CryptoScholarChain: Revolutionizing Scholarship Management Framework with Blockchain Technology

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***Abstract*—Scholarship management is a crucial aspect of higher education systems, aimed at supporting deserving students and reducing financial barriers. However, traditional scholarship management processes often suffer from challenges such as a lack of transparency, inefficient communication, and difficulty tracking and verifying scholarship applications. Recently, Blockchain technology has emerged as a potential solution to address these issues, offering a decentralized, transparent, and secure framework for scholarship management. Blockchain technology has emerged as a promising solution to address the challenges faced in scholarship management. However, existing literature lacks comprehensive solutions in critical areas such as scholarship management, storage facilities, payment systems, monitoring and auditing, and experimental validation. This research introduces an innovative smart scholarship management system leveraging Blockchain technology to overcome these limitations. The research presents an Ethereum-based implementation utilizing Solidity for backend smart contracts and ReactJS for the front end. Experimental evaluation validates the transaction execution gas costs and deployment cost.**

***Keywords*—Blockchain; smart scholarship management; smart contract; solidity**

I. Introduction

The landscape of higher education has witnessed the emergence of several dynamic initiatives, notably scholarships designed to empower economically disadvantaged students. These scholarships are designed to support deserving individuals pursuing their undergraduate and postgraduate studies, with each country having its own dedicated program. Scholarships funded by diverse entities, such as non-governmental organizations (NGOs), private donors, and corporate social responsibility initiatives, play a pivotal role in mitigating the financial burdens faced by students. However, the application process for these scholarships presents various challenges. These challenges include difficulty tracking application forms, potential loss of documents during transit, inadequate communication between students and their funders or NGO partners, and a lack of transparency. To overcome these limitations, this study presents an innovative smart scholarship management system built on Blockchain technology. The proposed system leverages Blockchain technology and integrates Smart Contracts to establish a user-friendly student environment, facilitating seamless and transparent communication between students and their respective NGOs.

A. Blockchain Technology and its Applications

Initially introduced as the underlying technology for crypto currencies like Bitcoin, Blockchain technology has gained significant attention due to its potential applications beyond finance [14]. The literature emphasizes the key features of Blockchain, including decentralization, immutability, transparency, and security [13]. Researchers have explored its applications in various sectors, including supply chain management, healthcare, and identity management [13]. However, limited studies have focused specifically on its application in scholarship management.

The study's structure for the remaining sections is as follows:

Section II conducts an extensive literature review, summarizing various Blockchain-based frameworks for efficient smart scholarship management. It offers a detailed exposition of the system's workflow and architectural design. It includes in-depth discussions of system components and employed algorithms and provides evidence of feasibility. Section III presents study outcomes, featuring visual representations like deployment and transaction cost graphs related to various smart contract functions. Finally, Section IV summarizes the study's findings and concludes with remarks highlighting the research's significance and implications.

II. Related Work

A. Traditional Scholarship Management Systems

Traditional scholarship management systems suffer from centralization, lack of transparency, and vulnerability to tampering. This research article introduces a decentralized Blockchain-based framework for smart scholarship management to address these limitations.

The framework involves three key stakeholders: donors, students, and NGOs. Donors include individual contributors, industrial corporate social responsibility (CSR), and governmental scholarship funds. Students are the beneficiaries who receive scholarships through NGOs, while NGOs serve as intermediaries responsible for record-keeping and auditing. The traditional centralized approach lacks transparency, traceability, and auditability, making it susceptible to attacks and manipulation. These challenges can be overcome by

leveraging a decentralized Blockchain framework, leading to a more efficient and secure scholarship management system.

