

# **BLOCKCHAIN ONLINE VOTING SYSTEM TO CURB VOTER INTIMIDATION**

**AFRICA RENEWAL UNIVERSITY- BULOBA**

**BY**

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**PROJECT REPORT SUBMITTED TO THE SCHOOL OF BUSINESS  
AND INFORMATION TECHNOLOGY IN PARTIAL FULFILMENT OF THE REQUIREMENTS  
FOR THE AWARD OF BACHELOR OF INFORMATION TECHNOLOGY  
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# **AFRICA RENEWAL UNIVERSITY**

SCHOOL OF BUSINESS AND INFORMATION TECHNOLOGY

DEPARTMENT OF INFORMATION TECHNOLOGY

BACHELOR OF INFORMATION TECHNOLOGY

BLOCKCHAIN ONLINE VOTING SYSTEM TO CURB VOTER INTIMIDATION

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A PROJECT REPORT SUBMITTED TO THE SCHOOL OF BUSINESS AND  
INFORMATION TECHNOLOGY FOR THE STUDY LEADING TO A PROJECT FOR  
THE SUBJECT BIT 3205 PROJECT.

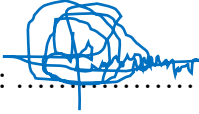
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BACHELOR OF INFORMATION TECHNOLOGY AT AFRICA RENEWAL  
UNIVERSITY.

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## DECLARATION

I **LUBANGAKENE Cyrus Brian** do hereby declare that this research report is my original work and has been written based on study activities performed and knowledge obtained from the attachment on 12<sup>th</sup> February through 30<sup>th</sup> April, 2024 from Africa Renewal University, Buloba.

No part of this material has been published or submitted by any student for academic purposes at Africa Renewal University or any other University.

Signature:  .....

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## **APPROVAL**

This report has been written and submitted for Examination with the approval of the undersigned supervision of Mr. Kathabasya Brian the university supervisor and Mr. Matovu Job as Co-supervisor and the report is now ready for submission to the Department of Information Technology for the award of a Bachelor's degree in Information Technology at Africa Renewal University

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## **DEDICATION**

I would like to dedicate this report to my mother, Achirocan Joyce Grace for all the financial support rendered, and to Eng. Lyndon Bermoy for the guidance, support, advice, and prayers. May the almighty God bless you abundantly.

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## LIST OF ACRONYMS

AfRU .....	Africa Renewal University
AI .....	Artificial intelligence
DFD .....	Data Flow Diagram
ECC .....	Elliptic Curve Cryptography
GBI .....	Gaba Community Institute
HTML .....	Hypertext Markup Language
LMS .....	Learning Management System
MFA .....	Multifactor Authentication
OOD .....	Object-oriented Diagram
PHP .....	Hypertext Preprocessor

## ABSTRACT

Most institutions of lower and higher learning such as primaries, secondaries, colleges, and universities all over the world provide an open Ballot paper voting process where pupils/students democratically elect their leaders. This is of great importance as Election is one of the important processes in a democratic society. Voting, which was formerly manual, will be altered by Information Technology, prompting discussions regarding the transition of this Web-based students' voting process using Blockchain for Africa Renewal University.

Presently voting is performed using traditional Ballot paper and the counting is performed by the persons, hence it consumes a lot of time and inconvenience not only to the voters (students) but also to the election facilitators. There can be the possibility of invalid votes. All these make the election a tedious task. In my designed Web-based student voting system, voting and counting are done with the help of smartphones, tablets, and computers. It saves time, avoids errors in counting and there will be no invalid votes. It makes the election process easy, secure, fast, accurate, user-friendly, reliable, and efficient.

Blockchain technology has been recognized as a potential solution for secure and transparent online voting systems. By leveraging the decentralization, immutability, and transparency of blockchain technology, online voting systems can prevent voters' intimidation, fraud, and manipulation, improve voter anonymity, and increase trust in the electoral process. Moreover, blockchain-based online voting systems can reduce the cost and time associated with traditional Ballot voting systems.

The decentralized and immutable features inherent in blockchain technology offer a promising solution to the vulnerabilities related to traditional and other online voting approaches. Blockchain technology can create a tamper-proof and transparent platform for conducting online voting. Blockchain-based online voting systems provide secure, verifiable, and auditable voting procedures through the integration of cryptographic techniques and consensus protocols

This paper describes using a Web-based student voting system as the basis for a project in my Information Technology course to reduce voters' intimidation during or after a university election. The system provides online voter registration forms for students where the admin registers and registered users are allowed to log in using students' registration numbers and passwords. The system allows preliminary voting and the results are graphically represented in percentage, computes, and gives the election results in pdf format for all the given positions.

**Keywords:** *Blockchain, institutions, voting/election, democratic manner, web-based, Ballot papers, election facilitators, preliminary voting, graphically represented, online voting, invalid votes.*

# CHAPTER ONE: GENERAL INTRODUCTION

## 1.1 INTRODUCTION

Africa Renewal University (AfRU) currently conducts its student elections using a traditional paper ballot system. This process has inherent challenges, including voter intimidation, lengthy voting processes, and the potential for manual errors. Voter intimidation has been a particularly significant problem, discouraging students from participating in elections.

The need for a more secure, transparent, and efficient election process led to the proposal of a web-based voting system using blockchain technology. This system aims to prevent voter intimidation by allowing students to cast their votes online from any location while maintaining security, transparency, and efficiency.

The current system does not verify and account for the persons to vote since no voting registration is done prior. This has been bringing some loopholes in that even a student who is not in session can queue and vote as long as he/she has a student identification Card. The current system does not also tell the number of expected voters since they rely on the population of the student of which not all students are interested in these elections.

This research focused to address and prevent voter intimidation in manual ballot paper voting processes in AfRU, as it is essential for election organizers and university authorities to implement clear guidelines, provide adequate security measures, ensure transparency in the voting process, and educate voters about their rights and how to report instances of intimidation through the development of the ***KAYE Web-based Student Voting System*** using ***Blockchain Technology*** that leads to an efficient and reliable electoral process by which any student can use his/her voting rights from anywhere in the country.

It can also include the transmission of ballots and votes over the phone, private computer networks, or the Internet, without the need to visit a polling place in person. The advantage of this web-based students' voting over queue ballot paper voting process is that voters can vote when it is convenient for them, and there is less congestion. It also reduces vote-counting mistakes and low attendance.

A voter can cast their votes from anywhere in the country without visiting to voting booths on campus, in a highly secured way. That makes voting fearless of violence and that increases the percentage of voting to reduce this problem of voter intimidations that can lead to low voter turnout and counts.

The employment of blockchain technology in online voting systems is attracting significant attention due to its ability to enhance transparency, security, decentralization, and integrity in digital voting. This study presents an extensive review of the existing research on web-based voting systems that rely on this blockchain technology. The study investigates a range of key research concerns, including the benefits, challenges, and impacts of such systems, together with technologies and implementations, and an identification of future directions.

## **1.2 BACKGROUND OF THE STUDY**

### **1.2.1 Case Study: Africa Renewal University**

Africa Renewal University (AfRU) was established in 2007 as the Gaba Bible Institute, later renamed Africa Renewal Christian College, before receiving a Provisional License in 2013 to operate as a private university. The university officially launched under its current name in early 2014. The university's establishment aimed to equip and transform leaders in various disciplines to become agents of change in their communities. The journey towards university status began with Gaba Bible Institute (GBI) and later Africa Renewal Christian College.

AFRU's vision is to be a premier Christian university dedicated to Transformational Leadership for the Church and Society, emphasizing rigorous study of Scripture, love for God, and service to the nations. The university upholds values such as Christ-centred education, integrity, accountability, excellence, biblical stewardship, community, and a global perspective of the body of Christ. AFRU's commitment lies in developing a new generation of Christian leaders through academic excellence and faithful service to society.

Elections have been held regularly to elect the Student Guild Council. However, in recent years, voter intimidation has led to a significant decline in voter turnout, with students feeling coerced or pressured during the voting process. This research aims to address the challenges in the current voting process by introducing a blockchain-based web voting system.

### **1.2.2 What is Voter Intimidation?**

Voters' intimations in the manual ballot paper voting process refer to actions that threaten, obstruct, or interfere with the free exercise of voting by registered voters' decisions. This can include the threat or use of force, violence, obstruction, interference, or deceptive communication that hinders the voting process. In AFRU 2016, voter intimidation undermined the democratic process by creating an environment of fear or coercion that influenced individuals from freely expressing their voting choices reducing the vote counts by 30% of the previous election activities that is 2014 and 2015.

In the context of AFRU, voter intimidation has occurred through physical or verbal threats, misinformation, and coercion, which significantly impacts the democratic process.

### **1.2.3 Blockchain Technology in Web-Based Voting Systems**

Blockchain technology offers a decentralized, transparent, and immutable ledger system, which can secure the voting process. By using blockchain, every vote is recorded in an encrypted, tamper-proof format, ensuring that the integrity of the voting process is maintained, and any attempt to manipulate results is prevented.

Blockchain technology has been gaining attention in various industries, including finance, supply chain management, and even voting systems. The idea of using blockchain for voting systems emerged as a potential solution to address concerns related to transparency, security, integrity, and efficiency in traditional voting methods.

### 1.3 MOTIVATION OF THE PROJECT STUDY

The decline in voter participation due to intimidation has raised concerns about the fairness and inclusiveness of AFRU's elections. Data from previous elections shows that voter turnout decreased by 30% between 2016 and 2023, significantly skewing election results.

The need for a secure, intimidation-free voting process has driven the motivation behind this project. Blockchain technology presents a viable solution for eliminating voter intimidation and ensuring transparency in university elections.

The effects of voter intimidation at this university had significant implications for the democratic process and the participation of young voters. Impact on Voter Turnout, according to the Fall 2023 election, general students appear less likely to vote in 2024 than they did in 2020 and 2015, which was a record-setting year for voter turnout.

Voter intimidation can significantly lower voter turnout in university elections. 10% of students lacked confidence in election fairness, potentially influenced by intimidation concerns.

University student leaders are the core link between the university students and the university administration. These leaders are therefore elected democratically to represent the interests of the students as per the University Act. It is always an expectation of every student that elections be held fairly and results computed accurately.

In today's rapidly evolving digital age, the traditional ballot paper method of conducting student elections in AFRU has been increasing voters' intimidation, time-consuming, resource-intensive, and prone to errors since 2013. Recognizing the need for a more efficient and inclusive approach, our motivation stems from the desire to streamline the voting process and empower students to actively participate in shaping their university's future.

Voter intimidation manifest in **different ways** within the context of manual ballot paper voting in Africa Renewal University. Some common examples include:

- **Physical Intimidation:** This involves physically blocking access to polling stations, following voters closely, or engaging in aggressive behaviour that makes voters feel unsafe or uncomfortable.
- **Verbal Intimidation:** Verbal intimidation includes using aggressive questioning, threatening language, shouting at voters, making derogatory remarks, or spreading false information to create fear or confusion among voters.
- **Coercion:** Coercive tactics involve pressuring individuals to vote a certain way through manipulation, bribery, blackmail, or other means that undermine the free and fair expression of voter choice.
- **Misinformation:** Spreading false information about the voting process, candidates, or election procedures constitutes voter intimidation by sowing doubt and confusion among individuals or groups of voters.



- **Presence of Unauthorized Personnel:** Having unauthorized individuals present at polling stations who attempt to influence voters or disrupt the voting process can contribute to an atmosphere of intimidation.

### 1.3.1 The consequences of voter intimidation

In AFRU, elections can have significant legal implications and undermine the democratic process. Voter intimidation is illegal and can lead to severe penalties. In the context of university elections, where students exercise their right to vote, it can create a hostile environment that deters individuals from freely expressing their voting choices.

Consequences of voter intimidation in university elections include:

1. **Legal Penalties:** Individuals who engage in voter intimidation can face fines and imprisonment.
2. **Violation of Voting Rights:** Voter intimidation violates the voting rights of individuals, compromising the integrity of the election process and undermining the principle of free and fair elections.
3. **Impact on Election Results:** Voter intimidation can distort election outcomes by influencing or suppressing the votes of individuals who feel threatened or coerced, leading to results that do not accurately reflect the will of the voters.
4. **Erosion of Trust:** Instances of voter intimidation erode trust in the electoral system and can discourage participation in future elections, impacting the overall legitimacy of the electoral process. leading to a lack of confidence in the outcomes.
5. **Suppression of student participation:** Can discourage students from participating in the electoral process out of fear or concern for their safety. This can lead to lower voter turnout and decreased representation of student voices in the election results.
6. **Undermining of democratic principles:** Undermines the principles of democracy by restricting the ability of individuals to freely and fairly participate in the election process.

Understanding the prevalence and impact of voter intimidation at Africa Renewal University is vital for ensuring inclusive and fair electoral processes, promoting democratic values, and safeguarding the rights of students and election workers. Understanding the extent of the problem through data and statistics, stakeholders can better address the issue, implement preventive measures, and promote a more inclusive and democratic electoral process on campus.

Following these challenges, I saw it as good to come up with a system that could curb these problems and speed up the election system to ensure free and fair elections. When a system that is based on pens and ballot papers is used for a large population, the results can be ambiguous, and that questions the intelligibility of the system used.

## **1.4 PROBLEM STATEMENT**

Voter intimidation at AfRU undermines the democratic process by creating an environment of fear, coercion, and misinformation can create a hostile environment that deters individuals from freely expressing their voting choices. Voter intimidation, which involves actions like aggressive questioning, physical blocking of polling places, using threatening language, disseminating false information, or disrupting voting lines, is illegal and can lead to severe penalties in the context of university elections, where students exercise their right to vote.

In a world free from voter intimidation, students would feel safe exercising their voting rights, confident in the knowledge that their votes would be counted accurately without any external influence. The blockchain-based voting system aims to create such an environment, reducing voter intimidation and ensuring transparency, security, and efficiency in the voting process.

This study seeks to design and implement a web-based student voting system using Blockchain Technology related to its transparency, security, integrity, efficiency, and reliable electoral process to reduce voter intimidation and foster a fair and transparent election process at AfRU by which any student can use his/her voting rights from anywhere in the country to transmit votes over the phones, private computers, or the Internet, without the need to visit a polling booth on campus in person.

## **1.5 OBJECTIVES OF THE PROJECT STUDY**

### **1.5.1 Main objectives:**

The main objective of this study is to design and implement a secure, efficient, fast, accurate, user-friendly interactive Web-based student voting system using Blockchain Technology to prevent voter intimidation in the AfRU student elections.

### **1.5.2 Specific objectives:**

1. To study how voter intimidation affects the current manual voting process at AfRU.
2. To design a blockchain-based voting system that enhances transparency, security, and systematic way of conducting voter registration and candidate applications.
3. To develop and implement the designed web-based voting system that properly manages the voters' rights in the election in a well-organized manner.
4. To test the designed system to ensure that it successfully prevents voter intimidation and maintains election integrity.

## **1.6 SCOPE OF THE STUDY**

### **1.6.1 Timing**

The study covers the AFRU student elections held from 2016 to 2023, focusing on challenges related to voter intimidation. The project took a period of 5 to 7 months of designing and testing to be relevant in the technology world of the market and especially among institutions.

### **1.6.2 Geography**

This study is limited to Africa Renewal University, located in Wakiso district, Uganda.

### **1.6.3 Technical Scope**

The technical scope includes designing and implementing a blockchain-based web voting system to address the identified challenges. The system includes user authentication, vote encryption, and tamper-proof recording using blockchain.

## **1.7 JUSTIFICATION OF THE PROJECT STUDY**

### **1.7.1 To science**

This study will contribute to the growing body of knowledge on blockchain-based voting systems, particularly in educational institutions. It will provide insights into how blockchain can be used to improve election security and transparency, and it may serve as a reference for future researchers in similar domains.

### **1.7.2 To Society**

By implementing this blockchain-based voting system, AfRU will benefit from a more secure, transparent, and efficient election process. The system will eliminate voter intimidation and encourage more students to participate in elections, leading to a more representative student council.

## **1.8 LIMITATION OF THE PROJECT STUDY**

While the designed system is expected to address voter intimidation and enhance election transparency, it may face limitations such as:

- Resistance to change from students and staff accustomed to the traditional ballot system.
- Internet accessibility issues that could limit the participation of students without reliable online access.
- The system includes login for the administrator and login for the students. The admin has the only rights to access the administration area and is authorized to access the transaction

such as adding, editing, and deleting information inside the system. The students will log in as voters.

- Time factor was the greatest barrier to the successful completion of this exercise since it had to be done within the semester. I also had financial constraints since all the activities involved were self-sponsored.

The system is designed solely for the student council election of Africa Renewal University and could append instantly voters and candidates. It is not applicable in other student council elections because the running positions will not be the same.

## **1.9 CHAPTER SUMMARY**

This chapter provided an introduction to the research, outlining the background, problem statement, objectives, scope, and justification for the study. The chapter highlighted the challenges posed by voter intimidation at AFRU and the potential for blockchain technology to provide a secure and transparent voting solution.

Subsequent chapters will build on this foundation by reviewing relevant literature, detailing the methodology, and describing the design and implementation of the designed system.

Online Voting Systems have many advantages over the traditional ballot voting system. Some of these advantages are less cost, faster generation results, easy accessibility, accuracy, and low risk of human and mechanical errors. It is very difficult to develop an online voting system that can allow security and privacy on a high level.

Future development focused on designing a system that can be easy to use and will provide security and privacy of votes on an acceptable level by proper authentication and processing section. It is easy to use and it is less time-consuming. It is very easy to debug

## CHAPTER TWO: LITERATURE REVIEW

### 2.1 INTRODUCTION

The literature review provides an understanding of the issues surrounding voter intimidation in manual ballot voting systems, the evolution of web-based voting systems, and the potential role of blockchain technology in securing online voting. This chapter explores global, regional, and local perspectives on these topics, leading to an analysis of research gaps that this study aims to fill.

Ballot voting is a democratic process whereby a group of individuals express their opinions and choices by way of casting a ballot. The ballot process involves presenting a voter with a list of choices to mark against their favourite choice. The ballot mechanism has been in existence since 139 BC [Wikipedia, 2013.] as practiced by ancient Romans. Indians adopted a ballot mechanism at around 920 AD. Variations of the ballot mechanism comprised scratching the names of choice candidates on pieces of broken pottery [Greece] and the use of Palm leaves with names of candidates, a practice known as **Kudavolai** in India. The United States was to employ ballot papers in 1629 to select a pastor for the Salem Church (BallotPedia, 2013).

With the onset of technology and computers, computerized processes have been invented the world over to improve the efficiency and credibility of voting processes. Two distinct approaches in computerized voting processes are electronic voting and online voting. While online voting aims to provide a web-based interface via which voters can cast their votes and get results of the election process, electronic voting has to do with the registration process being carried out electronically e.g., the use of biometrics and coded voter cards that that can be scanned by an electronic device to authenticate the voter. Thus, an electronic voting system may end up having human clerks tallying the votes upon termination of the election process (Emaase, 2011).

As a possible solution to the drawbacks of traditional voting, a system based on blockchain technology has been designed. Blockchain is a distributed ledger managed by a peer-to-peer consensus network, which allows its stored data to be transparent, verifiable, and tamper-resistant by nature. The aforementioned benefits and a lack of central authority make it a potentially ideal platform for digital voting.

Due to the growing popularity of blockchain technology, there are already multiple designed methods and existing commercial solutions that promise secure voting on the blockchain. For example, among the organisations offering blockchain-based services are Kaspersky Lab with their election-oriented solution Polys, and Nasdaq, whose main focus is voting in general meetings.

In light of that, this paper section aims to address the main research question of how blockchain technology can be used to enable online voting. To do so, a systematic literature review is carried out to study different solutions and to find out which types of voting blockchain technology can be used for, as well as the advantages and disadvantages of doing so.

## **2.2 OVERVIEW OF VOTER INTIMIDATION IN THE MANUAL BALLOT PAPER VOTING SYSTEM**

Voter intimidation in traditional voting systems is a common issue in various electoral processes globally. In many regions, voters experience coercion or threats, which prevent them from freely exercising their voting rights. This section explores the mechanisms through which intimidation occurs, with a focus on how these issues manifest in educational institutions like Africa Renewal University (AfRU).

