Integration Of Statistical Techniques For Improving Contact Tracing Efforts To Stop The Spread Of Covid-19 Cases In Nigeria

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Research Article

Keywords: COVID-19, Contact Tracing, Markov Chain Monte-Carlo (MCMC) Diagnostic, Reproductive Rate

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INTEGRATION OF STATISTICAL TECHNIQUES FOR IMPROVING CONTACT TRACING EFFORTS TO STOP THE SPREAD OF COVID-19 CASES IN NIGERIA

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Abstract

COVID-19 is battling with many countries in the world, including Nigeria, and it has affected various sectors. Contact tracing technique without Statisticians in the team as recommended by WHO is being used in Nigeria to curb the spread of COVID-19 virus, yet confirmed cases is on the increase daily. This study proposed the integration of Statistical techniques for improving contact tracing efforts to stop the spread of the virus. A fitted model using the R package, and Adaptive Cluster Sampling mechanism was embedded. Parameters of the model were estimated using Markov Chain Monte-Carlo (MCMC) Algorithm with Winbugs software. Trace plot and correlogram were used for MCMC diagnostics to examine the goodness of fit of the model. The fitted model was used to obtain a predictive distribution for predicting the estimated number of COVID-19 carriers in Nigeria. The model has a good fit since It converged to the representation of the target posterior within the 95% highest posterior density (HPD) interval, its chains mixed well, and autocorrelation is quite similar at each lag. Estimated number of COVID-19 carriers were well estimated and higher in each state than confirmed cases. The present contact tracing process is inefficient to track COVID-19 carriers, hence integrated contact tracing technique with the involvement of Statisticians was recommended.

Keywords: COVID-19, Contact Tracing, Markov Chain Monte-Carlo (MCMC) Diagnostic, Reproductive Rate.

Introduction

COVID-19 has been termed pandemic due to the rapid increase in the number of confirmed cases outside China and affecting several numbers of countries across the globe. COVID-19 was caused by a new strain of coronavirus (SARS-CoV-2) first discovered in Wuhan, China, having not been seen earlier in humans and reported to World Health Organization (WHO, 2020) on 31st December 2019. The confirmed cases had increased to 17,755,732 and 677, 752 deaths across the world as at 31st July 2020, 10:48 GMT, [1].

COVID-19 is a respiratory virus that spreads primarily through droplets generated from an infected person to the other. This virus infects people of all ages. It caused a range of symptoms, from mild illness to severe cases like difficulty in breathing and even deaths. However, older people (people over 60 years old); and those with underlying medical conditions (like cardiovascular disease, diabetes, chronic respiratory disease, and cancer) are at a higher risk of getting severe COVID-19 disease.

Nigeria first case was reported on the 27th February 2020, and since then, the number of confirmed cases had been on the increase. The latest statistics by Nigeria Centre for Disease Control (NCDC) revealed that Nigeria had recorded thus far 43,151 confirmed cases, 19,565 discharged and 879 deaths as at 31st July 2020 [2]. The total number of tests carried out to date is 286,091, with a total daily test of 2,175 samples across the country [3].

The total confirmed cases of COVID-19 started increasing from April 2020 in Nigeria and across the globe (see figures 1 and 2). From Figures 1 and 2, it is clear that the number of confirmed cases follows the exponential pattern, which implies a growth curve over time. Many measures such as lockdown, physical distancing, closure of schools, markets and places of worship were adopted, still confirm cases are still increasing.