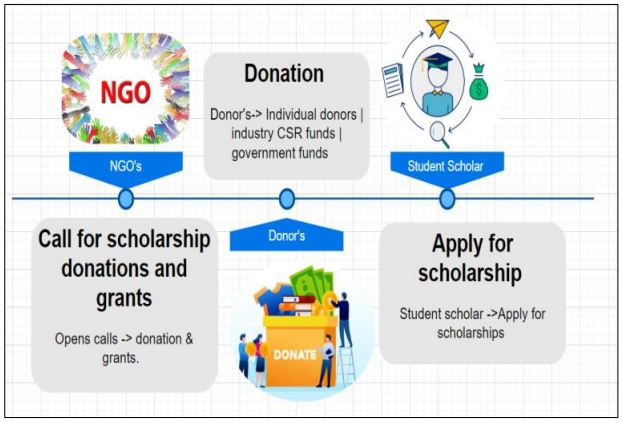

Fig. 1. Supply chain: Scholarship management process.

Fig. 1 shows the supply chain of a Blockchain-based smart scholarship system.

1) Stakeholder analysis: This section comprehensively analyzes the three major stakeholders in the traditional scholarship management system: donors, students, and NGOs. It discusses the roles and functionalities of each stakeholder, emphasizing the importance of their involvement in the scholarship management process.

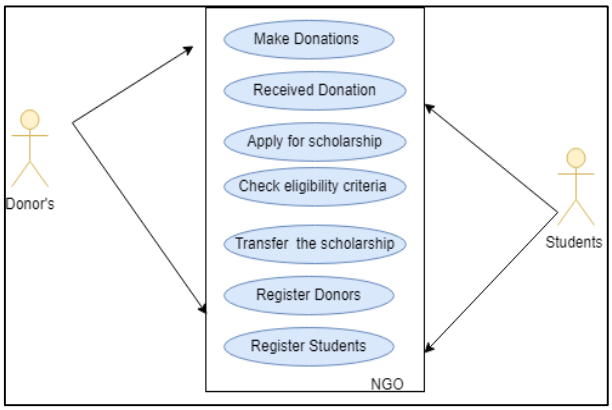

Fig. 2. Traditional scholarship management system.

The end users and their role and the operation the end user is performing with the system are depicted in Fig. 2. The students and Donors are considered an actor, and the NGO is considered a system with which donors and students perform different operations represented by different use cases. The depiction of end users and their roles and operations within the system is illustrated in Fig. 2. In this context, students and donors are regarded as actors. At the same time, the NGO is considered the system with which donors and students engage in various operations, each represented by distinct use cases.

2) Donors: Donors are of different types, including individual contributors, industrial CSR funds, and governmental scholarship funds. It highlights their functions, such as making donations and accessing tracking and auditability features. Blockchain enhances the integrity and transparency of this innovative fundraising approach, making it even more reliable [18].

3) Students: Students are the beneficiaries of scholarships. It discusses their roles in applying for scholarships and receiving funds through NGOs. It also emphasizes the importance of secure and efficient fund transfer mechanisms.

4) NGOs: NGOs act as intermediaries between donors and students. It outlines their responsibilities, including receiving donations, approving and transferring scholarships, and maintaining a ledger of all transactions. This emphasizes the significance of accurate record-keeping and auditing in ensuring transparency and accountability.

This research article introduces CryptoScholarChain, an innovative framework for managing scholarships that leverages Blockchain technology and smart contracts to enhance transparency, traceability, and efficiency in the scholarship ecosystem. Proposed system addresses the limitations of existing approaches and aims to improve the scholarship application process and financial transactions. Additionally, research work provides a prototype implementation of the framework using the Solidity programming language on the Ethereum platform.

B. Challenges in Traditional Scholarship Management

The traditional scholarship management system's limitations include its centralized and manual nature. It discusses the lack of transparency, traceability, and auditability, making it prone to attacks and tampering. This section examines the challenges associated with traditional scholarship management processes. Literature highlights issues such as lack of transparency in the selection process, difficulties verifying applicant information, delays in fund disbursement, and ineffective communication between students, scholarship providers, and educational institutions. These challenges have led researchers and practitioners to explore Blockchain technology as a potential solution.