### **2.2.1 Global Perspective**

Globally, voter intimidation can take various forms, including physical threats, misinformation, and emotional coercion. Studies have shown that voter intimidation has been prevalent in both developed and developing countries, affecting the democratic process by preventing free and fair elections (Smith, 2020).

### **2.2.2 Regional Perspective**

In Africa, particularly in the context of educational institutions, the practice of voter intimidation has been well-documented. Countries such as Uganda, Kenya, and Nigeria have reported cases where students feel coerced into voting for particular candidates, often due to social or organizational pressure (Okello, 2019). In Uganda, studies indicate that student elections are often influenced by powerful groups, making it difficult for students to vote independently (Mukasa, 2017).

### **2.2.3 Local Context: AFRU**

At AfRU, voter intimidation has significantly impacted student elections. The issue has been linked to aggressive campaigning, misinformation, and pressure from student organizations. Data from previous elections revealed a 30% drop in voter turnout between 2016 and 2023, primarily due to intimidation-related concerns. The manual ballot system, which lacks anonymity and security, exacerbates the problem by exposing voters to undue influence from their peers or groups.

Voter intimidation is a serious threat to the integrity of elections, even in manual paper ballot voting systems. Some common methods used to intimidate or discourage voters include:

Physically positioning individuals or groups near polling places in an overt, threatening manner. This can create an atmosphere of fear and discomfort that deters certain voters from casting their ballots.

Videotaping or photographing voters as they approach polling sites, often under the guise of "election monitoring". This tactic is intended to make voters feel watched and discourage them from voting.

Deceptive robocalls, flyers, or mailers that spread false information about voting procedures, such as incorrect polling hours or voter ID requirements. This can confuse and mislead voters, potentially causing them to abstain from voting.

Paper ballot voting systems are vulnerable to these intimidation tactics because they rely on in-person voting at designated polling places. The presence of unaffiliated individuals at these sites, as well as the potential for misinformation to spread, can create an environment that discourages participation.

## 2.3 EVOLUTION OF WEB-BASED VOTING SYSTEMS

The shift from traditional paper-based voting to web-based voting systems has been driven by the need for efficiency, transparency, and security. This section explores the development of web-based voting systems, their features, and their application in educational institutions.

The evolution of web-based student voting systems has been a journey marked by advancements in technology, security, and accessibility. This evolution has been driven by the need to provide students with a convenient, secure, and transparent method of participating in elections.

### 2.3.1 Early Web-Based Voting Systems

The adoption of web-based voting systems began in the late 1990s, primarily in developed countries. Early systems were basic, allowing voters to submit their votes electronically. However, they often lacked the necessary security protocols, making them vulnerable to hacking and fraud (Jones, 2002).

- **Limited Security:** Early systems often relied on simple password protection, which was easily compromised.
- **Lack of Auditability:** The lack of a comprehensive audit trail made it difficult to verify the integrity of the voting process.
- **Accessibility Issues:** These systems were not always accessible to students with disabilities.

### 2.3.2 Modern Web-Based Voting Systems

With advancements in technology, modern web-based voting systems have become more secure and accessible. These systems now incorporate encryption, multi-factor authentication, and real-time vote tracking, making them a viable solution for democratic processes. Many universities worldwide have adopted such systems for student elections, reducing costs, increasing participation, and minimizing human error (Wang & Lee, 2015).

- **Enhanced Security:** Systems began to utilize encryption, digital signatures, and multi-factor authentication to enhance security.

- **Improved Auditability:** The introduction of blockchain technology and other secure record-keeping methods provided greater transparency and auditability.
- **Accessibility Features:** Systems incorporated features like screen readers, keyboard navigation, and alternative input methods to improve accessibility for students with disabilities.

### 2.3.3 Web-Based Voting in Educational institutions

In the context of universities, web-based voting systems have significantly improved the election process. Institutions such as Stanford University and the University of Nairobi have reported increased voter participation and reduced instances of fraud and intimidation after implementing these systems (Chen, 2018).

In Africa, several universities have started exploring these systems, but widespread adoption remains limited due to infrastructure and financial constraints (Adjei, 2020).

**Current Trends:** Current trends in web-based student voting systems focus on:

- **Mobile-First Design:** Systems are being optimized for mobile devices to cater to the increasing use of smartphones and tablets.
- **Integration with Learning Management Systems (LMS):** Integration with LMS platforms allows for seamless access to voting systems and simplifies the voting process. (A Jain, 2020)
- **Artificial Intelligence (AI):** AI-powered features are being incorporated to enhance security, detect fraud, and improve the user experience.

**Key milestones in the development of these systems include:**

- The introduction of online voter registration and remote ballot casting, allowing students to participate in elections without the need to physically visit polling stations.
- The integration of features like real-time vote tallying and the ability to view election results online, enhancing transparency and reducing the time required to announce outcomes.
- The exploration of advanced authentication methods, such as the use of student ID numbers, biometrics, and zero-knowledge proof protocols, to ensure the integrity of the voting process.

### Features and Functionalities of Web-Based Student Voting Systems

Web-based student voting systems typically offer a range of features and functionalities tailored to the needs of student populations, including:

- Online voter registration and profile management, allowing students to easily update their information and verify their eligibility to vote.



- Secure and accessible ballot casting, enabling students to submit their votes remotely using computers, smartphones, or other internet-connected devices.
- Real-time vote tallying and the ability to view election results online, providing students with immediate feedback on the outcome of the vote.
- Administrative tools for election organizers, such as the ability to manage voter and candidate data, reset vote tallies, and generate reports.
- Integration with existing student information systems or campus networks to streamline the voting process and ensure accurate voter authentication

## 2.4 POSSIBLE APPLICATION OF WEB-BASED ONLINE STUDENTS' VOTING SYSTEMS

The possible application of web-based online students' voting systems in addressing voter intimidation in a manual ballot system can be understood in the context of leveraging computing knowledge to enhance the electoral process. By integrating web-based online voting systems, several aspects of voter intimidation in manual ballot systems can be addressed:

- **Enhanced Transparency:** Web-based voting systems can provide enhanced transparency by allowing voters to cast their votes remotely, reducing the risk of physical intimidation or coercion at polling sites.
- Additionally, voters can submit their votes without being observed or photographed. This can help protect against intimidation tactics like videotaping or photographing voters as they approach polling places
- **Improved Accessibility:** Online voting systems can increase accessibility by allowing voters to participate from any location with an internet connection, reducing potential barriers to voting for vulnerable demographic groups targeted by intimidation tactics.
- **Secure Identification and Authentication:** Computing knowledge can be applied to develop robust identification and authentication mechanisms in web-based voting systems, ensuring that only legitimate voters can participate, thereby mitigating the risk of unauthorized voting or voter impersonation.
- **Privacy Protection:** Through the application of encryption and secure communication protocols, web-based voting systems can protect the privacy of voters, ensuring that their choices remain confidential and safeguarding against potential coercion and intimidation tactics that seek to influence their votes.
- **Verification and Auditability:** Computing knowledge can be instrumental in designing online voting systems with built-in verification and auditability features, allowing for the tracking and verification of votes to ensure integrity and accuracy, thereby mitigating concerns about potential manipulation of election results.
- **Blockchain Technology:** Integration of blockchain technology in online voting systems offers decentralized and secure platforms for voting, providing end-to-end

verification and protection against tampering, thereby addressing concerns related to the accuracy and reliability of the electoral process.

- **Improved Monitoring and Auditing:** Web-based voting systems often include administrative tools that allow election organizers to closely monitor the voting process and quickly identify any irregularities or suspicious activity. This can enable rapid response to potential intimidation tactics and help ensure the fairness and integrity of the election.

By incorporating web-based online voting systems into the electoral process, computing knowledge can contribute to addressing various aspects of voter intimidation in manual ballot systems, thereby enhancing the integrity, fairness, and accessibility of the electoral process.

## 2.5 EVOLUTION OF BLOCKCHAIN TECHNOLOGY

### 2.5.1 Blockchain Fundamentals

The blockchain was invented by Satoshi Nakamoto in 2008 as a decentralized ledger technology that allows data to be stored across multiple computers, making it secure, transparent, and tamper-resistant and a public ledger for a cryptocurrency called Bitcoin.

It is an ever-growing distributed ledger that consists of records that are linked using cryptography. These records are called blocks. Each block contains a timestamp, a cryptographic hash of the previous block, and data of the transaction.

As a characteristic of the blockchain, it is managed by multiple nodes in a peer-to-peer network, each of which verify the validity of a transaction before adding it to the blockchain. This kind of decentralization ensures that individuals cannot modify or add invalid blocks to the blockchain without reaching a majority consensus on the network. As such, a blockchain can be considered secure by design (Dengo, 2020).

Currently, there are three main types of blockchain: **public blockchain**, **private blockchain**, and **consortium blockchain**. These blockchain types are characterized as follows: Public blockchain has no access restrictions. This means that anyone can read it, write to it by performing transactions, and even become a validator as one of the nodes. This type of blockchain is also called a *permissionless blockchain*.

Private blockchain has restrictions as to who can read and write to the chain, as well as validate it. It is generally controlled by an organization that aims to limit access to the blockchain internally. This type of blockchain can also be called a *permissioned blockchain*. Consortium blockchain is another type of permissioned blockchain.

However, instead of being restricted to use by a single organization, the ownership can be divided among several of them. The blockchain networks are used in some of the voting processes in this paper.

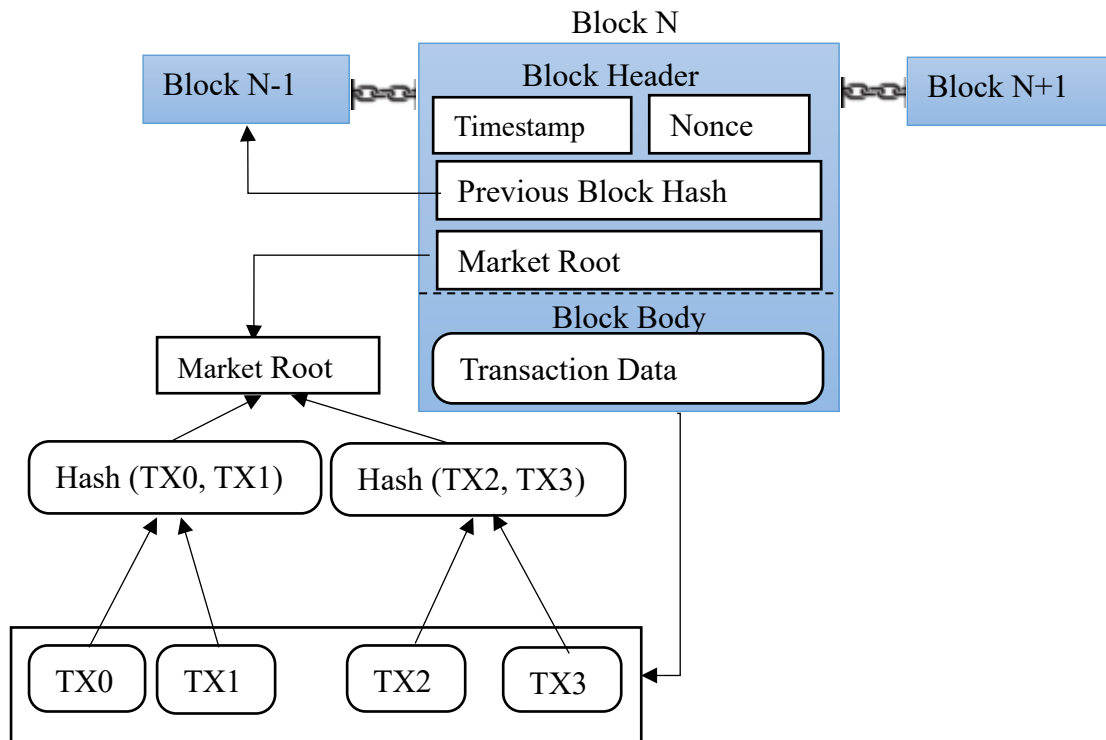


Figure 1.0: The blockchain structure [source: (Mohammad Hajian Berenjestanaki, 19 December 2023)]

Figure 2.5.1 represents an overview of the blockchain structure with the chain of blocks that encapsulate the transactions and secure them with hashes and other data. These blocks are broadcast and replicated across a network of peers.

### 2.5.2 Early Concepts and Reports (2008-2013)

The concept of using blockchain for voting systems can be traced back to the inception of blockchain technology itself. In 2008, Satoshi Nakamoto introduced the Bitcoin whitepaper, which described a decentralized digital currency system built on a distributed ledger. This led to the realization that blockchain could potentially be used for more than just financial transactions.

In 2013, a research paper titled “Swirlds: A Platform for Building Blockchain-Based Swirlds” was published by Swirlds Inc. The paper designed the idea of using blockchain technology for various applications, including voting systems. This marked the beginning of exploring blockchain’s potential in the voting sector.

### 2.5.3 Proof-of-Concept Implementations (2014-2016)

Several proof-of-concept implementations of blockchain-based voting systems emerged in the following years. These experiments aimed to demonstrate the feasibility and potential benefits of using blockchain technology in voting processes.

1. **Follow My Vote (2014):** Follow My Vote developed a blockchain-based voting platform that allowed users to cast encrypted votes, ensuring privacy and preventing vote manipulation. The platform used a public blockchain to store encrypted vote data, making it transparent and tamper-proof.
2. **ElectorEyes (2015):** ElectorEyes was another early blockchain-based voting system that aimed to provide transparency and security in the voting process. It used a private blockchain to record votes and allowed voters to verify the authenticity of their votes.
3. **Horizon State (2016):** Horizon State developed a blockchain-based voting platform for online decision-making in communities and organizations. The platform allowed users to participate in secure and transparent voting processes, with the blockchain ensuring the integrity of the voting results.

### 2.5.4 Pilot Projects and Trials (2017-2019)

As the potential benefits of blockchain technology in voting systems became more evident, several pilot projects and trials were conducted to test its effectiveness in real-world scenarios.

#### 1. West Virginia's Blockchain Voting Trial (2018):

West Virginia conducted a pilot project during the 2018 midterm elections, allowing overseas military personnel to cast their votes using a blockchain-based mobile voting app called Voatz.

The trial aimed to improve voting accessibility for military personnel stationed abroad while maintaining the security and integrity of the voting process.

#### 2. Sovrin Foundation's Voting Pilot (2019):

The Sovrin Foundation, a non-profit organization focused on self-sovereign identity, conducted a voting pilot using blockchain technology. The pilot aimed to demonstrate the potential of blockchain in ensuring secure, transparent, and verifiable voting processes for members of the Sovrin network.

#### 3. South Korea's Blockchain Voting System (2019):

South Korea's National Election Commission partnered with the Korea Internet & Security Agency to develop a blockchain-based voting system for overseas voters. The system was tested in a pilot project during the 2019 local elections, allowing overseas Koreans to cast their votes using a blockchain-based mobile app.

### 2.5.5 Current Developments and Future Prospects (2020-Present)

Blockchain technology in voting systems continues to evolve, with various organizations and governments exploring its potential.

1. **Estonia's Blockchain-Based e-Voting System:** Estonia has been working on a blockchain-based e-voting system since 2019, aiming to provide secure and convenient online voting options for its citizens. The system is expected to be implemented shortly, making Estonia one of the first countries to adopt a nationwide blockchain-based voting system.
2. **U.S. Presidential Election 2020:** In the 2020 U.S. Presidential Election, several countries experimented with blockchain-based voting solutions to improve the voting process and address concerns related to security and transparency. For instance, Denver County, Colorado, used a blockchain-based mobile voting app called Voatz to enable overseas military and overseas citizens to cast their votes.
3. **IBM's Blockchain Voting Solution:** IBM has been working on a blockchain-based voting solution called "Teesnail" since 2020. The platform aims to provide a secure, transparent, and efficient voting system for various organizations and institutions, including governments and educational institutions.

In conclusion, the history of blockchain technology in voting systems has progressed from early conceptualization to proof-of-concept implementations, pilot projects, and current developments. The potential benefits of blockchain in voting systems, such as increased transparency, security, and efficiency, have led to growing interest in adopting this technology in various countries and organizations. As research and development continue, blockchain-based voting systems will likely become more prevalent in the future.

### 2.5.6 Benefits of Blockchain Technology in Voting Systems

Blockchain technology holds the potential to address various challenges and vulnerabilities in traditional voting processes, thereby contributing to the enhancement of the integrity and fairness of voting systems.

The following comprehensive overview covers the key aspects of how blockchain technology can benefit voting systems and mitigate the problems associated with voter intimidation.

#### ➤ Enhancing Security, Transparency, and Auditability

Blockchain technology offers several key features that can enhance the security, transparency, and auditability of voting systems:

- **Tamper-Proof Transactions:** Blockchain's immutability ensures that once a vote is recorded, it cannot be altered or deleted without consensus from the majority of the network participants, thereby addressing issues of voter fraud and ballot tampering.

- **Cryptographic Security:** Through the use of cryptographic techniques, blockchain secures transactions and prevents unauthorized changes to the data, providing a robust defence against vote manipulation.
- **Transparent Ledger:** Blockchain provides a transparent and publicly accessible ledger where all transactions, in this case, votes, are recorded in chronological order, ensuring the integrity of the voting process through public verification and auditing.

#### ➤ **Improving Accessibility and Voter Participation**

Blockchain-based voting systems can enhance accessibility and voter participation, particularly for underrepresented or marginalized communities:

- **Remote Voting:** Online voting through blockchain technology can enable voters to participate from any location with an internet connection, mitigating physical barriers and increasing access for marginalized communities targeted by intimidation tactics.
- **Increased Trust:** The transparency and security provided by blockchain technology can foster trust among voters, potentially encouraging greater participation from communities that have historically faced disenfranchisement and intimidation.

#### ➤ **Providing Verifiable and Tamper-Proof Records of Votes**

Blockchain technology enables the creation of verifiable and tamper-proof records of votes, contributing to better oversight and public trust in the electoral process:

- **Transparent Verification:** The transparency and immutability of blockchain records ensure that all votes can be verified and audited, leading to increased trust in the accuracy and integrity of the electoral process.
- **Preventing Manipulation:** By design, blockchain's features deter fraudulent activities and manipulation, providing a robust foundation for maintaining the sanctity of votes cast

#### ➤ **Mitigating Risks of Centralized Control and Vulnerabilities**

The decentralized and distributed nature of blockchain can mitigate the risks associated with centralized control and vulnerabilities in traditional voting systems:

- **Reduced Single Points of Failure:** Blockchain's decentralized network reduces the risk of censorship, manipulation, or single points of failure in the voting process, enhancing the integrity and resilience of the electoral process.
- **Enhanced Security:** The distributed nature of blockchain makes it more resistant to attacks and manipulation, reducing the vulnerabilities associated with centralized control in traditional voting systems.

### ➤ **Real-World Examples and Lessons Learned**

Real-world examples and piloted initiatives of blockchain-based voting systems can provide valuable insights into the practical applications of this technology:

- **Lessons from Case Studies:** Analysing case studies of blockchain-based voting systems can offer valuable lessons and best practices for the implementation of such systems, enabling a deeper understanding of the benefits and challenges associated with this technology.

### ➤ **Addressing Technical, Legal, and Regulatory Challenges**

The adoption of blockchain-based voting systems is associated with various challenges, which require specific solutions and best practices:

- **Scalability Solutions:** Developing and implementing scaling solutions such as shading and sidechains is crucial to improve the scalability of blockchain voting systems and accommodate a larger number of transactions without compromising performance or security.
- **Privacy-Enhancing Techniques:** Implementing privacy-enhancing techniques such as zero-knowledge proofs and encryption protocols is essential to protect voters' privacy while maintaining the transparency and integrity of the voting process.
- **Legal and Regulatory Frameworks:** Establishing clear legal frameworks and regulatory guidelines for blockchain-based voting systems is necessary to ensure compliance with existing laws and regulations, addressing concerns such as voter eligibility, identity verification, and data protection (Pulse, 2018).

By comprehensively understanding the benefits and practical applications of blockchain technology in voting systems, it is possible to develop a well-researched report for addressing voter intimidation and enhancing the integrity and fairness of voting systems.

