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INVESTIGATING THE IMPACT OF PERMANENT VOTER CARDS IN REDUCING ELECTION RIGGING IN NIGERIA

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ABSTRACT
Electoral processes in Nigeria are susceptible to different types of rigging. The Independent National Electoral Commission (INEC) came up with some innovative measures in 2011 and 2015 to reduce rigging including the introduction of permanent voters cards (PVCs) and card readers. This study uses data flow diagrams, as well as sensitivity and scenario analyses to analyze how various factors and variables result in rigging during elections. An overview of data flow diagrams (DFDs) is given to illustrate their effectiveness in describing systems. The electoral processes for 2011 and 2015 are described and compared, and special DFDs are designed to model the two slightly different systems. With the help of these special DFDs, the mathematical relationships that connect these different components of rigging are worked out and these are used to create a template using SaSAT, a sampling and sensitivity analysis tool, that is used in estimating the final results of a hypothetical election exercise between two candidates based on some assumed variables. Using this tool, the relative impact of the various variables and moderating factors on electoral rigging are investigated. This leads to a detailed analysis on the extent to which the use of the PVCs and card readers can actually reduce such rigging during electoral processes. The results suggest that the introduction of PVCs and card readers reduces the level of rigging during the accreditation exercise but the other forms of rigging during registration, voting and vote counting can still substantially modify the results.

Keywords: Data Flow Diagrams (DFDs), Election Rigging, Permanent Voters Cards (PVCs), Card Readers, Sensitivity Analysis (SA)

INTRODUCTION
Since elections play a crucial role in determining those who emerge in leadership positions, the processes through which these elections are conducted are increasingly gaining importance in order to perfect them and make them less prone to (human or machine) error. In Nigeria, like in many other developing countries, these electoral processes are susceptible to different types of rigging including registration of ineligible voters, ballot stuffing, destruction of ballot boxes, voting by ineligible voters and willful alteration of results. However, it is gladdening to note that, over the years, there have been gradual improvements in the system leading to ever more credible elections. For the 2015 elections, the Independent National Electoral Commission (INEC) came up with some innovations including the distribution of permanent voter cards (PVCs) to all registered voters and the use of card readers to verify the identity of every PVC holder.

The elections have been acclaimed to have been fairly free and fair partly as a result of these innovations (Thomas-Greenfield, 2015) (IFES, 2015). However, there have been only veryfew qualitative and quantitative studies, such as Akonjom & Ogbulezie (2014), to determine the extent to which the use of these innovations has positively impacted on the reliability of the election processes. There is the need to further investigate the relationship between the innovations and their impacts. This paper attempts to develop a model, using the well-known software engineering tools of data flow diagrams (DFDs) that can represent the major details of the Nigerian electoral system especially the information flows that determine the level of rigging in the system. The model is applied to create a SaSAT (Sampling and Sensitivity Analysis Tool) template that captures all the equations derived from the model and allows estimates of results to be simulated by assigning hypothetical values to the different variables. Using sensitivity analysis and scenario analysis, the developed model is ultimately used to carry out two tasks; (1): a study of the ways in which the different types of rigging in the various electoral processes have an impact in election results, and (2): a study of the extent to which the use of the PVCs and card readers can actually reduce rigging during these electoral processes**.**

The rest of the paper is arranged as follows: Immediately after this introduction, there is a section on Previous/Related Work. This is followed by a section that describes the methodology used in the work which includes sub-sections on "an overview of DFDs", "Defining the Electoral Processes and Analyzing the Impact of Changes in 2015", "Development of a Model for Estimating Rigging" and "Using Sensitivity Analysis (SA) to Investigate the Impact of PVCs in Reducing Election Rigging."A summary of the results are then presented followed by a discussion of the results. The paper ends with a short conclusion.