In [11, 15, and 4], this research article provides an overview that explores different aspects of innovative models and frameworks within philanthropy, crowdfunding, and distributed ledger technology (DLT) like Blockchain. Each paper contributes to the understanding and advancement of community-based solutions, public welfare crowdfunding, decentralized electronic donation frameworks, and the relationship between charity, trust, accountability, and DLT. The findings and recommendations from these papers underscore the importance of collaboration among various stakeholders to address global challenges and support philanthropic engagement on a larger scale [11, 15, 4].

In [21, 11], this research article explores Blockchain technology's application in various aspects of charity, crowdfunding, and nonprofit organizations (NPOs). The papers discuss frameworks for a transparent and auditable charity collection, Blockchain-based crowdfunding platforms, charity systems, and the sustainable development of NPOs using Blockchaintechnology. These studies contribute to advancing transparent and efficient systems for managing charitable activities, improving crowdfunding platforms, enhancing the

accountability of charity systems, and promoting the sustainable development of NPOs [21, 11].

C. Comparative Analysis

The literature reveals several benefits of implementing Blockchain-based frameworks for smart scholarship management. These include increased transparency, improved data integrity, enhanced security, streamlined communication, and reduced administrative overheads. Blockchain-based systems also enable efficient tracking and verification of scholarship applications, ensuring fairness and reducing the potential for fraud. Table I discusses the features and limitation of the existing literature.

TABLE I. ADVANTAGES AND LIMITATIONS OF EXISTING SYSTEMS

Authors	System	Features	Limitations
Li Q et al. [19]	Charity application based on Blockchain technology	Secure and transparent charity applications	Limited scalability, potential regulatory challenges
Turkanović M et al. [23]	Blockchain-based higher education credit platform	Streamlined credit transfer and recognition in higher education	Dependence on network connectivity, potential resistance to change
Rangone A et al. [9]	Managing Charity 4.0 with Blockchain during Covid-19	Enhanced transparency and accountability in charity operations	Adoption challenges, integration with existing systems
Farooq MS et al. [8]	Transparent and auditable charity collection using Blockchain	Transparency and Auditability in the Charity Collection	Technical complexity, integration with existing systems
Wu H et al. [24]	The reliable service system of charity donations during the Covid-19 outbreak	Enables reliable charity donations during the Covid-19 outbreak	Limited to the context of the Covid-19 outbreak
Tomlinson B et al. [22]	Sustainability analysis of "Blockchain for Good" projects	Assessing the sustainability of Blockchain projects for social good	Project-specific findings, limited generalizability
RejebDet al. [20]	Contributions of Blockchain and Smart Contracts to the Zakat Management System	Enhanced efficiency and transparency in Zakat management	Adoption challenges, regulatory considerations
Cerf M et al. [5]	Improving decision-making for the public good using Blockchain	Transparent and accountable decision-making for the public good	Technical complexity, scalability
AlassafAOet al. [1]	Decentralized fundraising and distribution using Blockchain	Decentralized fundraising and distribution for charities	Adoption challenges, potential security risks
ElsdenCet al. [6]	Co-designing Blockchain applications for charitable giving	Exploring co-designing of Blockchain applications for charitable giving	Context-specific findings, limited generalizability
KakraniaAet al. [16]	Secure E-Donation System using Blockchain Technology	Provides a secure e-donation system leveraging Blockchain	Technical complexity, user adoption challenges
Cali et al [4]	Novel Donation-Sharing Mechanisms to Contend Energy Poverty Problem	Addresses energy poverty through novel donation-sharing mechanisms	Limited to the energy poverty problem context
Shin EJet al. [21]	Sustainable development of NPOs with Blockchain technology	Investigates sustainable development of nonprofit organizations using Blockchain	Context-specific findings, limited generalizability
Hassija Vet al. [11]	BitFund: A Blockchain-based crowdfunding platform for the future smart and connected nation	Facilitates Blockchain-based crowdfunding for smart and connected nations	Limited to the crowdfunding context
Khanolkar AA et al. [17]	Blockchain-based Trusted Charity Fundraising	Ensures trust and transparency in charity fundraising	Technical complexity, adoption challenges

