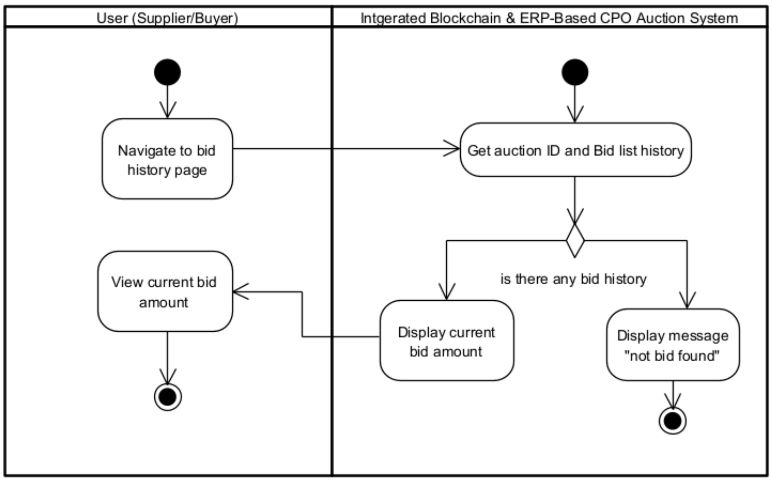

Figure 51 View current bid amounts on CPO lots (F9)

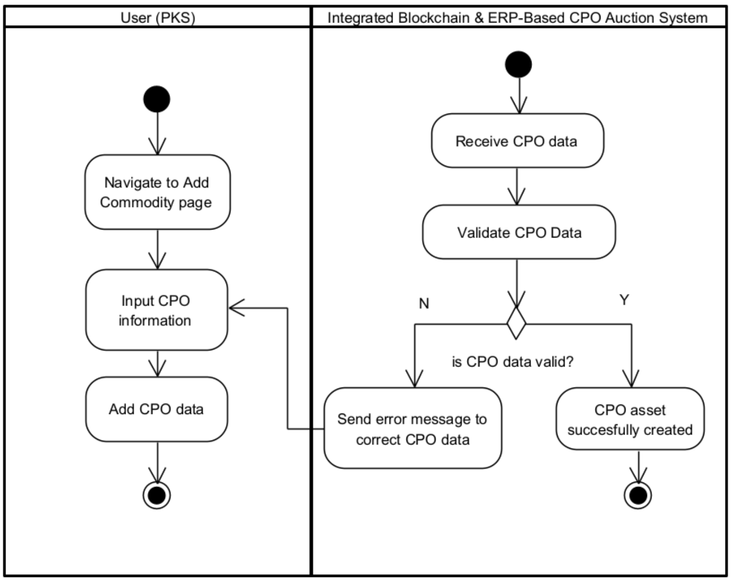

Figure 52 Store and display CPO Asset (F10)

Appendix 3. Source Code IBEA System

The source code for the IBEA System, protected by copyright, can be accessed via the link below. Accessing the code allows developers, researchers, and enthusiasts to study, analyze, or contribute while respecting copyright laws. It promotes collaboration and innovation while honoring the intellectual property associated with the IBEA System.

