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Evaluation in Serious Game Supply Chain Management with Blockchain Smart Contract

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Abstract

Blockchain game technology and Smart Contracts bring significant changes for users by enabling direct transactions without intermediaries. This innovation allows faster and more efficient payments and transactions and reducing costs typically charged by traditional financial institutions. However, the development of blockchain game technology often neglects user perspective in supply chain management. This study evaluates the involvement of various actors (farmers, Village Unit Cooperatives, distributors, and customers) to ensure the effective application of smart contracts., which are cryptographic agreements digitally verified by participants. The Heuristic Evaluation method was applied, focusing on User Interface and User Experience, with usability testing conducted on 30 participants using the System Usability Scale (SUS). The results show that the application's navigation design allows users to track data easily and promotes transparency among actors in decentralized agricultural product transactions. The evaluation results were: User Registration (UR) 100%, Farmer Stock 80%, Farmer Shop (FSH) 90%, Farmer KUD Transaction (FK) 75%, KUD Stock (KS) 100%, KUD Shop (KSH) 90%, KUD Consumer Transaction (KD) 78%, Farmer Auction(FA) 55%, Farmer KUD Bidding Transaction (FBT) 75%, and Consumer Stock (CS) 88%. Additionally, usability testing using the SUS method produced an average score of 81.083, classified as "marginal-excellent."

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I. INTRODUCTION

Serious games are gaming whose purpose is not only entertainment but also the achievement of goals such as learning, simulation, and education, thereby requiring users to accomplish specific targets [1], [2]. The implementation of serious games is applied in several sectors, one of which is supply chain management, where issues often arise due to third-party involvement in buying and selling products [3]–[5]. As a result,, the selling price to consumers significantly increases because it passes through several intermediaries. Thus, a technology is needed to address this problem, namely Smart Contract technology on a blockchain network. Smart Contracts enable automatic agreements in digital transactions between sellers and the buyers, stored within the cryptographic code of each node in the blockchain. These transactions are verified, and their authenticity is guaranteed without the need a central authority [6]-[8]. Smart Contracts allow both parties to transact without the necessity of knowing or trusting each other. The transactions are stored in the ledger to minimize data modification, ensure transparency, and provide efficiency. They also reduce the additional transaction costs by eliminating third parties while ensuring simple verification and user data privacy [9]-[11]. The application of serious games as a simulation of blockchain-based supply change management facilitates decision-making by actors and increases benefits for both farmers and consumers [12], [13].

Game Supply Chain Management with Blockchain Smart Contract requires evaluation from the users' perspectives, particularly regarding the navigation design. This evaluation is necessary to ensure use of use, accurate tracking of data, and transparency among actors in decentralized agricultural product transactions [14], [15]. We employ the Heuristic Evaluation method, focusing on the user interface of the game's graphics display. This method is expected to ensure that the game can be easily understood by actors involved in the serious game. Moreover, User Experience is considered

to assess the suitability of features and users' needs, thereby preventing errors in blockchain-based smart contract transactions[16].

Several related studies [17]-[19] highlight the role of heuristic evaluation as a method that produces analytical results in the form of recommendations for user groups, thereby supporting the evaluation of serious games.

Several previous studies conducted by Matteo Galli et al. (2021) examined multiplayer serious games in supply chain management, which were used as decision-making strategies to identify optimal market segments. [20] . Reverberi et al. (2022) investigated serious games for scheduling orders, determining quantity, price quality, and customer-supplier agreements, evaluating through Alpha testing [3]. Research conducted by Stefan et al. (2019) explored serious games as a simulation for decision-making to reduce the bullwhip effects by maintaining prices in supply chains, where communication among players facilitated information sharing about order quantities, warehouse costs, and delivery delays [15]. Ansh Mittal et al. (2021) studied serious games using blockchain technology for supply chain management, emphasizing enhanced security and increased interaction with non-player characters based on player responses [21].

