World Journal of Advanced Engineering Technology and Sciences

eISSN: 2582-8266

Cross Ref DOI: 10.30574/wjaets

Journal homepage: https://wjaets.com/

(Research Article)

# Design and implementation of an electronic voting system for optimal electoral process

Ekerette W. Milton, Imo E. Nkan and Unwana M. Ekpe *

*Department of Electrical and Electronic Engineering, Akwa Ibom State University, Ikot Akpaden, Nigeria.*

World Journal of Advanced Engineering Technology and Sciences, 2024, 13(01), 132–139

Publication history: Received on 31 July 2024; revised on 07 September 2024; accepted on 10 September 2024

Article DOI: https://doi.org/10.30574/wjaets.2024.13.1.0413

## Abstract

Electronic voting is a tool for increasing the credibility and efficiency of elections in several democracies around the world. In Nigeria, many elections have conducted sub-optimally due to the manual methods employed in voting and transmission of election results. In such cases, electoral officials have been accused of colluding with politicians to alter election results while the results are being transmitted from polling units to results collation centres. To address this problem, this paper proposes and presents a framework for electronic voting and transmission of election results. The proposed system is designed and implemented using a C++-based Visual Studio Integrated Development Environment (IDE) and a MATLAB/Simulink application. This setup allowed for the simulation of the voting process, encryption of voting data, transmission of voting results and decryption of election results. The simulation-based results obtained for the proposed system was compared with that of the existing system. The results indicate that for sample sizes ranging from 2,000 to 7,000 voters, the proposed system accurately accredited an average of 85% of voters, compared to 73% for the existing system. Specifically, for 2,500, 4,000, 5,500, and 7,000 accredited voters, the existing system had 684, 1,095, 1,505, and 1,916 failed voters respectively. In comparison, there was a significant reduction in the number of failed voters for the proposed system and this stood at 364, 582, 801, and 1,019 respectively. Additionally, the quality of verified feedback for 3,000, 4,500, 6,000, and 7,000 accredited voters showed that the proposed system had quality scores of 0.362, 0.138, 0.019, and 0.000, compared to 0.549, 0.197, 0.024, and 0.001 for the existing system. In conclusion, the proposed system has proven to be highly effective, credible, secure, and transparent in safeguarding the integrity of the electoral process and it is therefore recommended for hardware implementation in subsequent general elections.

**Keywords:** Electoral process; Electronic voting; Simulation; Voter accreditation; Credibility

## 1. Introduction

There is a strong desire by many nations to move from the traditional paper voting systems to electronic voting system and several research efforts such as [1], [2] have been devoted to this. The functions of elections in democratic systems has been studied in [3], and it was found that elections not only serve as a means of selecting political representation but also help to legitimize political representation and foster political accountability. Electoral umpires such as Nigeria's Independent National Electoral Commission (INEC) formulate and implement the rules guiding electoral processes [4] and it has been reported in [5] and [6] that the electoral systems the world over have witnessed tremendous improvement over the years. Interestingly, the operation of public administration has been digitalized in many countries and this allows tasks to be performed more efficiently. When digitization is applied to voting, the possibilities of having a transparent election can be dramatically improved.