### 2.5.7 Challenges of Implementing Blockchain Technology in Voting Systems

Blockchain technology has gained significant attention in recent years due to its potential to revolutionize various industries, including voting systems. The implementation of blockchain in voting systems can enhance security, transparency, and trust in the electoral process. However, integrating this technology into voting systems is not without challenges. This section discusses the major challenges of implementing blockchain technology in voting systems.

In implementing blockchain technology in voting systems, it is essential to address the challenges associated with this implementation. The challenges to include in the literature review are as follows:

#### 1. Technical Challenges:

- **Scalability Issues:** Blockchain systems face limitations in handling a large number of transactions during elections, leading to potential delays and increased transaction costs.
- **Integration with Existing Infrastructure:** Integrating blockchain with existing voting infrastructure and legacy systems poses technical challenges, requiring seamless interoperability.
- **Privacy and Anonymity:** Balancing privacy and transparency while maintaining the anonymity of voters is a complex technical challenge that requires the implementation of privacy-enhancing cryptographic techniques.
- **Identity Management and Authentication:** Developing robust identity management and voter authentication mechanisms to prevent identity fraud and ensure the eligibility of voters is essential.

#### 2. Regulatory Challenges:

- **Compliance with Election Laws and Regulations:** Aligning blockchain-based voting systems with existing election laws and regulations to ensure legal compliance.
- **Data Privacy and Security:** Addressing concerns around data privacy, security, and compliance, particularly regarding the protection of sensitive voter information.
- **Legal and Regulatory Frameworks:** The implementation of blockchain technology in voting systems faces significant regulatory challenges due to the lack of legal and regulatory frameworks governing the technology's use in elections. The absence of clear guidelines and regulations makes it challenging to integrate blockchain technology into existing voting systems (Bellare M., 2017).



### 3. Adoption and Implementation Barriers:

- **Building Trust and Overcoming Scepticism:** Overcoming public scepticism and building trust in the new technology among voters, election officials, and the general public.
- **Accessibility and Inclusivity:** Ensuring accessibility and inclusivity for all eligible voters, including those without access to technology or with limited technological literacy.
- **Addressing Voter Coercion and Intimidation:** Mitigating concerns around the potential for voter coercion and intimidation in blockchain-based voting systems.

### 4. Potential Vulnerabilities and Risks:

- **Security Vulnerabilities:** Addressing the threat of attacks and other security vulnerabilities to protect the integrity and immutability of the voting records in blockchain-based systems.

**In conclusion**, the implementation of blockchain technology in voting systems faces significant challenges, including technical, regulatory, and societal challenges. Addressing these challenges requires a collaborative effort between stakeholders, including policymakers, technology developers, and the public, to ensure the successful integration of blockchain technology in voting systems.

## 2.5.8 Potential Impact of Blockchain Technology on Voting Systems

The potential impact of blockchain technology on voting systems is vast and far-reaching. By leveraging blockchain's capabilities, governments can enhance the security and integrity of elections, reduce costs associated with traditional voting methods, and increase voter trust and participation.

Blockchain technology has the potential to revolutionize the way elections are conducted by providing a transparent, secure, and efficient platform for recording and counting votes. It can also enable new forms of democratic participation, such as online voting and decentralized decision-making processes.

Overall, adopting blockchain technology in voting systems can transform democracy by making elections more secure, transparent, and accessible to all citizens.

## **2.6 THEORETICAL AND CONCEPTUAL FRAMEWORK**

This section presents the theoretical and conceptual frameworks that underpin this research. The theories explored provide insights into how blockchain technology can address voter intimidation and enhance electoral integrity.

### **2.6.1 Theoretical Framework: Game Theory and Secure Elections**

Game theory provides a framework for understanding strategic decision-making in competitive environments like elections. In the context of voter intimidation, game theory helps explain how blockchain technology can deter coercive actions by ensuring that no party can manipulate the outcome without detection (Myerson, 1991).

### **2.6.2 Conceptual Framework: Blockchain and Web-Based Voting**

The conceptual framework for this study is based on the integration of blockchain technology within web-based voting systems. Blockchain provides the security and transparency needed to protect voters from intimidation, while the web-based interface ensures accessibility and ease of use. Together, these technologies create a system that is both secure and user-friendly, allowing students to vote without fear of manipulation.

## **2.7 RESEARCH GAP**

Although blockchain technology has been applied in various electoral systems globally, there is limited research on its application in educational institutions, particularly in Africa. While some studies have explored blockchain's role in preventing voter fraud, few have addressed its potential in preventing voter intimidation in student elections. This study aims to fill this gap by evaluating the effectiveness of blockchain-based voting systems in reducing intimidation at Africa Renewal University.

The search results indicate that while blockchain technology offers significant potential benefits for enhancing the security, transparency, and auditability of voting systems, its adoption and implementation in the context of student elections or referendums has been limited. The existing research has primarily focused on the theoretical advantages of blockchain-based voting systems, such as:

- Improved security and tamper-resistance of the voting process
- Enhanced transparency and verifiability of election results
- Increased accessibility and participation through remote voting
- Mitigation of centralized vulnerabilities and risks of voter intimidation

However, there is a lack of comprehensive evaluations and real-world case studies that assess the practical implementation and effectiveness of blockchain-based voting systems in addressing voter intimidation challenges within student populations. The search results highlight some pilot initiatives and proof-of-concept projects, but there is a need for more in-depth research and analysis on:

- The specific technical, legal, and regulatory hurdles encountered in deploying blockchain-based voting systems for student elections
- The user experience and adoption challenges faced by students, election organizers, and other stakeholders
- The comparative performance and security of blockchain-based systems versus traditional web-based or paper-based voting methods in the context of student elections
- The long-term sustainability, scalability, and maintenance considerations for blockchain-based student voting systems

**To address this research gap, future studies should focus on:**

1. Conducting detailed case studies and pilot deployments of blockchain-based voting systems in various student election scenarios, evaluating their effectiveness in mitigating voter intimidation and other security threats.
2. Exploring the integration of blockchain technology with other emerging solutions, such as biometric authentication or zero-knowledge proofs, to enhance the privacy and security of student voting systems.
3. Investigating the legal and regulatory frameworks required to enable the widespread adoption of blockchain-based voting systems for student elections, addressing issues like voter eligibility, ballot secrecy, and electoral oversight.
4. Analysing the user experience and accessibility considerations to ensure that blockchain-based voting systems are inclusive and user-friendly for diverse student populations.
5. Developing comprehensive guidelines, best practices, and reference architectures for the design and implementation of secure, transparent, and scalable blockchain-based voting systems for the education sector.

By addressing this research gap, future studies can provide a more robust and evidence-based understanding of the practical applications and limitations of blockchain technology in enhancing the integrity and fairness of student voting systems, ultimately contributing to the mitigation of voter intimidation and the strengthening of democratic processes within educational institutions.

## 2.8 CHAPTER SUMMARY

This chapter reviewed existing literature on voter intimidation, the evolution of web-based voting systems, and the potential of blockchain technology in securing the voting process. The chapter identified a research gap in the application of blockchain to prevent voter intimidation in educational institutions. The next chapter will outline the research methodology used to develop and test the proposed system.

The aim of the thesis was to address the main research question of how blockchain technology can be used to enable secure electronic voting. This was done by carrying out a systematic literature review. By doing so, it was found that blockchain voting can be used for both polls and elections of various scales.

Four main methods were identified to provide a general overview of a blockchain-based voting process, including voting with smart contracts, Zcash, custom blockchain, and cryptographic signatures.

The advantages and limitations of blockchain voting were also determined. As a result of the literature review, a framework was created providing an overview along with references for different blockchain-based solutions.

The resulting framework could be beneficial to someone intending to design, develop and implement secure voting systems as it provides a way of finding relevant studies quickly and efficiently.

Future work can be done by identifying additional papers that provide recent solutions for using blockchain technology in a voting system. The data from these additional papers can then be extracted, analysed, and used to improve the existing framework.

In this way, the framework can always stay functional and up to date for as long as it is maintained.

## **CHAPTER THREE: RESEARCH METHODOLOGY**

### **3.1 INTRODUCTION**

The research methodology provides the framework for conducting the study. This chapter outlines the research design, development methodologies, data collection, and analysis methods used to explore and address the issue of voter intimidation in Africa Renewal University's manual ballot voting system.

The primary goal is to design, develop, and test a blockchain-based web voting system to prevent voter intimidation and enhance election security, transparency, and efficiency. The chapter provides a detailed explanation of the approaches and techniques used to gather and analyse data, ensuring that the findings are valid, reliable, and relevant.

### **3.2 RESEARCH DESIGN CHOICE**

A research design serves as a blueprint for the study, guiding how data is collected, analysed, and interpreted. For this study, a mixed-methods research design is chosen, combining both qualitative and quantitative approaches to gain a holistic understanding of the problem and solution.

The qualitative component will involve an in-depth literature review, stakeholder interviews, and case study analysis to gain a comprehensive understanding of the problem domain and the potential of blockchain technology in addressing voter intimidation. The quantitative aspect will focus on the development and testing of the blockchain-based prototype system, including performance evaluations, security assessments, and user experience studies.

#### **3.2.1 Qualitative Approach**

The qualitative component of this study aims to understand the experiences of students, election officials, and administrators in relation to voter intimidation. Semi-structured interviews and focus group discussions are used to gather insights into the prevalence and impact of intimidation in student elections. The qualitative approach helps capture subjective experiences and deeper insights into the motivations and behaviours associated with voter intimidation.

#### **3.2.2 Quantitative Approach**

The quantitative component involves surveys and system performance testing. Surveys are distributed to a broader student population to gather data on their experiences with intimidation and their views on the proposed blockchain voting system. Quantitative data is also gathered through performance metrics during system testing, focusing on security, speed, and user satisfaction.

The mixed-methods approach allows the research to collect comprehensive data, providing both depth (through qualitative data) and breadth (through quantitative data).

### 3.3 DEVELOPMENT METHODOLOGY CHOICE

For the development of the blockchain-based voting system, the **Agile methodology** was chosen, specifically the **Scrum framework**. Agile is an iterative, incremental approach to software development that allows for flexibility and rapid adaptation to changes. It also ensures continuous stakeholder feedback, which is essential in developing a system tailored to the unique needs of AFRU's election process.

#### Why Agile?

- **Flexibility:** Agile allows for continuous improvement and changes throughout the development process. Since the system needs to address specific security and usability issues, the flexibility of Agile ensures these can be integrated iteratively.
- **Stakeholder Engagement:** Regular feedback from users (students and election officials) ensures that the system meets their requirements and addresses voter intimidation effectively.

#### 3.3.1 Agile Phases

- **Sprint Planning:** The project is broken down into multiple sprints, each focusing on specific system features, such as voter registration, encryption protocols, and result tabulation.
- **Sprint Execution:** Each sprint delivers a working version of the system, which is tested and reviewed with feedback from the development team and users.
- **Sprint Review and Retrospective:** After each sprint, the development team reviews the completed work, gathers feedback, and plans the next sprint.

### 3.4 DESIGN METHODOLOGY CHOICE

In this study, a combination of **Object-Oriented Design (OOD)** and **Data-Flow Oriented Design (DFD)** methodologies were used to design the system, ensuring that both the flow of data and the relationships between system components are clearly mapped out.

#### 3.4.1 Object-Oriented Design (OOD)

OOD is used to structure the system into objects (voter, admin, ballot, etc.) that interact with one another. This methodology ensures the system is modular, scalable, and easy to maintain. Key design components include:

- **Use Case Diagrams:** These represent the various interactions between the system and its users (e.g., how a student log in and votes).
- **Class Diagrams:** These represent the structure of the system, identifying key classes (e.g., Voter, Ballot, Admin) and their relationships.

### 3.4.2 Data Flow-Oriented Design (DFD)

DFD is used to map the flow of data between the different components of the voting system. It helps in understanding how data (votes, voter details) flows from one point to another, ensuring that there are no bottlenecks or security gaps in the system. Key diagrams include:

1. **Context-Level DFD (Level 0):** This represents the entire system, showing how votes flow from voters to the blockchain, and how results are processed.
  - **External Entities:** Voter, Admin, Blockchain Network
  - **Process:** KAYE Online Voting System
  - **Data Stores:** Voter Database (MySQL), Vote Data Store (Blockchain)
  
2. **High-Level DFD (Level 1):** This shows the major processes within the voting system.
  - **Voter Registration:** Inputs: Voter submits registration details (Name, Registration Number, Email). Process: Voter data is validated and stored in the Voter Database. Outputs: Confirmation email sent to the voter.
  - **Vote Casting:** Inputs: Voter logs in and selects candidates. Process: Voter credentials are authenticated. Vote is securely cast and stored on the Blockchain. Outputs: Confirmation email sent to the voter.
  - **Vote Tallying:** Inputs: Admin requests election results. Process: Votes are tallied from the blockchain. Outputs: Results displayed on the admin dashboard and voters can view the final election outcome.

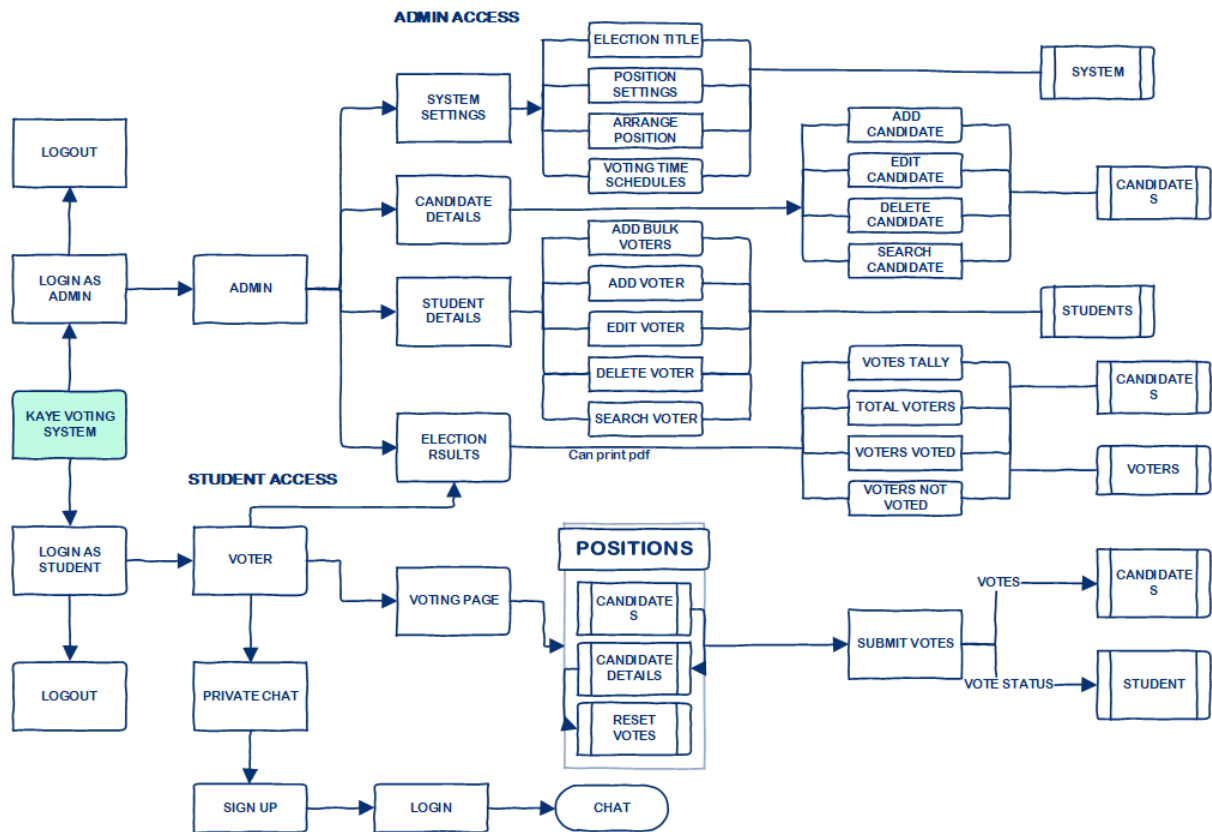


Figure 3.0.1: Data Flow Diagram (DFD) of the KAYE Online Voting System

Figure in 3.4.2 shows the, illustrating the movement of data between the user interface, server, database, and blockchain components.

### 3.4.3 Database Design

The Database Design of the KAYE Online Voting System ensures the secure storage of voter information, candidate details, and voting records. The database is structured around key entities such as Voter, Admin, Candidate, Vote, and Position. Relationships between these entities ensure data integrity and support the voting process.

The database consists of the following key tables:

- **User Table:** Contains voter details, such as id, registration number, first name, last name, email, password, photo, and date created.
- **Votes Table:** Records the votes cast by each voter, linking them to candidates and positions.
- **Candidates Table:** Stores information about the candidates running for different positions.
- **Admin Table:** Contains information about the administrators managing the election process.
- **Positions Table:** Stores the names and IDs of the positions available in the election.



**Relationships:**

## 1. User-Vote:

- One-to-Many relationship indicating that a user can submit multiple votes.
- Relationship Label: “Submits”

## 2. User-Election:

- One-to-Many relationship indicating that a user can manage multiple elections.
- Relationship Label: “Manages”

## 3. Election-Candidate:

- One-to-Many relationship indicating that an election can have multiple candidates competing.
- Relationship Label: “Competes In”

## 4. Vote-User:

- One-to-One relationship indicating that a vote is cast by a single user.
- Relationship Label: “Cast By”

## 5. Vote-Candidate:

- One-to-One relationship indicating that a vote is cast for a single candidate.
- Relationship Label: “Cast For”

Each voter can cast multiple votes (one per position), and each candidate can receive votes for the positions they are contesting. The Vote table forms the bridge between the Voter and Candidate entities, while the Position table ensures that votes are cast in the correct context.

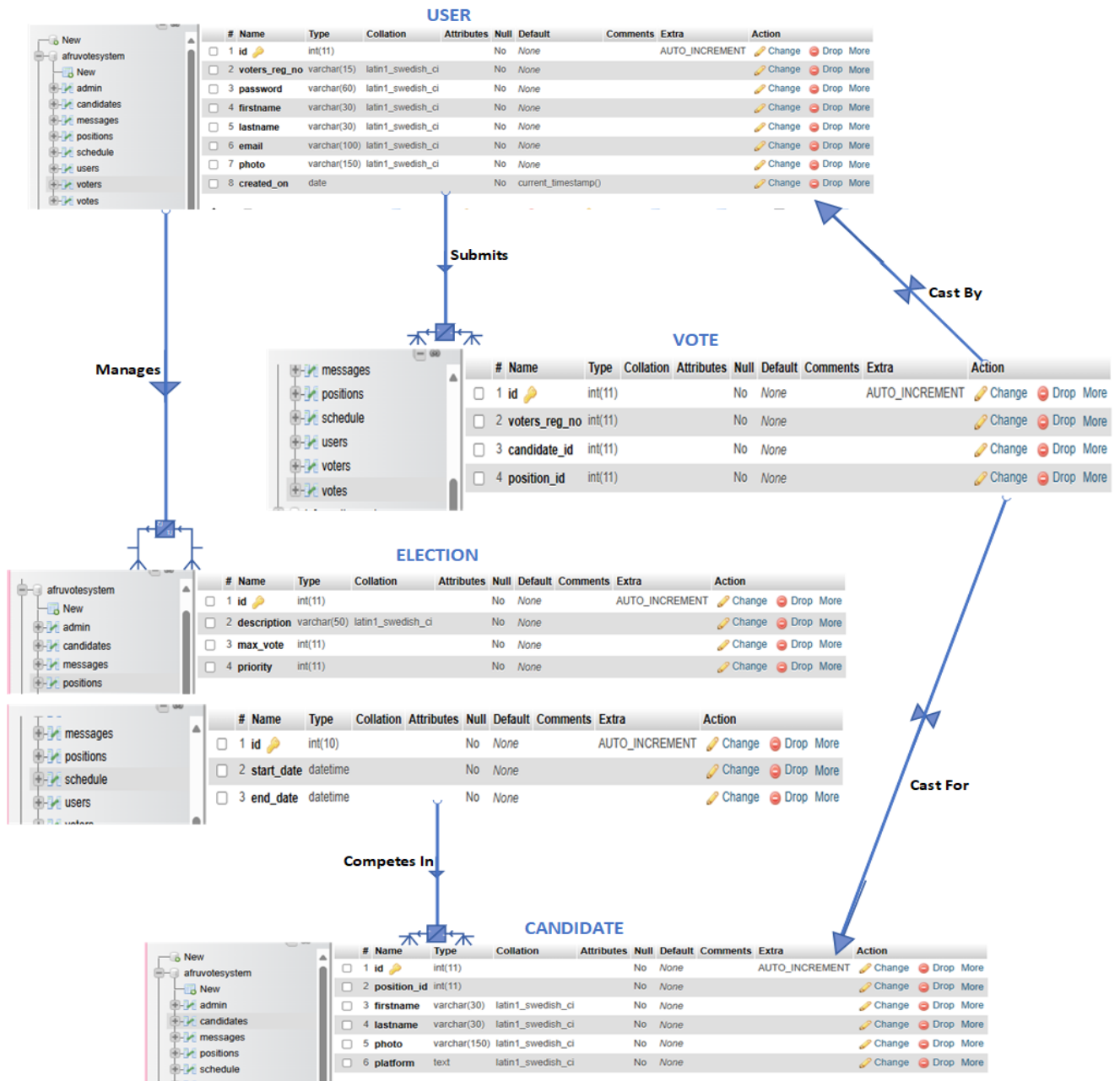


Figure 3.0.2: Entity Relationship Diagram (ERD)

This ER diagram outlines the structure of the online voting system database, including the entities, their attributes, and the relationships between them.