This research aims to conduct a user-centered evaluation of serious games, referring to the work of Alessandro Di Stefano et al. (2020), which applied heuristics game theory to blockchain-based multiplayer network modeling for analyzing agents' decision behavior in blockchain transactions regarding trust, weight and time [22]. Furthermore, research conducted by Natalia et al. (2014) investigated serious games using the heuristic evaluation method in usability inspections, identifying challenges in the design and implementation process. Their findings emphasize aspects such as player concentration, social interaction, immersion, and specialized simulation games [23]. The game design elements on heuristic evaluation further emphasizes user experience, motivation, satisfaction, and psychological needs in gameplay [18]. In addition, research from the blockchain perspective highlights evaluation design strategies using heuristic evaluation approach in decentralized exchanges, focusing on usability testing to better understand Function, operation and modification [17].

Based on related research [1], [2], [3]–[23], the implementation of serious games in supply chain management focuses on coordinating blockchain-based smart contracts to reduce a bullwhip effects in inventory decisions, rising costs, uncertain supply chain stocks, and price fluctuations. These challenges are largely caused by insufficient coordination among actors and significant information uncertainty, which contribute to delays in marketing and distribution. The heuristic evaluation method is particularly relevant in this research, as it evaluates the user interface and user experience in this context.

The novelty and originality of this research lie in the lack of prior studies integrating serious games, supply chain management, and blockchain with direct testing by user actors. Therefore, this research makes a valuable contribution by evaluating application effectiveness through a user-centered approach.

II. METHODS

A. *User-Centered Evaluation for Serious Game Supply Chain Management in Blockchain*

Implementation of blockchain in serious game supply chain management occurs because of issues arising from third-party involvement in buying and selling transactions within the supply chain network. This challenge is addressed through a blockchain smart contract-based simulation of supply chain management, which enables communication among the actors involved [16], [24]. User-Center Evaluation of Serious Game Supply Chain Management in Blockchain is conducted based on users as actors in the system. This approach employs heuristic evaluation to identify application usage, system operations (including interface design), game features, user satisfaction, and overall assessment in terms of efficiency and effectiveness [25].

B. *User-Centered Evaluation for Serious Game Supply Chain Management using Blockchain Smart Contract*

User-centered design illustrates how communication is implemented between game users, particularly in blockchain-based supply chain management. User experience is a critical aspect in this context, emphasizing an engaging and easy-to-use game interface [26], [27].

In addition, interface usability, and social communication are also necessary in the smart contract blockchain, where transactions are recorded in a decentralized ledger among actors participating in the game-making process. The success of this series of games depends on whether actors can understand and respond effectively to the simulation of buying and selling transactions through the blockchain network. This is evaluated through user interface and user experience methods, as shown in Fig 1. [28], [29].

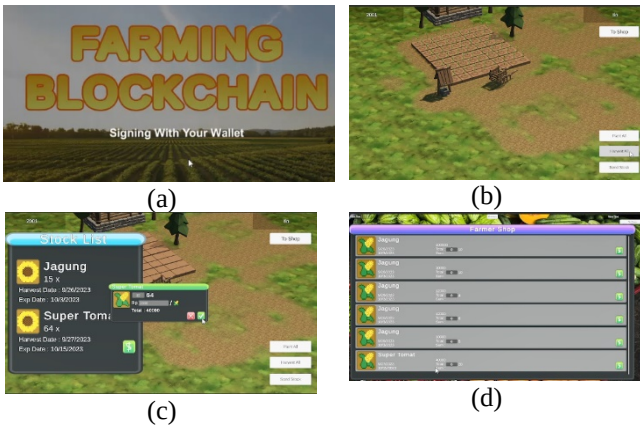

Figure 1. (a) Actor Login Blockchain via Metamask Wallet on Blockchain (b) Transaction Activity as a Farmer Planting Crops in the Serious Game (c) Farmer Fills in Selling Prices (d) Farmer Sells to the Village Unit Cooperative

Figure 1 illustrates a transaction facilitated through blockchain using Smart Contracts, with the database stored in a decentralized manner across users. This setup simplifies interactions between actors (players) by enabling direct and trustless exchanges.