* Corresponding author: Unwana M. Ekpe

Today's digital electronics technology has opened more access to the use of electronic voting systems. However, some criticisms have emanated to challenge the credibility of such technology especially as it applies to security issues [7], [8] and the power of incumbent government officials to influence the manufacture, distribution, and use of such devices [9]. Whatever the level of human introduced errors and fraudulent tendencies associated with elections, the introduction of electronic voting systems usually leads to better outcomes. This paper therefore proposes modifications to the electronic voting system in existence in Nigeria. This is to help build confidence in the electorates and prepare them to readily accept electronic voting systems. Similar works have been found in the literature such as the methodology developed in [10], which aimed at designing and developing a real-time electronic voting system with emphasis on security and veracity of results. Also, [11] investigated the voting systems used in many parts of the world and found them to be characterized by fundamental challenges which in many instances can result in corrupt contestants winning elections. Their work identified the shortcomings of existing systems and proposed a highly secure electronic voting system. In [12], it was noted that the key component of electronic government of the future will be electronic voting. This, according to the authors, would be used as a means of facilitating the participation of citizens in elections and public debates. The authors report that the Nigerian 2015 general elections witnessed the use of electronic voter register, permanent voter's card (PVC) and smart card readers for voter authentication. Their study proposed an improved framework for electronic voting system that can be adopted for use in Nigeria. The framework was found to be capable of handling electronic ballots for presidential, gubernatorial and legislative elections at the same time while also catering for the integrity of election processes by meeting the essential requirements of privacy, authenticity, accuracy and security. Building on existing works, this paper presents the design and implementation of an electronic voting system for optimal electoral process within the Nigerian context. The rest of the paper is organized as follows. Section 2 presents the materials and methods used while section 3 presents and discusses the results obtained. Conclusions and recommendations for further work are given in section 4.

## 2. Materials and Method

The materials used for the design include data programming software for encryption and decryption and a design simulation software for real time monitoring and analysis of the electoral process. The materials specifically comprise a Microsoft Windows-based computer system equipped with 32 Gb of memory and an Intel core i7 4770 3.4 GHz CPU, a C++ based Visual Studio integrated development environment (IDE) for data encryption and decryption, and a MATLAB/Simulink IDE application for simulation and result validation.

The method for developing adequate encryption and existing decryption algorithms relies on comparison with the building blocks of the existing system. The existing system contains only two electronic units, which are the bimodal verification and accreditation system (BVAS) and the result transmission system. The units are connected to an electoral database where user details can be downloaded. Only two security protocols at the accreditation and transmission units are employed in securing the existing system at the voter verification point and at the data uploading point. As an improvement on the existing system, the proposed system has four electronic units. These are the conventional BVAS, a biometric voting system, an electronic transmission unit and an electronic data verification unit to secure against malware, hackers and viruses.

### 2.1. System Design Architecture

The system is designed such that the BVAS unit uses two biometric processes to identify and accredit voters. Once the name of the registered voter (NOV) is confirmed against the entry in the voter database, the two biometric metrics used in verifying the identity of the intending voter are the face biometric of the voter (FBV) and the fingerprint biometric of the voter (FPB). A flowchart of the BVAS accreditation system is shown in Figure 1 and it can be observed that the intending voter has a maximum of two accreditation attempts.