ipb.link/source-code-ibea

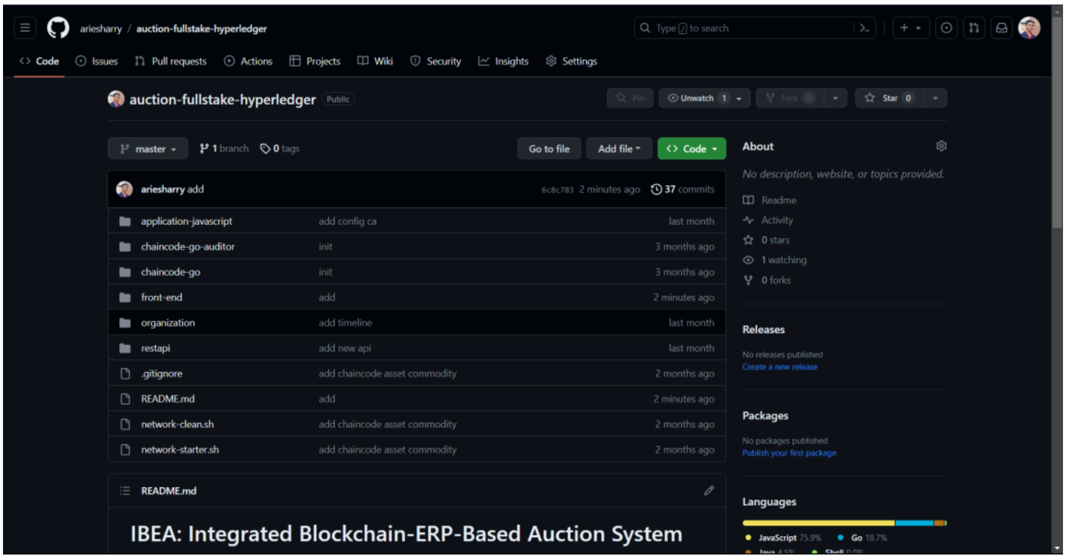

Figure 53 Source code IBEA System

Appendix 4. Data Test

Table 17 Data Auction

Attribute	Value
ID	3
COMMODITY	CPO
SELLER	PTPN4
QUANTITY	2000
RESERVE PRICE	10900
START TIME	12.30
END TIME	14.45

Table 18 Data Commodity

Attribute	Value
Issuer	PTPN4
Owner	PTPN4
Id	00004
Issue Date	07/04/2020
Maturity Date	07/04/2020
Quantity	2000
Commodity	CPO
Lot Number	00001
Quality	Grade A
Producer	PTPN4
Certification	ISPO
Port of Loading	Sosa/Dumai
Delivery Conditions	FOB

Table 19 Data Bid

Bidder	Quantity	Price
PHPO	500	10018
NPO	500	10018
IBP	500	9996
SMART	500	9750
KJA	500	9850
SDS	500	9956
WNI	1000	10018

Table 20 Data PKS Profile

Name	Location	Contact information	Operational status	Mill capacity	Certification details
PT. Perkebunan Nusantara V Sei Galuh	0.5452, 101.2294	0821345678	Active	60	ISPO
PT. Perkebunan Nusantara V Sei Garo	0.6445, 101.11	0821345679	Active	30	ISPO
PT. Perkebunan Nusantara V Sei Pagar	0.3262, 101.3505	0821345680	Active	30	ISPO
PT. Perkebunan Nusantara V Tandun	0.5991, 100.6925	0821345681	Active	45	ISPO
PT. Perkebunan Nusantara V Terantam	0.5781, 100.7509	0821345682	Active	60	ISPO
PT. Perkebunan Nusantara V Tanah Putih	1.7446, 100.511	0821345684	Active	60	ISPO
PT. Perkebunan Nusantara V Tanjung Medan	1.583, 100.5868	0821345685	Active	30	ISPO
PT. Perkebunan Nusantara IV	0.5452, 101.2294	0821345678	Active	350	ISPO

Table 21 Data PKS Sales/Supply for Auction

Name	Date	Volume
CPO	07/01/2020	2000
CPO	08/01/2020	1000
CPO	09/01/2020	2000
CPO	10/01/2020	2000
CPO	13/01/2020	2000

CPO	14/01/2020	3000
CPO	15/01/2020	1000
CPO	16/01/2020	2000
CPO	17/01/2020	2000
CPO	20/01/2020	2000
CPO	21/01/2020	2000
CPO	22/01/2020	2000
CPO	23/01/2020	1000
CPO	24/01/2020	2000
CPO	27/01/2020	2000
CPO	28/01/2020	2000
CPO	29/01/2020	1000
CPO	30/01/2020	2000
CPO	31/01/2020	2000
CPO	03/02/2020	2000
CPO	04/02/2020	1000
CPO	05/02/2020	2000
CPO	06/02/2020	2000
CPO	07/02/2020	2000
CPO	10/02/2020	2000
CPO	11/02/2020	2000
CPO	12/02/2020	2000
CPO	13/02/2020	3000
CPO	14/02/2020	2000
CPO	17/02/2020	2000
CPO	18/02/2020	2000
CPO	19/02/2020	2000
CPO	20/02/2020	2000
CPO	21/02/2020	2000
CPO	24/02/2020	2000
CPO	25/02/2020	2000
CPO	26/02/2020	2000
CPO	27/02/2020	2000
CPO	28/02/2020	2000
CPO	02/03/2020	2000
CPO	03/03/2020	2000
CPO	04/03/2020	2000
CPO	05/03/2020	2000
CPO	06/03/2020	2000
CPO	09/03/2020	2000
CPO	10/03/2020	2000
CPO	11/03/2020	2000
CPO	12/03/2020	2000
CPO	13/03/2020	2000
CPO	16/03/2020	2000
CPO	17/03/2020	2000

CPO	18/03/2020	2000
CPO	19/03/2020	2000
CPO	20/03/2020	2000
CPO	23/03/2020	2000
CPO	24/03/2020	2000
CPO	25/03/2020	2000
CPO	26/03/2020	2000
CPO	27/03/2020	2000
CPO	30/03/2020	2000
CPO	31/03/2020	2000
CPO	01/04/2020	2000
CPO	02/04/2020	2000
CPO	03/04/2020	2000
CPO	06/04/2020	2000
CPO	07/04/2020	2000