PREVIOUS/RELATED WORK

In many countries of the world today, political leaders are selected through elections that are organized by electoral commissions whereby qualified citizens are allowed to cast their votes for the contestants vying for various posts. Because of the critical importance of such elections, these electoral commissions have to set up elaborate electoral systems to ensure that the elections are free, fair and transparent (Kuhne, 2010). Nevertheless, these systems are hardly foolproof as there often exist lapses and loopholes that people and their parties exploit to willfully change the results of elections (Wright and Rogers, 2014). There have been various efforts to use technology in order to improve the quality of elections(European Commission, 2012). As explained in Singhai (2012), such types of technology generally fall into three broad groups namely those used in voter registration, those employed for the logistic preparations for the elections and those used during actual voting and collation of election results. Technologies used for voter registration are primarily database management systems, as described in Klein and Merloe (2001) but in places like Nigeria, the use of biometric technologies in direct data capture (DDC) devices, as described in NDI(2007) has greatly enhanced the verification of voters. For the logistic preparations leading to elections, geographic information systems (GISs) are very useful in tasks such as redistricting of voting districts and when they are integrated with global positioning systems (GPSs) they can also help in monitoring the movement of sensitive election materials which is vital in preventing electoral fraud (Hanewicz, 2012). Technologies used for the actual voting and vote-collation processes have been around for a long time and are used in many countries, as explained in Goldsmith & Ruthrauf (2013). There have been many studies on their use and effectiveness especially after the 2000 US elections (Kohno et al., 2003). In spite of their widespread use, there are quite a number of challenges in the use of such technologies (Achieng and Rahode, 2013), (Bruck et al., 2010). In Nigeria, the fear and apprehension of politicians and voters that e-voting technologies will be used to bring about more rigging rather than result in more credible elections has led to the explicit ban on the use of such technologies in election processes (NASS, 2010). With the rapid proliferation of the Internet and mobile telephony, there have also appeared a multitude of ways, as explained in Galadanci (2014), in which citizens as well as election management bodies can enhance the validity of elections and reduce rigging. Clearly, therefore, technology is playing an increasing role in improving the quality of elections all over the world. The electoral body in Nigeria, the Independent National Electoral Commission (INEC), in an attempt to reduce rigging, was able to come up with some innovative ideas on the use of some technologies – not e-voting – during the 2015 General Elections that are being hailed as having been responsible for the successful conduct of the exercise (Thomas-Greenfield, 2015) (Agbu, 2015). The principal innovations were the distribution of permanent voter cards (PVCs) to all registered voters and their authentication using card readers on Election Day. PVCs are ordinary looking ID cards that have small chips inside them that store lots of information about the holder of the card including biometrics. Such information can be accessed by the use of card readers. Anybody who did not have a PVC or whose PVC could not be read by a card reader was not allowed to vote. It is interesting to note that only few electoral commissions in the world have instituted the use of such biometric PVCs and card readers, as done in Nigeria, in their electoral systems (USAID, 2011). While their use is generally considered to reduce rigging during elections, there have been very few quantitative and qualitative analyses of the impact of PVCs and card readers. In Alebiousu (2015), the advantages of using PVCs and card readers are discussed especially with respect to the 2015 elections in Nigeria while in Ayinde & Idowu (2015), the voters' perceptions on their use are analyzed. InAkonjom et al.(2014), it is shown that the application of contactless card reading technology reduces service time, queue length and waiting time for voters. There has been considerable work on modeling election processes (Simidchieva et al., 2008) and also on modeling and analyzing faults (Simidchieva et al., 2010). These are all based on the use of a process modeling language, namely Little-JIL, to concisely define and model the various processes in systems that comprise human and software agents and extensively analyze the possible faults in such processes(Cass et al., 2000). There have also been a number of studies in modeling election fraud such as those described in Klimek et al. (2012) and Leemann and Bochsler (2014). However, these methods do not quantitatively measure the impact of particular faults in the various processes. In our work, we use the concept of data flow diagrams (DFDs) in a novel way to represent the election processes in detail and to especially model the quantitative impact of the various variables and moderating factors that result in rigging. This provides a way of easily analyzing the robustness or otherwise of electoral systems and how particular improvements improve the reliability of the systems.

METHODOLOGY

In our work, we first use qualitative techniques to intricately understand the election processes in Nigeria to the finest details. We then use the concept of data flow diagrams to represent these election processes. In contrast to the conventional method of using DFDs to capture general data flows, we use a novel approach of attaching equations to each data flow thereby being able to specify the exact variables that determine each data flow and the equations that . This allows us to model the election processes very well especially the various ways in which rigging can take place. SaSAT, a sampling and sensitivity analysis tool in MATLAB, is used to develop a template to capture all the equations derived from the model which allows estimates of results to be calculated by assigning hypothetical values to the different variables. Because a number of fundamental changes were made in the processes before the 2015 elections, the differences between the system prior to the changes and after the changes are appropriately captured in our model. Using sensitivity analysis, we then investigate the elasticities of all the variables and remove those with low elasticities. This enables us to analyze the degree of the impact of the remaining variables by trying all their possible combinations having two possible values; a low value and a high value. Finally, we analyze the impact of PVCs and card readers in reducing rigging in Nigerian elections by comparing the hypothetical results of the system prior to the 2015 changes with those of the system after the 2015 changes.

OVERVIEW OF DFDS

Data flow diagrams are very important tools that are used in pictorially defining systems. Often used in the requirements analysis phase of the software development process, they mainly consist of oval shaped processes with the data flows (both inputs and outputs) as arrows. One of their most important advantages is that they can be drawn at differing levels of details. At the highest level, they take the form of context diagrams which show the system as a single round process with input and output arrows showing the relationships of the system with the external world. Through repeated iterations, this top level data flow diagram can then be gradually expanded to include lower level details. In each expansion, processes are broken down into their component sub-processes with their associated input and output data flows. The process stops when the desired level of details is reached or the processes and data flows cannot be broken down further. The main advantage of data flow diagrams is that they are easy to understand, they describe in a simple format the details of a system at different levels together with the system boundaries, and they are fairly easy to translate into code. Their major drawback is that as the systems get more complex they become very cumbersome (Donald, 2000).

In using DFDs to model elections, and especially to analyze the impact of the use of certain technologies in curbing rigging, it is worth noting that rigging generally depicts itself in the changes that take place to the data flows while the processes that constitute the electoral system are being executed. DFDs, with their emphasis on how input data flows into a process and becomes transformed into output data, provide strong tools by means of which the various types of rigging can be more clearly identified, analyzed, understood and probably addressed (INEC, 2011).