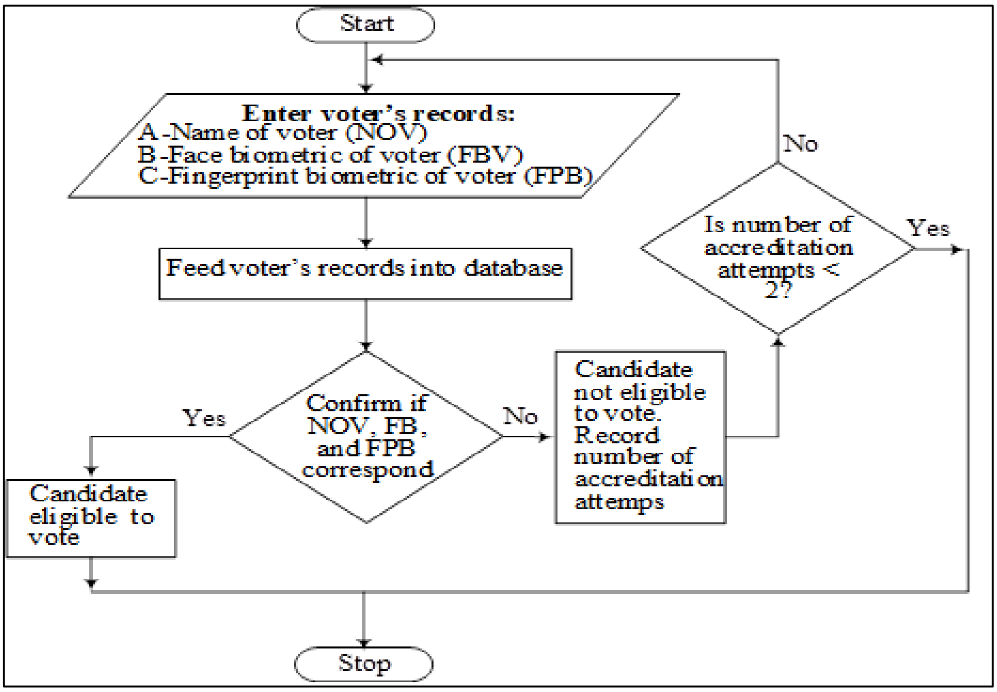


**Figure 1** Flowchart of the BVAS accreditation system

Upon successfully verifying the identity of the intending voter, the proposed system allows for electronic voting following the steps shown in Figure 2. A major advantage of the proposed system is that it eliminates the use of traditional ballot papers and boxes. However, the electronic ballot needs to be securely transmitted and the backend data security and the process of verifying the authenticity of the transmitted results need to be carefully considered. Secure results transmission and verification therefore consists of plain text encryption and decryption. The voting decision, which is rendered in plain text, is transformed into an unreadable cypher text form using an encryption algorithm before transmission. On receiving the transmitted cypher text, decryption is carried out using the proper decryption key. The encryption and decryption process is beyond the scope of this research and shall not be discussed further.

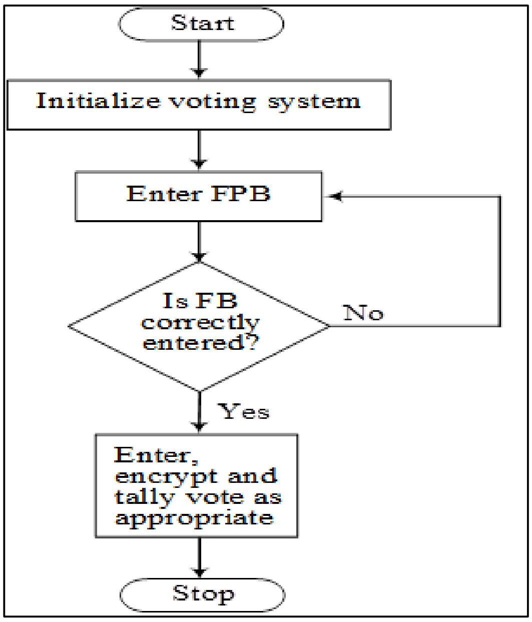


**Figure 2** Flow chart of the proposed voting system

### 2.2. Mathematical Description of the Proposed Electronic Voting System

Considering that access to vote (accreditation) is only given when biometrics have been successfully confirmed, this section presents mathematical formulations that describe the proposed electronic voting system. The number of successfully accredited voters is given as;

$$N_{sav} = N_r - N_{fav}, \qquad \text{.....................(1)}$$

where $N_r$ is the total number of people that registered for a voting exercise and $N_{fav}$ is the number of failed accredited voters.

Let the number of successful biometric matches be given by

$$N_{sb} = N_{sav} - N_{fbr}, \qquad \text{...................(2)}$$

where $N_{fbr}$ is the number of failed biometric entries that lead to a retry.

The number of voters that fail the accreditation process and are not eligible to cast their votes is given as

$$N_{fav} = N_r - N_{sav} \text{ ... ... ... ... ... ....(3)}$$

The number of failed bimodal biometric verification is given as

$$N_{fBVBSr} = N_{sav} - N_{SBVBS}, \qquad \text{.....................(4)}$$

where $N_{SBVBS}$ is the number of successful bimodal biometric verification attempts.