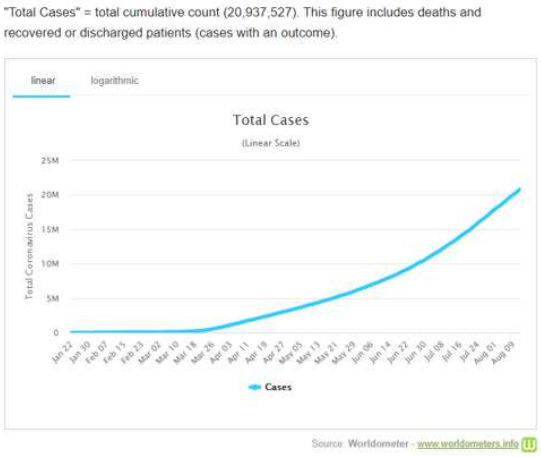


Figure 1: Total confirmed cased in the world

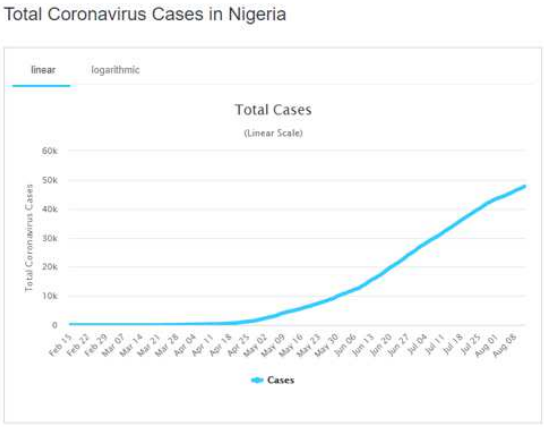


Figure 2: Total confirmed cases in Nigeria.

Contact Tracing Process in Nigeria

Contact tracing is the method of identifying, assessing, and managing people who have been exposed to COVID-19 carriers to prevent continuous flow of the virus. [4]. It is one of the greatest strategies used in detecting carriers of epidemic diseases such as COVID-19 over the years. Comprehensive techniques, identification and confirmation of cases, isolation of carriers, testing, contact tracing and quarantine of carriers are essential activities to prevent the spread of Corona Virus Diseases. This method requires systematically identifying people who may have been in contact with COVID-19 carrier and following them up on daily basis for fourteen days from the last point of exposure. According to World Health Organization [4], a contact is any person with direct physical contact with a COVID-19 case or a person providing direct care for patients with COVID-19 disease without using proper personal protective equipment (PPE) or has been within one meter of COVID-19 case for more than fifteen minutes.

The estimated number of contact persons to be traced, the monetary, technological and physical logistics of getting to the affected communities and contact persons, behavioural and cultural context, socio-political factors, security issues and methods of contact tracing are factors to be considered in composition of workforce requirements for contact tracing. Contact tracing teams include lead epidemiologist, field epidemiologist, supervisor, contact follow up team, Investigation team and Statisticians [5]. These teams may require administrative materials, and other logistics supports such as identity cards, transport bus, electronic or paper materials to record information, mobile telephones and credits. The contact tracers should also be equipped with appropriate protective devices such as masks, hand sanitizers, and gloves.

Greiner[6], described the five most prominent contact tracing challenges to include problem

on how to identify contact persons, locating the contact-persons, enrolling contact people, managing contact tracing teams, and ensuring contact tracing performance. As essential and efficient contact tracing is in identifying, controlling and eliminating COVID-19 cases, any delay or inefficiency can result in fruitless efforts and failure to get to zero cases. Though, contact tracing challenges may be dependent on each country's unique economic, social, geopolitical, and cultural context, there have been common issues encountered throughout the West African region. WHO [5]suggested involvement of Statisticians in contact tracing team. In Nigeria, Nigeria Centre for Disease Control (NCDC) team is solely responsible for contact tracing. Statisticians are not well represented in contact tracing process and due to that, contact tracing efforts have not really reduce the spread of COVID-19 in Nigeria because NCDC team does not have the know- how to handle certain challenges namely but not limited to, not at home; hard to reach; non response due to sensitive issues; hard core, and many other factors related to non-response they are encountering in the process of contact tracing to get COVID-19 carriers tracked. Inability of the NCDC team to track all the COVID-19 carriers has leads to further spread of the virus. Hence, this study proposed integration of Statistical techniques for improving contact tracing efforts to stop the spread of COVID-19 cases and ultimately, this will lead to prevention of large-scale Corona virus outbreaks in the future and putting the cases into final extinction.