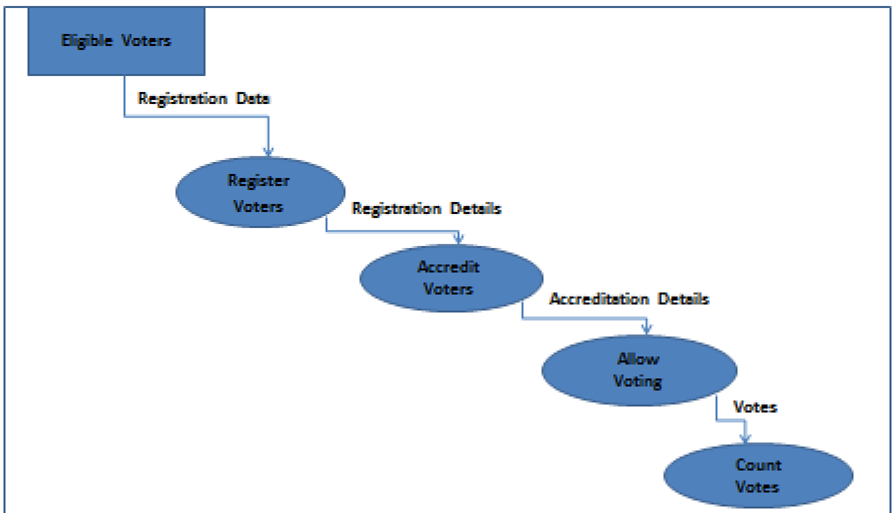

Fig 1: DFD Showing Electoral Processes

DEFINING THE ELECTORAL PROCESSES USING DFDS AND ANALYZING THE IMPACT OF CHANGES MADE IN 2015

The electoral processes in Nigeria, like in many other countries, are comprised of five main components namely registration of voters, accreditation of voters, actual voting, counting of votes and collation of results. These components, excluding the collation of results, are depicted in the DFD of Fig.1. As can be seen in the diagram, eligible voters complete the process of registration by giving their personal details (such as name, address and age) and allowing their fingerprints to be scanned. These details are stored in the voters register and each voter is given a voter's card which has his/her picture, some of his/her biometric details and other personal details. When the voter comes on Election Day, he/she is first accredited and then allowed to vote. When voting is completed, the ballots are counted and the results are collated and announced (INEC, 2015).

In order to analyze the impact of changes made in 2015, it is necessary to understand the actual changes that were made. Comparing the election manuals in 2011 (INEC, 2011) and 2015 (INEC, 2015), it can be seen that one of the major changes is the introduction of permanent voter cards (PVCs) in 2015. In the 2011 process, registered voters were given temporary voters' cards after the registration exercise. On Election Day, an intending voter would present his/her temporary voter's card and the number of the card would be crosschecked against the voters register. If the voter's number is found, it is confirmed that he is the owner of the card by looking at his/her face and comparing it with the picture in the card. Once this authentication is done, a tick is made on the Register of Voters to verify that the voter has been accredited, indelible ink is applied to the cuticle of one of the finger-nails of the voter and s/he is given a duly signed accreditation tag that has his/her serial number (from the Register of Voters). At the end of the accreditation exercise, the number of accredited voters is counted from the Register of Voters and this number as well as the total number of voters in the Register are entered into the appropriate forms.

The main change in 2015 was that card readers were introduced to authenticate all intending voters. Also, where temporary voters' cards, which were just made from plain paper, were used in the 2011 Elections, in 2015, they were replaced by permanent voters' cards, which had special embedded chips that could be read by the card readers. Thus, the registration processes in 2011 and 2015 are virtually the same except that in 2015, a voter who had earlier registered in 2011 would collect his/her permanent voter card (PVC) while anybody whose PVC could not be found or who had not registered before would be required to follow the registration process, identical to the one done in 2011, after which s/he would be given a temporary voter's card. Eventually, s/he would come to pick up the PVC when it became ready.

As a result of the introduction of PVCs and card readers, the accreditation process in 2015, is markedly different from the one in 2011. As explained in (INEC, 2015), a voter would present his/her PVC which would be read by the card reader. If the PVC does not belong to that polling unit (PU), it would be rejected. On the other hand, if it belongs to that PU, the details of the voter would come up on the screen and, in particular, the picture of the voter on the screen would be verified with the face of the card holder. The voter would then be required to have his fingers scanned and they are verified with the finger prints saved when s/he originally registered. If all is well, the voter is verified in the same way as was done in 2011 and s/he is given an accreditation tag. If the card reader fails to verify the finger prints, the voter is still given an accreditation tag that allows him/her to vote but it is required to fill an incidence form in order to report this anomaly. At the same time, the card reader keeps track of those that have been fully accredited including those where such anomalies occurred. At the end of the accreditation exercise, the number of voters verified from the Card Reader is read, sent to the Cloud, compared with the number of accredited voters in the Register of Voters and these figures are entered into the appropriate forms.