The number of successful bimodal biometric verification attempts after retrial is given as

$$N_{SBVBS\bar{r}} = N_{fBVBSr} - N_{fBVBS\bar{r}}, \text{ ................(5)}$$

where $N_{fBVBS\bar{r}}$ is the number of failed bimodal biometric accreditation attempts.

The total number of successful bimodal verification biometric is given as

$$N_{tBVBS} = N_{SBVBS} + N_{SBVBS\bar{r}} \text{ ................(6)}$$

The accreditation accuracy ratio is defined as the ratio of possible outcomes from an accreditation process to the total number of outcomes of the accreditation process. This is given as

$$A_{ar} = \frac{N_{sav}}{N_r} \times \frac{N_{fbr}}{N_{sb\bar{r}} + N_{fbr}} \text{ ... ... ....(7)}$$

The voting accuracy ratio is defined as the ratio of possible outcomes from the voting process to the total number outcomes of the voting process and this is given as

$$V_{ar} = \frac{N_{tBVBS}}{N_{sBVBS}} \times \frac{N_{fBVBSr}}{N_{sBVBS\bar{r}} + N_{fBVBS\bar{r}}} \qquad \text{................(8)}$$

The quality of verification feedback, $Q_{OV}$ is a measure of the efficiency of the voting system. It is determined by obtaining the first and second derivative of the voting coverage area, ∅ and respectively multiplying these with the terms for accreditation accuracy and voting accuracy as follows.

$$Q_{OV} = A_{ar}\frac{d^2\emptyset}{dt^2} + V_{ar}\frac{d\emptyset}{dt} \qquad \text{..................(9)}$$

By considering a population sample for the coverage area ∅, the sample size is defined as

$$S = \emptyset^2 NP(1 - P) \div d^2(N - 1) + \emptyset P(1 - P), \qquad \text{.............(10)}$$

where, P represents the population in the voting area, $\emptyset^2$ is the second derivative of the value of chi-square for 1 degree at a desired confidence level, N represents the population size and d represents the degree of accuracy.

### 2.3. Implementation of the Voting Architecture in Matlab/Simulink

The proposed system needs a fuzzy logic inference system to make decisions on voter identity, secure transmission of results and accurate deciphering of transmitted results. The outputs of the decision boxes of Figures 1 and 2 are therefore controlled by a fuzzy inference system and these are implemented in the Matlab/Simulink environment for the accreditation unit, voting unit and transmission units. Figure 3 shows the overall system architecture, which was used in studying the accreditation rate and the voting rate.