Effects of COVID-19 on Nigeria's Economy, Employment, Education, Tourism and Others.

The effects of Corona virus disease (COVID-19) is beyond imagination as it came in at an unexpected period. The whole world is at a great state of pandemic as no one could predict or stipulate its end time. Great and developed nations with buoyant economy were seriously affected let alone the underdeveloped and developing ones. Many social and economic activities were postponed and seriously crippled. Economic sectors, tourism industries, educational institutions and even religious centres were not left out. In this paper, the focus is on the impacts of COVID-19 on Nigeria's economy, education, employment, tourism among others.

Various researchers had shown that economic meltdown or crisis is often caused by external trade and price shocks, political instability and civil unrest [7]. There is no doubt that COVID-19 has also shown that a pandemic could also be a cause for economic crisis. Ozili [8] discussed the five main ways through which the COVID-19 pandemic affected Nigeria. These include, incapability of borrowers' to service loans, decline in oil price, shortage in crucial supplies (e.g. pharmaceutical supplies, spare parts e.t.c.) due to closure of boarders, national budget deficit as a result of low oil price and high stock market investors lost.

The emergency of the pandemic forced many countries to put some policies in place to curb its spread. Nigeria government imposed total lockdown, social distance rules, curfew, and ban on interstate, local and foreign travels. These policies imposed restrictions in spending and shortage in consumptions. Many industries and companies cut down production and shutdown services rendered while some laid off their staff to reduce personnel costs. These actions resulted into drastic increase in unemployment rate and poverty level. Recently, Nigeria has been declared as the world poverty capital with an estimation of eighty seven million people living below $2 a day threshold [9].

The WHO stated that the children and aged people are the most vulnerable people to COVID-19. As a result of this, primary, secondary schools and tertiary institutions in the country were shutdown. This affected the pupils and students intellectually. Teachers and even staff of higher institutions were redundant. Many conferences and seminars were suspended even though some were replaced with online mode. Nevertheless, the pandemic diseases had put a stop to many academic activities in all levels of education in the country.

Tourism according to Vijaya [10] was defined as people travelling abroad for period of over 24 hours. The air transport is however an important sector of the Nigeria's economy. Sixty percent of four hundred aircrafts registered in Nigeria are used for commercial purposes [11]. A deficit of over $200 billion was predicted to be recorded by tourism industry globally due to the travel restrictions not including other loss of revenue for tourism travel [12]. Ozili and Arun [12] stated that in the tourism industry, COVID-19 majorly affected Nigeria airlines, travel agencies, hotels and hospitality. Measures such as targeted cash transfers, mortgage reliefs, Tax waivers and deductions, filing extension, interest free loans, employment reliefs, payment of moratorium among others need to be put in place to cushion the effect of the pandemic COVID-19 on our economy. Figures 3 and 4 show the effects of COVID-19 on Nigeria's Economy.