C. System Overview of the Serious Game with Blockchain Smart Contracts

Algorithms include UserRegistrationUR(),Farmer KUD Transaction (FK) (), and Farmer Shop (FSH) are implemented using Moralis, Unity 3D, and Smart Contract Blockchain network nodes.

Table 1
Specification of the system/tool

Development Platform	Unity 3D 2021.3.18f1
Operating System	Windows 10
Programming Language	Solidity
Editor	Visual Studio Code
Front-End Interaction	Tezos Unity
Network Environment	Tezos Blockchain
Database	Redis Enterprise, MonggoDB Compass
Testnet	Ghostnet

Table 2
Algorithm UserRegistrationUR() from smart contract blockchain

Alghorithm 1 UserRegistrationUR ()

```
void RegisterUser() {
        Loader.Instance.ShowLoader();
        UserData data = new UserData();
        data.userAddress =
UserDataPersistent.Instance.User.userAddress;
        data.name = inputName.text;
        data.registeredEmail = inputEmail.text;
        data.idCard = inputIdCard.text;
        data.role = GetRole(dropdownRole.value);
        dataUser.data.role = data.role;
        UserDataPersistent.Instance.User = data;
        string jsonData = JsonUtility.ToJson(data);
        StartCoroutine(FarmingAPI.PostRequest(Const.URL_USER,
jsonData, onCallbackRegisterUser));
      }
```

Table 3
Algorithm farmer KUD transaction (FK)

Alghorithm 2 Farmer KUD Transaction (FK) ()

```
public void BuyItem(string owner, int itemID)  {
        const string entryPoint = "buy";
        Debug.Log($"owner {owner}");
        var parameter = new MichelinePrim {
          Prim = PrimType.Pair,
          Args = new List<Imicheline> {
            new MichelineString(owner),
            new MichelineInt(itemID)  } }.ToJson();
        Logger.LogDebug(contractAddress + " " + entryPoint +
parameter);
      Tezos.Wallet.CallContract(contractAddress, entryPoint,
parameter, 0);
```

D. Heuristic Evaluation Based on User Experience

User experience refers to the suitability of game features and user needs. In this study, it evaluates how familiar actors interact with transactions using blockchain-based Smart Contracts.

Table 4
Explanation of heuristic evaluation for user experience

Number Task	Task	Explanation
Task 1	User Registration (UR)	Sign Up and Login Wallet Blockchain account via Metamask
Task 2	Farmer Stock (FS)	Farmer stock data planting plants to harvest in Serious Games
Task 3	Farmer Shop (FSH)	Display of farmers' harvests to be sold to the Village Unit Cooperative
Task 4	Farmer KUD Transaction (FK)	Selling and buying transaction activities of crop yields from Farmer and Village Unit Cooperative
Task 5	KUD Stock (KS)	Data on Sales Stock Salesvillage Unit Cooperative Serious Game
Task 6	KUD Shop (KSH)	Display of the Cooperative Unit Cooperative Unit harvest that will be sold to the customer
Task 7	FarmerAuction (FA)	Display of the harvest that will sell two at the auction or smart bidding
Task 8	FarmerKUDBidding Transaction (FBT)	Smart bidding transaction between Farmer and Village Unit Cooperative
Task 9	KUD CustomerTransaction (KD)	Selling and buying transaction activities of harvests from Village Unit Cooperative and Customer Unit
Task 10	Customer Stock (CS)	Customer data bought from the harvest from the Village Unit Cooperative

E. User Interface-Centered Testing

The user interface of the graphical display of the game is expected to be easily understood by the actors involved in the serious games.