### 3.4.4 System Flowchart

The **System Flowchart** for the **KAYE Online Voting System** provides a visual representation of the steps involved in the voting process, from voter authentication to vote submission and tallying. This diagram outlines the logical flow of actions taken by both the voters and the system, helping to ensure that all critical operations are executed in sequence.

The flowchart includes the following key steps:

1. **Voter Login:** Voters authenticate themselves using their registration number and password.
2. **Voter Authentication:** The system checks the validity of the credentials.
  - If valid, the voter proceeds to the next step.
  - If invalid, an error message is displayed, and the voter is asked to retry.
3. **Vote Casting:** The voter selects candidates for the available positions.
4. **Vote Submission:** The voter submits the ballot, and the system stores the vote securely on the blockchain.
5. **Confirmation:** After submission, the voter receives a confirmation message and email.
6. **Vote Tallying:** Admins access the tallying process, where votes are counted, and results are displayed.

The following figure illustrates the overall flow of the KAYE Online Voting System, detailing the sequence of operations for voters and admins.

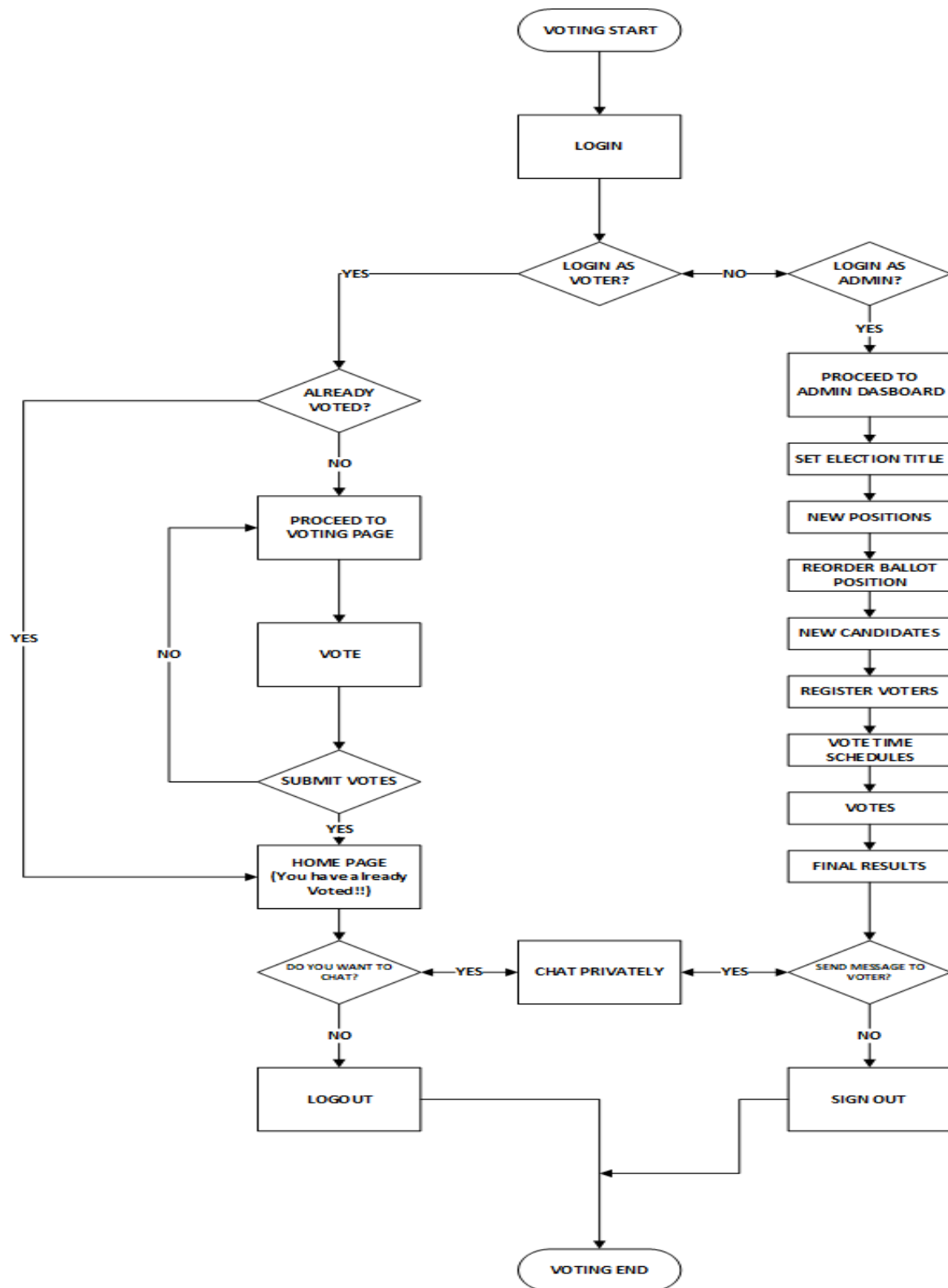


Figure 3.0.3: System Flowchart

The use of these complementary design methodologies will help the research team to thoroughly analyse, design, and document the blockchain-based solution, facilitating its implementation and future enhancements.

## 3.5 POPULATION AND SAMPLING DESIGN

To ensure the study's findings are representative, a carefully considered sampling design is employed.

### 3.5.1 Target Population

The target population includes:

- **Students of Africa Renewal University:** Both undergraduate and graduate students, as they are the primary voters.
- **Election Officials:** Those responsible for organizing and managing the election process at AFRU.
- **IT Staff and Admin:** Staff who have experience managing the current voting system and who will oversee the transition to the web-based system.

### 3.5.2 Sampling Design

A **stratified random sampling** approach was used to ensure representation across different demographics (e.g., year of study, gender, department). This method ensures that the sample accurately represents the broader student body, providing a balanced view of the issue.

## 3.6 DATA COLLECTION METHODS

Data collection involves gathering both qualitative and quantitative data through a variety of tools to ensure a comprehensive understanding of voter intimidation and the system's performance.

### 3.6.1 Collection

- **Surveys:** A structured survey is distributed to students to collect data on their experiences with voter intimidation, their views on the current voting process, and their acceptance of the proposed blockchain solution.
- **Interviews:** Semi-structured interviews with election officials and IT staff focus on the challenges of the current voting system and their expectations for the new system.
- **Observation:** Direct observation of the voting process (during testing phases) helps identify usability issues and potential security gaps.

### 3.6.2 Cleaning, Coding, and Analysis

Collected data is cleaned to remove any incomplete or invalid responses. Qualitative data from interviews is coded thematically to identify recurring patterns or concerns related to voter intimidation. Quantitative data from surveys is analyzed statistically to measure factors such as voter turnout, voter satisfaction, and the system's performance (e.g., response time, security breaches).

### 3.7 RESEARCH PROCEDURES

The research procedures outline the specific steps followed in conducting the study.

1. **Preliminary Research:** A review of existing literature on voter intimidation, web-based voting systems, and blockchain technology.
2. **System Design and Development:** Using Agile and object-oriented methodologies, the blockchain voting is developed over several sprints, with regular stakeholder feedback.
3. **Pilot Testing:** The system is tested in a controlled environment with a subset of students to evaluate its performance and gather feedback.
4. **Data Collection:** Surveys and interviews are conducted during and after the pilot testing to gather qualitative and quantitative data.
5. **Final Testing:** The system is deployed in a real election scenario to test its effectiveness in preventing voter intimidation.

### 3.8 IMPLEMENTATION APPROACH

The blockchain-based voting system is implemented using **Ethereum**, a widely used blockchain platform known for its robust security and scalability. The system incorporates:

- **Smart Contracts:** To automate election processes, including voter registration, vote casting, and result tabulation.
- **Cryptographic Security:** Votes are encrypted and securely stored on the blockchain, ensuring that they cannot be altered or tampered with.
- **Decentralized Ledger:** Ensures that election data is stored across multiple nodes, preventing a single point of failure or manipulation.
- **Blockchain Framework Selection:** The research team will evaluate and select an appropriate blockchain framework, such as Ethereum, Hyperledger, or Corda, based on factors like scalability, security, and ease of integration with existing vote infrastructure.
- **System Architecture Design:** A comprehensive system architecture will be designed, incorporating the selected blockchain framework, secure voter authentication mechanisms, tamper-resistant ballot casting and tallying processes, and transparent result verification procedures.
- **User Interface and Integration:** User-friendly interfaces will be developed for voters, election officials, and other stakeholders to interact with the blockchain-based voting system, ensuring seamless integration with existing voting infrastructure and processes.
- **Security and Privacy Measures:** Advanced security and privacy-preserving techniques, such as zero-knowledge proofs, homomorphic encryption, and secure

multi-party computation, will be integrated into the blockchain-based solution to protect voter anonymity and prevent unauthorized access or tampering.

### 3.9 DATA ANALYSIS METHOD

Data analysis involves both qualitative and quantitative approaches: Qualitative data will be analysed thematically, identifying patterns and themes related to voter intimidation and the usability of the blockchain-based voting system. Quantitative data will be analysed using statistical methods to assess the system's effectiveness in mitigating voter intimidation and enhancing the integrity of the electoral process.

The data collected during the research process will be analysed using a combination of qualitative and quantitative methods:

**Thematic Analysis:** Used to analyze qualitative data from interviews, identifying key themes such as the impact of intimidation and the usability of the new system.

**Descriptive Statistics:** Used to analyze survey data, measuring key variables such as voter turnout, satisfaction levels, and system performance.

**Performance Metrics:** During system testing, metrics such as response time, security breaches, and vote accuracy are analyzed to evaluate the system's effectiveness.

The findings from both the qualitative and quantitative analyses will be triangulated to provide a comprehensive understanding of the research problem and the viability of the blockchain-based solution.

### 3.10 CHAPTER SUMMARY

This chapter outlined the research design, development methodologies, data collection methods, and analysis techniques used in the study. The mixed-methods approach ensures that both qualitative insights and quantitative data are gathered to provide a comprehensive evaluation of the blockchain-based voting system's effectiveness in addressing voter intimidation. The Agile development methodology allowed for iterative improvements, ensuring the final system is secure, transparent, and user-friendly. The following chapter will present the results of the system testing and data analysis.

The implementation of the blockchain-based solution will involve the selection of an appropriate blockchain framework, the design of a secure and transparent system architecture, the development of smart contracts, and the integration of advanced security and privacy measures.

The findings from this research will contribute to the growing body of knowledge on the application of blockchain technology in enhancing the integrity and fairness of voting systems, ultimately helping to address the critical challenge of voter intimidation.

## CHAPTER FOUR: ARTEFACT IMPLEMENTATION

### 4.1 INTRODUCTION

This chapter presents the system design methodology and the implementation approach for the blockchain-based voting system aimed at preventing voter intimidation at Africa Renewal University. The chapter covers the design and architecture of the system, the technologies employed, and the step-by-step process of developing the web-based voting system. Additionally, it discusses the protocols, models, and tools used in the implementation, as well as the key challenges faced and how they were addressed.

### 4.2 SYSTEM DESIGN METHODOLOGY

The system design methodology follows a combination of **Object-Oriented Design (OOD)** and **Data Flow-Oriented Design (DFD)** approaches. This dual-method ensures that the structure of the system is both modular and scalable, with a clear data flow for all voting-related processes.

#### 4.2.1 Object-Oriented Design (OOD)

The system is broken down into interacting objects (e.g., Voter, Admin, Ballot, and Results). Each object encapsulates specific functions and attributes, making the system easier to maintain, update, and scale. The key components of the OOD methodology are:

- **Classes and Objects:** Each object represents a real-world entity (voter, admin, etc.), with its own set of data and behavior.
- **Use Case Diagrams:** These diagrams show the interactions between the system and its users, ensuring that all system functionalities are accounted for (e.g., voter registration, vote casting).
- **Class Diagrams:** Represent the system's structure, outlining the relationships between objects and their attributes. Key classes include Voter, Ballot, Admin, Election, and Blockchain.

#### 4.2.2 Data Flow-Oriented Design (DFD)

Data Flow-Oriented Design maps out the flow of data between different components of the system, ensuring that all information is processed and transmitted securely and efficiently. Key diagrams include:

- **Level 0 DFD:** This diagram represents the entire system as a single process, showing the data flow between voters, the blockchain, and the results processing system.
- **Level 1 DFD:** This breaks down specific processes such as voter registration, voting, and result tabulation, showing how data is processed at each step.



## 4.3 ARTEFACT ANALYSIS

The blockchain-based voting system consists of several key artefacts that are integral to its operation. These artefacts include the blockchain ledger, smart contracts, user authentication protocols, and cryptographic security measures.

The system's architecture integrates blockchain technology with traditional voting mechanisms to create a secure, user-friendly voting platform. The architectural design of the blockchain-based voting system is based on the Ethereum blockchain framework, utilizing smart contracts to govern the voting process and ensure the integrity of the system.

### 4.3.1 System Components

1. **Blockchain Network:** The core component of the system, the blockchain stores each vote as a transaction in a decentralized ledger, ensuring that all votes are securely recorded and cannot be tampered with.
2. **Smart Contracts:** These are self-executing contracts with the terms of the election encoded directly into the blockchain. Smart contracts handle the processes of voter registration, vote casting, and result tallying.
3. **User Authentication:** The system uses **multi-factor authentication (MFA)** to verify the identity of voters. Each voter must provide both their student registration number and a secure password to log in.
4. **Encryption Protocols:** The system uses **Elliptic Curve Cryptography (ECC)** to encrypt votes before they are stored on the blockchain, ensuring voter anonymity and security.

### 4.3.2 System Architecture

The architecture of the blockchain-based voting system is designed to ensure maximum security, transparency, and efficiency. The architecture consists of the following layers:

- **User Interface Layer:** The web-based front end through which voters interact with the system. It includes features for voter registration, voting, and viewing election results.
- **Blockchain Layer:** The backend where all votes are stored and managed. Each vote is added to the blockchain as a new block, ensuring that votes cannot be altered or deleted once submitted.
- **Smart Contract Layer:** Handles the logic of the voting process. Smart contracts govern who can vote, how votes are cast, and how results are calculated.
- **Database Layer:** A distributed ledger stored on multiple nodes to ensure data redundancy and security.

## 4.4 TECHNOLOGIES USED

Several key technologies were used in the design and implementation of the system. These technologies ensure that the system is secure, scalable, and user-friendly.

### 4.4.1 Blockchain Platform: Ethereum

**Ethereum** is a decentralized, open-source blockchain platform that enables the creation of smart contracts and decentralized applications (dApps). It was proposed in 2013 by **Vitalik Buterin** and launched in 2015. Unlike Bitcoin, which is primarily used for financial transactions, Ethereum is designed to be more flexible and programmable, allowing developers to build a wide range of applications.

- **Purpose:** It serves as an underlying infrastructure on which developers can run various decentralized applications, including my blockchain-based voting system.
- **Smart Contracts:** Ethereum allows developers to write smart contracts, which are self-executing contracts with the terms and conditions of the agreement directly written into code. It is not a platform but rather a concept that is executed on platforms like Ethereum. For this voting system, smart contracts handled voter registration, vote casting, and result tallying in a secure and automated manner.
- **Decentralization:** Ethereum operates on a decentralized network of computers (nodes), ensuring that no single entity has control over the system. This decentralization is crucial for the transparency and security of your voting system, as it prevents tampering or manipulation of votes.
- **Security and Transparency:** Each vote in my system is stored on the Ethereum blockchain, making it immutable and publicly verifiable. The transparency of Ethereum ensures that the voting process is auditable, while its security protocols (such as cryptography) protect against fraud and unauthorized access.

Ethereum is an ideal platform for my blockchain-based voting system because it provides a secure, transparent, and decentralized environment for handling sensitive voting data.

### How Ethereum and Smart Contracts Work in my Project

#### 1. Ethereum as the Blockchain Platform

- **Decentralization:** Ethereum is decentralized, meaning it doesn't rely on a central authority to verify or store data. For my project, this means no single entity (like election officials or system administrators) can manipulate or control the voting process. Once votes are cast, they are securely distributed across thousands of nodes (computers) on the Ethereum network.
- **Immutability:** Once a vote is recorded on Ethereum's blockchain, it cannot be changed or deleted. This guarantees that votes are final and tamper-proof, ensuring **election integrity**.

- **Transparency:** The blockchain is transparent, meaning anyone can verify the number of votes cast. However, privacy is maintained as each voter's identity is secured using cryptography. For my voting system, this makes the entire election process auditable and trustworthy.

## 2. Smart Contracts in My Voting System

- **Automated Voting Process:** Smart contracts automate the election. They handle everything from voter registration to casting votes, tallying results, and even verifying election deadlines. Once deployed on Ethereum, these contracts self-execute, meaning the process is fully autonomous with no need for manual intervention.
- **Voter Registration:** A smart contract can handle voter registration. It will verify the student's identity (e.g., registration number), ensure they are eligible to vote, and store their information securely.
- **Vote Casting:** The smart contract ensures that each student can only cast one vote. When a vote is cast, it is encrypted and added to the blockchain. The smart contract validates the vote and stores it securely in the blockchain, ensuring anonymity.
- **Vote Tallying:** At the end of the election, the smart contract automatically counts the votes and generates the results. This process is fully transparent, and since the data is stored on the blockchain, it is immutable.
- **Security:** Every vote is encrypted and stored securely on the Ethereum blockchain. The decentralized nature of the blockchain ensures that no single person or group can alter the votes. Smart contracts also ensure that each voter's identity is protected and that only authorized individuals can vote.