The Table II discusses about Comparative analysis of existing literature. The table summarizes various research studies on Blockchain applications for charity and social good. It highlights the systems or frameworks developed in each study, their key features, and the limitations or challenges they face. These studies collectively explore how Blockchain technology can enhance transparency, accountability, and efficiency in charitable activities while acknowledging the obstacles, such as technical complexity and adoption challenges that must be addressed for successful implementation.

TABLE II. COMPARATIVE ANALYSIS

Authors	Objective	1	2	3	4	5
Muhammad ShoaibFarooq et al. [8]	Secure collection of donations	Y	Y	Y	N	N
H.L. Gururaj et al. [12]	Secure crowdfunding	Y	Y	Y	N	N
Baokun Hu et al. [3]	Create a trustworthy network for charity foundations	Y	Y	N	N	N
Eun-Jung Shin, Hyoung-Goo Kang et al.[7]	Improve trust in philanthropic organizations	Y	Y	N	N	N
Rangone et al. [9]	Highlight the impact of Blockchain on the development of charity 4.0	Y	Y	N	N	N
Li et al. [19]	Increase charity transparency and credibility in China	Y	Y	Y	N	N
Bedi P et al.[2]	Automated scholarship distribution, reduced administrative overhead	Y	Y	N	N	Y
Purposed	CryptoScholarChain: Blockchain-based framework for smart scholarship management	Y	Y	Y	Y	Y

*1- Architecture and Framework, 2- Algorithm, 3- Performance evaluation,4- IPFS storage,5- Scholarship management, and tracking, Y-Yes, N-No

Table II summarizes various authors' objectives and the presence of key features in their research related to Blockchain applications in charity and scholarship management. The

majority aim to enhance security and transparency in these domains, with some focusing on automated processes and reduced administrative overhead. The proposed CryptoScholarChain framework encompasses these objectives and features comprehensively.

D. Benefits of Blockchain-based Scholarship Management

Blockchain-based Frameworks for Smart Scholarship Management: Several studies have proposed frameworks to enhance scholarship management processes. These frameworks leverage the inherent features of Blockchain to address the challenges faced in traditional systems. For example, a Blockchain-based framework ensures transparency by recording scholarship-related transactions on a distributed ledger, making them accessible to all stakeholders. Smart contracts powered by Blockchain enable automating application verification, fund disbursement, and scholarship agreement enforcement. Nonprofit organizations leverage blockchain technology to open up opportunities for global donations from a diverse range of donors [10].

E. CryptoScholarChain

CryptoScholarChain is a novel framework that utilizes Blockchain technology and smart contracts to revolutionize the management of scholarships. Proposed system ensures trust, accountability, and traceability in the scholarship process by providing an immutable and transparent audit trail. The research discusses how CryptoScholarChain overcomes the limitations of traditional approaches, such as lack of transparency and difficulty in tracking donations.

F. Ensuring Transparent and Prompt Financial Transactions

CryptoScholarChain recognizes the importance of financial transparency and timely payments' importance in scholarship management. To address this, CryptoScholarChain incorporates a secure payment mechanism within the system. This feature guarantees transparency and facilitates seamless transactions between donors, NGOs, and students, ensuring that scholarship funds reach the intended recipients promptly.

CryptoScholarChain integrates corporate social responsibility (CSR) funding through NGOs and government-sponsored scholarship programs, providing students with diverse scholarship opportunities. By leveraging these funding sources, framework facilitates access to scholarships and streamlines the application process, making it more efficient and inclusive.