Appendix 5. Existing Meta Data

Table 22 Existing Meta Data

Table	Attribute	Data Type
Auction	Auction No.	String
	Commodity Code	String
	Catalog Type	String
	Order Method	String
	Auction Place	String
	Start Time	Time
	End Time	Time
	Status	String
Bid	Currency	Integer
	Status	String
	Enter Bid	Integer
	Last Bid	Integer
	Highest Bid	Integer
Commodity	Commodity	String
	Type Commodity	String
	Vol	Integer
	Nilai	Integer
Customer	Commodity	String
	Customer	String
	Vol	Integer
	Nilai	String
Supplier	Commodity	String
	PTPN	String
	Vol	Integer
	Nilai	String
Counter	Last Bid	Integer
	Bid	Integer
	Ranking	Integer
	Counter Offer	Integer
	Counter Bid	Integer

Appendix 6. Existing Auction Final Report

TENDER FINAL

Commodity: SAWIT	Tender No. :0002/KPBN/SAWIT/CPO/LOCAL/I/2021	
	Tender Date. :Tuesday, 05 January 2021	
Catalog Type: CPO	Open Bid: 12:30	Tender Place:PT.KPBN	Fax No : 3106685
	Close Bid: 13:45	Order Type:Local	Email : sawit@inacom.co.id
YOUR BID FOR REPLY HERE: Tuesday, 05 January 2021 LATEST AT 12:30 JAKARTA TIME			PRICE IN IDR, PER KG

No	Produsen			Product Quality	Quantity				Result				
	Name	Type	POL	Grade	Symbol	Qty(KG)	CTR	PACK	Traded	Counter	Bid	Buyer	State
1	PTPN I	CPO	Franco Pabrik Pembeli Medan/ Belawan	CPO - Kelas A (ALB 3, 51% s/d 5, 00%) dan M+I 0,50%	KANTOR PUSAT	500000	-	-	10018	10018	10018	PHPO	accepted
									-	10018	9996	MM	withdraw
									-	10018	9725	SMART	withdraw
2	PTPN III	CPO	Franco PT. SAN Unit Dumai	CPO - Kelas A (ALB 3, 51% s/d 5, 00%) dan M+I 0,50%	KANTOR PUSAT	500000	-	-	10018	10018	10015	NPO	accepted
									-	10018	9996	IBP	withdraw
									-	10018	9850	KJA	withdraw
3	PTPN IV	CPO	Franco PT. SAN Unit Belawan	CPO - Kelas A (ALB 3, 51% s/d 5, 00%) dan M+I 0,50%	KANTOR PUSAT	500000	-	-	10018	10018	10018	PHPO	accepted
									-	10018	9996	MM	withdraw
									-	10018	9956	SDS	withdraw
4	PTPN IV	CPO	Franco PP Medan/ Belawan/ Kuala Tanjung	CPO - Kelas A (ALB 3, 51% s/d 5, 00%) dan M+I 0,50%	KANTOR PUSAT	500000	-	-	10018	10018	10018	PHPO	accepted
									-	10018	9996	MM	withdraw
									-	10018	9750	SMART	withdraw
5	PTPN IV	CPO	Franco Pabrik Pembeli Sekitar Sosa/ Dumai	CPO - Kelas A (ALB 3, 51% s/d 5, 00%) dan M+I 0,50%	KANTOR PUSAT	500000	-	-	-	10018	10010	NPO	withdraw
									10018	10018	9996	IBP	accepted
									-	10018	9850	KJA	withdraw
6	PTPN V	CPO	Franco Pabrik Pembeli Sekitar Dumai	CPO - Kelas A (ALB 3, 51% s/d 5, 00%) dan M+I 0,50%	KANTOR PUSAT	1000000	-	-	10018	10018	10015	NPO	accepted
									-	10018	9996	IBP	withdraw
									-	10018	9880	PII	withdraw
7	PTPN VI	CPO	Franco Pabrik Pembeli Talang Duku/FOB Talang Duku	CPO - Kelas A (ALB 3, 51% s/d 5, 00%) dan M+I 0,50%	KANTOR PUSAT	1000000	-	-	9868	9868	9853	PHPO	accepted
									-	9868	9529	WNI	withdraw
									-	9868	8800	SDS	withdraw
Total Volume						4500000	-						

Note :
1. Pembayaran selambat-lambatnya 15 hari kerja efektif sejak tanggal kontrak.
2. Penyerahan selambat-lambatnya 15 hari kerja efektif setelah tanggal jatuh tempo pembayaran.
3. Bid dapat diajukan pada alamat website http://portal.kpbn.co.id/
4. Harga penawaran TIDAK termasuk PPN 10% (Exclude) dan tanpa decimal poin (bilangan bulat).

PT. Kharisma Pemasaran Bersama Nusantara
Receipt at Attorney and on behalf of PTPN(Persero)
Board of Director

Arif Budiman

Tender No : 21011000002

Figure 54 Existing Auction Report