The voting processes for 2011 and 2015 are identical. An accredited voter would present his/her PVC and accreditation tag. Once it is ascertained that they belong to him/her and s/he has not previously voted, the Register of Voters would be ticked beside his/her name to indicate that s/he has voted, indelible ink would be applied to another finger-nail and s/he would be given a ballot paper to thumbprint on and deposit in the ballot box. On the other hand, the processes of sorting, counting of ballots and recording of votes slightly differ between 2011 and 2015. In 2011, the process begins by counting unused ballot papers, spoiled ballot papers and the counterfoils of used ballot papers. Their quantities and serial numbers are recorded on the appropriate forms and they are placed in the envelopes provided. The used ballots are then sorted out; first on the basis of which election and then into separate piles for each party and one pile for rejected ballots. Rejected and tendered ballots are counted, recorded in the appropriate forms and put in the envelopes provided. Then, the votes scored by each party are counted, announced and recorded in the appropriate form. Where the total number of votes cast in a PU is more than the total number of registered voters for that PU, the result of the election for that PU is declared null and void. In filling the form, the number of used ballot papers (which includes spoilt, rejected and valid ballots) is crosschecked against the number of ballot papers issued minus the number of unused ballot papers. If they are not the same, the anomaly is reported on the form but it is not enough to cancel the result of the election. At the end of the exercise, it is verified that the form for recording of votes has been properly filled and the presiding officer (PO) at the PU as well as the agents of the various parties are requested to sign it.

In 2015, the process is very similar to that of 2011 but there are two main differences. First, at the beginning of the process, all unused ballots are cancelled so that they cannot be used in other places. Secondly, at the end of the process, if the number of votes cast in a PU is more than the total number of accredited voters for that PU, the result of the election for that PU is declared null and void. This is in addition to the rule on the number of registered voters which states that if the number of votes cast in a PU is more than the total number of registered voters for that PU, the result of the election for that PU is declared null and void.

A MODEL FOR ESTIMATING RIGGING

Typically, a DFD is used to analyze either an existing manual system in order to appreciate how it functions or a proposed computerized system so as to clearly understand its requirements. The arrows within the system are often just generally descriptive of the data flows not the specifics. In the current context however, the arrows linking the oval shaped processes describing the system will be used to capture more detailed specific data representing critical information relating to the conduct of elections at a particular PU such as the number of eligible voters, the number of registered voters, the number of accredited voters and the number of those who actually vote and number of votes that a particular candidate gets. More importantly, the data flows would try to capture the different components of rigging that can change these numbers. With the help of this special DFD, the mathematical relationships that connect these different components of rigging are worked out and these are used to create an Excel worksheet that is used in estimating the final results of a hypothetical election exercise between two candidates based on some assumed variables.

A close look at the DFD in Fig. 2 shows how these different components are related. Each process in this diagram is shown with three (3) data flows entering it. These are described in subsequent diagrams. This DFD is further expanded in Fig.3, Fig. 4, Fig. 5 and Fig. 6. It can be seen that there are 3 data flows entering the first process "Register Voters". The first data flow represents the w eligible voters of the PU.This is the only valid flow. The second data flow, with a $P_{i-e,r}$ probability ratio, denotes the v-w ineligible voters who could be registered as a result of some form of rigging where v is the maximum number of voters that can be registered in that PU. The third data flow, also w, with a $P_{e,n-r}$ ratio, represents eligible voters who, as a result of rigging, may not get registered. In the final analysis, as explained in INEC (2011), the number of those who ultimately get into the Voters Register, x, is a combination of these 3 data flows as shown in the equation below:

$$x = w + (v-w)P_{i-e,r} - wP_{e,n-r} \quad (1)$$

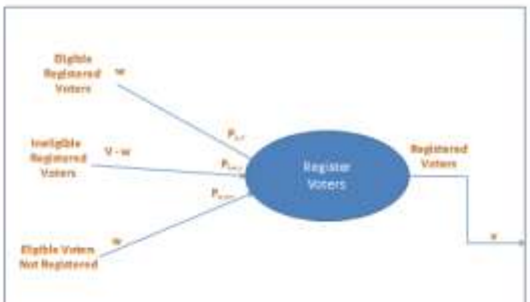

Fig 3: DFD for Register Voters

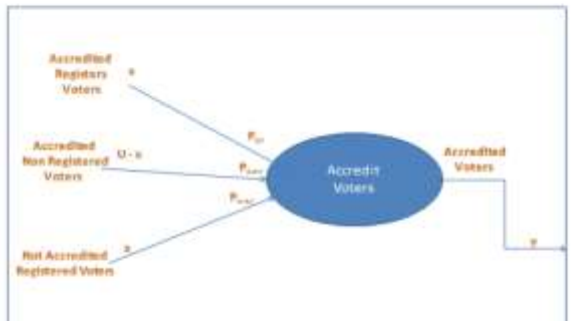

Fig 4: DFD for Accredit Voters

In the same way, there are 3 data flows going into the "Accredit Voters" process which are all related to x, the number of voters in the Voters Register. They are u, those registered that come out for accreditation, x-u,non registered voters who get accredited as a result of rigging, with a $P_{a,n-r}$ ratio and u again, registered voters who are not accredited as a result of rigging with a $P_{n-a,r}$ probability ratio. The combination of these data components gives y, the number of accredited voters as shown in the equation below:

