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Selecting Achievement-Based Students Using Blockchain and AHP: Semarang University Case Study

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Abstract

The current learning process requires students to be active, creative, and innovative both in activities and lectures. Students are one of the main indicators in the accreditation of a university. Therefore, a tertiary institution is also required to be able to receive and provide assistance to students and graduates in the form of scholarships, such as achievement scholarships. At present, it is quite difficult to determine students who have excelled at tertiary institutions in considering and determining students who are entitled and appropriate to receive them. The Decision Support System is a solution to be able to assist in managing student achievement data and determining the right scholarship recipients, and is supported by blockchain technology so that security is guaranteed and protected so that it is not easily hacked and information can be tracked by parties who are given access, so that they can share information transparently. This study uses the waterfall system development method with the Analytcal Hierarchy Process (AHP) problem solving method for the analysis model of the decision support system , blockchain algorithms, and open source software used solidity ethreum. The actual results will be that a decision support system with the AHP model combined with Blockchain can help provide more precise decisions to determine more appropriate scholarship recipient students, as well as increase trust in parties in tracking every transaction information on student achievement activities transparently and safely.

Keywords: AHP , Blockchain , Scholarships, Universities, Tracking

1. INTRODUCTION

The selection of outstanding students at a university is not an easy task, considering the large number of high-achieving students and the various considerations in determining the right candidate at the national level [1]. The University of Semarang has a large student population, which poses significant challenges. Scholarships are provided to its students to encourage higher achievement. These scholarships include KIPK (Indonesia Smart Card Program), non-academic achievements (athletes), academic achievements, and community-

based scholarships, each with specific requirements for students to fulfill. The Analytic Hierarchy Process (AHP) is an analytical model used in decision support systems that breaks down complex problems into a hierarchy, assigning subjective values to the importance of each variable and determining which variable holds the highest priority in influencing the outcome [2]. Thus, the results obtained can support decision-making by administrators in determining the most appropriate scholarship recipients. Administrators can also adjust the weight values and criteria according to the policies set by the university.

Blockchain is a distributed ledger that records transactions between network nodes, where the recorded information is public and immutable. Smart contracts are automated contracts that run based on code and are stored on the blockchain [3], [4], [5]. Blockchain technology has been developed in three main stages: Blockchain 1.0 for simple transactions such as cryptocurrency, Blockchain 2.0 which introduced smart contracts, and Blockchain 3.0, which is applied in sectors like government, education, and healthcare. Smart contracts are computer program protocols that automatically execute when certain conditions are met [6] [7], [8]. This concept was introduced in 1994 by Nick Szabo for use in transactions such as product sales, inheritance, and insurance. The goal is to reduce the need for manual labor, thus saving time, and to automate existing systems [9].

Blockchain and smart contracts offer information security through encryption and are used to create a secure and credible data-sharing system [10]. In the field of education, this technology helps in effectively recording student achievements using a distributed database governed by timestamps, which also minimizes the risk of fraud and data corruption [11], [9], [12], [13]. Both blockchain and smart contracts will be combined with the AHP analysis model to manage and verify student achievement data at the university level. The goal is to enhance student productivity in achieving success with the support of scholarships. Additionally, data security and protection are crucial to prevent hacking, ensure information is easily traceable, and maintain transparency, with access restricted to relevant parties [7]. The hash model in blockchain technology is used to convert the original message (plaintext) into a random code by converting the text or file into a text string that has a fixed length for both input and output. [9].This blockchain technology can enhance the security of certificates, ensuring the authenticity and validity of data while minimizing data duplication. Furthermore, the use, function, and benefits of certificates as proof of ownership issued by relevant authorities or institutions will serve as evidence of student achievements. [6], [14]

Study by [2] applied the AHP method to determine the criteria for selecting outstanding scholarship recipients. The considered criteria include academic performance, student achievements, and social aspects. Each criterion was assigned a weight for comparison, resulting in a priority ranking, with academic

performance at the top, followed by student achievements, and lastly social aspects. Research by [15] utilized a Decision Support System with the AHP method to determine scholarship recipients, employing Rapid Application Development (RAD) and Unified Modeling Language (UML) for system modeling. The selection process, which previously only considered academic grades, has now been computerized, facilitating decision-making and reducing the likelihood of errors. Bitcoin cryptocurrency transactions, allowing users to transact directly without intermediaries, using hash models to convert original messages (plaintext) into random codes to maintain data security and confidentiality against hacking. Study by [16] discussed the implementation of a blockchain system to secure certificates, thereby reducing the risk of counterfeiting. Study by [9] explored the use of blockchain-based smart contracts for a Gamification scholarship scheme, aimed at reducing the need for manual labor and automating existing systems for greater time efficiency.