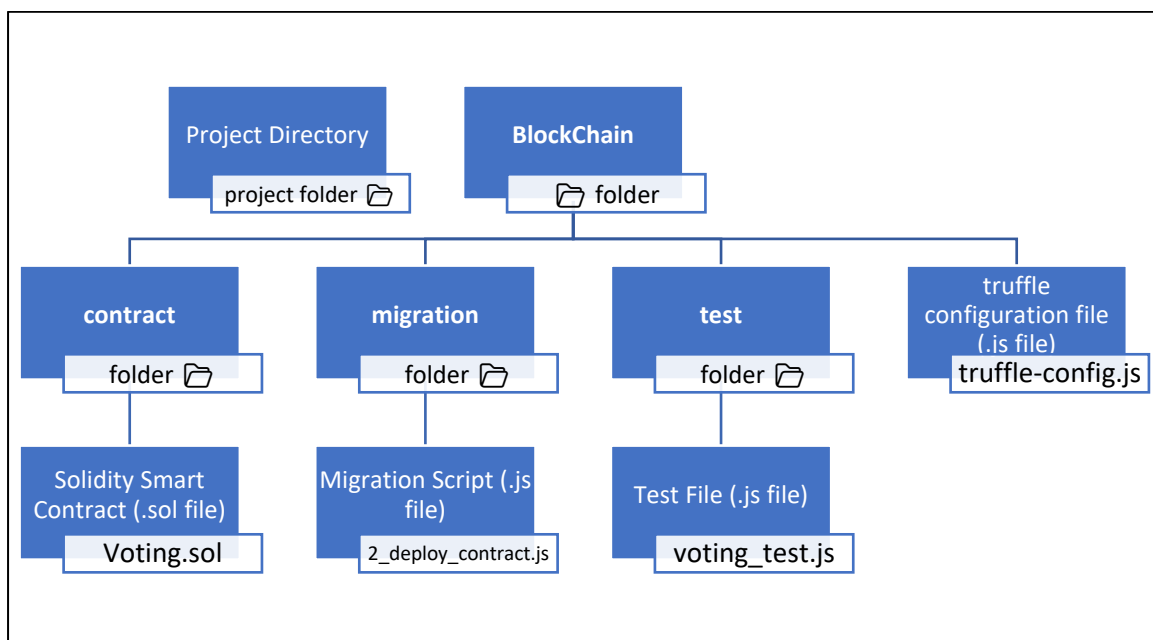


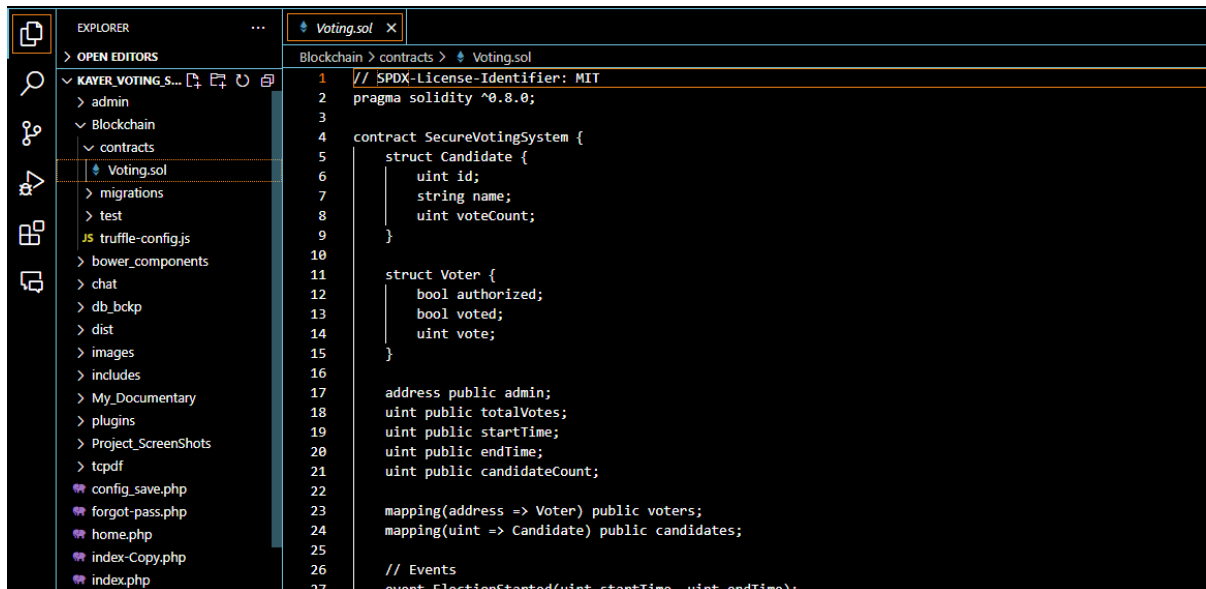
Figure 4.0.1: Structure of how I Included the Solidity Contract in my voting system

File Types and Extensions in my folder Blockchain:

### 1. Solidity Contract File (.sol):

This is the file where I wrote my smart contracts.

- **Location:** ../BlockChain/contracts/
- **File Name:** Voting.sol



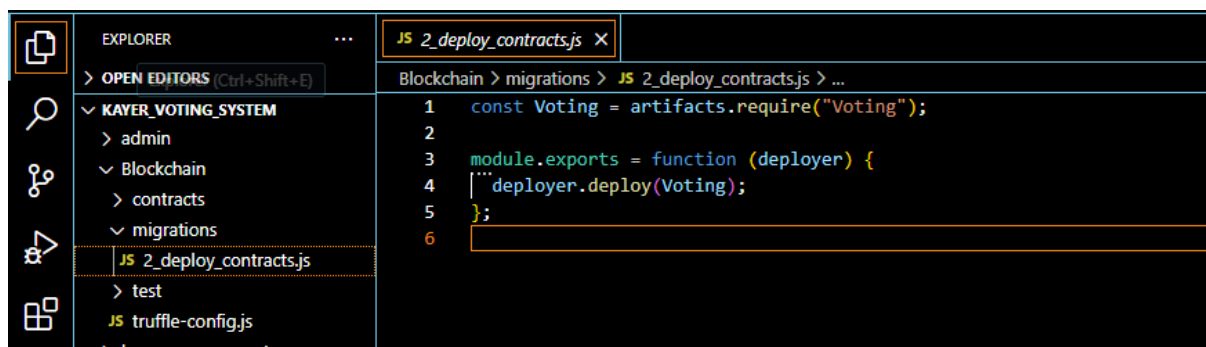
```
1 // SPDX-License-Identifier: MIT
2 pragma solidity ^0.8.0;
3
4 contract SecureVotingSystem {
5     struct Candidate {
6         uint id;
7         string name;
8         uint voteCount;
9     }
10
11     struct Voter {
12         bool authorized;
13         bool voted;
14         uint vote;
15     }
16
17     address public admin;
18     uint public totalVotes;
19     uint public startTime;
20     uint public endTime;
21     uint public candidateCount;
22
23     mapping(address => Voter) public voters;
24     mapping(uint => Candidate) public candidates;
25
26     // Events
27     event ElectionStarted(uint startTime, uint endTime);
```

Figure 4.0.3: voting.sol for Solidarity Contract File

### 2. Migration File (.js):

This JavaScript file helps deploy my smart contract onto the blockchain.

- **Location:** ../BlockChain/migrations/
- **File Name:** 2\_deploy\_contracts.js



```
1 const Voting = artifacts.require("Voting");
2
3 module.exports = function (deployer) {
4     deployer.deploy(Voting);
5 };
6
```

Figure 4.0.4: To deploy Smart contract I used 2\_deploy\_contracts.js

### 3. Test File (.js):

I used JavaScript to write unit tests for my smart contract to ensure it behaves as expected.

- **Location:** ../BlockChain/test/
- **File Name:** voting\_test.js

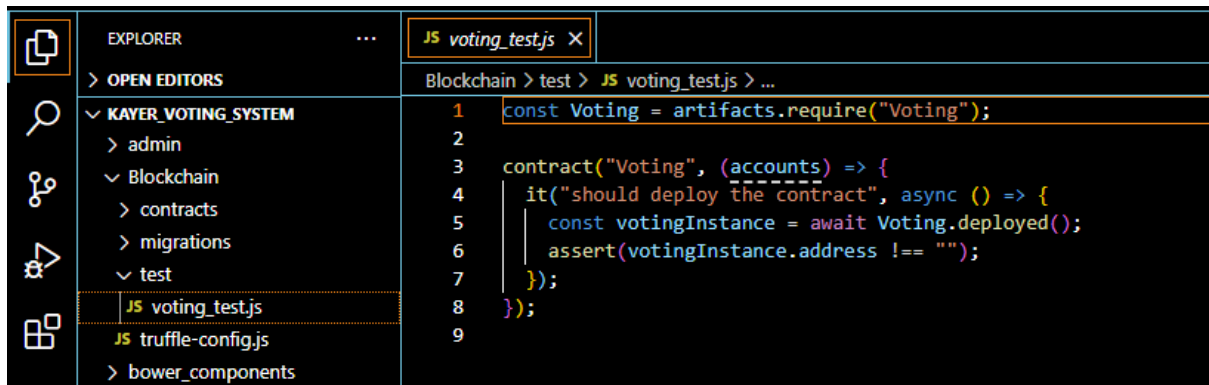


Figure 4.0.5: To write unit tests for my smart contract used voting.js

### 4. Configuration File (.js):

This is the configuration file for **Truffle**, where I set up the connection to my blockchain network (e.g., Ethereum testnet or local blockchain).

- **Location:** ../BlockChain/
- **File Name:** truffle-config.js

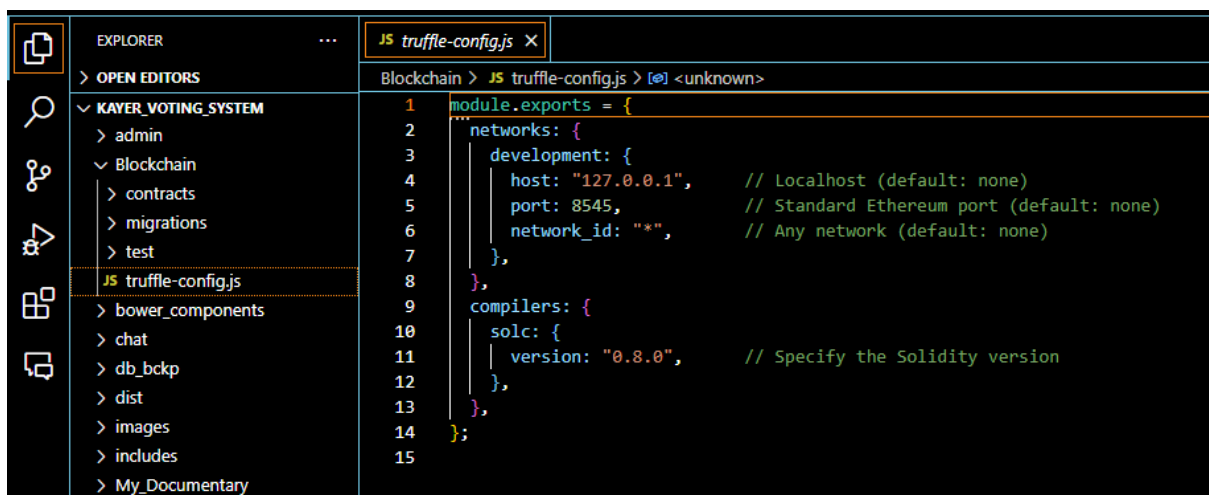


Figure 4.0.6: Configuration file for truffle-config.js

## 4.4.2 Programming Languages

The development of the blockchain-based voting system relies on various programming languages and frameworks for both the **frontend** and **backend**. These tools ensure that the system is secure, responsive, and user-friendly.

## ❖ Frontend Technologies

### 1. HTML (HyperText Markup Language):

- **Purpose:** HTML is the standard markup language used to structure content on the web. It is used to create the skeleton of the web-based voting interface, defining the structure of web pages, including elements such as forms for voter registration, voting buttons, and candidate lists.
- **Role in the Project:** HTML is used to create the voting system's user interface (UI), ensuring that it is visually structured and accessible to all voters.

### 2. JavaScript:

- **Purpose:** JavaScript is a versatile programming language used to add interactivity to web pages. It handles the dynamic behaviors of the voting system, allowing the system to respond to user inputs, validate voter forms, and communicate with the backend (e.g., submitting votes).
- **Role in the Project:** JavaScript manages frontend operations such as form validation (e.g., checking that all required voter information is entered correctly) and sending data to the server or blockchain using Ajax.

### 3. AJAX (Asynchronous JavaScript and XML):

- **Purpose:** AJAX allows web pages to communicate with the backend asynchronously without needing to reload the entire page. This is essential for creating a smooth user experience.
- **Role in the Project:** In the voting system, AJAX is used for real-time communication between the frontend and the backend. For example, it enables live updates on the voting progress, such as dynamically displaying confirmation messages after a vote is cast, without refreshing the page.

### 4. jQuery:

- **Purpose:** jQuery is a fast, small JavaScript library that simplifies tasks such as HTML manipulation, event handling, and AJAX calls.
- **Role in the Project:** jQuery is used to simplify JavaScript code for frontend tasks. For instance, it provides an easier way to handle form submissions, AJAX calls, and animations on the voting interface.

### 5. Bootstrap:

- **Purpose:** Bootstrap is a popular CSS framework that provides pre-designed templates for responsive web design. It ensures that the web-based voting system is visually appealing and works well on various devices, including desktops, tablets, and smartphones.

- **Role in the Project:** Bootstrap is used to create a responsive voting interface. This ensures that the system is user-friendly across different screen sizes, providing a consistent experience for voters on both mobile devices and desktops.

## ❖ Backend and Database

### 1. PHP (Hypertext Pre-processor):

- **Purpose:** PHP is a server-side scripting language commonly used for backend development in web applications. It handles server-side logic, database connections, and API calls.
- **Role in the Project:** PHP is used to handle backend operations such as voter registration, authentication, and database interactions with MySQL. When a voter registers or logs in, PHP scripts verify credentials and ensure the right data is fetched from the database.

### 2. MySQL (Relational Database):

- **Purpose:** MySQL is a widely used open-source relational database management system. It stores structured data and allows for easy querying and retrieval.
- **Role in the Project:** MySQL is used to store non-voting-related data such as voter registration details (name, email, student ID) and candidate information. While votes themselves are stored on the blockchain for security, voter data is stored in MySQL, allowing the system to easily authenticate voters and ensure that only eligible users participate in the election.

### 3. Solidity:

- **Purpose:** Solidity is a high-level programming language used to write smart contracts on Ethereum's blockchain. It allows for decentralized applications to run securely on the Ethereum platform.
- **Role in the Project:** Solidity is used to create smart contracts that automate the voting process, ensuring security and transparency. The smart contracts handle critical tasks like vote casting, vote tallying, and enforcing election rules. For example, once a vote is cast, the Solidity smart contract automatically encrypts and stores the vote on the Ethereum blockchain, making it immutable and tamper-proof.
- **Blockchain Role:** Solidity is the core language used to interact with the Ethereum blockchain, ensuring that all transactions, including votes, are securely recorded and that results are transparently auditable.

### 4.4.3 Cryptographic Security

The system uses **Elliptic Curve Cryptography (ECC)** to encrypt all votes before they are submitted to the blockchain. This ensures that votes remain anonymous and secure from external tampering.

### 4.4.4 Smart Contract Tools

- **Truffle Suite:** Used for smart contract development and testing.
- **MetaMask:** Used for connecting the web interface to the Ethereum blockchain, allowing voters to interact with the system via their browsers.

## 4.5 PRESENTATION OF COLLECTED DATA

The research phase involved the collection of both qualitative and quantitative data to inform the design of the blockchain-based voting system. Qualitative data was gathered through semi-structured interviews with election officials, voter advocacy groups, and technology experts. The interviews focused on understanding the practical challenges of voter intimidation, the requirements for a blockchain-based solution, and the potential barriers to adoption.

Quantitative data was collected through online surveys distributed to a wider audience of stakeholders, including voters and election administrators. The surveys gathered information on the perceptions, experiences, and requirements related to voter intimidation and blockchain-based voting systems. The collected data was analysed using thematic analysis and descriptive statistics to identify key themes, patterns, and insights.

The analysis of the collected data revealed several critical requirements for the blockchain-based voting system to effectively address voter intimidation:

1. **Secure and anonymous voter authentication:** The system ensured that only eligible voters can participate in the election while preserving their anonymity and preventing voter coercion or intimidation.
2. **Tamper-resistant ballot casting and tallying:** The voting process designed to prevent any unauthorized modifications or tampering with the ballots, ensuring the integrity of the election results.
3. **Transparent and verifiable voting records:** The system provided a transparent and auditable record of the voting process, allowing voters and election officials to verify the accuracy and fairness of the election outcomes.
4. **User-friendly and accessible interface:** The system's user interface is intuitive and accessible to all voters, regardless of their technological proficiency, to encourage broad participation and reduce barriers to voting.



## 4.6 PROOF OF CONCEPT

The **KAYE Online Voting System** is designed to eliminate voter intimidation, improve security, and enhance transparency in the election process at Africa Renewal University (AFRU). The system has two main components: the **Admin Section** for managing the election process and the **Voter Section** for voter participation.

The proof of concept demonstrates how the system works by showing the core functionalities and validating them through real-world testing and simulations. Below is a detailed explanation of what the system does and how it operates:

### 4.6.1 ADMIN SECTION

The Admin Section provides election officials with the tools to manage voter registrations, monitor voting schedules, and tally the election results. The following features are available to the admin:

#### 1. Admin Login and Dashboard

- A login page with the AFRU logo and a more aesthetically designed user interface for the admin.

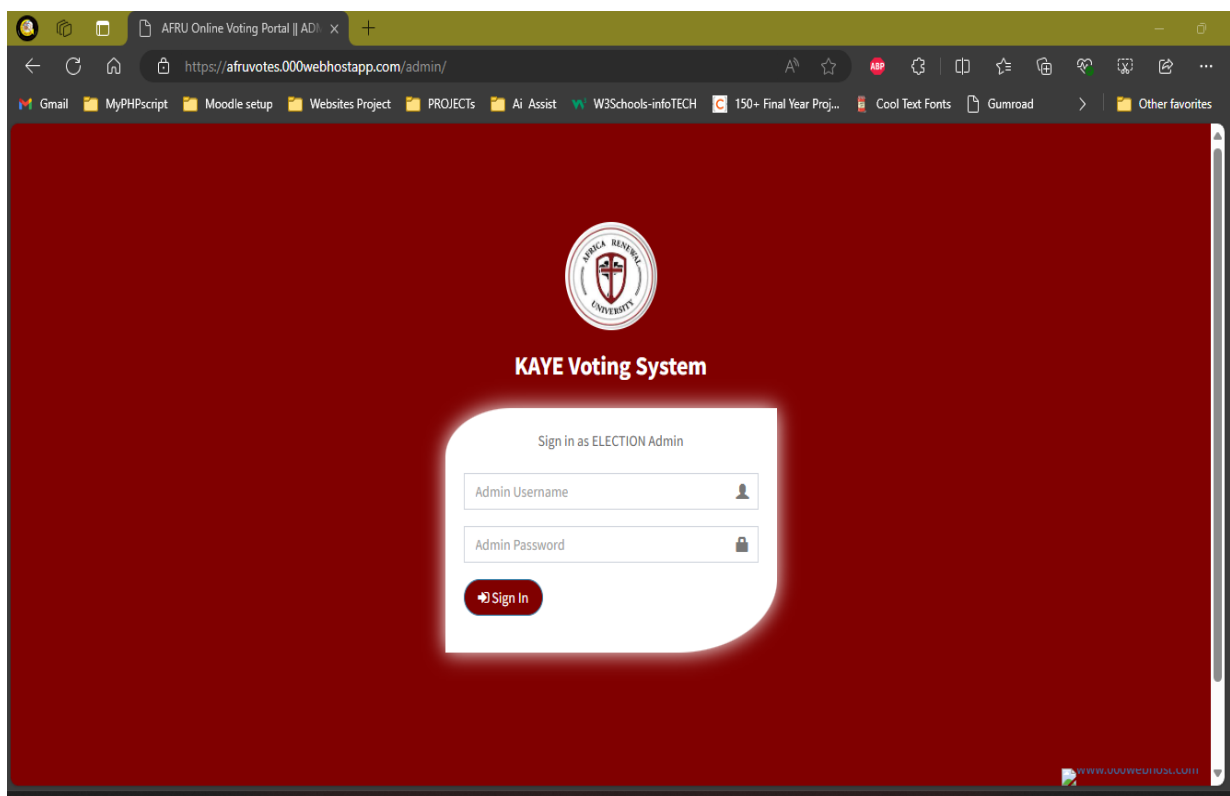


Figure 4.0.7: Admin Login Page

- Admin dashboard with a redesigned UI featuring box-shadows, enhanced icons, and a link to display the overall results.