$$y = u + (x-u)P_{a,n-r} - uP_{n-a,r} \quad (2)$$

The same logic applies to the "Allow to Vote" process where there are again 3 data flows entering including y (the number of those accredited), x-y (non accredited voters who get to vote as a result of rigging) with a $P_{n-a,v}$ ratio and y again (accredited voters who are not allowed to vote as a result of rigging) with a $P_{a,n-v}$ probability ratio. The combination of these data components gives z, the number of those allowed to vote as shown in the equation below:

$$z = y + (x-y)P_{n-a,v} - yP_{a,n-v} \quad (3)$$

This number, z, coming out from the "Allow to Vote" process, can be broken down into two data flows, a and b, representing the ballots that have been casted for the candidates, assuming for the sake of simplicity that there are only 2 candidates contesting and there are no spoilt ballots. This is as shown in the equation below:

$$z = a + b \quad (4)$$

In the data flow diagram depicting the vote counting exercise, we concentrate on the votes for Candidate A (a) leaving those for Candidate B (b) so as not to clutter the diagram. This time there are 2 additional data flows as a result of rigging. They are d (the number of ballots destroyed) with a ratio of P_d and s (the number of ballots stuffed) with a probability ratio of P_s. In the final analysis, the results of the election after the vote counting exercise, (a_f for Candidate A and b_f for Candidate B), are given in the equations below:

$$b_f = b - b*P_d \quad (5)$$

$$a_f = a + s*P_s \quad (6)$$

It is rather disturbing to see that these final results can be substantially different from the ballots a and b that have been casted for the candidates. This will be more clearly seen in the results next section.

For the sake of simplicity, it is assumed that no rigging takes place during the collation exercise, whether at the intermediate collation centers or at the final collation centre that could be the state INEC office (in the case of gubernatorial elections), the INEC Headquarters (for presidential elections) or some other suitable location (for Senatorial, Federal House of Representatives or State Assembly elections). This is a reasonable thing to do because the task of collating results is mechanical just involving simple additions with some checks and thus very little rigging takes place other than situations whereby a party, with the collusion of security agents, takes over control of a collation centre, drives away all agents and observers except its own people and forces INEC personnel to concoct results and fill the necessary forms. These situations, normal as they were before, are getting very rare.

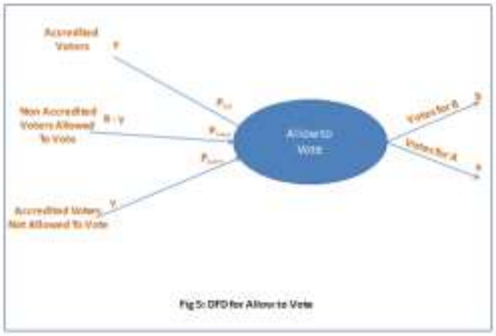

Fig 5: DFD for Allow to Vote

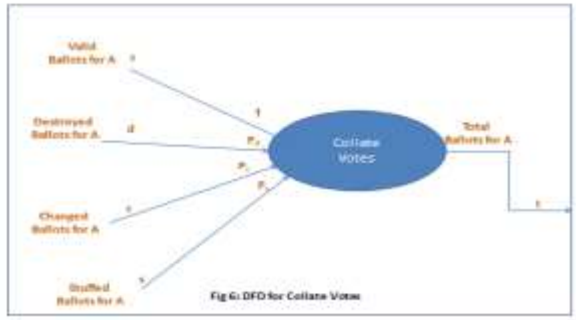

Fig 6: DFD for Collate Votes

In the final analysis, it can be seen that there are eight distinct rigging variables that affect the simplified overall electoral model so far developed. They are $P_{e,n-r}$ (the Probability of not registering eligible voters), $P_{n-e,r}$ (the probability of registering non-eligible voters), Pa,n-r (the probability of accrediting non registered voters), $P_{n-a,r}$ (the probability of not accrediting registered voters), $P_{v,n-a}$ (the probability of allowing non accredited voters to vote), $P_{n-v,a}$ (the probability of not allowing accredited voters to vote), $P_{b,d}$ (the probability of ballots being destroyed) and $P_{b,s}$ (the probability of ballot stuffing). They represent the various ways in which candidates, their parties or other stakeholders can willfully rig the elections in their favour. These variables are moderated by three (3) external factors which the candidates may not have much control over but which ultimately affect the the level of impact of the rigging variables. They are the number of eligible voters in a polling unit, the percentage of eligible voters who come out to register and the percentage of registered voters who come out on Election Day for accreditation.

USING SENSITIVITY ANALYSIS (SA) TO INVESTIGATE THE IMPACT OF PVCS IN REDUCING ELECTION RIGGING

Sensitivity Analysis (SA) is a technique used to determine how different values of an independent variable will impact a particular dependent variable under a given set of assumptions. SA is a popular technique used in many fields for developing hypothesis, understanding the relationship between input and output variables, developing simulation models and decision making. In our work, we have used SA to investigate the relationships between an output variable (the difference in results of Candidate A and Candidate B) and some input variables (probabilities of various types of rigging during election processes). The steps used, to a large extent but with minor modifications, are similar to those presented in Pannell (1997) and are summarized below:

1. Select the parameters to be varied.
2. Conduct sensitivity analyses for each parameter individually, using two parameter values (high and low or maximum and minimum). Conduct sensitivity analysis for each discrete scenario individually.
3. Identify parameters and discrete scenarios to which the key decision variables are relatively unresponsive
4. Exclude unresponsive parameters and scenarios from further analysis.
5. Get scenarios from all possible combinations of the high and low values of the remaining parameters
6. Carefully analyze the scenarios in order to investigate the relative impact of each variable.