This research combines blockchain technology and smart contracts with the AHP analysis model, using Ethereum's Solidity as open-source software, and employs a waterfall model for its development. The AHP method can aid in multi-criteria decision-making, combined with blockchain technology to enhance security and transparency in student achievement data. With blockchain, each achievement record and transaction between students and the university are stored in an encrypted activity log, minimizing the risk of manipulation and increasing user trust. Blockchain not only protects data from unauthorized access but also allows all information to be traceable by involved parties. This technology is implemented using a programming language designed for writing smart contracts, namely Solidity on Ethereum, chosen for its capabilities in developing smart contracts that enable secure and automated data management on a public blockchain network. The actors involved include students, the university, the Ministry of Education and Culture (Kemendikbud), the Student Affairs Department, and the Scholarship Subdivision. This approach simplifies the selection of outstanding students for KIPK scholarships and serves as an innovative solution for decision-making in the education sector. The goal of this study is to enhance trust and benefit both parties by assisting administrators in more accurately determining scholarship recipients and enabling transparent tracking of every transaction regarding student achievement activities.

2. METHODS

This research utilizes a problem-solving method involving blockchain algorithms and the open-source software Solidity on Ethereum, along with a waterfall model for system development. The Waterfall model consists of five stages: requirements analysis, design, code implementation, testing, and maintenance [17] [18].Here is

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an overview of the waterfall system development model [19], which can be seen in Figure 1.

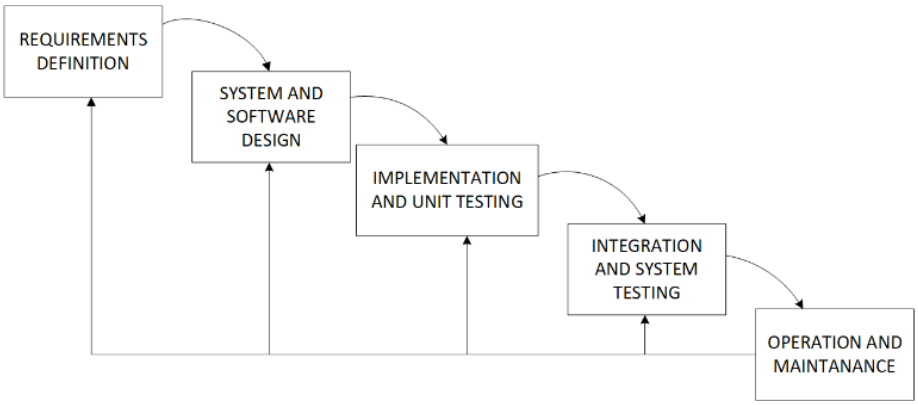

Figure 1. Waterfall Method [19]

The first stage of this research involves analysis, specifically analyzing the requirements needed for the design, including documents and other sources that can aid in determining solutions to existing problems. This stage also describes the hierarchical structure of the AHP as shown in Figure 2 [20], [21].

