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Statistical Modelling for Prediction of Covid - 19 cases in North-Central Nigeria.

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Abstract
This paper aims at building a model that can predict cases of Covid-19 in North-Central States of Nigeria including Abuja, the Federal Capital. Data was obtained from the National Center for Disease Control and converted to percentages. Multiple Linear Regression was employed using R. The prediction model is: Confirmed Cases $(\hat{y}_i)$ *= - 0.003198 + 0.02566 Active + 0.9640 Recovered + 0.01045 Deaths. Parameter associated with active variable* $\hat{\beta}_1(0.02566)$ *is positive; it is the effect of the virus on confirmed cases adjusting for other predictors. A unit increase in number of active cases, brings about an average increase in number of confirmed cases by 25.66%; with recovered and death cases held constant. Increase in number of recovered cases by 1 unit, increases confirmed cases by an average unit of 96.66%; with active and death cases held constant. An increase of death cases by 1 unit, gives an average increase of 1.01% in confirmed cases, with active and recovered cases held constant. In conclusion, recovered cases have greater influence on the value of confirmed cases compared to other variables based on emperical results. With predictor variables set at zero (0), i.e., Confirmed Cases* $(\hat{y}_i)$ *= - 0.003198 + 0.02566(0) + 0.9640(0) + 0.01045(0), the region will experience 31.98% decrease in number of confirmed cases.* R^2 *of 1.0 implies 100% of variation in confirmed cases are explained by the model with 0% unexplained; making the model good and fit. This result gives policy makers and government first-hand information for productive policies that can avert the trend of infected cases of Covid- 19.*

Key words: **Statistics, Prediction, Multiple Linear Regression, Model, COVID-19**

1.0. INTRODUCTION:

Building a resilient community is very pertinent since no community is immune from disaster both natural and man-made. The novel Coronavirus Disease (Covid-19) pandemic is one of such disaster that has affected most countries of the world, including Nigeria (Ugwu *et[t]al*,2020), and the North Central region is not an exception. Statistics, comprehensively defined as the science that is concern with the collection, organization, presentation, analysis and interpretation of numerical data (or information), such that the degree of uncertainty in the conclusion drawn from the data is minimized and assessed in its entirety has played an effective role in charting the course for adequate data collection, strategic policies, decision making and drawing valid conclusions in this regard.

The North Central Region of Nigeria is made up of six states (Benue, Kogi, Kwara, Nasarawa, Niger and Plateau) and (FCT), Abuja. While the states have 114 Local Government Areas with a total of over 20 million, the FCT has 6 council areas with a population of 1.41 million. (Google.com search, 2023).

The government of every nation or country in spite of its size, whether large or small will always desire to expand her territories. No nation can be said to be healthy and can thrive in any form of infrastructural development when its citizenry is evaded with a pandemic. The outbreak of the Covid - 19 virus in 2019, spread from China to several nations of the world with the North Central region of Nigeria inclusive in the year 2020. Businesses were put at a standstill, movements were halted, all forms of activities operated at skeletal levels given the rapid spread of the virus and how contagious it is. On January, 30, 2020, the World Health Organization (WHO) described the Covid-19 disease as a Public Health Emergency of International Concern, while the disease was finally declared a global pandemic on March 11, 2020 (Balkhair, 2020).

Before the COVID-19 era, Nigeria had over 13 million employed youths, accounting for over 23% of her youth labour force (National Bureau of Statistics, 2018); however, it is estimated that the rate of unemployed youths in Nigeria will rise to over 33% by the end of December 2020 because of the effects of the pandemic (Obiezu, 2020). Furthermore, the Nigerian economy has been affected significantly by COVID-19 and its resultant lockdown as a control measure. This have really challenged the sustained livelihood of daily wage income earners who form about 60% of the entire population including the North Central Region of the country. People were in some case forced to stay indoors and in most times advised to use nose mask and observed some distance rules to avoid contacting the virus. Globally, Corona Virus Disease (COVID19) has posed unprecedented challenges to various communities in the health, economic, education, social and many other sectors. COVID-19 is a severe acute respiratory syndrome coronavirus 2 (WHO, 2020a). It has brought about severe setback in public health and led to heavy socio-economic crises in the affected countries (Ajisegiri, Odusanya & Joshi, 2020). As at October 20, 2020, over 215 countries have reported a covid-19 case with a total of forty million, nine hundred and twenty- one thousand, six hundred and sixty (40,921, 660).