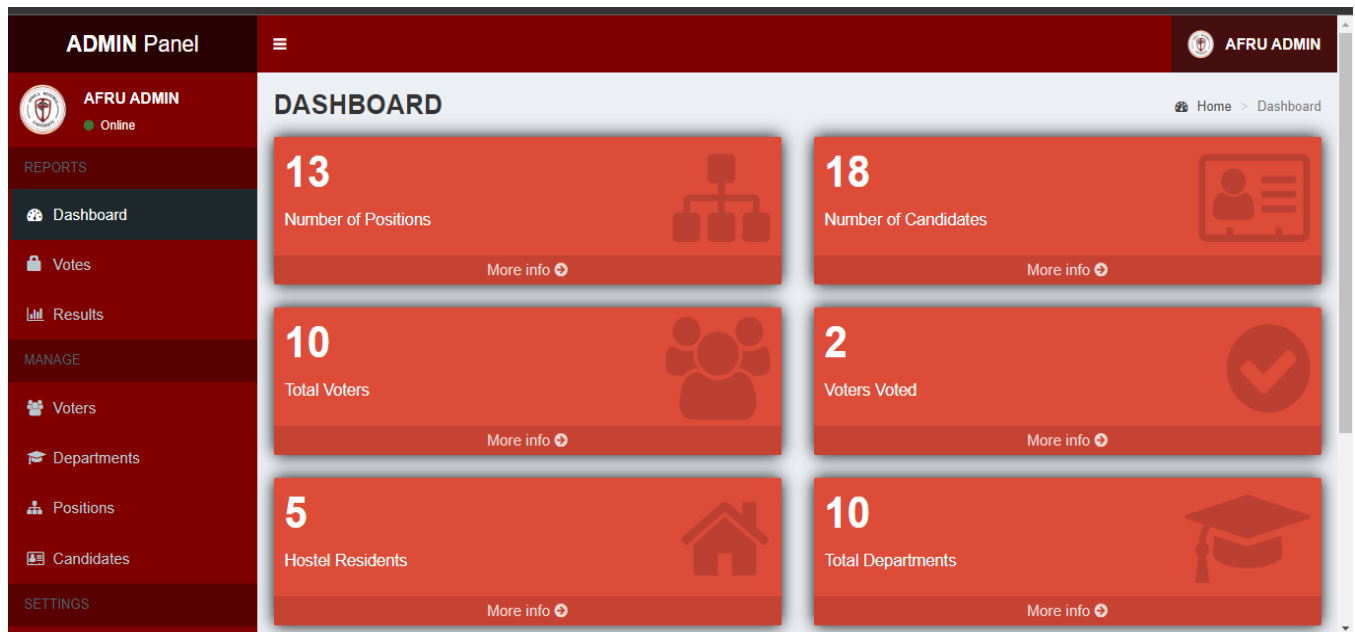


Figure 4.0.8: Admin dashboard Page

## 2. Voter Registration Management

The KAYE Online Voting System begins with voter registration, where voters can be added individually or in bulk using an Excel CSV file. The system ensures that only registered students can participate in the election. Key features of the registration process include:

- **Bulk voter addition:** Admins can add voters in bulk via an **Excel CSV upload**, making it easy to register a large number of voters.

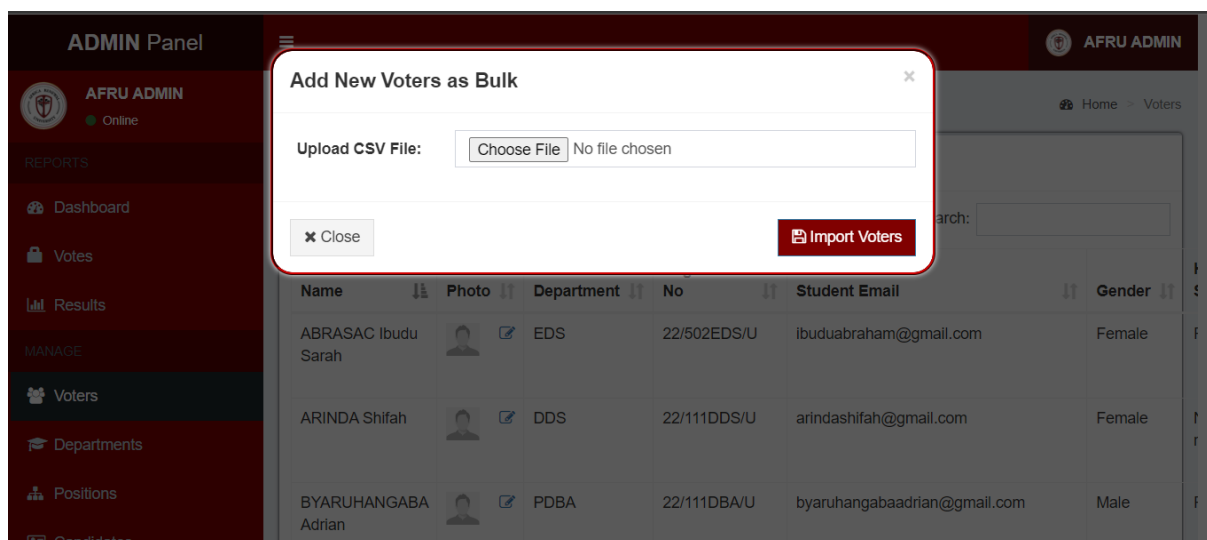


Figure 4.0.9: Adding Voters as Bulk

- Admins can manage voter information, including the addition of **email addresses** during registration for email notifications.

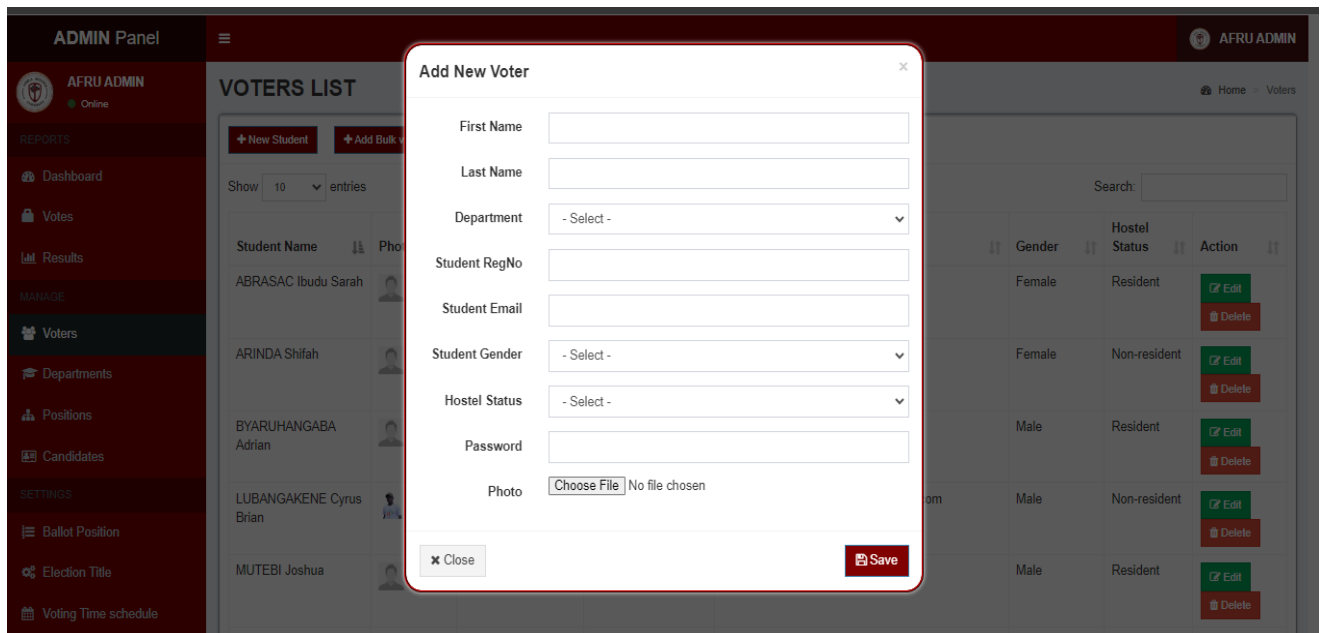


Figure 4.0.10: Voters Registration UI

- **Sending emails:** Once registration is complete, the system automatically sends confirmation emails to all registered voters.

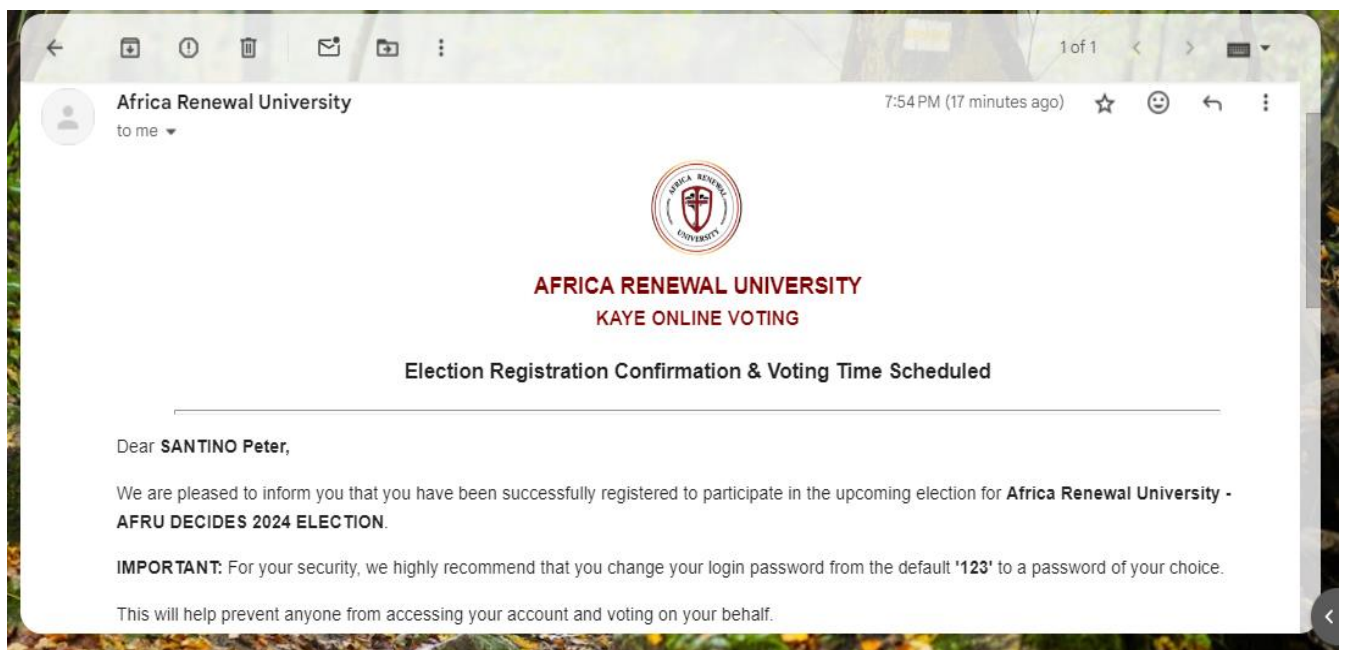


Figure 4.0.11: Confirmation emails to all registered voters

### 3. Voting Schedule Management

- Admins can create and update the **voting schedule**, specifying the start and end times for voting.

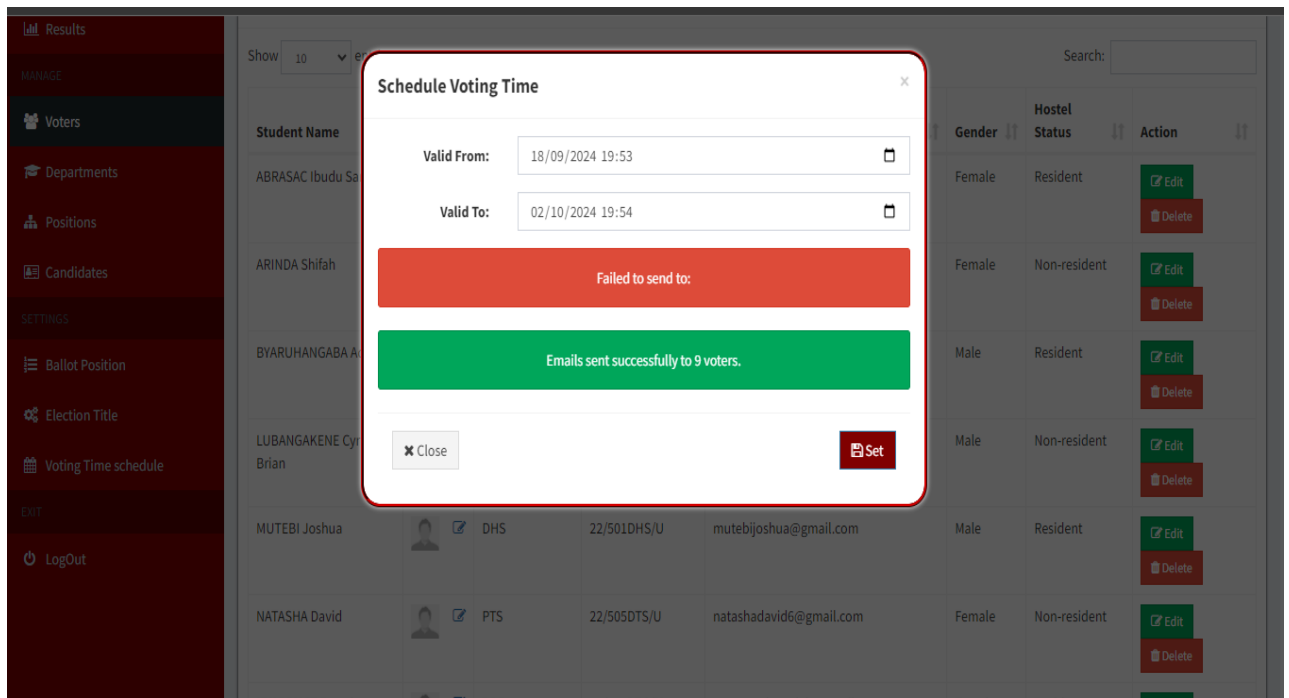


Figure 4.0.12: Voting Schedule Page

- Once the voting time is scheduled, the system sends email notifications to all voters, informing them of the upcoming election.

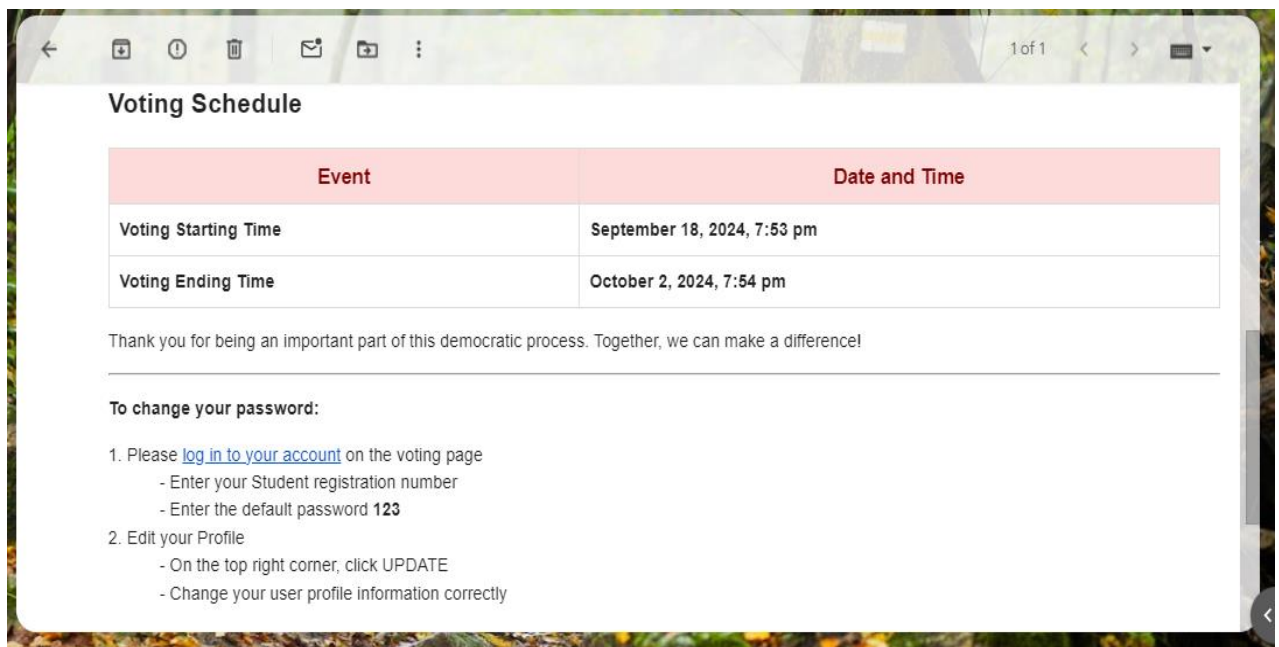


Figure 4.0.13: Email notification on Voting Schedule

- A countdown timer is displayed on the voting page, showing voters how much time is left before auto-submission. The system features a **5-minute countdown**, and votes are automatically submitted when time expires.



Figure 4.0.14: Voting Page with Countdown Timer

#### 4. Votes Tallying and Results Reporting

- Admins can view and manage the **votes tally**, with a link on the dashboard to display the overall election results.

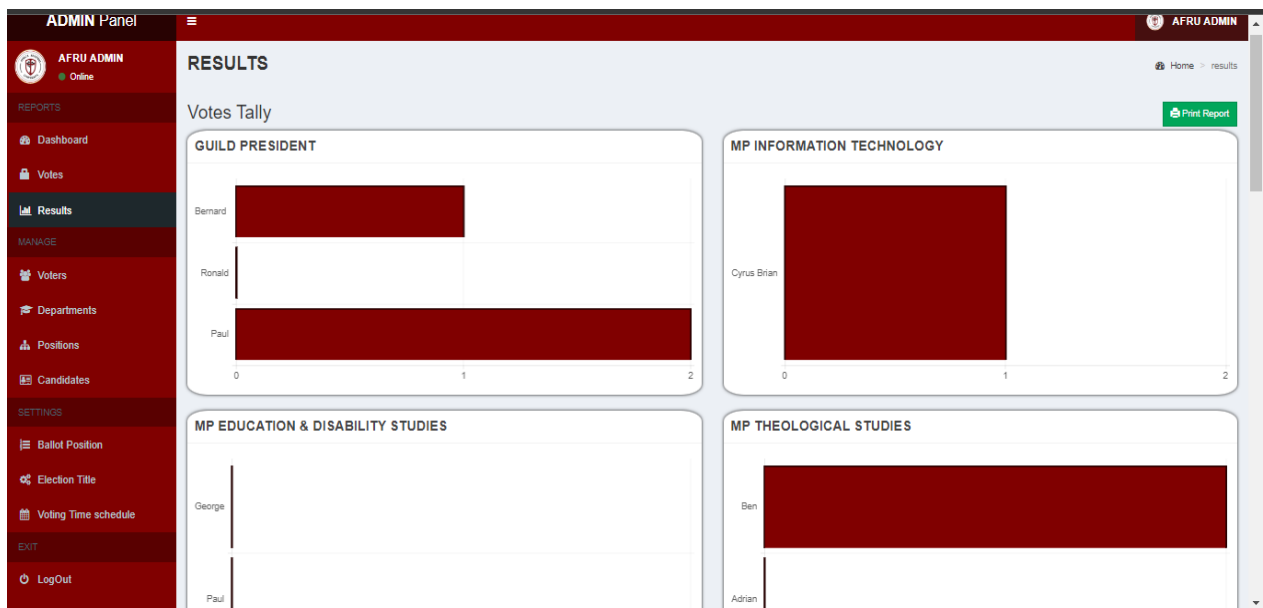


Figure 4.0.15: Election Results after Election

- The system allows for printing the overall summary of results, including the breakdown of votes and information about voters who participated or did not vote.
- **PDF generation:** Admins can print a detailed report of the election results, including registered voters and vote tallies.