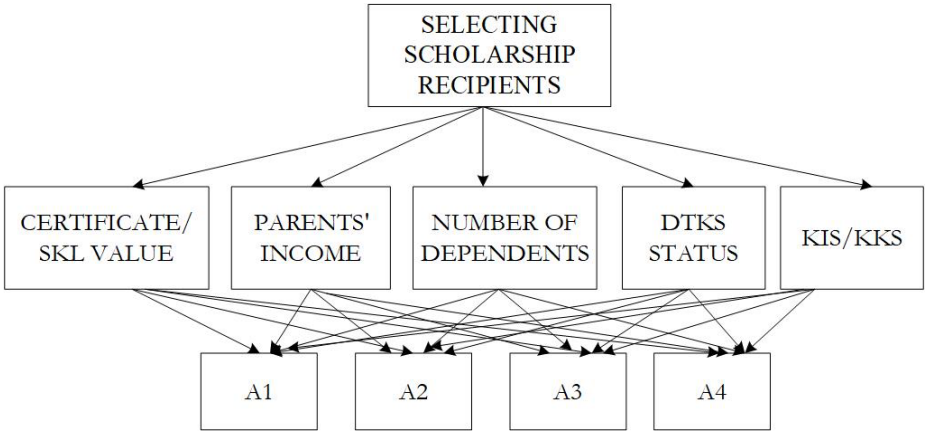

Figure 2. AHP Hierarchical Structure

The hierarchical structure of the Analytic Hierarchy Process (AHP) typically consists of three levels:

1. Goal: The top level represents the main objective of the decision-making process (e.g., selecting scholarship recipients).

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2. Criteria: The second level includes the criteria or factors that influence the decision. These might be further divided into sub-criteria, depending on the complexity of the decision.
3. Alternatives: The bottom level consists of the alternatives or options being evaluated (e.g., the candidates for the scholarship).

Next, a pairwise comparison matrix is created to illustrate the relative contributions or influences of each element concerning the respective goals and criteria as shown in Table 1.

Table 1. Pairwise Comparison Matrix

	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5
Criteria 1	K11	K12	K13	K14	K15
Criteria 2	K21	K22	K23	K24	K25
Criteria 3	K31	K32	K33	K34	K35
Criteria 4	K41	K42	K43	K44	K45
Criteria 5	K51	K52	K53	K54	K55

Next, the pairwise comparison matrix is determined using the comparison scale in AHP as shown in the following Table 2.

Table 2. Appeal Scale in AHP

Level of Importance	**Defition**
1	Equally Important
3	Slightly More Important
5	Very Important
7	Clearly More Important
9	Absolutely More Important
2,4,6,8	When in doubt about the value between two adjacent values

The process involves calculating the eigenvalues and testing for consistency. If the results are inconsistent, the data collection should be repeated. Then, the eigenvector for each pairwise comparison matrix is calculated, with the eigenvector values serving as the weights for each element. Next, the consistency of the hierarchy is checked; if the consistency ratio exceeds 10%, the judgment data must be revised.

Table 3. Criteria

CRITERIA	**DESCRIPTION**
C1	CERTIFICATE/SKL VALUE
C2	PARENTS' INCOME
C3	NUMBER OF DEPENDENTS

CRITERIA	DESCRIPTION
C4	DTKS STATUS
C5	KIS/KKS

a. Calculate the eigenvalues and test for consistency; if the results are inconsistent, the data collection should be repeated.

Table 4. Normalized Eigenvector Values

CRITERIA	EVN (Eigen Vektor Normalisasi)
C1	0.46
C2	0.30
C3	0.15
C4	0.06
C5	0.03

Table 5. Determining the Pairwise Comparison Matrix

	grades of skl/diploma	income of parents	parent's dependents	amount of DTKS assistance	assistance card
grades of skl/diploma	1	3	4	5	7
income of parents	0.33	1	4	5	7
parent's dependents	0.25	0.25	1	4	5
amount of DTKS assistance	0.20	0.20	0.25	1	3
assistance card	0.14	0.14	0.20	0.33	1
Total	1.93	4.59	9.45	15.33	23.00

Table 6. Table for Determining Priorities

Criteria	C1	C2	C3	C4	C5	Setting Priorities	
alternative							
A1	0.284	0.300	0.298	0.351	0.365	**Choice**	
A2	0.238	0.287	0.298	0.231	0.209	0.399	1
A3	0.218	0.213	0.158	0.139	0.148	0.223	2
A4	0.136	0.127	0.158	0.139	0.148	0.123	3
A5	0.125	0.074	0.089	0.139	0.129	0.079	4

The second stage involves the application design, which is divided into two parts: procedural design and material collecting. Procedural design refers to the design

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of the Ethereum Solidity blockchain to determine the sequence or flow for accessing each function within the application. Material collecting is the stage of gathering materials/data for creating the Ethereum Solidity blockchain, using student application input data as the primary data source. This data is input periodically each semester into the Ethereum Solidity and managed for each student's information. The third stage is code implementation, where developers will transform the design results into the implementation of the Ethereum Solidity program code and the Yii2 web framework. The fourth stage involves testing the program code and the system modules that have been designed and integrated into a complete system. The testing conducted includes the functionality of the created system and the performance of data storage transactions on the public Ethereum Solidity Blockchain and AHP.