G. Prototype Implementation on the Ethereum Platform

To validate the feasibility and effectiveness of CryptoScholarChain, provide a prototype implementation using the Solidity programming language on the Ethereum Blockchain. This implementation demonstrates the practicality of proposed framework and serves as a basis.

It includes in-depth discussions of system components and employed algorithms and provides evidence of feasibility.

Decentralized Blockchain-Based Framework -introduces the proposed decentralized Blockchain-based framework for smart scholarship management.

H. The Flow of the System

The flow of the system involves the registration of donors and students, verification by NGOs, authentication of donor proofs, storage of required documents on a distributed storage platform, the opening of donation calls by NGOs, deployment of smart contracts on the EthereumBlockchain, and the creation of a decentralized application (DApp) for interaction between donors, students, and NGOs.

I. The Architecture of the Proposed System

Fig. 3 depicts the overall system components of the proposed framework. The system hosts a set of smart contracts (Registra tionSc, MakeDonationSc, TransferscholarshipSc, ApplyForScholarshipSc).

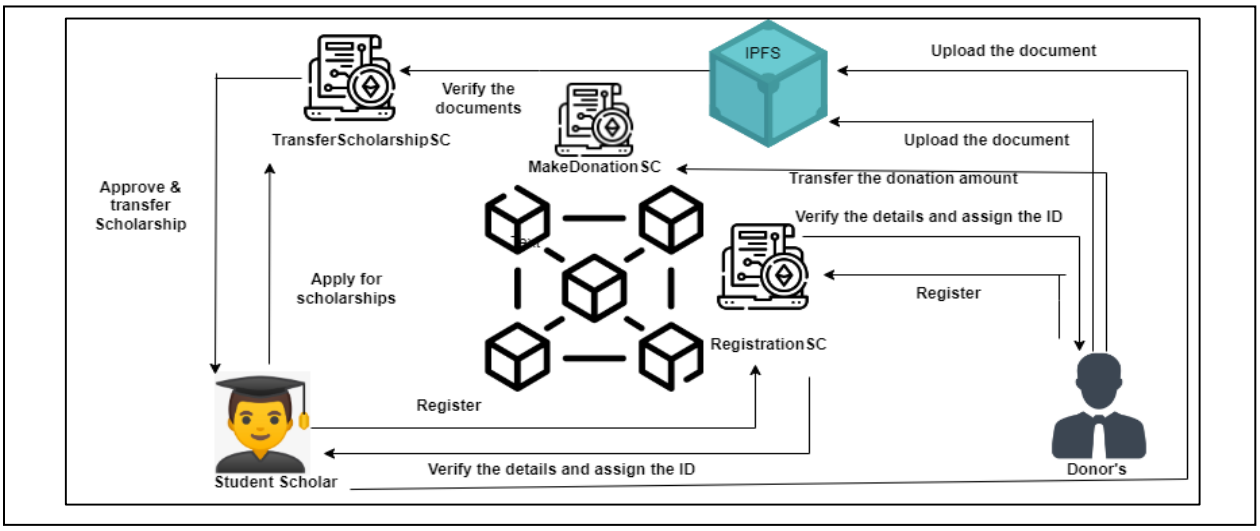

Fig. 3. Overall architecture of the proposed system.

J. Module and Algorithms of the Proposed System

1) Registration: The system requires users to register their information through the RegistrationSc smart contract. The information is encrypted using the Attribute Authority's public key to maintain privacy. Verification is conducted through an automated API or offline document verification, with scanned documents stored on a decentralized system like IPFS. The encrypted file hash is stored on the Blockchain for identity verification. The charity publishes verification results and parameters on the Blockchain through the smart contract for transparency and reliability. Registration describes the first step of the flow, where donors and students register on the platform. NGOs are responsible for verifying the registrations and assigning unique IDs to the stakeholders. The verification process ensures the authenticity and credibility of the participants.