A human-centered mechanism evaluation in blockchain-based games aims to evaluate how the game design considers user interests and experiences while leveraging the unique potential and characteristics of blockchain technology. This evaluation involves several aspects, including:

1. User Experience: It involves an assessment of the extent to which users can interact with blockchain-based games comfortably and intuitively. Key factors include the user interface, navigation, and instruction clarity to ensure a positive experience.
2. Transparency and Security: It evaluates the extent to which blockchain technology ensures transparency and security in games. Elements such as transaction traceability, decentralized validation, and data protection must be analyzed.
3. User Satisfaction: It measures the level of user satisfaction with blockchain-based games, considering aspects such as difficulty level, entertainment value, engagement, and incentives or rewards.
4. Scalability: This considers the game's ability to accommodate growth in both users and transactions over time, ensuring a smooth and efficient gaming experience.

Table 5
Satisfying user experience

Alghorithm 3 Farmer Shop (FSH) ()

```
public void AddItemToMarket(int itemID, int price, string
entryType = “farmer”)  {
    Debug.Log(“Adding Item “ + itemID + " to Market with the price
of " + price);
        string entryPoint = "addToMarket";
        var parameter = new MichelinePrim {
          Prim = PrimType.Pair,
          Args = new List<IMicheline> {
            new MichelinePrim  {
              Prim = PrimType.Pair,
              Args = new List<IMicheline>  {
                new MichelineInt(0), // (currency ID = 0)
represents coins
                new MichelineInt(price), } },
            new MichelineInt(itemID), // ini adalah item id int
            new MichelineString(entryType) // ini adalah item id
string
          } }.ToJson();
      Tezos.Wallet.CallContract(contractAddress, entryPoint,
parameter, 0);
```

Heuristic evaluation methods help identify usability issues by analyzing user interactions and assessing the ease and comfort of engaging with the serious game. Although evaluating actors in the Supply Chain Management game requires a large amount of time and resources, it is essential for measuring satisfaction in interactions among participants. The User Interface and User Experience method was conducted with 30 users (20 men and 10 women) aged 18 to 40 years, with an average age of 30. Among them, 10 participated as farmers (F), 5 as Cooperative Unit Village (K), 3 as distributors (D), and 12 as customers (C). All users were not familiar with Ethereum, blockchain, and smart contracts prior to the study. Nevertheless, they expressed enthusiasm for the application because of its novelty. The game allowed participants to test blockchain transactions in a safe and controlled environment. Users installed the Metamask application on their smartphones, created accounts in the blockchain-based Serious Game Supply Management application, and registered as their assigned roles.

III. RESULT

As many as 30 participants conducted a User Registration (UR) transaction, with 10 acting as Farmer, 6 acting as Village Unit Cooperative members, 4 as distribution, and 10 as consumers. Farmers also carried out planting transactions up to the harvesting stage in Farmer Stock (FS) tasks, with 10 participants acting as farmers and 5 participants engaging in Farmer Shop (FSH) transactions. Additionally, 5 participants acted as members of the Village Unit Cooperative.

Farmer KUD Transaction (FK) involved 9 participants, with 5 acting as farmers and 4 as Village Unit Cooperatives to conduct buying and selling of crop yields.

KUD Stock (KS) tasks were performed by 5 participants acting as Village Unit Cooperative members. In KUD Shop (KSH), 6 participants acted as Village Unit Cooperatives, displaying harvests purchased from farmers. Additionally, 2 participants acted as Village Unit Cooperative members, 1 as a distributor, and 3 as customers.

KUD Consumer Transaction (KD) involved Sale and Purchase Transactions between Village Unit Cooperative and Farmer. These tasks involved 5 participants acting as Village Unit Cooperative members and 5 as consumers. Consumer Stock (CS) tasks involved 12 participants: 3 farmers, 5 Village Unit Cooperative members, and 4 consumers. Auction system transactions using Smart Bidding Farmer Auction (FA), involving 12 participants acting as farmers and Village Unit Cooperative members. Farmer KUD Bidding Transactions (FBT) were also evaluated. The application testing results are presented in Table 6 and Figure 2.