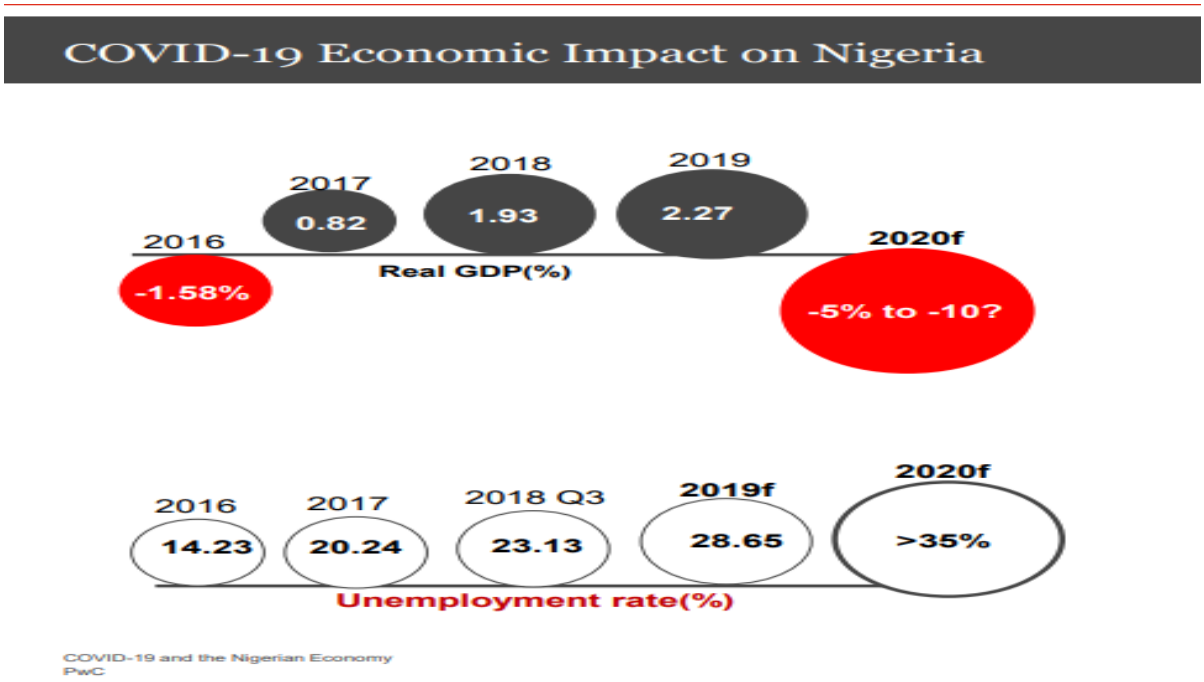
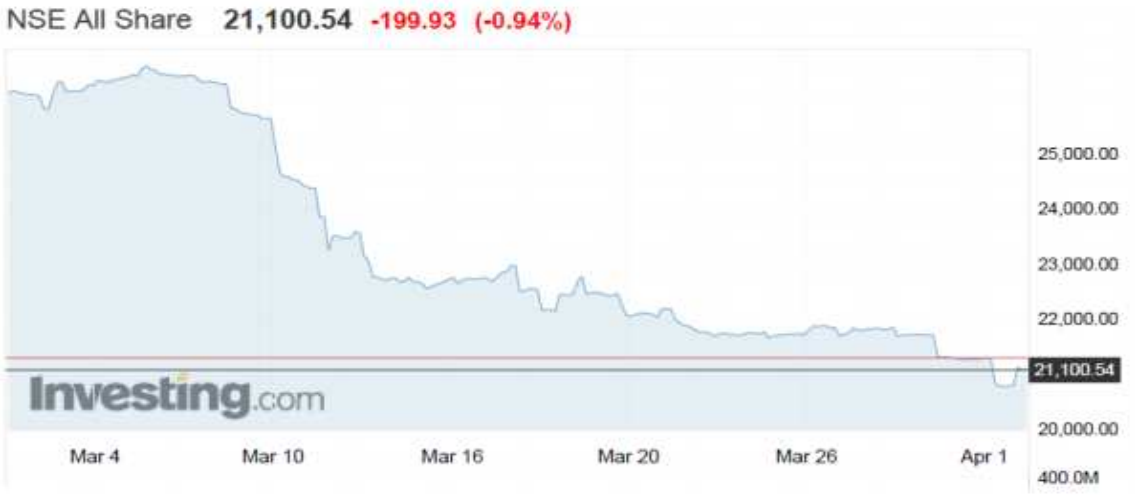


Figure 3: Graph showing economic impact of COVID-19 on Nigeria's GDP and Unemployment.