Authentication and Document Storage focus on the authentication of donor proofs. Donors are required to provide necessary documents for authentication, such as registration numbers and related documents for industry CSR funds. These proofs are securely stored on a distributed platform like the InterPlanetary File System (IPFS). Students need to provide various documents, including unique identification numbers (such as Aadhaar Card Number), college ID, fee receipts, family income proofs, and mark sheets for 10th and 12th grade. These documents are also stored on the IPFS platform for secure and accessible storage.

2) Make donations: NGOs open calls for donations for different scholarship projects, creating opportunities for donors to contribute. The donation process involves various types of donors, including individual contributors, industrial CSR funds, and governmental scholarship funds. Each type of donor has a specific function in providing financial assistance to deserving individuals or students. Individual contributors donate personal funds directly to scholarship programs or organizations. Industrial CSR funds are contributed by companies as part of their social initiatives and are allocated to support education and scholarships. Governmental scholarship funds are allocated by governments to promote equal opportunities and are managed by government agencies. Donors also have access to tracking and auditability features, allowing them to monitor the utilization of their funds and ensure transparency and accountability. These features help donors assess the impact of their contributions and make informed decisions for future donations.

Algorithm 1: Algorithms for MakeDonationSC

```
Contract MakeDonation uses Register
        balanceOf<- mapping that stores the address of accounts
procedure donate(User id, Amount)
        require for checking that the sender is the owner
        call procedure sendViaCall
        increment balanceOf[owner] by amount
return true
end procedure
procedure sendViaCall(Owner Address)
        Send ether to the owner's address
end procedure
```

Algorithm 1 extends the Register contract and adds the functionality to make donations by calling the donate function. The sendViaCall function is used to send Ether to the owner's address. The balance of mapping keeps track of the balance for each address.

3) Transfer scholarship: The approval and transfer of scholarships follow a structured process. Students submit their applications, undergo evaluation based on criteria, and receive approval notifications. Documentation submission is required from approved recipients. Upon acceptance, the scholarship funds are transferred to designated accounts. Recipients are monitored for compliance with requirements, and the TransferScholarshipSC smart contract facilitates the entire process.

Algorithm 2: TransferScholarshipSC

```
Contract TransferScholarship uses MakeDonation, Register{
 Student Address<- store address of users where the role is student
procedurecompareStrings(String1,String2)
        return true if strings are equal
end procedure
procedureaddAddress()
        for i<donors.length do
                if compareStrings
studentAddress<- donors[i].address
        end for
end procedure
procedure Transfer()
        for i<studentAddress.length do
callSend Via Call function
end procedure
```

K. Proof of Concept

The proof of concept for the solution was implemented on the Ethereum platform, employing Solidity as the programming language. The frontend interface was developed using ReactJS to ensure a user-friendly experience. To securely store the documents uploaded by the stakeholders, such as Aadhaar cards or ID cards, integrated the InterPlanetary File System (IPFS) as a decentralized storage solution.

III. Results and Discussions

The factors influencing the deployment cost of a smart contract on the Ethereum network are represented in equations:

- Contract Complexity: C
- Contract Size: S: The complexity of the smart contract code.
- Initialization Code: I: The size of the compiled bytecode of the smart contract.
- Gas Price: GP: Additional computations performed during contract initialization.
- Gas Limit: GL: The price set for each gas unit in gwei. The maximum amount of gas allowed for the deployment transaction.
- Network Conditions: NC: The state of the Ethereum network, including congestion and demand.

- With these parameters, the equation for estimating the deployment cost of a smart contract can be written as follows:

$$\text{Deployment Cost} = (C + S + I) * GP \quad (1)$$

Equation (1) assumes that the gas used during deployment (C + S + I) does not exceed the gas limit (GL) set for the transaction. If the gas limit is insufficient, the deployment may fail.

The effect of network conditions (NC) on the gas price (GP) is not directly represented in the equation, as it is dynamic and can change rapidly. It is important to consider the current gas prices and network conditions when setting the gas price for accurate cost estimation.