3. RESULTS AND DISCUSSION

3.1 System Implementation

This process for selecting of Achievement-Based Students Blockchain Using AHP Method at Semarang University, can apply the waterfall phases as follows.

1. Requirements Definition: Collect and define requirements for the system, focusing on criteria for student achievement selection and incorporating blockchain and AHP for transparent, efficient, and accurate selection. Untu penyelesaian metode AHP kriteria yang dibuat certificate/skl value,parents' income, number of dependents, dtks status, KIS/KKS.
2. System and Software Design: Design the architecture of the selection system, including the integration of blockchain for data security and transparency, as well as the AHP method for decision-making.

The results and discussion of this research can be seen in Figure 3, which displays an overview of the workflow of the decision support system utilizing AHP, blockchain, smart contracts, and Ethereum Solidity.

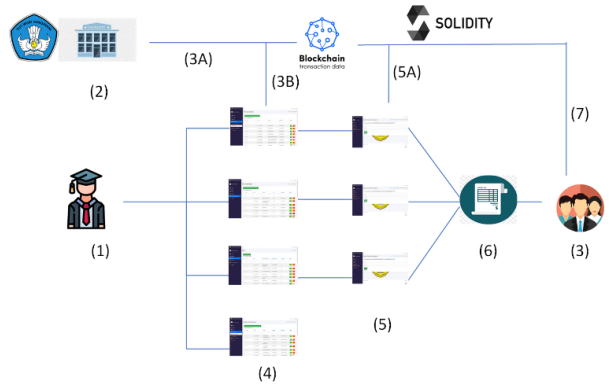

Figure 3. Workflow of the Decision Support Systemz

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The process begins with students, who are at the core of this system. Universities and the Ministry of Education and Culture (Kemendikbud) oversee and manage the broader framework, ensuring policies and resources align with student needs. Within this structure, the Student Affairs Department and the Subdivision of Scholarships play a critical role. Their responsibilities include tracking reports for scholarship recipients and checking and updating the details of these recipients. Furthermore, academic achievements, KIPK (the Indonesian Smart College Card), community development contributions, and non-academic achievements are entered into the system for comprehensive data management. These data points are then integrated into the Solidity Blockchain Wallet, where they are checked and updated for secure storage and tracking. Finally, the results of student achievements are processed to inform future decisions and maintain a robust record of accomplishments.

Figure 4. illustrates the flow diagram for the Student Affairs Department and Subdivision of Scholarships in inputting KIPK and registering to the Solidity Blockchain Wallet first to securely process transactions during the selection process using AHP. Subsequently, the results from the decision support system will display rankings that can be viewed by both students and the University of Semarang, as well as the Ministry of Education and Culture.

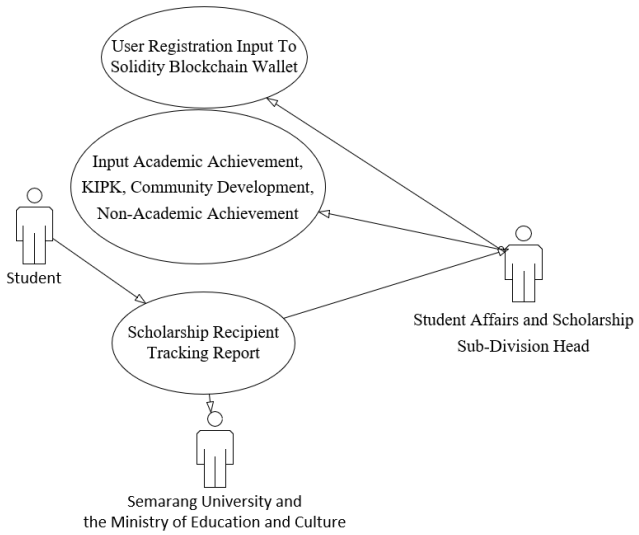

Figure 4. Flow Diagram of the Decision Support System

Figure 5 illustrates the flow of calculations in the Decision Support System using AHP. The Student Affairs Department or Subdivision of Scholarships checks the data; if it is invalid, an error message will appear. If the data is correct, the system will proceed to verify the applicant's data and perform the calculations. The results from this process will be processed within the Ethereum blockchain.