 <p><b>AFRICA RENEWAL UNIVERSITY</b> KAYE ONLINE VOTING - TALLY RESULTS</p>	
<b>AFRU DECIDES 2024 ELECTION</b>	
<b>GUILD PRESIDENT</b>	
<b>Candidates</b>	<b>Votes</b>
KISAKYE Paul	2
KZZA Bernard	1
AYESIGAMUKAMA Ronald	0
<b>MP INFORMATION TECHNOLOGY</b>	
<b>Candidates</b>	<b>Votes</b>
LUBANGAKENE Cyrus Brian	1
<b>MP EDUCATION &amp; DISABILITY STUDIES</b>	
<b>Candidates</b>	<b>Votes</b>
ABRASAC Paul	0
LUAL George	0
<b>MP THEOLOGICAL STUDIES</b>	
<b>Candidates</b>	<b>Votes</b>
KIWANUKA Ben	1
BYARUHANDABA Adrian	0
<b>MP BUSINESS STUDIES</b>	
<b>Candidates</b>	<b>Votes</b>
NATASHA Angel	0
<b>MALE HOSTEL REPRESENTATIVE</b>	
<b>Candidates</b>	<b>Votes</b>
TAMALE Joshua	2
TWINAMASIKO John Paul	0
<b>MP HEALTH SCIENCES</b>	
<b>Candidates</b>	<b>Votes</b>
<b>FEMALE HOSTEL REPRESENTATIVE</b>	
<b>Candidates</b>	<b>Votes</b>
ARINDA Cleopatra	0

Figure 4.0.16: PDF generation tool

<b>Registered Voters</b>				
No	Registration Number	Full Name	Hostel Status	Email
1	21/511BIT/U	LUBANGAKENE Cyrus Brian	Non-resident	ocyrusbrianlubangakene015@gmail.com
2	22/501DHS/U	MUTEBI Joshua	Resident	mutebijoshua@gmail.com
3	22/502EDS/U	ABRASAC Ibudu Sarah	Resident	ibuduabraham@gmail.com
4	22/503DTS/U	SANTINO Peter	Non-resident	santinopeter@gmail.com
5	22/504TVS/U	OCEM Emma	Resident	ocenemma@gmail.com
6	22/505DTS/U	NATASHA David	Non-resident	natashadavid5@gmail.com

7	22/111DBS/U	NYASONGE Branda	Resident	nyasongebrendah@gmail.com
8	22/111JMS/U	OCEM Peter	Non-resident	ocenpeter@gmail.com
9	22/111DBA/U	BYARUHANDABA Adrian	Resident	byaruhangabaadrian@gmail.com
10	22/111DDS/U	ARINDA Shifah	Non-resident	arindashifah@gmail.com

<b>Registered Voters Who Voted</b>			
No	Registration Number	Full Name	Email
1	21/511BIT/U	LUBANGAKENE Cyrus Brian	ocyrusbrianlubangakene015@gmail.com
2	22/503DTS/U	SANTINO Peter	santinopeter@gmail.com
3	22/111DBA/U	BYARUHANDABA Adrian	byaruhangabaadrian@gmail.com

<b>Registered Voters Who Did Not Participate</b>			
No	Registration Number	Full Name	Email
1	22/501DHS/U	MUTEBI Joshua	mutebijoshua@gmail.com
2	22/502EDS/U	ABRASAC Ibudu Sarah	ibuduabraham@gmail.com
3	22/504TVS/U	OCEM Emma	ocenemma@gmail.com

## 4.6.2 VOTER SECTION

The **Voter Section** is designed to provide a user-friendly and secure platform for voters to cast their ballots. It includes the following features:

### 1. Voter Login and Registration

- The voter login page features a well-designed interface, with an option for "**Forgot password**" to assist users who cannot access their accounts.

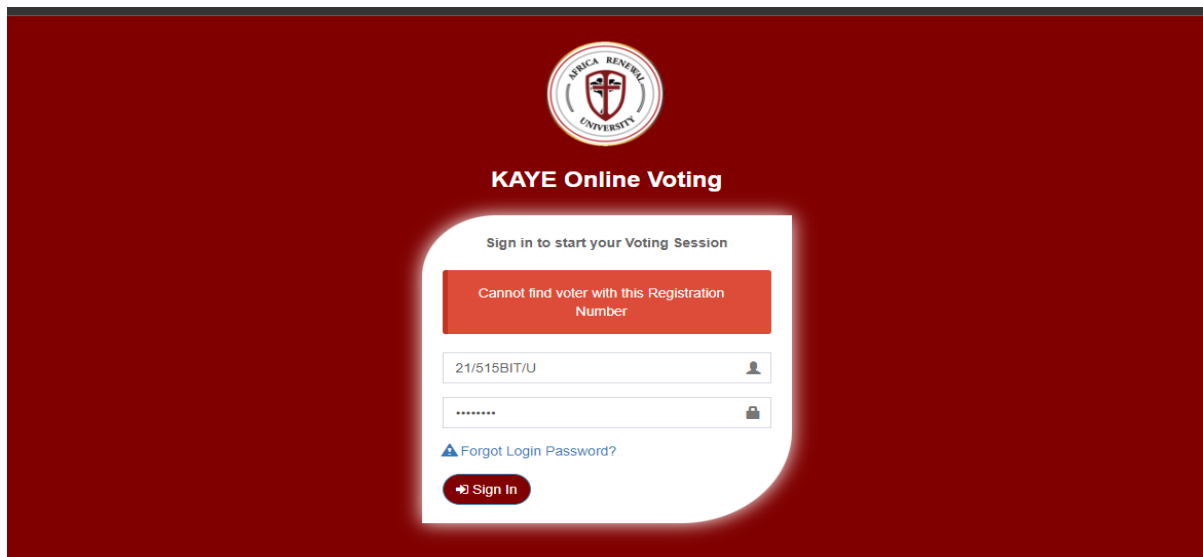


Figure 4.0.17: The voter login page

- Voters can view and update their profiles through a **profile dropdown**, which displays their registration number, name, and registration date. However, the registration number cannot be edited.

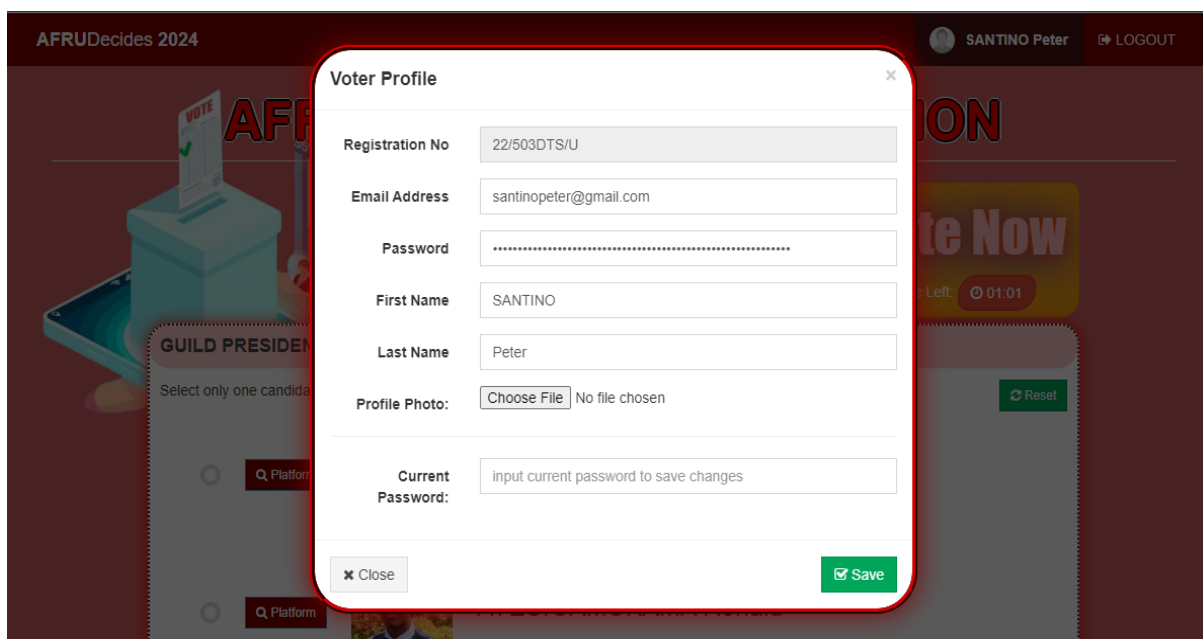


Figure 4.0.18: Voter's Profile setting



## 2. Voting Process

- **Countdown timer:** A countdown timer is displayed during the voting process, giving voters a limited time (e.g., 5 minutes) to cast their ballots. Votes are automatically submitted when the timer expires.
- After submitting their vote, voters receive a **confirmation email** notifying them that their vote has been successfully recorded.

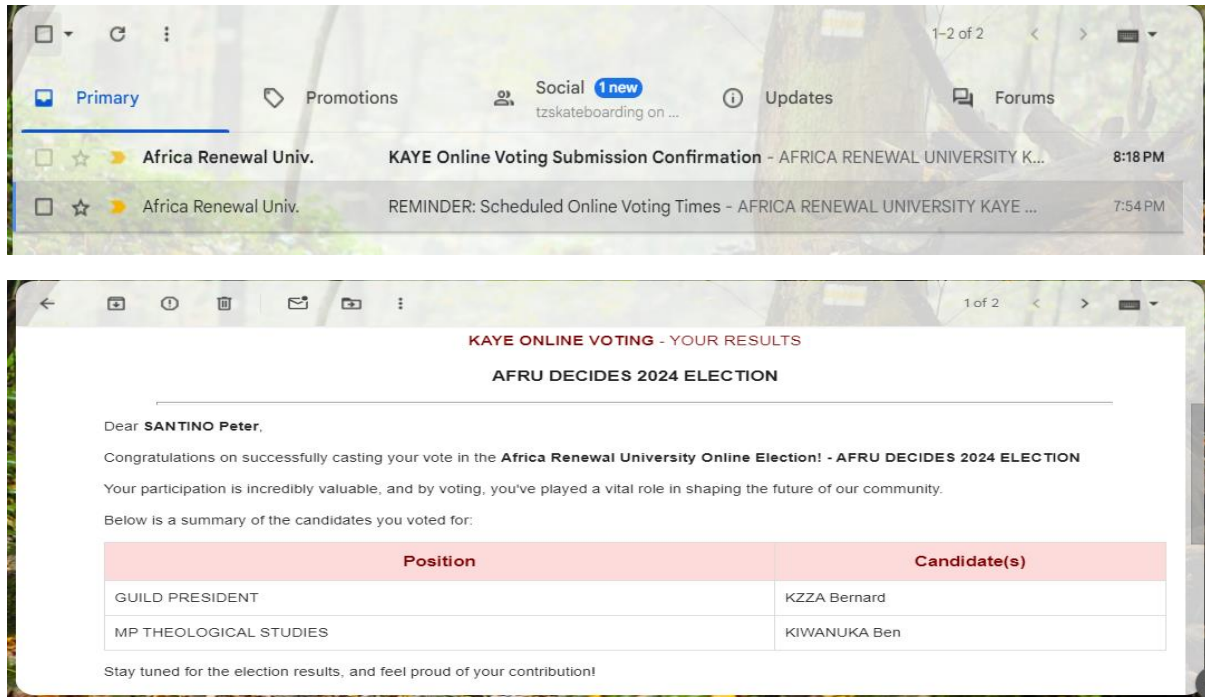


Figure 4.0.19: voters receive a confirmation email

## 3. Real-Time Chat and Communication

Voters can use the **real-time chat feature** to communicate with election officials and other students who has already voted during the voting period for any clarifications or assistance.

Figure 4.0.22: Voter registering for chat

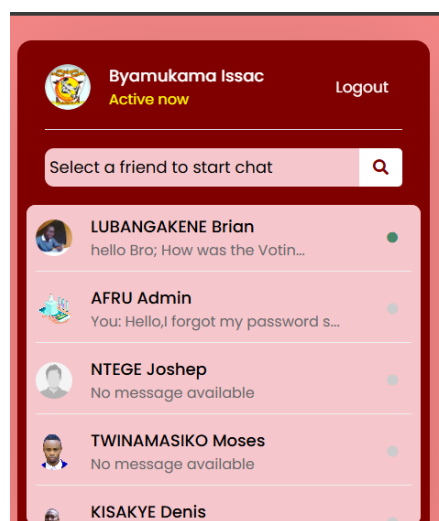


Figure 4.0.21: Chat List for Available chats

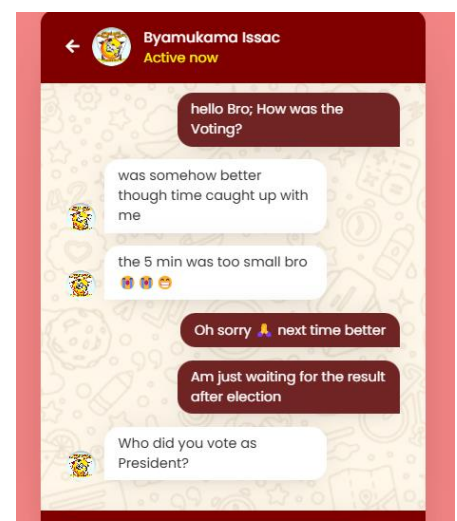


Figure 4.0.20: Chat Page interface



**real-time chat system** is integrated also into the admin dashboard, allowing communication with voters who need assistance or clarification during the voting process.

#### 4. Viewing Results

- After the election, voters can view the overall election results. A warning message is displayed to ensure voters understand that results are final once posted.
- The results are **tallied in real-time** by the smart contract on the Ethereum blockchain, ensuring that no votes are tampered with.

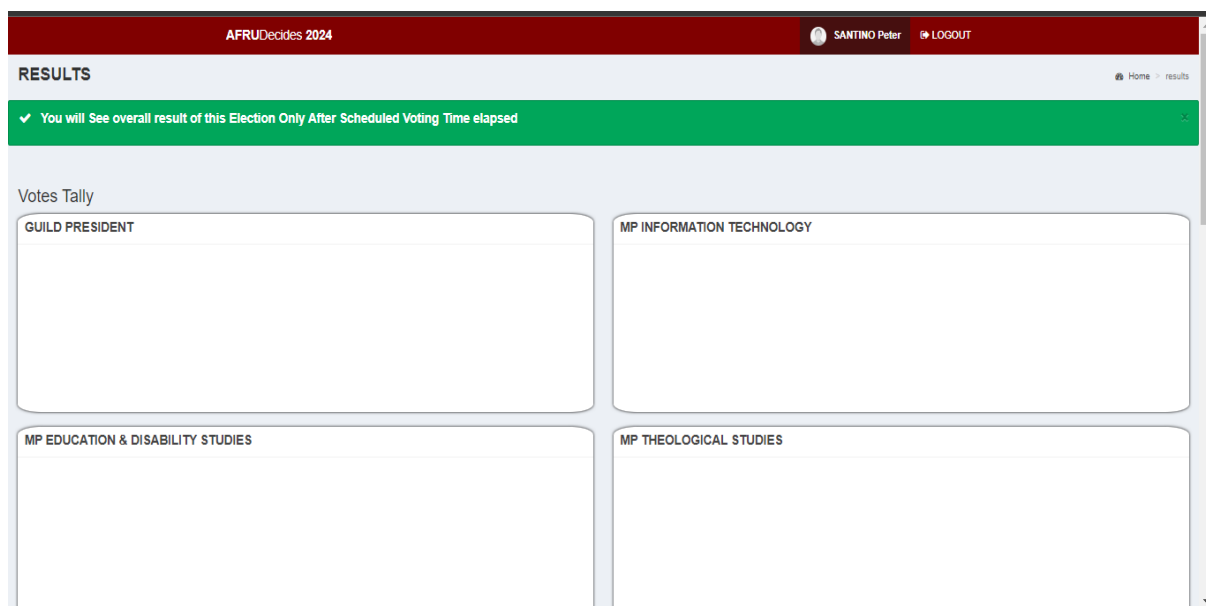


Figure 4.0.23: Overall results page

### 4.6.3 Security and Transparency

To maintain the integrity of the election, the KAYE Online Voting System uses a combination of blockchain technology and web security measures:

- **Blockchain:** Each vote is encrypted and securely stored on the Ethereum blockchain, ensuring that it cannot be altered or deleted once cast.
- **Multi-factor authentication (MFA):** Voters are authenticated through a combination of their registration number and password, ensuring that only eligible students can access the system.
- **Data encryption:** All sensitive information is encrypted to prevent unauthorized access.

This Proof of Concept demonstrates how the KAYE Online Voting System ensures the election process is transparent, secure, and free from intimidation, using blockchain technology and secure web development practices. The next phase of testing involves implementing the system in real-world AFRU elections and gathering feedback from users.

## 4.7 ARTEFACT REQUIREMENTS (OPERATING ENVIRONMENT)

The successful implementation of the **KAYE Online Voting System** requires both hardware and software components to ensure optimal performance, security, and scalability. This section outlines the operating environment necessary for the system to function effectively, including hardware, software, and network requirements.

### 4.7.1 Hardware Requirements

#### 1. Voter Devices

The system is designed to be accessible via various devices, ensuring that voters can cast their ballots securely and conveniently. The following devices are supported:

- **Personal Computers (PCs):** Voters can access the system using desktop or laptop computers with a modern web browser.
- **Smartphones and Tablets:** The voting interface is responsive, allowing voters to use mobile devices for voting.
- **Minimum Specifications:** Devices should have at least 2GB of RAM and a processor with 1.5 GHz or higher.

#### 2. Server Infrastructure

To host the system and handle election operations, the following server infrastructure is required:

- **Web Server:** The system should be deployed on a secure web server such as **Apache** or **Nginx**.
- **Cloud-Based or Dedicated Server:** A cloud-based infrastructure (e.g., AWS, Google Cloud) or dedicated server should be used to ensure scalability, uptime, and reliability during election periods.
- **Backup and Redundancy:** Implement redundant backup systems to store data safely and maintain high availability in case of server failure.

#### 3. Blockchain Nodes

The Ethereum blockchain operates on decentralized nodes. These nodes store voting data and execute smart contracts:

- **Minimum Nodes:** At least two nodes are required for redundancy, with each node having a reliable internet connection and sufficient storage to handle blockchain data.
- **Node Specifications:** Each node should have a minimum of 4GB RAM, 250GB of SSD storage, and a modern multi-core processor.

## 4.7.2 Software Requirements

### 1. Blockchain Network

- The voting system is built on the **Ethereum blockchain**, which ensures that all votes are securely stored and cannot be tampered with. The Ethereum network also supports the smart contracts that automate voting, tallying, and result generation.
  - **Blockchain Client:** Ethereum clients such as **Geth** or **Parity** should be installed on the nodes to interact with the blockchain.
  - **Smart Contract Deployment:** The voting smart contracts, written in **Solidity**, need to be deployed on the Ethereum network using **Truffle** or **Hardhat** development frameworks.

### 2. Web Server

- The system's frontend is hosted on a web server that interacts with the backend (blockchain and database):
  - **Web Server Software:** Use either **Apache** or **Nginx** for hosting the web interface.
  - The server must have PHP 7.4 or higher installed, as it powers the backend logic, including user authentication, email handling, and data interactions
  - **Security Protocols:** Ensure the server has **SSL certificates** to secure communication between the client devices and the server. Encrypted HTTPS connections must be used throughout the voting process.

### 3. Database

- MySQL is used to store non-blockchain data such as voter profiles, registration details, and general system settings.  
Minimum version: **MySQL 5.7** or higher.voting periods when large volumes of data are processed
- **Security Protocols:** The web server must support SSL/TLS to ensure that all communications between the client (voter) and the server are encrypted, particularly during login, vote submission, and result viewing.

### 4. Mail Server:

- **PHPMailer** is integrated with the system for sending automatic emails to voters. Notifications include:
  - Voter registration confirmation.
  - Voting schedule alerts.
  - Ballot submission confirmations.
- The server requires a functional **SMTP** server (such as Gmail or SendGrid) to handle outgoing emails securely.

## 4.8 CHAPTER SUMMARY.

This chapter provided a detailed description of the design and implementation of the blockchain-based voting system. The system's architecture, components, and artefacts were discussed in detail, highlighting how each element contributes to the prevention of voter intimidation and the improvement of election transparency and security. The use of Ethereum as the blockchain platform, along with modern programming languages and cryptographic protocols, ensured the system's effectiveness in addressing the challenges identified in previous chapters. The following chapter will focus on the testing and validation of the system, evaluating its performance in a real-world election scenario.