TABLE III. DEPLOYMENT COST OF CONTRACT

The deployment cost of each contract			
Smart Contract	*Transaction gas cost(gwei)*	*Actual Cost(ether)*	*USD*
RegisterSC	969111	0.000969111	1.69
MakeDonationSC	1195306	0.001195306	2.08
TransferScholarshipSC	1835557	0.001835557	3.2

Table III depicts the smart contract deployment costs analysis, indicating that the contract functionality's complexity influences the associated expenses on the Blockchain. The results emphasize the importance of considering contract complexity and associated costs in Blockchain projects. Further research is needed to explore deployment costs in various contexts and optimize resource allocation for efficient contract deployment.

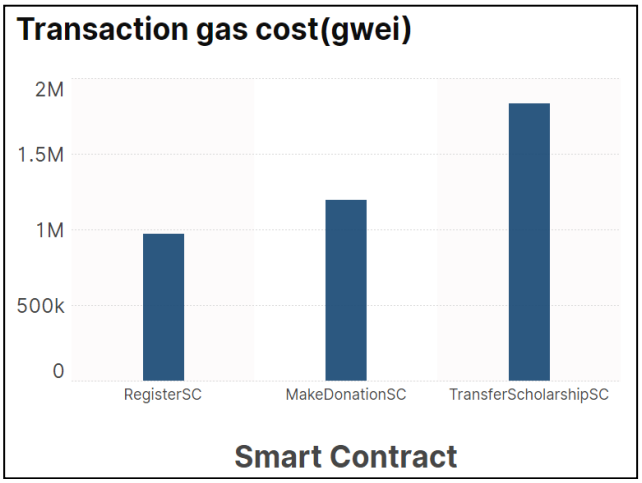

Fig. 4. Graph of deployment cost of the contract

Fig. 4 depicts the graph of the smart contract's deployment cost. The findings reveal that the gas costs for RegisterSC, MakeDonationSC, and TransferScholarshipSC were 969,111 gwei, 1,195,306 gwei, and 1,835,557 gwei, respectively. This translates to actual costs of $1.69, $2.08, and $3.2.The execution cost of each function in a smart contract is determined by the computational work required to execute the instructions within the function. This computational work is measured in terms of gas, a unit of measurement in the Ethereum network.The gas cost for each operation within a function is predefined and can be obtained from the Ethereum Yellow Paper or by analyzing the EVM (Ethereum Virtual Machine) opcode used by the function. Each opcode has a specific gas cost associated with it. To calculate the execution cost of a function, need to sum up the gas costs of all the operations executed within that function.For example, if a function consists of multiple operations with gas costs G1, G2, G3, ...,Gn, the execution cost of the function would be:

$$\text{Execution Cost} = G1 + G2 + G3 + \ldots + G_n \quad (2)$$

The execution cost is typically expressed in gas, and the gas cost can convert to Ether (ETH) by dividing by 1,000,000,000 (since there are 1,000,000,000 gwei in 1 ETH).

TABLE IV. EXECUTION COST OF EACH FUNCTION

Execution cost of each function			
Function	*Transaction gas cost(gwei)*	*Actual Cost(ether)*	*USD*
Random	22323	0.000022323	0.039
registerMe	209555	0.000209555	0.37
seeDonors	2812	0.000002812	0.0049
Donate	49874	0.000049874	0.087
sendViaCall	22304	0.000022304	0.039
compareStrings	24297	0.000024297	0.042
addAddress	23347	0.000023347	0.041
Transfer	23391	0.000023391	0.041

Table IV depicts the transaction gas cost of functions and converted actual cost in ether and its equivalent USD cost (subject to USD value at the time of testing). The findings are as follows.