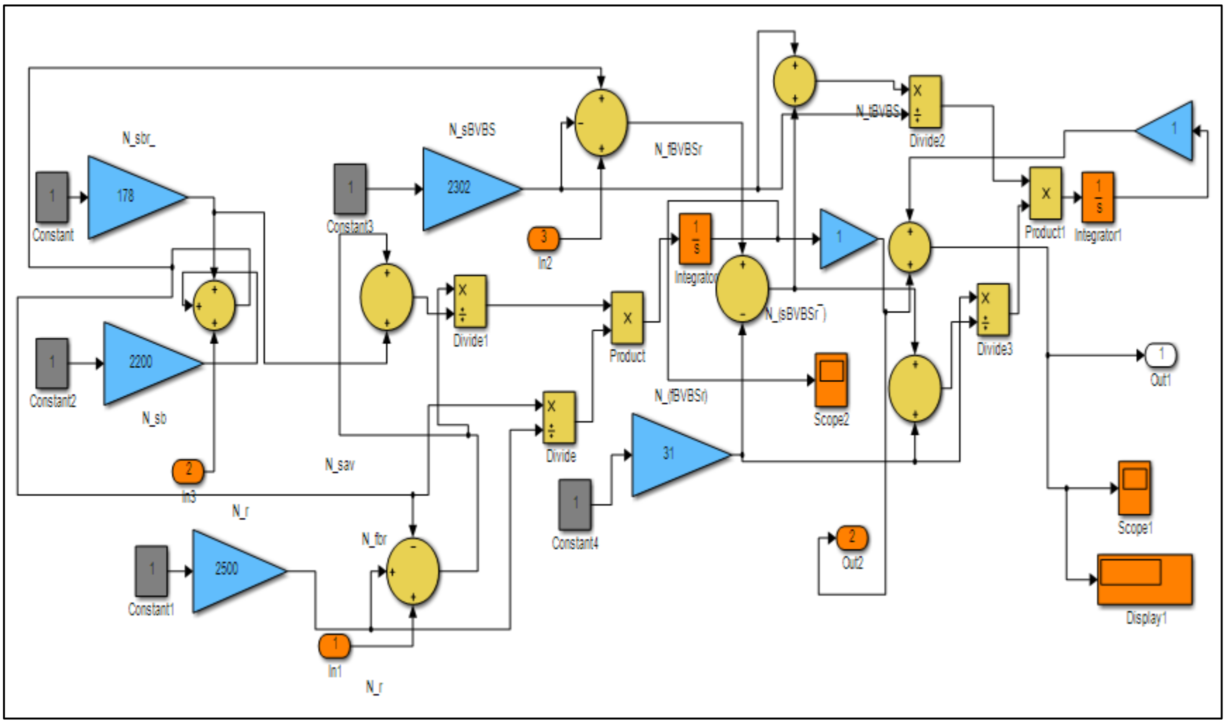


**Figure 3** Simulink implementation of the fuzzy logic-based voting architecture

Data and insights from the 2023 Nigerian general election as respectively sourced from [13] and [14] were then used in simulating the voting process. The results obtained are presented and discussed in the next section.

## 3. Results and Discussion

Analysis of election data in [13] reveal that in Akwa Ibom State, the average number of registered voters per polling unit was 542 while the total number of polling units was 4,353 and the total number of registered voters was 2,357,418. For the whole country, the average number of registered voters per polling unit was 529 while the total number of polling units was 176,846 and the total number of registered voters was 93,469,008. Leveraging on the presented data and using the parameters derived in equations (1) to (10), the voting process based on the proposed fuzzy logic-based voting architecture was simulated in MATLAB/Simulink. Inputting a baseline number of 688,837 accredited voters, the system outputted the number of successfully accredited voters as 599,480. Also, the number of voters that failed biometric authentication after two trials was 2,704, the total number of successful biometric entries was 591,776, while the total number of voters that were successfully authenticated through bimodal verification was 588,576.

### 3.1. Voting Accuracy Rate and Quality of Verified Feedback

The voting accuracy rate of the proposed architecture is based on comparing the total number of successful bimodal biometric verification with the total number of accreditation attempts. The metrics for successful and failed biometric after the first retry was obtained using the accreditation rate curve generated from MATLAB/Simulink. It was observed that as the number of voters decreased, the voting accuracy ratio increased, indicating that both architectures will perform better with fewer voters. However, the proposed architecture exhibited around 0.03 voting accuracy rate as it gradually decreased with a decrease in the number of voters. It was observed that the proposed architecture can only simulate up to 7000 voters per polling unit while maintaining high levels of accuracy in voting outcomes.

The feedback transmission rate is influenced by the accreditation accuracy ratio and the voting accuracy ratio. This is computed by counting the number of matches between the private and public keys of the election results transmitter (at the polling unit) and the results receiver (at the collation centre) as simulated in the C++-based Visual Studio Integrated Development Environment (IDE). Table 1 presents the verified feedback rates on a scale of zero (0) to one (1) consequently, it is observed that the feedback transmission rate between the transmission unit at the polling center and the receiver at the database is dependent on the voter count. Table 1 also compares the quality of the architecture used for verification feedback purposes.