The existence of parastatals like the National Center for Disease Control (NCDC) in Nigeria were barely known until this time for the purpose of containing the virus; necessitatingthe need for data collection on persons confirmed to have contacted the virus, data on active cases, those who recovered after medication was administered to them and of course mortality rate (deaths). The essence of this data was to aid Government, stakeholders and relevant agencies in policy and decision making in the face of such daunting challenge. An attempt to profering solutions to such menace like the Covid - 19 is in itself building communities to be resilient, and when communities are built, men are invariably built, and they eventually become the population that is key in fostering sustainable development.

Resilence is about building in a community of persons the capacity to bounce back in the event of any disaster like an earth quake, famine or a pandemic such as the Covid - 19. The usual tradition of providing palliatives will go a long way in cautioning this effect but this is temporal. It will not in any way profer long-lasting solution to the situation. Thus, the need to forsee into the future to to ascertain the probability of the reoccurence of the situation is critical in averting a come - back of the pandemic based on available data. Statistically speaking, the North Central Region of the country can only put in place measures that can contain or completely avert the reoccurence of this menace if there are handy information (data) or results that are pointers to economic set-backs by producing a model that can predict cases of Covid - 19 in the population.

Resilient communities, capable of withstanding and recovering from adverse events, are essential for fostering sustainable development in the face of evolving global challenges. Statistics, as a powerful tool in evidence-based decision-making, plays a fundamental role in facilitating the development of resilient communities and promoting sustainable development. This paper aims to present convincingly how effective statistics is as a tool in constructing a model that can predict cases of Covid - 19 in the North Central region of Nigeria using the Multiple linear regression analysis approach as a statistical tool to examine the relationship between confirmed cases of Covid 19 of the Nigeria state as the dependent variable; compared with independent variables like, active cases and rate of mortality (deaths) in the population.

1.1. Statement of the Problem

Building resilience and capacity in communities to be able to contain the outbreak of health disasters like the Covid 19, will demand information on its source, how it has affected the population, how it can be managed and how government and stakeholders can promptly respond in terms of aids. Thus, the need to have fore knowledge on the impart of Covid 19 on our population, so as to proffer strategic policies to ameliorate the situation is what have necessitated the need for this research.

1.2. Aim and Objective of the Study

This research is embarked upon to show with available data how statistics can be employed as an effective tool for building a model that can further predict cases of Covid - 19 in the north central region of Nigeria for a given time period.

Objectives:

i. To ascertain whether we can infer with enough evidence that a relationship exits between the number of confirmed cases of Covid 19 in the north central region of Nigeria in comparison with active cases, recovered cases and cases of deaths in the entire population.

ii. To inform and convince policy makers, government and other stakeholders on the need to employ statistics as a tool for proffering solution to issues bothering on disaster management and population.

iii. That the constructed model from the available data should be able to predict with some level of precision the expected number of active cases of Covid 19, the possible number of recovered persons and ofcourse the number of deaths in the population for a given period of time. This will inform government and policy makers on how to plan ahead so as to avert future occurrence of any negative event through available statistical information from the model.

1.3 Significance of the Study

No doubt the significance of this study will awaken the consciousness of government, decision makers, and other stakeholders on the need to employ statistics in their day to day running of the affairs of governance. Given available outcome of this study, government will have information on allocation of palliatives to affected persons in the event of the outbreak of any pandemic and bringing closer and closer the dividends of governance to the entire populace. Researchers will also find it an inevitable tool for reference purposes and for further research.

2.0. LITERATURE:

The importance of statistics in building statistical models that can predict cases of Covid - 19 as a panacea for building resilient communities and promoting sustainable development has been highlighted by several scholars in multidisciplinary fields. For instance, Smith and colleagues (2014) emphasized the role of statistical modelling in identifying vulnerabilities and designing effective strategies for community resilience. Their study employed regression analysis to assess the impact of various socio-economic factors on community resilience in the aftermath of natural disasters.

Furthermore, Jones (2017) focused on the application of statistical methods, such as multivariate analysis and spatial statistics, in assessing the vulnerability of communities to climate change- related risks. By using these statistical techniques, the author demonstrated the importance of understanding the spatial distribution of vulnerabilities to inform targeted interventions that enhance community resilience.