We have used Microsoft Excel to do the sensitivity analysis. Excel's powerful functionalities and ease of use have made it a suitable platform for scenario analysis and sensitivity analysis as explained in Fairhurst (2012). Using the equations derived from the relationships captured in the DFDs, a SaSAT (Sampling and Sensitivity Analysis Tool) template was developed to help in analyzing the effect of various types of rigging in determining the ultimate results of elections at the PU level. (See Appendix) At the same time, the worksheet is used to evaluate the impact of the various measures introduced in 2015 to minimize rigging. With the help of the worksheet, different scenarios are considered ranging from best case scenarios where it is assumed that rigging is reduced to the barest minimum to worst cases where the different rigging components are assumed to be at their maximum levels. In all the scenarios, it is assumed that, at the beginning, there are equal numbers of supporters for each of the two candidates, A and B. However, we suppose that all the rigging is being done to make Candidate A to win and Candidate B to lose. Therefore, at the end of the registration exercise, the numbers begin to change in favor of Candidate A. This continues during the accreditation, voting and vote counting phases. It is important, in particular, to note that during the vote counting exercise, ballot stuffing means adding to Candidate A's ballots and ballot destruction means that Candidate B's ballots are the ones that are destroyed.

RESULTS

We begin our analysis by individually investigating the impact of rigging at the different levels of registration, accreditation, voting and collation. each level, since there are three (3) moderating factors, if it is assumed that each of the factors can take a low value or a high value, there would be eight (8) scenarios. This gives a total of 32 scenarios. If they are added to a first set of 8 scenarios, where the moderating factors are tested in a situation where it is assumed there is no rigging at all, the number of scenarios jump to 40. Table 1 shows a summary of the results of these first 40 scenarios considered.

Table I: Difference of Votes b/w Candidate A and B

Electoral Process	Sum of Diff of Votes b/w Candidate A and B
Registration	217
Accreditation	114
Voting	114
Vote-Counting	148

It can be seen that, for the scenarios where it is assumed there is no rigging at all, the results are consistently 0 and so the sum is also 0. For the scenarios, where it is assumed there is maximum rigging during registration but no other rigging, the sum is 217. On the other hand, for the two sets of scenarios where there is either maximum rigging during accreditation or voting but no other rigging, the sum is 114 but, for the scenarios where there is maximum rigging during collation but no other, the sum is 148.

Table II: Sensitivity Indices for Rigging Variables and Moderating Factors

Variable	**Definition of the Variable**	**SI**
Pn-e,r	The probability of registering non-eligible voters	0.58
Pe,n-r	The Probability of not registering eligible voters	0.10
Pa,n-r	The probability of accrediting non registered voters	0.08
Pn-a,r	The probability of not accrediting registered voters	0.02
Pv,n-a	The probability of allowing non accredited voters to vote	0.09
Pn-v,a	The probability of not allowing accredited voters to vote	0.01
Pb,d	The probability of ballots being destroyed	0.01
Pb,s	The probability of ballot stuffing	0.10
NeV	The number of eligible voters in a PU	0.10
%eVR	The % of eligible voters that come out to register	0.10
%rVA	The % of registered voters that come out for accreditation	0.04

We have individually evaluated the impact of rigging during the different election processes namely registration, accreditation, voting and vote counting.

In Table II, we show the sensitivity index of each variable and each moderating factor. Using a cut off value of 0.05, as is the normal practice in statistical analysis as explained in Beaumont(2012), five (5) out of the eight (8) rigging variables and two (2) moderating factors are significant. We can therefore eliminate the variables that are insignificant thereby limiting the number of scenarios to 2^7 (128) in our analysis of the cumulative effect of the rigging variables and moderating factors. The insignificant variables are kept at average values of 0.5 while the significant ones are used to create scenarios by considering both high and low values. In order to investigate the relative impact of each variable, we simulate for each variable and each moderating factor the estimated difference in votes between Candidate A and Candidate B for all the created scenarios when the given variable (or moderating factor) is at its maximum value and calculate the total of all the estimated differences from all the scenarios. We then simulate again for the same situations but with the given variable (or moderating factor) at its minimum value. The difference between the two corresponding values measures the relative impact of rigging for each rigging variable (or moderating factor) as shown in Table III. The % relative impact of rigging is the ratio of the estimated difference in votes to the total estimated number of rigged votes for all the scenarios.