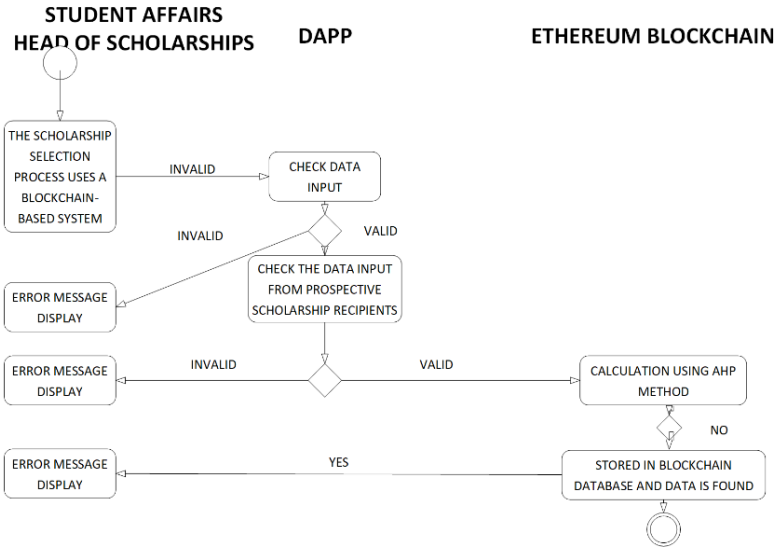

Figure 5. Calculation Flow of the Decision Support System

3. Implementation and Unit Testing: Begin coding and building the system modules, implementing blockchain functionalities and the AHP algorithm. Each module undergoes unit testing to ensure proper functionality. Figure 6 below displays the decision support system application with data of prospective scholarship recipients obtained from the Student Affairs Department and Subdivision of Scholarships.

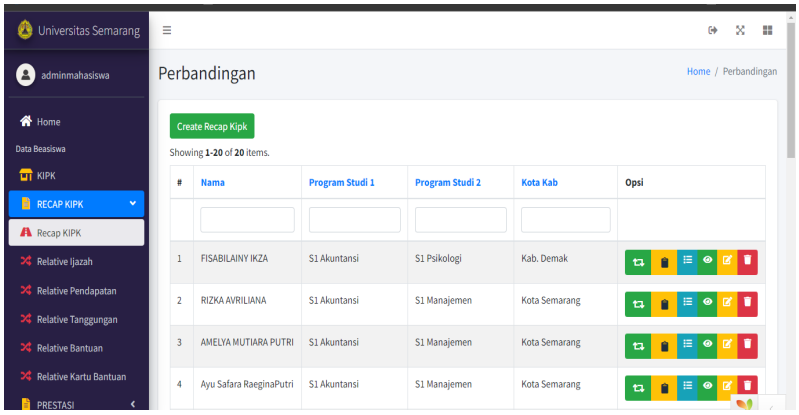

Figure 6. Display of Prospective Scholarship Recipients' Data

Figures 7(a) to 7(e) show the comparisons across each criterion, including: diploma, parental income, number of dependents, social assistance, and assistance cards.

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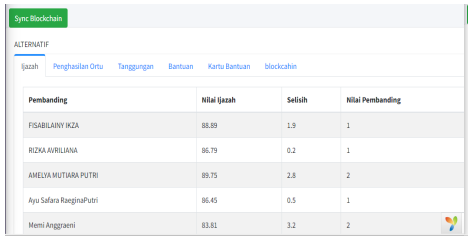
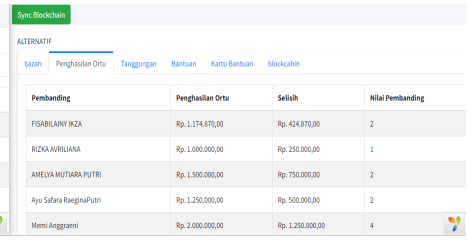