Still on the crucial role of statistical models as an effective tool for building resilient communities in sudden disaster; Wu and colleagues (2020) for instance, conducted a similar regression analysis to examine the relationship between COVID-19 cases and socio-economic variables in China in understanding and managing public health crises. Their results revealed significant associations between various indicators, such as population density and GDP per capita, with the COVID- 19 infection rates. This study underscores the importance of statistical techniques in identifying factors that contribute to the transmission of diseases within communities.

Additionally, Khan and colleagues (2021) conducted a study on the COVID-19 situation in various countries, including Nigeria. Their research employed statistical analysis to assess the impact of different socio-economic, demographic, and healthcare-related factors on the number of COVID- 19 cases. Their results demonstrated the potential of statistical models to inform policymakers and implement targeted interventions to mitigate the spread of the virus.

2.3. COVID-19 and Statistical Analysis

The COVID-19 pandemic has highlighted the critical role of statistical analysis in public health emergencies. The use of statistical models and regression analysis has been instrumental in predicting infection rates, assessing the impact of interventions, and guiding resource allocation decisions (Ferguson et al., 2020). Understanding the relationship between COVID-19 cases and various factors at a regional level can contribute to the development of targeted interventions and resilience-building strategies. Indeed, statistical techniques provide a means to measure, monitor, and evaluate progress towards sustainable development goals. By analysing data related to economic growth, social well-being, and environmental indicators, statistical analysis can inform evidence-based policies and interventions (United Nations, 2015).

3.0. METHODOLOGY:

Firstly, a comprehensive review of existing literature is conducted, encompassing scholarly articles, policy documents, and reports on the relevance of statistical modelling in matters of prediction, specifically the prediction of Covid - 19 cases in North central Nigeria. The literature review is guided by the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta- Analyses) guidelines to ensure a rigorous and replicable process (Moher et al., 2009). The multiple linear regression was employed on the collected data to build a model for prediction of Covid - 19 cases and to ascertain level of linearity between the dependent variable (confirmed cases) and other independent variables like; active cases, recovered cases and rate of

mortality (deaths). The R studio software for statistical analysis was used to analysed the data. The results from the printout were interpreted with further conclusions made based on empirical findings.

3.1. Data collection

In this study, the secondary method of data collection was employed through the official reports provided by the website of Nigeria Centre for Disease Control (NCDC), Abuja; ensuring the reliability and validity of the dataset. The multiple linear regression analysis approach was used as a statistical tool in analyzing the data in R studio with each states of the North Central Region of Nigeria as an individual data point. The number of reported COVID-19 cases serves as the dependent variable, while active, recovered and death cases respectively were considered as independent variables in the analysis. The COVID-19 data are cumulative values from March 13,2020 to March 29, 2022 during which time there has been over 255,415 confirmed cases, 2,672 confirmed deaths and 3142 in the entire states of Nigeria.

Data Preprocessing:

The data was cleaned, addressing missing values, outliers, and inconsistencies. Transform variables if necessary (e.g., normalization, logarithmic transformations). Identify relevant features that could influence the spread of COVID-19. This might include factors like population density, mobility data, weather conditions, healthcare facilities, and public health measures.

Model Selection

An appropriate statistical model was chosen. Common choices include regression models (linear, logistic, etc.), time series models (ARIMA, SARIMA, etc.), or machine learning models (Random Forest, Gradient Boosting, etc.). In this analysis, the researchers chose to use the linear regression, specifically the multiple linear regression method to analyse the data.

Model Evaluation,Validation and Tuning

The model was validated by testing set to ensure it generalizes well to new data. Fine-tune hyperparameters if necessary predictions and interpretation:

3.2. Multiple Linear Regression Analysis

The multiple linear regression is useful for modelling the relationship between a numeric outcome or dependent variable (Y) and multiple explanatory or independent variables (X). In this research, the multiple linear regression analysis was chosen because it captures and covers widely the relationship between the number of confirmed COVID-19 cases (dependent variable), and active, recovered and death cases (independent variables); modelled as a function of several explanatory variables. To perform multiple linear regression with p explanatory variables in R, we use the command:

$$lm(response\ \ explanator_1 + explanatory_2 +, ..., explanatory_p)$$

Regression can be restrictive because it relies on a fixed set of parameters β_0, β_1, β_2, β_3 and assumes a linear relationship between variables, i.e.,$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3$. An important objective of multiple linear regression analysis is to estimate the unknown parameters β_0 (intercept) and β_1, β_2, β_3 (slopes) in the regression model. This process is called fitting the model to the data. We use the Ordinary Least Square (OLS) method with our data to find estimates of β_0, β_1, β_2, and β_3, denoted by $\hat{\beta}_0$, $\hat{\beta}_1$, $\hat{\beta}_2$ and $\hat{\beta}_3$ respectively.