Table III: Relative Impact of Rigging Variables and Moderating Factors

Variable	**Definition of the Variable**	**Relative Impact of Rigging**	**% Relative Impact of Rigging**
Pn-e,r	The probability of registering non-eligible voters	12,195	0.36
Pe,n-r	The Probability of not registering eligible voters	-1,641	0.05
Pa,n-r	The probability of accrediting non registered voters	1381	0.04
Pn-a,r	The probability of not accrediting registered voters	1586	0.05
Pb,s	The probability of ballot stuffing	1940	0.06
NeV	The number of eligible voters in a PU	1616	0.05
%eVR	The % of eligible voters that come out to register	3825	0.11

In order to evaluate the impact of the changes made in 2015, it is necessary toanalyze the impact of rigging at all the levels with the impact when rigging is possible during registration, voting and vote-counting but not during accreditation. This is because both the PVC and the card reader have virtually removed the possibility of rigging during accreditation. This analysis can be made by comparing the results from scenarios where it is assumed that there is a cumulative impact from rigging at the four (4) different levels from corresponding scenarios where there is possible rigging from the processes of registration, voting and vote-counting but not during accreditation. The impact of the changes is best seen by studying Table IV which gives the difference between the combined effect of rigging in different levels before and after the 2015 changes. It is interesting to note that in all the cases examined, the possible difference in number of votes between Candidate A and Candidate B is lower, showing less possibility of rigging for the 2015 elections as a result of the new measures introduced.

Table IV: Comparing b/w Rigging With and Without PVCs

Description	**Without PVCs**	**With PVCs**	**Difference**
Reg: A - B	34,055	30,468	
Accr: A - B	26,412	16,432	
Difference	7,643	14,036	6,393

It is clear from Table III that the use of PVCs reduces rigging by only 1250 compared to 6393 brought about by the regulation on number of accredited voters. In order to understand this, it is useful to investigate the relative impacts of the various rigging variables and moderating factors by measuring their sensitivity index (SI) values but this time by comparing across four (4) different situations with the first corresponding to the regulations in place during the 2011 elections, the second assuming a situation where the regulation on the number of accredited voters is enforced but PVCs are not used, a third assuming a situation where PVCs are used but the regulation on the number of accredited voters is not enforced and a fourth situation corresponding to what obtained during the 2015 elections. The comparison of the SI values for the different rigging variables and moderating factors across the four situations is given in Table V.

DISCUSSION OF RESULTS

The results obtained for the individual analysis of rigging during the various electoral processes for the 2011 elections suggests that rigging during the registration process, when considered alone, is likely to cause more harm than that encountered from other levels. This is followed by rigging during the vote-counting process. Rigging from accreditation and voting are the least harmful. These results are consistent with the findings from the sensitivity analysis (SI) which showed that Pe,n-r, the probability of registering non-eligible voters has the highest value followed by Pv,n-a, The probability of allowing non accredited voters to vote and then Pa,n-r, the probability of accrediting non registered voters.

When the cumulative impact of the various rigging variables and moderating factors is investigated, it is again found that the relative influence of rigging from $P_{n-r,e}$ is the highest. It is alarming that both from the sensitivity index and the analysis of the relative impact of the rigging variables and moderating factors, the gap between its relative influence and that of other variables and moderating factors is by a factor of at least 5. Investigating the impact of PVCs and the other measures introduced during the 2015 elections (and used in 2019) produces the most interesting results. A comparison of the SI values of all the various rigging variables and moderating factors for the four different situations shows that the SI of $P_{n-r,e}$ remains fairly constant at around 0.6 showing that neither the introduction of PVCs nor the provision of the regulation on number of accredited voters does anything to reduce its impact. All the other rigging variables and moderating factors are affected in one way or another by the PVCs or the regulation on number of accredited voters as shown in Table V. With the elimination of most of the sources of rigging due to the use of PVCs and the introduction of the regulation on the number of accredited voters, the main type of rigging that remains is that of registering ineligible voters. This is greatly facilitated by the moderating factor, %rVA, the percentage of registered voters that come out for accreditation. When this percentage is high and it happens that majority of them are ineligible voters, the amount of rigging can be extensive

Table V: Comparing Sensitivity Index (SI) Values for Rigging Variables and Moderating Factors for Different Situations

Variable	Definition of the Variable	SI (Pre 2015)	SI (2015& 2019) No PVCs	SI (2011) With PVCs	SI (2015& 2019) With PVCs
Pn-e,r	The probability of registering non-eligible voters	0.58	0.60	0.59	0.60
Pe,n-r	The Probability of not registering eligible voters	0.10	0.07	0.08	0.07
Pa,n-r	The probability of accrediting non registered voters	0.08	0.35	0.00	0.00
Pn-a,r	The probability of not accrediting registered voters	0.02	0.02	0.00	0.00
Pv,n-a	The probability of allowing non accredited voters to vote	0.09	0.00	0.17	0.00
Pn-v,a	The probability of not allowing accredited voters to vote	0.01	0.02	0.02	0.07
Pb,d	The probability of ballots being destroyed	0.01	0.02	0.02	0.07
Pb,s	The probability of ballot stuffing	0.10	0.00	0.20	0.00
NeV	The number of eligible voters in a PU	0.10	0.07	0.08	0.07
%eVR	The % of eligible voters that come out to register	0.10	0.07	0.08	0.07
%rVA	The % of registered voters that come out for accreditation	0.16	0.77	0.11	0.75