**Table 1** Quality of verified feedback

| **Quality of Verified Feedback** | | |
|---|---|---|
| **Number of Accredited Voters** | **Proposed System** | **Existing System** |
| 2000 | 0.5804 | 0.873 |
| 2500 | 0.4891 | 0.700 |
| 3000 | 0.3620 | 0.549 |
| 3500 | 0.2733 | 0.407 |
| 4000 | 0.2053 | 0.293 |
| 4500 | 0.1375 | 0.197 |
| 5000 | 0.0739 | 0.128 |
| 5500 | 0.0422 | 0.053 |
| 6000 | 0.0189 | 0.024 |
| 6500 | 0.0004 | 0.001 |
| 7000 | 0.0001 | 0.001 |

### 3.2. Number of Successful Voters to Number of Accreditation Metrics

Results of accredited voters and the number of successful voters is represented in Figure 4 as bar chart plots comparing the number of successful voters to the number of accredited voters for both the proposed and existing systems. It can be observed that the proposed system consistently and successfully accredits more voters compared to the existing system. Specifically, there is a 17% improvement in number of accredited voters for every increment of 500 voters.

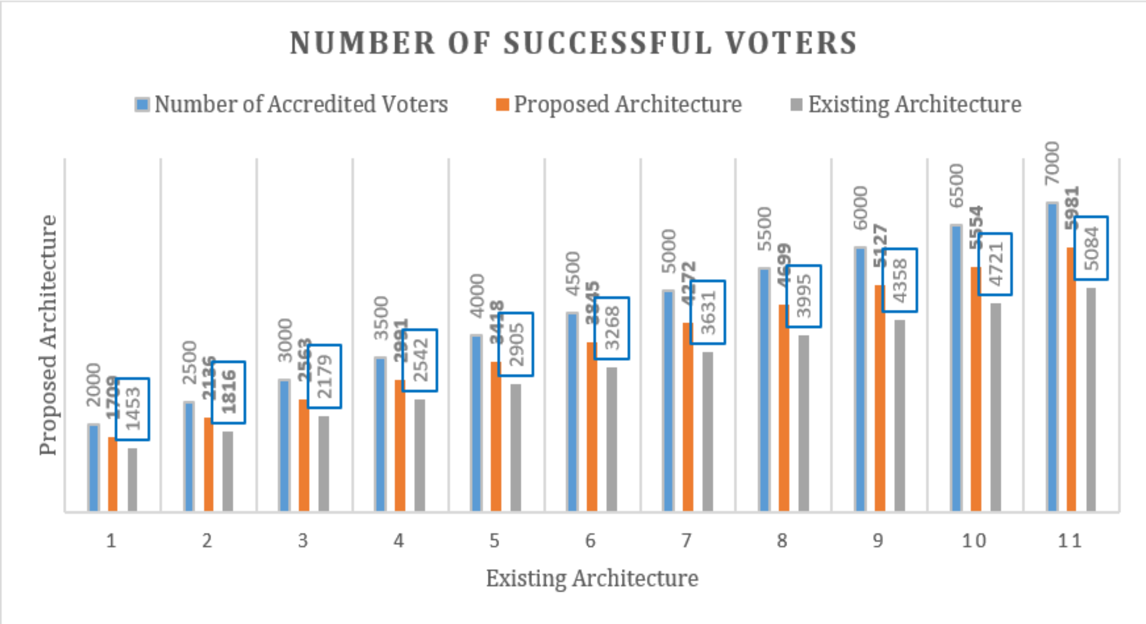


**Figure 4** Number of successful voters against number of accredited voters

### 3.3. Number of Accredited Voters to Number of Failed Voters

Table **2** compares the number of failed voters and accredited voters for both the proposed and existing systems. The table presents how the proposed system reduces the number of failed accredited voters during the accreditation process, thereby improving the overall voting procedure for a total of 7,000 voters.