To understand the effectiveness of the fitted linear model, we present summary statistics available through the *summary*() command in *R*. These statistics gives us detailed information on the models performance and coefficients, including standard errors, *t*-statistics, *p*-values, and the *F*- test results. However, we usually cannot detect departures from the underlying assumptions in our model by examining the standard summary statistics, such as *t* or *F* statistics or R^2 . These are global model properties, and as such, they do not ensure model adequacy. Therefore, we also check the adequacy of our multiple linear model.

4.0. STATISTICAL MODELLING OF COVID - 19 DATA

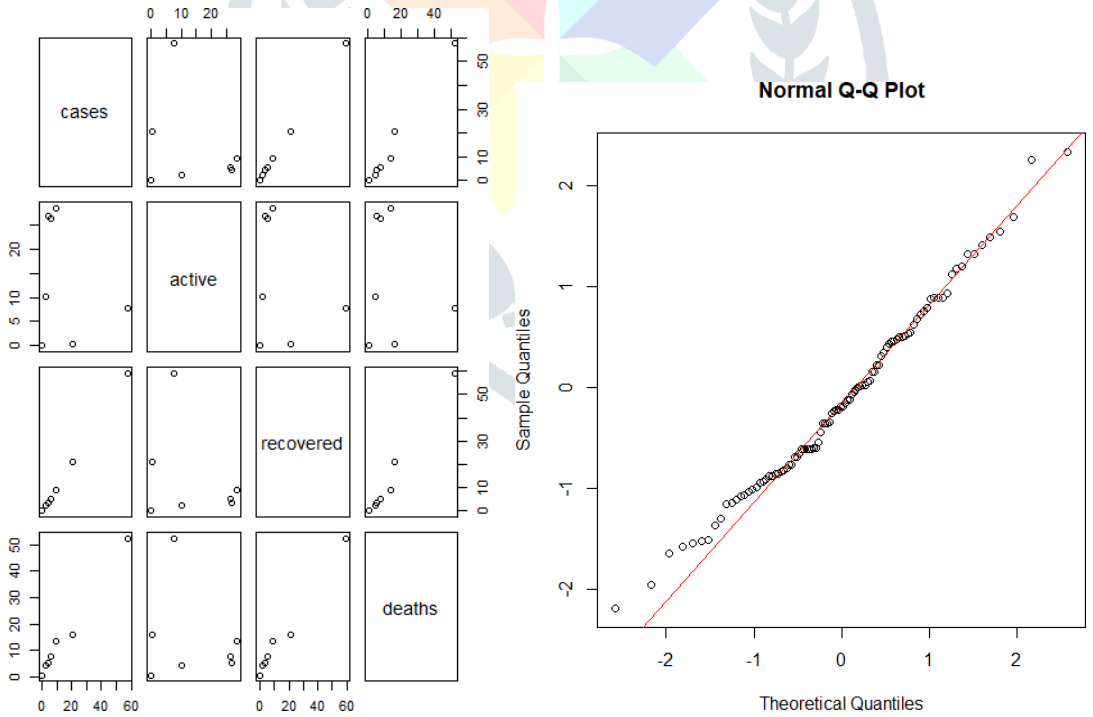
In this section, an analysis was carried out to estimate the coefficients of our estimated model, β_0, β_1, β_2, β_3, test of hypothesis, and verify the assumptions of the linear model for three individual cases; percentage of confirmed cases vs percentage of active cases vs percentage of recovered cases vs percentage of death cases in the population. The fitted multiple linear regression model is:

$$\hat{y} = \hat{\beta}_0 + \hat{\beta}_1 x_1 + \hat{\beta}_2 x_2 + \hat{\beta}_3 x_3 + E_i$$

where, *i* represents the population of confirmed cases of Covid 19 of the north central region of Nigeria state (*j* = 1,2,.....36), represents the number of active, recovered and death cases (*j*= 1,2,3), in the model *y* is the number of confirmed cases in the population densities of the various states in the region respectively. E_i represents the random term (also called the error variable) that is, the difference between the actual data (confirmed cases) of Covid 19 and the estimated active, recovered and death cases of Covid 19 based on the size of the population.