CONCLUSION AND FUTURE WORK

In this paper, we have used special data flow diagrams (DFDs), conventionally used in the requirements analysis phase of the system development cycle, as tools by means of which the various types of rigging during election processes in Nigeria can be more clearly identified, analyzed, understood, modeled and addressed. We use the data flows to capture detailed data representing critical information relating to the conduct of elections at a particular PU such as the number of eligible voters, the number of registered voters, the number of accredited voters and the number of those who actually vote as well as the different components of rigging that can change these numbers. With the help of these special DFDs, eight (8) rigging variables and three (3) moderating factors are identified, the mathematical relationships that connect these different components of rigging are worked out and these are used to create a Microsoft Excel worksheet that is used in simulating and estimating the final results of a hypothetical election exercise between two candidates based on some assumed variables. The worksheet is used on different possible scenarios to analyze the impact of different types of rigging. In order to limit the number of scenarios, sensitivity analysis is used to eliminate the rigging variables and moderating factors whose sensitivity index (SI) values are less than 0.5 leaving five (5) rigging variables and two (2) moderating factors. The reduced number of scenarios allows a detailed analysis of the relative impact of each of the rigging variables and each of the moderating factors on the extent of rigging. Four separate models are then developed with the first corresponding to the regulations in place during the 2011 elections, the second assuming a situation where the regulation on the number of accredited voters is enforced but PVCs are not used, a third assuming a situation where PVCs are used but the regulation on the number of accredited voters is not enforced and a fourth situation corresponding to what obtained during the 2015 and 2019 elections. These four separate models are used to analyze in details the impact of both the use of PVCs and the introduction of the regulation on the number of accredited voters.

The overall analysis shows how the different types of rigging individually and collectively affect the different electoral processes leading to the final counted votes. The results clearly show that rigging at each of the electoral processes, even when considered individually, can lead to substantially modified results but rigging during the registration process has the greatest impact, especially that caused by registering ineligible voters.

Investigating the impact of PVCs and the other measures introduced during the 2015 (and again used in 2019) elections produces the most interesting results. A comparison of the SI values of all the various rigging variables and moderating factors for the four different situations shows that the SI of $P_{n-r,e}$ remains fairly constant at around 0.6 showing that neither the introduction of PVCs nor the provision of the regulation on number of accredited voters does anything to reduce its impact. Our work has shown how we can develop a model, using the well-known software engineering tools of data flow diagrams (DFDs), that can represent the major details of any electoral system in the world especially the information flows that determine the level of rigging in the system. The model can then be used to create a SaSAT (Sampling and Sensitivity Analysis Tool) template that captures all the details of the system and allows estimates of results of elections to be simulated by assigning hypothetical values to the different variables. Using sensitivity analysis and scenario analysis, the developed model can be used to study the ways in which the different types of rigging in the various electoral processes have an impact in election results and to simulate and investigate how specific measures can actually reduce rigging during these electoral processes**.** In our future work, we will attempt to automate the process of creating the mathematical models from the DFDs. We also hope to develop other tools that would not only be used in analyzing electoral processes but also in designing electoral systems that are less prone to rigging.

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APPENDIX

Table 6: Microsoft Excel Simulation WorkSheet Used to Calculate Sensitivity Indices for the Rigging Variables and Moderating Factors

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	S21	S22
Max No of Reg Voters (V)	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
No of Eligible Voters (X)	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	400	100	250	250	250	250
% of Eligible Voters Who Come Out for Registration	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.8	0.2	0.5	0.5
Pn-e,r	0.8	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Pe,n-r	0.5	0.5	0.8	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
% of Reg Who Come for Accreditation	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.8	0.2
Pa,n-r	0.5	0.5	0.5	0.5	0.8	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0
Pn-a,r	0.5	0.5	0.5	0.5	0.5	0.5	0.8	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0
Pv,a	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pv,n-a	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.8	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Pn-v,a	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.8	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Pb,d	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.8	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Pb,s	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.8	0.2	0.5	0.5	0.5	0.5	0.5	0.5
Total Counted Votes (Reg)	394	169	263	300	281	281	281	281	281	281	281	281	281	281	281	281	300	263	300	263	281	281
Total Counted Votes (Accr)	288	119	194	213	245	161	198	208	203	203	203	203	203	203	203	203	213	194	213	194	241	56
Supporters of Candidate B	2	2	1	3	2	2	1	3	2	2	1	3	1	3	2	2	3	1	3	1	3	2
Supporters of candidate A (Reg)	363	152	244	272	268	247	259	257	270	246	258	258	258	258	272	244	272	244	272	244	265	222
Supporters of candidate A (Accr)	286	117	193	209	243	159	198	205	201	201	202	200	202	200	201	201	209	193	209	193	238	55
PRE 2015 (A - B)	361	150	243	269	266	245	258	254	268	244	257	255	257	255	270	242	269	243	269	243	262	220
2015 (A - B)	284	115	192	206	241	157	197	202	199	199	202	197	202	197	199	199	206	192	206	192	234	53
Difference	78	36	51	63	25	88	61	52	68	45	55	58	55	58	71	43	63	51	63	51	27	167