Table 6
Level of success application testing

Number Task	Task	F	K	D	C	Success Rate
1	User Registration (UR)	V	V	V	V	100%
2	Farmer Stock (FS)	V				80%
3	Farmer Shop (FSH)	V	V			90%
4	Farmer KUD Transaction (FK)	V	V			75%
5	KUDStock (KS)		V			100%
6	KUDShop (KSH)		V	V	V	90%
7	FarmerAuction(FA)	V	V			55%
8	FarmerKUDBidding Transaction (FBT)	V	V			75%
9	KUD CustomerTransaction (KD)			V	V	78%
10	Customer Stock (CS)	V	V	V	V	88%

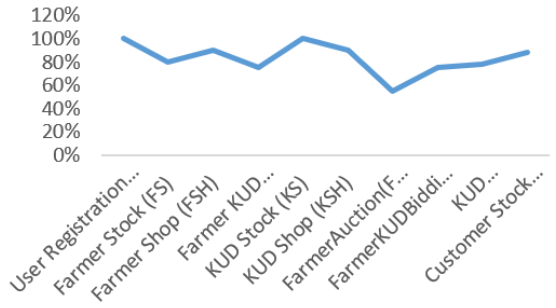

Figure 2. Success Rate in Serious Game Supply Chain Management

This research test uses the SUS (System Usability Scale) method, commonly applied to measure system usability (Karami et.al., 2024). The following are the steps undertaken with the SUS method:

a. Participants: 30 end-user participants were selected for system testing.
b. The following are some questions related to the SUS method used for usability testing; the results are shown in the figures and tables below:
    1. Is the User Registration (UR) transaction easy to understand from creating an account to logging in? (Positive)
    2. Is the Farmer Stock (FS) display too complicated for farmer actors in the process of planting to harvesting? (Negative)
    3. Is the Farmer Shop (FS) that occurs in sales transactions to the Farmer Stock (FS) shop in accordance with the amount of harvest? (Positive)
    4. Is the Farmer KUD Transaction (FK) sales transaction between farmers and KUD confusing? (Negative)
    5. Is the KUD Stock display easy to use? (Positive)
    6. Is there any inconsistency in KUD Shop (KSH) for sales to KUD stock in accordance with the results of purchases from farmers? (Negative)
    7. Can the farmer auction display make it easy for farmers to use in carrying out the auction process? (Positive)

8. Is FarmerKUDBiddingTransaction too confusing in the auction sales process between farmers and KUD? (Negative)
9. Can the KUD ConsumerTransaction (KD) sales transaction between KUD and consumers be used? (Positive)
10. Is the consumer stock display difficult to understand as information from consumers? (Negative)

c. Testing employed a Likert-scale usability method to measure positive and negative responses to each statement. The scale ranged from 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, to 5 = strongly agree.

d. To calculate the SUS score, the questionnaire were distributed to respondents, who rated the 10 items. Scores were then calculated as follows:
   1. For each odd-numbered question, subtract 1 from the user's score result. [User assessment - 1 = question score]
   2. For each even-numbered question, subtract 5 from the user's score result. [5 - User assessment = question score]
   3. Add up all question scores for each respondent, and multiply the result by 2.5.
      [[Question score 1] + [Question score 2] + … + [Question score n] * 2.5 = respondent score]
   4. Add the scores for each respondent who has gone through steps 1 to 3 above, calculate the average value.
      [Total respondent score] / number of respondents = SUS Score Result