4.0. Results and Discussion

4.1. Results



(a) **SCATTER PLOT OF COVID - 19 CASES in North Central Region** (b) **Normality and Outliers of Confirmed Covid 19 Cases**

Figure 1: **Scatter Plot and Q-Q Plot of the Data**

4.1. Discussion: SCATTER PLOT

In plot (a), the researchers confirm from the output of the scatter plot from *R*, that recovered cases of Covid - 19 and death cases do have a strong correlation. Active cases and death cases

Estimate	Std. Error	*t* value	Pr(> |*t*|)	
Intercept	- 003198	0.0060577	-0.528	0.6341
Active (β_1)	0.02566	0.0004594	55.851	1,26e-05***
Recovered (β_2)	0.9640	0.0018982	507.842	1.68e-08***
Deaths(β_3)	0.01045	0.0021941	4.763	0.0176*

Table 1: **Ordinary Least Square Coefficients for the Model**

do not really have anything in common in terms of correlation, the same outcome for active cases compared to recovered cases. We observe that confirmed cases have a very strong correlation with recovered and death cases of Covid. Though this is the case, we will go ahead to develop our predicted model for the data.

First, rows were removed with NAs in the dataset if there be any using: *na.omit*() or *complete.cases*()functions in *R*. This activity is to help sanitize the dataset and check for normality of the dependent variable by creating our quantile-quantile (Q-Q) plots using the *qqnorm*() function in *R* as observed in plot (b). The dataset does appear to follow a normal distribution given that the data points of the 6 states in the North Central Region of Nigeria tested for Covid - 9 and are confirmed to have the virus fall along a straight diagonal line in the Q-Q plot.

4.0. Interpretation of the Model

Fitting the linear model was done using the *commandlm*() and the *summary*() functions in *R* using OLS. Our goal is to ascertain if there exists any linear relationship between these variables and to produce a model suitable for prediction of future cases of Covid - 19 in the region. Table 1.0 contains coefficients for $y = \hat{\beta}_0 + \hat{\beta}_1 x_1 + \hat{\beta}_2 x_2 + \hat{\beta}_3 x_3 + E_i$, where β_0 is the *y*-intercept and β_1, β_2, β_3, is the slope. The values for our β_0 the intercept = - 0.003198, while β_1 = 0.025661, β_2 = 0.963988, β_3 = 0.010451 . Thus, our linear model based on the results provided by the *R* software above is given as:

Confirmed Cases $(\hat{y}_i)$ **= - 0.003198 + 0.02566 Active + 0.9640 Recovered + 0.01045 Deaths**

Notice that in the coefficient table above, all the parameters are statistically significant. These results are considered as values of our model. The parameter associated with active cases of Covid - 19 variable $\hat{\beta}_1$, given as 0.02566 is positive; implying that the slope is positive. $\hat{\beta}_1$ here is the effect of active cases of the virus on confirmed cases of Covid - 19 adjusting or controlling for other independent variables. This implies that for 1 unit change in the number of active cases, there is a corresponding increase of 0.02566 in the number of confirmed cases in the population. In other words, if we increase the number of active cases in the population by 1 unit, the number of confirmed cases obviously increases by 0.02566 or 25.66% on the average; while recovered and death cases respectively are held constant. In addition, if we increase the number of recovered cases in the population by 1 unit, the number of confirmed cases obviously increase by 0.9640 or 96.66% on the average; while active and deaths are held constant.

Finally, if we increase the number of death cases = 0.01045 by 1 unit, the number of confirmed cases will increase by 0.01045 or 1.01% on the average, while active and recovered cases are held constant.

To illustrate this conclusion, suppose we set the value of:

Active cases = 3, Recovered cases = 2, Death cases = 2

if recovered and death cases are held constant, we notice that:

$$\textbf{Confirmed Cases } (\hat{y}_i) = \textbf{- 0.003198 + 0.02566 (3) + 0.9640 (2) + 0.01045 (2) = 2. 0227}$$

Which is 25.66% increase compared to the previous value. In the case of recovered cases, suppose we set the change at 3, active cases = 2, deaths = 2; that is active and death cases are held constant at 2.

$$\textbf{Confirmed Cases } (\hat{y}_i) = \textbf{- 0.003198 + 0.02566 (2) + 0.9640 (3) + 0.01045 (2) = 2. 9610}$$

The value of confirmed cases will now becomes 2.9610 which is a 96.40% increase compared to the previous value.