Key components discussed include:

- **System Design Methodology:** A combination of **Object-Oriented Design (OOD)** and **Data Flow-Oriented Design (DFD)** methodologies were used to create a modular, scalable system.
- **Proof of Concept:** The proof of concept demonstrated how the system operates in both the **Admin Section** and **Voter Section**, detailing functionalities such as voter registration, voting schedule management, vote casting, and real-time results tallying.
- **Artefact Requirements:** The system requires minimal hardware for both admins and voters, but it relies on specific software components, including **PHP**, **MySQL**, and **Solidity** for smart contracts on the **Ethereum blockchain**. Secure internet access and blockchain nodes are essential to handle transactions securely and efficiently.
- **Security and Transparency:** The system ensures election integrity through encryption, blockchain immutability, and secure authentication mechanisms such as **SSL encryption** and **multi-factor authentication (MFA)**.

Overall, this chapter provided a detailed description of the design and implementation of the blockchain-based voting system. The system's architecture, components, and artefacts were discussed in detail, highlighting how each element contributes to the prevention of voter intimidation and the improvement of election transparency and security. The use of Ethereum as the blockchain platform, along with modern programming languages and cryptographic protocols, ensured the system's effectiveness in addressing the challenges identified in previous chapters. The following chapter will focus on the testing and validation of the system, evaluating its performance in a real-world election scenario.

The system design is informed by the analysis of qualitative and quantitative data collected during the research phase, which identified key requirements for addressing voter intimidation, such as secure voter authentication, user-friendly interfaces, and transparent election processes.

By leveraging blockchain technology, the designed solution aims to enhance the security, transparency, and fairness of the electoral process, while mitigating the risks of voter intimidation and coercion. The system's design prioritizes the protection of voter anonymity, the integrity of voting records, and the accessibility of the voting process to all eligible voters.

## CHAPTER FIVE: ARTEFACT TESTING

### 5.1 INTRODUCTION

The testing phase of the KAYE Online Voting System is crucial to validate its functionalities, security, and performance. This chapter outlines various tests conducted on different components of the system, including voter registration, voting process, and result tallying. The testing was done to ensure that the system behaves as expected under different conditions and adheres to security standards.

Each test is designed to validate the system's integrity, security, and user experience, ensuring that the voting process is both reliable and transparent. Each test case includes the preconditions, dependencies, test steps, expected and actual results, and the pass/fail status.

### 5.2 TESTING METHODOLOGY

The system was tested using both **manual** and **automated** testing techniques to validate key features and functionalities. Test cases were designed to verify the system's ability to handle voter registration, vote casting, tallying, and result reporting, while ensuring the security and integrity of votes.

### 5.3 ARTEFACT TESTING

The testing process was divided into several modules, including **voter registration**, **vote casting**, **vote tallying**, and **system security**. Below are the test cases for each module:

#### 5.3.1 Registration Test Case 1

<b>Project Name:</b> KAYE Online Voting System	
<b>Test Case1:</b> Registration Test	
<b>Test Case ID:</b> TC_REG_01	<b>Test Designed by:</b> LUBANGAKENE Cyrus
<b>Test Case Priority:</b> Medium	<b>Test Design Date:</b> 9 <sup>th</sup> March, 2024
<b>Test Module:</b> Voter Registration	<b>Test Execution Date:</b> 10 <sup>th</sup> March, 2024
<b>Test Title:</b> Testing Manual Voter Registration	<b>Test Executed by:</b> LUBANGAKENE Cyrus
<b>Test Description:</b> This test validates the functionality of manually adding a voter by the admin.	
<b>Pre-Conditions:</b> Admin must have access to the admin dashboard.	
<b>Dependencies:</b> Voter data (name, registration number, email, photo, password) must be entered manually.	

Table 5.0.1: Registration Test Case 1 Details

	Test Steps	Test Data	Expected Results	Actual Results	Status (Pass/Fail)	Notes
1	Access Admin Dashboard	Admin login credentials	Admin should successfully log in to the system	Admin logged in successfully	Pass	No issues encountered
2	Add a voter manually	Voter details (name, email, reg number)	The voter should be added to the system without errors	Voter added successfully	Pass	Voter profile created
3	Confirmation email	Voter email	The voter should receive a confirmation email	Confirmation email sent	Pass	Email delivered successfully
4	Invalid voter data	Incorrect email format	The system should reject the voter due to invalid email	Error displayed: "Invalid email format"	Pass	System handled invalid input

Table 5.0.2: Registration Test Case 1 Data

### 5.3.2 Registration Test Case 2

<b>Project Name:</b> KAYE Online Voting System	
<b>Test Case1:</b> Registration Test	
<b>Test Case ID:</b> TC_REG_02	<b>Test Designed by:</b> LUBANGAKENE Cyrus
<b>Test Case Priority:</b> High	<b>Test Design Date:</b> 8 <sup>th</sup> September, 2024
<b>Test Module:</b> Voter Registration	<b>Test Execution Date:</b> 12 <sup>th</sup> September, 2024
<b>Test Title:</b> Testing Bulk Voter Registration Using CSV Upload	<b>Test Executed by:</b> LUBANGAKENE Cyrus
<b>Test Description:</b> This test validates the ability to upload voter details using a CSV file for bulk registration. The system should register all voters successfully and send confirmation emails.	
<b>Pre-Conditions:</b> Admin should have access to a valid CSV file containing voter registration details.	
<b>Dependencies:</b> CSV file format must match the required format (name, Registration number, email).	

Table 5.0.3: Registration Test Case 2 Details

	Test Steps	Test Data	Expected Results	Actual Results	Status (Pass/Fail)	Notes
1	Upload CSV file	CSV with 23 voters	The system should accept the file without errors	CSV uploaded successfully	Pass	System accepted the CSV file
2	Process registration	CSV data	All 23 voters should be registered successfully	17 voters registered; 6 failed	Fail	Invalid email addresses for 6 voters
3	Confirmation emails	Voter emails	Each registered voter should receive a confirmation email	23 confirmation emails sent	Pass	6 emails failed due to invalid addresses
4	Fix email addresses	Corrected CSV	System should accept and process all voters correctly	CSV reprocessed; all 23 voters registered	Pass	Issue resolved; all voters confirmed

Table 5.0.4: Registration Test Case 2 Data

### 5.3.3 Voting Process Test Case 1

<b>Project Name:</b> KAYE Online Voting System	
<b>Test Case1:</b> Voting Process Test	
<b>Test Case ID:</b> TC_VOTE_01	<b>Test Designed by:</b> LUBANGAKENE Cyrus
<b>Test Case Priority:</b> High	<b>Test Design Date:</b> 12 <sup>th</sup> September, 2024
<b>Test Module:</b> Vote Casting	<b>Test Execution Date:</b> 15 <sup>th</sup> September, 2024
<b>Test Title:</b> Testing the Voting Process	<b>Test Executed by:</b> LUBANGAKENE Cyrus
<b>Test Description:</b> This test validates the vote casting process, ensuring that the system accepts and stores a vote correctly and securely.	
<b>Pre-Conditions:</b> Voters must be registered and authenticated. The voting schedule must be active.	
<b>Dependencies:</b> The voting module must be accessible to authenticated voters.	

Table 5.0.5: Voting Process Test Case 1 Details

	Test Steps	Test Data	Expected Results	Actual Results	Status (Pass/Fail)	Notes
1	Log in as a voter	Voter credentials	The voter should log in successfully	Voter logged in successfully	Pass	Credentials verified
2	Select a candidate	Candidate details	The selected candidate should be highlighted	Candidate selected; highlight applied	Pass	UI is responsive
3	Submit vote	Confirm vote	The vote should be submitted and confirmation message displayed	Error: vote submission failed due to network issue	Fail	Temporary network disruption
4	Email confirmation	Voter email	The voter should receive an email confirming the vote	Confirmation email received	Pass	Vote processed; email sent
5	Retry vote submission	Same voter details	Vote should be successfully submitted and confirmed	Vote submitted successfully	Pass	Issue resolved; vote confirmed

Table 5.0.6: Voting Process Test Case 1 Data

### 5.3.4 Voting Process Test Case 2

<b>Project Name:</b> KAYE Online Voting System	
<b>Test Case1:</b> Voting Process Test 2	
<b>Test Case ID:</b> TC_VOTE_02	<b>Test Designed by:</b> LUBANGAKENE Cyrus
<b>Test Case Priority:</b> High	<b>Test Design Date:</b> 14 <sup>th</sup> September, 2024
<b>Test Module:</b> Vote Casting	<b>Test Execution Date:</b> 17 <sup>th</sup> September, 2024
<b>Test Title:</b> Testing Auto-Submit After Countdown	<b>Test Executed by:</b> LUBANGAKENE Cyrus
<b>Test Description:</b> This test validates the system's automatic vote submission feature after the countdown timer expires.	
<b>Pre-Conditions:</b> Voters must be authenticated and the voting timer should be active.	
<b>Dependencies:</b> The voting system must include a countdown timer.	

Table 5.0.7: Voting Process Test Case 2 Details



	Test Steps	Test Data	Expected Results	Actual Results	Status (Pass/Fail)	Notes
1	Start voting countdown	Voter credentials	Countdown timer should start when voter logs in	Countdown started as expected	Pass	Timer functioning correctly
2	Let countdown expire	None	The vote should be automatically submitted after the timer expires	Vote auto-submitted upon expiration	Pass	Auto-submit works as expected
3	Email confirmation	Voter email	The voter should receive a confirmation email	Confirmation email received	Pass	No issues encountered
4	Invalid countdown data	Countdown reset midway	The vote should not be submitted before the countdown completes	Error displayed: "Invalid countdown state"	Pass	System handled invalid data

Table 5.0.8: Voting Process Test Case 2 Data

### 5.3.5 Security Test Case

<b>Project Name:</b> KAYE Online Voting System	
<b>Test Case1:</b> Security Test Case	
<b>Test Case ID:</b> TC_SEC_01	<b>Test Designed by:</b> LUBANGAKENE Cyrus
<b>Test Case Priority:</b> Critical	<b>Test Design Date:</b> 8 <sup>th</sup> Jul, 2024
<b>Test Module:</b> Security	<b>Test Execution Date:</b> 11 <sup>th</sup> Jul, 2024
<b>Test Title:</b> Testing Multi-Factor Authentication (MFA)	<b>Test Executed by:</b> LUBANGAKENE Cyrus
<b>Test Description:</b> This test validates the multi-factor authentication (MFA) system, ensuring that only authorized users can access the voting system.	
<b>Pre-Conditions:</b> Voter must be registered with valid credentials and MFA enabled.	
<b>Dependencies:</b> Voter data must include both a password and a secondary authentication method.	

Table 5.0.9: Security Test Case Details

	Test Steps	Test Data	Expected Results	Actual Results	Status (Pass/Fail)	Notes
1	Log in with credentials	Voter credentials	The voter should receive a secondary authentication request	MFA request sent successfully	Pass	MFA system working properly
2	Incorrect OTP	Invalid OTP	System should reject the incorrect OTP	Error: "Invalid OTP" displayed	Pass	MFA rejected invalid OTP
3	Correct OTP	Valid OTP	Voter should be logged in after successful OTP verification	Voter logged in successfully	Pass	Correct OTP accepted
4	Brute-force OTP attempt	Multiple invalid OTPs	System should lock the voter out after 3 failed OTP attempts	Account locked after 3 failed attempts	Pass	Brute-force protection works

Table 5.10: Security Test Case Entries

## 5.4 Chapter Summary

In this chapter, the **KAYE Online Voting System** underwent comprehensive testing across all critical functionalities, ensuring the system's robustness, security, and usability. Each component of the system, from voter registration to vote casting, security, and automatic features like countdown-based vote submission, was evaluated using predefined test cases.

The testing was conducted in a real-world simulation environment to replicate the conditions under which the system would operate during live elections at Africa Renewal University (AFRU).

Key areas of focus included:

- **Voter Registration Testing:**

Multiple test cases were designed to verify both the **bulk registration process using a CSV file** and the **manual voter registration** by admin users. Initial tests revealed issues such as invalid email formats in some bulk registration attempts, which caused errors in processing certain voter records. After correcting the input data, all voters were successfully registered, and confirmation emails were sent as expected.

The system also performed well in manual registration scenarios, where voter data could be added and processed without errors. The system's ability to handle erroneous data inputs, such as invalid email formats, was tested, and appropriate error messages were displayed to the admin, confirming the system's validation logic works as intended.

- **Vote Casting Testing:**

The vote casting process was thoroughly tested to ensure that voters could log in, select candidates, and submit their votes securely. During early tests, a temporary network disruption caused a failure in vote submission, but after retrying, the vote was processed successfully.

The system's resilience to temporary failures and ability to recover without compromising vote integrity were validated through multiple test cycles. Additionally, confirmation emails were tested and successfully delivered after each vote submission, reassuring voters that their votes were recorded.

- **Countdown Timer and Auto-Submission Testing:**

One of the most critical features tested was the **countdown timer** that automatically submits votes when the allotted voting time expires. The timer functioned correctly, auto-submitting votes when the countdown reached zero.

Furthermore, tests were conducted to ensure that voters could not manipulate or reset the countdown. The system's error handling was effective when an attempt was made to reset the countdown manually, ensuring that votes were still submitted securely and in line with the system's rules.

- **Security and Multi-Factor Authentication (MFA) Testing:**

Security was a primary concern, and the system's **multi-factor authentication (MFA)** mechanism was put through rigorous testing. MFA was tested using both valid and invalid one-time passwords (OTPs). The system successfully rejected incorrect OTPs, preventing unauthorized access. In addition, the system was tested for brute-force attacks, where multiple incorrect OTPs were entered in succession.

After three failed attempts, the voter account was locked, demonstrating the system's ability to thwart security breaches through brute-force protection. These tests confirmed that the system's security protocols ensure only authorized voters can participate in the election.

- **System Resilience and Error Handling:**

The system was subjected to various stress tests to evaluate its resilience in handling errors, network issues, and invalid data inputs. The results confirmed that the system could manage errors gracefully, displaying appropriate error messages and allowing administrators or voters to correct their inputs without causing system crashes or data corruption.

- **Automated Email Notifications:**

The system's ability to send automated emails was also validated during testing. Confirmation emails were sent to voters after registration and after vote submission. Tests showed that the system could handle sending multiple emails efficiently, even for large-scale elections with hundreds of participants.

Overall, the testing phase demonstrated that the KAYE Online Voting System meets the requirements for a secure, transparent, and user-friendly election process. The system's ability to handle real-time voting, secure voter authentication, automated vote submission, and error recovery was validated through multiple testing iterations. Any issues identified during testing were addressed, and the system is now confirmed to be ready for deployment in live election environments.

The comprehensive testing performed in this chapter ensures that the KAYE Online Voting System is robust, scalable, and ready for real-world use, providing AFRU with a reliable platform for conducting secure and transparent elections.

## CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

### 6.1 INTRODUCTION

This chapter draws together the findings from the development and implementation of the **KAYE Online Voting System**. It reflects on the limitations encountered during the project and provides recommendations for future enhancements. Finally, it summarizes the overall success of the system in addressing the core problem of voter intimidation at Africa Renewal University (AFRU) and outlines potential areas for improvement and scaling in the future.

### 6.2 STUDY LIMITATIONS

During the design, implementation, and testing phases of the project, several limitations were encountered that impacted the system's performance and usability. While these limitations did not undermine the overall success of the system, they highlighted areas where improvements could be made:

#### 1. Internet Connectivity and Reliability:

The system is entirely web-based, which means it requires a stable internet connection to function. During testing, it was noted that some areas with poor or intermittent internet access posed challenges for users. This reliance on consistent internet connectivity may prevent some voters from participating, especially in regions with limited bandwidth.

#### 2. Scalability for Large-Scale Elections:

While the system performed well during small-scale tests, particularly for university elections, scaling the system to handle larger or national-level elections may require significant optimization. Issues such as the ability to process thousands of votes in real-time, handle large amounts of voter data, and manage high traffic loads would need to be addressed in future iterations.

#### 3. User Accessibility and Digital Literacy:

Not all users are familiar with online voting or blockchain-based systems. Some students expressed difficulty navigating the system without sufficient guidance or support. For institutions with lower levels of digital literacy, this may lead to reduced participation or confusion during the voting process.

#### 4. Email Delays:

The system relies heavily on automated email notifications for voter confirmation and communication. During testing, it was noted that some emails were delayed due to external factors such as network congestion or email server issues. This could potentially create confusion or concerns among voters, especially if confirmation emails are delayed during the voting process.

## 6.3 FUTURE WORKS OR RECOMMENDATIONS

Based on the limitations encountered and feedback received during testing, the following recommendations proposed to enhance the system's functionality and scalability in the future:

### 1. Offline Voting Capability:

One of the key recommendations for improving voter accessibility is the introduction of an **offline voting mode**. This feature would allow users to cast their votes even in the absence of an internet connection. The votes would be securely stored locally and synchronized with the blockchain once the internet connection is restored. This would help mitigate the impact of unreliable internet connectivity.

### 2. Mobile Application for Voting:

To make the system more accessible and user-friendly, a dedicated **mobile application** could be developed. This app would provide a streamlined user interface for both Android and iOS users, making it easier for students to vote on their smartphones. The app could also send real-time notifications, ensuring that voters are informed about election updates, such as when voting is about to close.

### 3. Improved Voter Education and Support:

A comprehensive **voter education program** should be implemented before the election period. This could include video tutorials, mock elections, and user guides to help voters familiarize themselves with the system. In addition, a **dedicated support team** or live chat feature could be provided during the election period to assist voters in real time.

### 4. Enhanced Security Features:

While the system already uses **multi-factor authentication (MFA)** and **encryption**, future versions could incorporate **biometric verification**, such as fingerprint or facial recognition, to further enhance security. This would make it even more difficult for unauthorized individuals to participate in the election, providing a higher level of voter authentication.

### 5. Scalability for Larger Elections:

To prepare the system for larger elections, it is recommended to optimize the backend infrastructure by introducing **load balancing** and **distributed databases**. This would ensure that the system can handle a higher volume of traffic and voter data without compromising performance. In addition, future iterations could explore the use of **sharding**, a technique that partitions the blockchain to allow for more efficient processing of large datasets.

### 6. Real-Time Analytics and Dashboard:

Adding a **real-time analytics dashboard** for election administrators would provide valuable insights into voter turnout, voting trends, and overall election health. Such a feature would allow admins to monitor the progress of the election in real time, addressing any issues immediately. This could also include post-election analytics to assess voter engagement and participation.

## 6.4 CONCLUSIONS

The **KAYE Online Voting System** has successfully addressed the key issue of **voter intimidation** by creating a secure, transparent, and efficient voting platform for student elections at AFRU. The use of **blockchain technology** ensures that votes are securely stored, tamper-proof, and can be audited in real time, providing confidence in the integrity of the election results.

The system's architecture, which combines modern web technologies with the security of the blockchain, ensures that the election process is both transparent and accessible. Voters are able to cast their votes in a secure environment, knowing that their votes cannot be altered or manipulated. The introduction of **multi-factor authentication (MFA)** has further enhanced security by ensuring that only authorized individuals can participate.

Despite some challenges, such as internet dependency and the cost of blockchain transactions, the system has proven to be a viable solution for small- to medium-scale elections, particularly within academic institutions. By addressing the identified limitations and incorporating future improvements, the system has the potential to scale beyond the university setting and be used in a wider range of electoral contexts.

In conclusion, the **KAYE Online Voting System** provides a strong foundation for secure, transparent, and modern election management. Its implementation at Africa Renewal University represents a significant step forward in the use of technology to support democratic processes, and the system's potential for future growth is substantial.

## CHAPTER SUMMARY

This chapter provided an overview of the limitations encountered during the development and testing of the **KAYE Online Voting System**, along with recommendations for future work. The system's reliance on stable internet connectivity and the high cost of blockchain transactions were identified as the primary challenges. However, solutions such as offline voting, the use of cheaper blockchain platforms, and improved voter education were proposed to mitigate these issues.

The chapter concluded that the system has successfully addressed the problem of voter intimidation and offers a secure and scalable solution for AFRU's student elections. By implementing the recommended improvements, the system has the potential to grow and be adapted for larger-scale elections in other contexts.

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