Figure 7(a). Diploma Criteria



(b). Parental Income Criteria

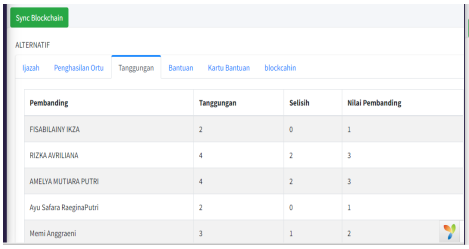
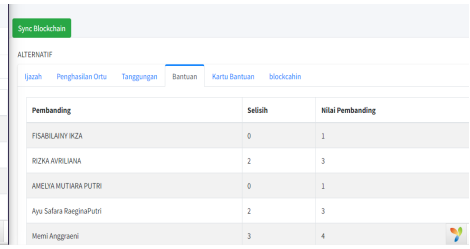


Figure 7(c). Dependents Criteria



(d). Assistance Criteria

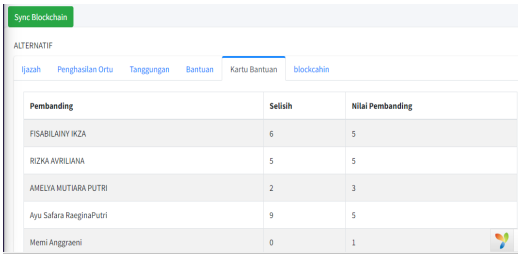


Figure 7(e). Comparison of Assistance Card Criteria

4. Integration and System Testing: Combine all modules and conduct system-wide tests to verify interoperability, performance, and adherence to requirements. After processing the comparison data for each criterion, the next step is the data transmission process, along with securing and storing the data using blockchain synchronization, as shown in Figure 8.

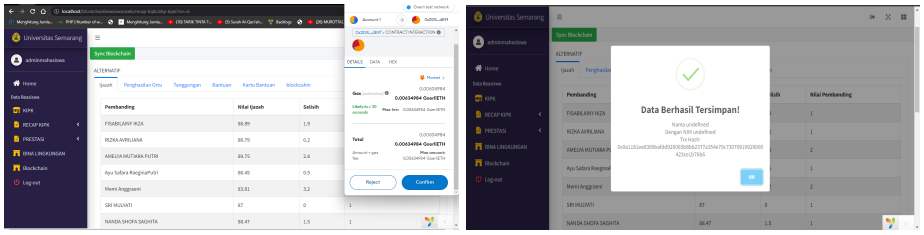


Figure 8. Data Transmission and Storage Using Blockchain

The results of the data storage process using blockchain technology are illustrated in Figure 9, which showcases the system's successful integration and secure management of data. This figure highlights how blockchain stores data immutably and transparently, ensuring both security and reliability for sensitive information such as student records and scholarship details. The functionality of the system extends further with the implementation of a smart contract, as demonstrated in Figure 10. This figure provides detailed insights into the execution and outcomes of the smart contract deployed within the blockchain. Users can access and verify the data stored and processed via a scan on Etherscan, a blockchain explorer. Etherscan enables stakeholders to review transaction details, contract interactions, and the integrity of the stored data, presenting a clear and comprehensive display of blockchain activity. Figures 9 and 10 collectively emphasize the integration of blockchain and smart contracts as pivotal components in ensuring a secure, transparent, and efficient data management system.