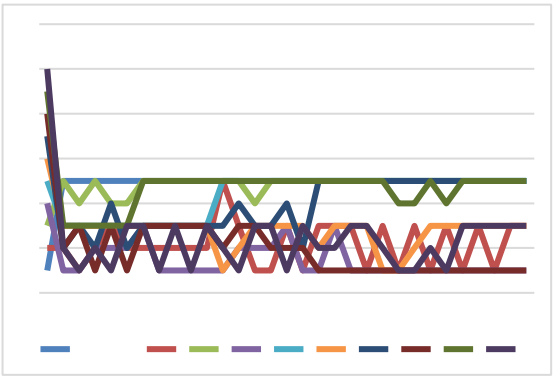

Figure 3. Chart of usability on stakeholder transaction times and transaction fees

Table 8 and Figure 4 present transaction times and gas fees. Based on the exchange rate pf Polygon (MATIC) to USD, 1 MATIC equals to 1,096 USD.

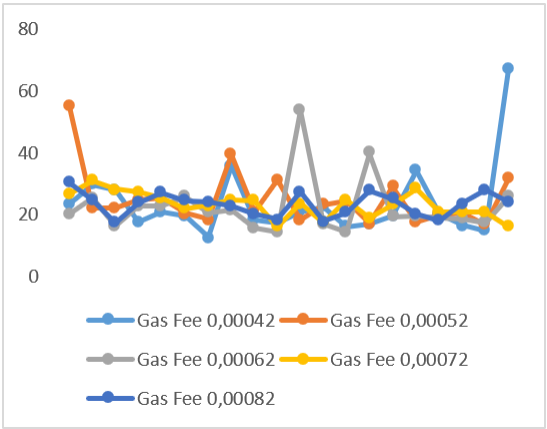

Figure 4. Use of Gas Fee in Serious Game Supply Chain Management

Table 7
Usability testing problems

	Heuristic	Both	User Testing
User Registration (UR)	Connect button not visible.	QR code scanning process is outdated and causes delays entry to the main page	
Farmer Stock (FS)	Diplay of planting and harvesting in the stock list is appropriate.		
Farmer Shop (FSH)	Stock quantiy does not automatically update when farmers make sales.	Inconsistent text and chart colors	
Farmer KUD Transaction (FK)	Green "$" button for farmer sales should display the label "Select".	KUD transactions require system feedback on buy/sell orders both at login and during transactions. Icons and transaction changes lack desscriptive labels..	No feedback on gas fees or updates to the total transaction icon. Information on gas fee transactions are missing.
KUD Stock (KS)	Green "$" button should display "Select," and the warehouse view for KUD stock is missing.		
KUD Shop (KSH)	KUD sales are recorded on the Blockchain (transaction hash), but these records are not displayed in the game.	Icons and transaction changes are not described during the transaction.	There is no feedback for buying or selling orders
FarmerAuction(FA)	Farmer Auction Transaction (FA) is acceptable.	Gas fee information is not provided.	
FarmerKUDBidding Transaction (FBT)	Farmer KUD Bidding Transaction (FBT) display lacks gass fee information.		
KUD CustomerTransaction (KD)	Sales transactions between KUD and customers lack icon descriptions and transaction change indicators. presented at the time of the transaction.	Gas fee information is not provided.	There is no feedback for the amount of gas fee or changes in the total transaction icon.
Customer Stock (CS)	Customer Stock display does not show detailed consumer identity.		

Table 8
Use of gas fees and transactions

GAS FEE	TRANSACTION 1	2	3	4	5	6	7	8	9	10
0,000	23,319	29,415	27,823	17,575		19,465	12,543	35,653	18,286	17,234
42	24	1	28	9	20,84883	16	21	55	19	18
0,000	54,735	22,182	22,192	24,812	25,222	20,303	18,388	39,325	20,784	31,064
52	76	3	62	57	17	6	31	37	05	58
	20,188	25,224	16,267	22,786	22,669	25,536	20,450	21,276	15,491	14,169
0,00062	62	58	36	1	75	08	32	02	17	37
0,000	26,481	30,950	28,088	27,387	25,454	21,670	22,885	24,546	24,413	15,947
72	08	96	79	59	98	81	27	24	48	9
0,000	30,308	24,787	17,256	23,754	26,842	24,390	23,905	22,733	20,136	18,416
82	24	3	05	33	92	17	28	26	5	69