- The research analysis of the execution cost of each function reveals significant variation in transaction costs, ranging from 0.0049 to 0.37 ether.
- Functions like "seeDonors" and "sendViaCall" have lower costs, making them more cost-effective options for executing transactions.
- The "register" function stands out with a higher cost of 0.37 ether, suggesting the need for optimization to reduce expenses.
- Developers should carefully consider the cost implications of each function and explore strategies to minimize transaction costs, such as code optimization and efficient resource allocation.
- Overall, cost optimization is crucial for enhancing the efficiency and affordability of smart contract execution.

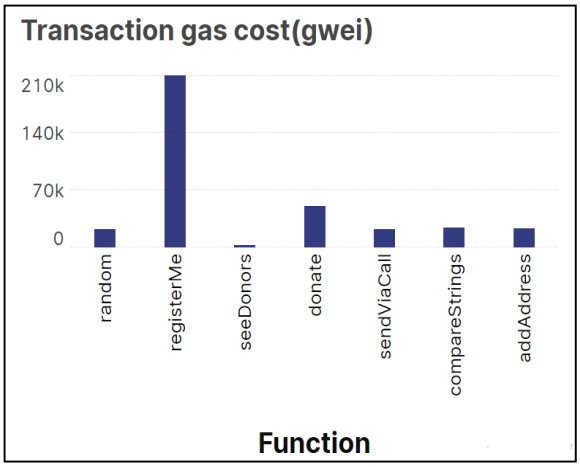

Fig. 5. Graph of execution cost of function.

Fig. 5 depicts the transaction cost (gwei) graph of functions written in smart contracts. Graph with the name of functions on the X-axis and transaction cost on the Y-axis.

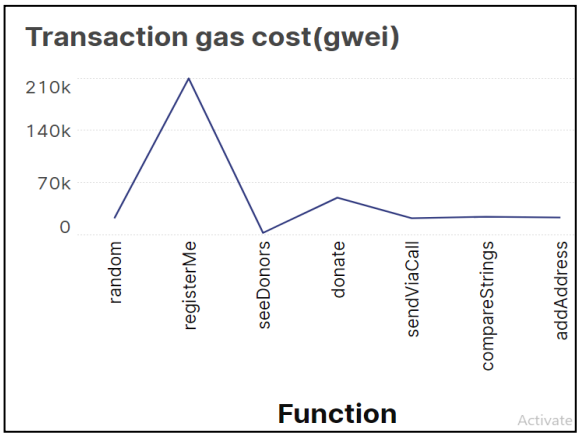

Fig. 6. Line graphs of functions.

Fig. 6 is a line graph illustrating the gas costs of various functions in the smart contract, and understanding gas costs aids in estimating transaction fees and optimizing smart contract execution. Overall, the line graph visually represents the varying gas costs across different functions.

IV. Conclusion

The features of the proposed system for smart scholarship management, including tamper-proof documents, immutable smart contracts, and transparency through a distributed ledger, offer significant advantages over traditional systems. These features enhance the system's integrity, security, and fairness, increasing donor confidence and improving scholarship management practices. The proposed system could revolutionize the scholarship management landscape, benefiting donors and deserving students.

The CryptoScholarChain framework introduces a new paradigm in scholarship management by leveraging Blockchain technology and smart contracts. Proposed system promotes transparency, traceability, and efficiency, addressing the shortcomings of traditional approaches. By integrating corporate social responsibility funding and government scholarship programs, CryptoScholarChain aims to provide equal access to scholarships for students. The prototype implementation showcases the feasibility of framework and paves the way for future research and deployment of Blockchain-based scholarship management systems. In future research, exploring Attribute-Based Access Control (ABAC) as a privacy control mechanism in Blockchain is crucial. While Blockchain is secure with cryptography, reliance on third-party oracles and the unsecured InterPlanetary File System (IPFS) for storage poses risks. Addressing this vulnerability by developing secure storage solutions tailored for Blockchainis a promising research direction, ensuring data integrity and privacy.

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