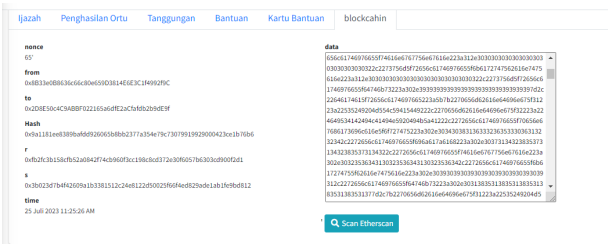


Figure 9. Display of Data Storage Results Using Blockchain

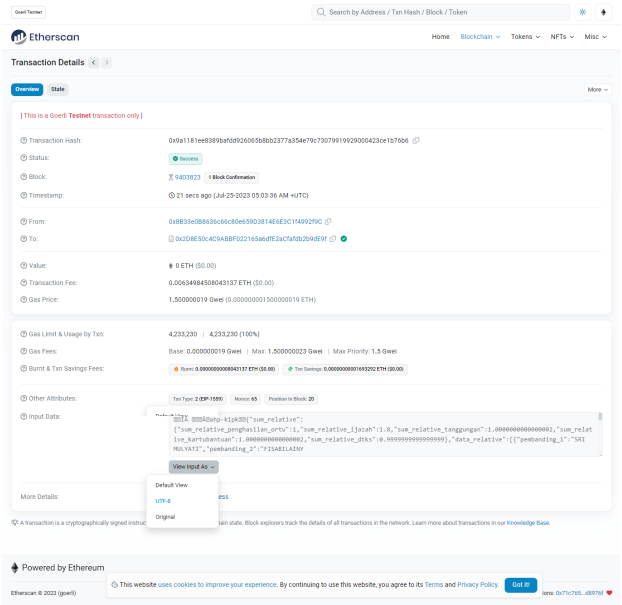


Figure 10. Details of Blockchain and Smart Contract

5. Operation and Maintenance: Deploy the system for operational use and provide maintenance to address any post-deployment issues or updates based on user feedback or system requirements.

3.2 Discussion

The background issue in this research is the challenge of objectively and transparently selecting the right students to receive scholarships. Awarding scholarships to high-achieving students is essential for universities to enhance institutional accreditation, yet the selection process is often hindered by limited transparency and the risk of data manipulation. Therefore, this study proposes a Decision Support System (DSS) based on the Analytic Hierarchy Process (AHP) method and blockchain technology, enabling more objective and secure scholarship decisions[20], [22], [23].

The AHP method was chosen to manage multi-criteria decisions in assessing achievements, while blockchain is utilized to ensure the security and transparency of student achievement data. Every recorded data and transaction is stored in encrypted form, reducing the risk of data manipulation and increasing user trust. This technology is implemented using Ethereum's Solidity language due to its capability in building smart contracts that can manage data automatically and securely within a public blockchain network.

Compared to other DSSs that employ Multi-Criteria Decision Making (MCDM) methods, such as TOPSIS or Fuzzy methods, the AHP method combined with blockchain provides enhanced transparency in decision-making and stronger data security. The blockchain-based DSS in this research excels in enabling real-time transaction tracking, which is distinct from conventional DSSs that typically store data in centralized databases without adequate encryption[24], [25] .

During implementation, key challenges included data consistency, user training, and system adaptation. The data consistency challenge was addressed by creating layered validation through Solidity smart contracts, ensuring that the input data meets the established formats and standards. User training was also a focus, as blockchain and AHP technology may be new to most users in the academic environment. To address this, the research included in-depth training and easy-to-follow technical guides, enabling users to effectively manage and monitor the system.

The research results indicate that integrating AHP and blockchain not only improves accuracy in determining scholarship recipients but also reduces the potential for human error in recording achievements. This solution has the potential to be widely applied to other institutions and various types of

scholarships. Future studies are expected to test the system's effectiveness in different educational contexts and to add data analytics features for more comprehensive and in-depth analysis.

4. CONCLUSION

The current learning process requires students to be active, creative, and innovative in both academic and non-academic activities. High-achieving students are a key indicator in university accreditation, thus higher education institutions need to provide financial assistance in the form of merit scholarships. However, identifying students who truly qualify for such scholarships remains a challenge. A Decision Support System (DSS) based on blockchain and the Analytic Hierarchy Process (AHP) offers a solution for managing student achievement data securely and transparently. Blockchain technology supports the management of data for prospective scholarship recipients and verification by university administrators, ensuring that stored data is private, secure, and protected from hacking, while enabling transparent, trackable information sharing accessible only to involved parties. This research utilizes the waterfall system development method and open-source Ethereum Solidity technology. Management is carried out using Solidity blockchain as a means of securing data and storing an encrypted database. Each data entry by students on the website, as well as transactions between students and university administrators, is recorded in an activity log for tracking purposes. The data used in this research includes records from prospective KIPK scholarship recipients at Semarang University. By reducing human error in recording student achievements, this technology helps produce more accurate decisions in determining scholarship recipients. This model holds potential for scaling to other educational institutions and adapting to various scholarship types. Future research could explore the adaptability of this system in diverse educational environments or incorporate additional features for enhanced, real-time data analysis.

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