GAS FEE	TRANSACTION 11	12	13	14	15	16	17	18	19	20
0,000	20,650	22,415	15,879	16,743	19,373	33,951	20,234	16,371	14,558	67,045
42	26	73	43	64	38	23	8	2	39	46
0,000	18,232	23,031	24,228	17,043	28,764	17,581	19,637	20,577	16,510	31,392
52	14	03	83	92	58	07	59	16	3	36
0,000	53,576	16,769	14,355	39,748	19,091	19,500	18,924	18,450	17,187	25,716
62	98	6	67	81	53	73	89	74	41	01
0,000	23,572	17,329	24,732	18,696	23,022	28,207	20,847	20,698	20,864	
72	48	35	22	49	38	64	71	73	79	15,937
0,000	27,310	17,722	20,370	27,684	25,062	20,003	17,936	23,569	27,970	23,986
82	86	39	04	69	76	67	22	2	57	42

Table 9
Usability results of questions to stakeholders

User	Questions 1	2	3	4	5	6	7	8	9	10
1	5	2	5	1	3	3	2	2	3	2
2	5	1	4	1	3	3	3	3	3	1
3	5	2	5	2	3	3	2	1	3	2
4	5	3	4	2	3	3	4	3	3	1
5	5	2	4	2	3	3	2	1	3	3
6	5	2	5	3	3	3	3	3	5	3
7	5	2	5	1	3	3	3	3	5	1
8	5	2	5	1	3	3	3	3	5	3
9	5	2	5	1	3	3	3	3	5	1
10	5	2	5	1	3	3	3	3	5	3
11	5	5	5	1	5	1	3	2	5	2
12	5	3	5	2	5	2	4	3	5	1
13	5	1	4	2	5	3	3	3	5	3
14	5	1	5	2	5	3	3	2	5	3
15	5	3	5	3	5	3	4	2	5	1
16	5	1	5	1	5	3	2	2	5	3
17	5	3	5	1	5	2	5	1	5	2
18	5	3	5	3	5	3	5	1	5	2
19	5	3	5	1	5	3	5	1	5	3
20	5	1	5	1	5	3	5	1	5	3
21	5	3	5	1	5	1	5	1	5	2
22	5	1	5	1	5	1	5	1	4	1
23	5	3	5	1	5	2	5	1	4	1
24	5	1	5	1	5	3	5	1	5	2
25	5	3	5	1	5	3	5	1	4	1
26	5	1	5	1	5	3	5	1	5	3
27	5	3	5	1	5	3	5	1	5	3
28	5	1	5	1	5	3	5	1	5	3
29	5	3	5	1	5	3	5	1	5	3
30	5	3	5	1	5	3	5	1	5	3

Table 10
Usability score processing using the SUS method

SUS Calculation Result Score Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Total	Total x 2,5
4	3	4	4	2	2	1	3	2	3	28	70
4	4	3	4	2	2	2	2	2	4	29	72.5
4	3	4	3	2	2	1	4	2	3	28	70
4	2	3	3	2	2	3	2	2	4	27	67.5
4	3	3	3	2	2	1	4	2	2	26	65
4	3	4	2	2	2	2	2	4	2	27	67.5
4	3	4	4	2	2	2	2	4	4	31	77.5
4	3	4	4	2	2	2	2	4	2	29	72.5
4	3	4	4	2	2	2	2	4	4	31	77.5
4	3	4	4	2	2	2	2	4	2	29	72.5
4	0	4	4	4	4	2	3	4	3	32	80
4	2	4	3	4	3	3	2	4	4	33	82.5
4	4	3	3	4	2	2	2	4	2	30	75
4	4	4	3	4	2	2	3	4	2	32	80
4	2	4	2	4	2	3	3	4	4	32	80
4	4	4	4	4	2	1	3	4	2	32	80
4	2	4	4	4	3	4	4	4	3	36	90
4	2	4	2	4	2	4	4	4	3	33	82.5
4	2	4	4	4	2	4	4	4	2	34	85
4	4	4	4	4	2	4	4	4	2	36	90
4	2	4	4	4	4	4	4	4	3	37	92.5
4	4	4	4	4	4	4	4	3	4	39	97.5