**Table 2** Number of failed voters to number of accredited voters

| Number of Accredited voters | Number of failed voters | |
|---|---|---|
| | Proposed System | Existing System |
| 2000 | 291 | 547 |
| 2500 | 364 | 684 |
| 3000 | 437 | 821 |
| 3500 | 509 | 958 |
| 4000 | 582 | 1095 |
| 4500 | 655 | 1232 |
| 5000 | 728 | 1369 |
| 5500 | 801 | 1505 |
| 6000 | 873 | 1642 |
| 6500 | 946 | 1779 |
| 7000 | 1019 | 1916 |

## 4. Conclusion and Recommendation

This paper has presented a system for electronic voting and transmission of election results. The system was implemented using Visual Studio IDE, C++ and MATLAB/Simulink. The simulations carried out allowed for the proposed system to be compared with that of an existing system in terms of quality of verified feedback, number of accredited voters, and number of successful and failed voters. It was observed that the proposed system achieved an average of 85% success rate in accrediting voters compared with 73% for the existing system. The proposed system also achieved a significant reduction in the number of failed voters and an improvement in the quality of verified feedback. Based on these promising results, the proposed system is recommended for hardware implementation and further testing. It is envisaged that a successful hardware implementation of the proposed system would allow it to be deployed for real elections in the near future, and thus contribute to improving the electoral process in Nigeria.

## Compliance with ethical standards

*Disclosure of conflict of interest*

No conflict of interest to be disclosed.

## References


[1] A. Shuaibu, A. Mohammed and A. Ume, A Framework for the Adoption of Electronic Voting System in Nigeria, International Journal of Advanced Research in Computer Science and Software Engineering, vol. 7, no. 3, pp. 258-268, 2017.

[2] S. A. Adeshina and A. Ojo, Factors for E-Voting Adoption: Analysis of General Elections in Nigeria, Government Information Quarterly, vol. 37, no. 3, 2020.

[3] W. Waldemar, Functions of Elections in Democratic Systems, University of Silesia, Katowice, 2013.

[4] A. M. Jega, Improving elections in Nigeria: Lessons from 2011 and looking to 2015, African Programme Meeting Summary, London: Chatham House, 2015.

[5] M. Ahmed and U. M, The impact of technology on Nigeria's democratic development: An analysis of the card reading machine, International Journal Multidisciplinary Research Modern Education, vol. 1, no. 2, pp. 116-125, 2015.

[6] N.-C. Bormann and M. Golder, Democratic Electoral Systems around the world, 1946-2020, Electoral Studies, vol. 78, no. 102487, pp. 1-7, 2022.

[7] M. Musial-Karg, Implementation of Electronic Voting and the Matter of Security, Annales Universitatis Mariae Curie-Sklodowska Lublin - Polonia, vol. XXII, no. 1, pp. 119-134, 2015.

[8] E. Z. Meza and D. S. Supe, Vulnerabilities and Securities in the Electronic Voting: A Review, Revista Odigos, vol. 2, no. 1, pp. 55-67, 2021.

[9] R. Alguliyev and F. Yusifov, Multi-Criteria Evaluation of Electronic Voting System Security Threats, Voprosy Kiberbezopasnosti, vol. 3, no. 27, pp. 16-21, 2018.

[10] S. Abdulhamid, O. Damian, D. Mohammed and O. Adebayo, The design and development of real-time e- voting system in Nigeria with emphasis on security and result veracity., International Journal of Computer Network and Information Security, vol. 5, pp. 9-18, 2013.

[11] O. S. Adewale, O. K. Boyinbode and A. S. E, A Review of Electronic Voting systems: Strategy for a Novel, International Journal of Information Engineering and Electronic Business, vol. 12, no. 1, pp. 19-29, 2020.

[12] O. Okediran and G. R. Adesina, A Framework for Electronic Voting in Nigeria, International Journal of Computer Applications, vol. 129, no. 3, pp. 75-87, 2015.

[13] INEC, Report of the 2023 General Election, Independent Natonal Electoral Commission - ISBN 13-978-55464-8-4, Abuja, 2024.

[14] C. T. DII, Voters' Disposition and the Outcome of 2023 General Elections in Nigeria, International Journal of Development and Management Review , 2023.