Finally, if we change death to 3, active = 2, recovered = 2; that is active and recovered cases are held constant at 2, then;

$$\textbf{Confirmed Cases } (\hat{y}_i) = \textbf{- 0.003198 + 0.02566 (2) + 0.9640 (2) + 0.01045 (3) = 2. 0075}$$

The value of confirmed cases becomes 2.0075, which is 1.05% increase compared to the previous value. We may also conclude that recovered cases as a variable has greater influence on the value of confirmed cases compared to other variabes, based on emperical results.

In addition, to interpret the intercept which is = **- 0.003198**, we consider that the predictor variables (active, recovered and death cases) are zero (0). That is:

$$\textbf{Confirmed Cases } (\hat{y}_i) = \textbf{- 0.003198 + 0.02566 (0) + 0.9640 (0) + 0.01045 (0)};$$

this puts the total number of confirmed cases in the region at zero (0), that is there is completely no cases at all, then the region willl experience a total reduction at: - 0.003198. This means that if the active cases, recovered cases and death cases of Covid - 19 in the North Central Region reduces minimally, the value of confirmed cases of Covid - 19 will also drop by - 0.003198, which is a decrease of 31.98% in confirmed cases in the region.

Using the Statistical Model for prediction

Obviously, we develop models so that we can do some predictions as captured in the title of this research. This is achieved by using the $prediction()$ function in *R*.

$$> predict(model, data.frame(active = 2, recovered = 3, deaths = 2), +interval = "confidence")$$

fit	lwr	upr 2.960989	2.944035	2.977942

Table 2: **Model Prediction**

This gives the output below:

Thus; the fitted value (2.960989) is the average and it can go from 2.930118 to 740.34. These are the lower and upper bounds of the 95% confidence interval. We are therefore 95% confident that the overall average value for cases of Covid - 19 in the North Central region of the country will fall between these bounds.

Multiple *R* squared:

from the *R* printout, the multiple *R* squared is set at 1.0; This implys that approximately 100% of variation in the confirmed cases of Covid - 19 in the Northern region of Nigeria can be explained by our model (active, recovered and deaths). In case of F - Statistics, we can see that the *F* - Statistics and *P* - value for an overall test of significance of our model. This tests the null hypothesis that all the coefficients are zero (0). in this research;

$$H_0 : \beta_1 = \beta_2 = ... = \beta_k = 0$$

$$H_1 : \beta_1 active \; /= \; \beta_2 recovered \; /= \; \beta_3 deaths \; /= \; 0$$

The residual standard error gives an idea of how far observed

5.0. CONCLUSION:

It is obvious that from the above results obtained, there exists a linear relationship between all the cases of Covid -19 in the North Central region of Nigeria. The statistical model built from the collected data is appropriate for the prediction of future cases of Covid - 19 namely; confirmed cases, active cases, recovered cases and death rate in the population. If this is true, given available results, then policy makers, strategists and the government have first-hand information on how to avert this trend in their respective states; not just making palliatives available for the population as a way of cushioning the effect of the virus without without information on the probability of a reoccurence.

Finally, room for investigation into the effective use of statistics as a tool for building resilient communities is quite enormous and vast. If given the opportunity of extending this research for a period of say three months, there are aspects not covered in this research that the researchers will definitely want to explore and make improvements for the future. Aspects such as the use of Multinomial Logistics Regression in sampling the opinions of a given population on the promptness of Government in the event of disaster. And also, the use of other modelling tools where the Backward and Forward method of selection will be applied, Multinomial Logistics regression as mentioned above, Chi-Square Test of Independence etc. In the meantime, while we wait and look forward to such a time, it is hoped that this piece of work will lay a foundation for future researchers who will equally expand and improve on aspects where the need arises.

5.1. Recommendations:

With the available results, the researchers wish to recommend the following:

1. Government should as a matter of urgency ensure that modalities are put in place to create awareness through television, radio, etc on the need for every state to get its people tested for Covid - 19.

2. Strategic policies should be employed to ensure that drugs meant for confirmed Covid - 19 patients are in circulation. This will gradually set the result of confirmed cases to a fixed constant of zero (0) as seen in the illustration.

3. Active cases of Covid 19 will lead to the untimely deaths. The ministry of health should ensure that retroviral drugs meant to contain the escalation of the virus to this extent be made readily available and accessible to those concern.

4. Government through the help of some non - governmental organization should encourage the use of face mask to minimize the spread of the virus.

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