SUS Calculation Result Score											
Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Total	Total x 2,5
4	2	4	4	4	3	4	4	3	4	36	90
4	4	4	4	4	2	4	4	4	3	37	92.5
4	2	4	4	4	2	4	4	3	4	35	87.5
4	4	4	4	4	2	4	4	4	2	36	90
4	2	4	4	4	2	4	4	4	2	34	85
4	4	4	4	4	2	4	4	4	2	36	90
4	2	4	4	4	2	4	4	4	2	34	85
4	2	4	4	4	2	4	4	4	2	34	85
Average											81.08333333

Table 9 shows the usability results based on stakeholders questionnaires completed by respondents. Processing with the SUS method produced an average of 81.083, which falls within the "marginal-excellent" interpresentation scale, as presented in Figure 5.

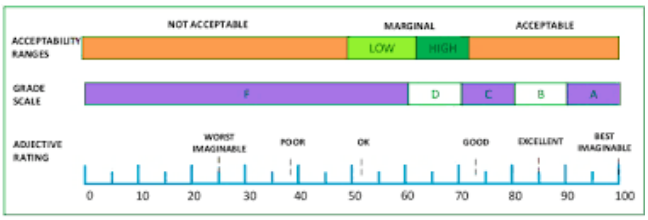

Figure 5. Interpretation scale of SUS method score results

IV. CONCLUSION

The results of the heuristic evaluation, based on the user interface and graphical display of the game, show that the system can be easily understood by actors involved in the serious game. The user experience evaluation further demonstrated that the features and design align with the needs of the user, supporting accurate participation blockchain-based smart contract transactions and reducing the risk of user error. The evaluation results are summarized as follows: User Registration (UR) 100%, Farmer Stock (FS) 80%, Farmer Shop (FSH) 90%, Farmer KUD Transaction (FK) 75%, KUD Stock (KS) 100% , KUD Shop (KSH) 90%, KUD Consumer Transaction (KD) 78%, Farmer Auction (FA) 55%, Farmer KUD Bidding Transaction (FBT) 75% and Consumer Stock (CS) 88%. In addition, usability testing with stakeholder questionnaires, processed using the SUS method, yielded an average score of 81.083, categorized as "marginal-excellent".

Future research should explore additional evaluation methods and the development of more advanced serious games that integrate Artificial Intelligence, Deep Learning, and Machine Learning. Such integration will further increase the benefits of blockchain-based serious games. Possible directions include:

1) Providing dynamic and adaptive user interface recommendations based on real-time user interaction patterns,
2) Allowing the system to learn from user behavior to automatically improve user experience, and
3) Integrating predictive analysis to predict fluctuations in agricultural commodity market prices, enabling supply chain actors to make more timely and strategic decisions.

With these advancements, the application will not only function as a transparent and efficient transaction tool but also evolve into a smart, adaptive, and proactive platform that supports decision-making in the agricultural ecosystem.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

AUTHOR CONTRIBUTION

The authors confirm contribution to the paper as follows:
A.N.P: study conception and design, draft manuscript preparation.
Y.M.A: Methodology
P.H: draft manuscript preparation
S.H : Data Collection and analysis and interpretation of findings
M.H.R.N: Programmer, study conception and design
P.S: Programmer, study conception and design
All authors had reviewed the findings and approved the final manuscript.

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