(source: investing.com)

Figure 4: Graph showing economic impact of COVID-19 on NSE

Model for Estimating Number of COVID-19 Carriers in Nigeria

In order to improve capturing of more COVID-19 carrier in Nigeria, this study fitted a statistical model to estimate number of carriers in Nigeria and suggested appropriate sampling method that can be adopted for tracking carriers.

Let controls the expected number of COVID-19 carriers in a region, controls the conditional expected number of regions with COVID-19 carriers, the expected number of confirmed COVID-19 cases in each region, and the variable $Y = Y_1, Y_2, \ldots, Y_p$ describe the number of regions in each COVID-19 carrier network, where a network is a collection of one or more regions with COVID-19 carriers.

A model was fitted using R package for the Number of networks in Q by specifying the joint distribution of X, P, Y and N. Adaptive Cluster Sampling mechanism which leads to adaptive sample $s = \{i_1, \ldots, i_m\}$ of m out of − + networks was embedded in the model. Where M is the number of regions Q in the country, a region is nonempty if it contains at least one COVID-19 carrier and empty otherwise. Let $X \leq M$ be the number of regions with COVID-19 carriers in Q. Let $P \leq X$ be the number of COVID-19 networks (collection of neighbouring regions) in the Nigeria population Q and $Y = Y_1, Y_2, \ldots, Y_p$ denote the number of regions with COVID-19 carriers within each networks so that $X = \sum_{i=1}^{P} Y_i$. As there are $M - X$ regions without COVID-19 which are defined to be networks of regions without COVID-19 of size one, therefore, there are $M - X + P$ networks in R. Joint distribution of X, P, Y and N for Q was specified and then we model the structure of networks with/without COVID-19 carriers (determined by X, P and Y) conditionally on the network structure and the number of COVID-19 carriers (N) networks of regions with COVID-19. The unknown parameters α, β and in the model were estimated using a Markov Chain Monte-Carlo (MCMC) [13] algorithm with Winbugs [14] software. Trace plot and correlogram were used for the MCMC Diagnostics to examine goodness of fit of the model. The fitted model was used to obtain a predictive distribution for predicting N. The predictor of N (estimated total number of COVID-19 carriers) is given as

$$\hat{N} = 1_{P_0}^{T} N_0 + 1_{P_1}^{T} N_1 \quad \text{----------(1)}$$

Discussion of Results

The fitted model for predictor of estimated number of COVID-19 carriers for Nigeria in Eq (1) converged to representation of the target posterior within the 95% highest posterior density (HPD) interval as shown in Figure 5. Trace plot and correlogram in Figure 6 and Figure 7 showed that the chains from the model mixed well and its autocorrelation is quite similar at each lag, which confirmed that the model is efficient for estimating number of COVID-19 carriers in Nigeria.

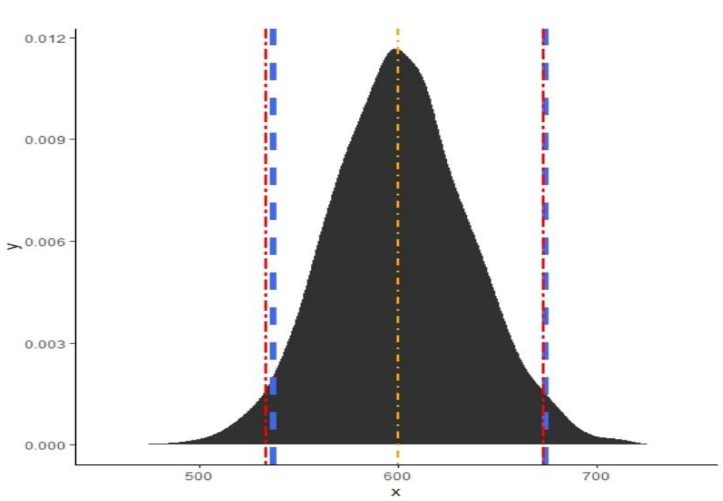


Figure 5: 95% Credible Interval for Posterior Total Estimation for COVID-19 carriers

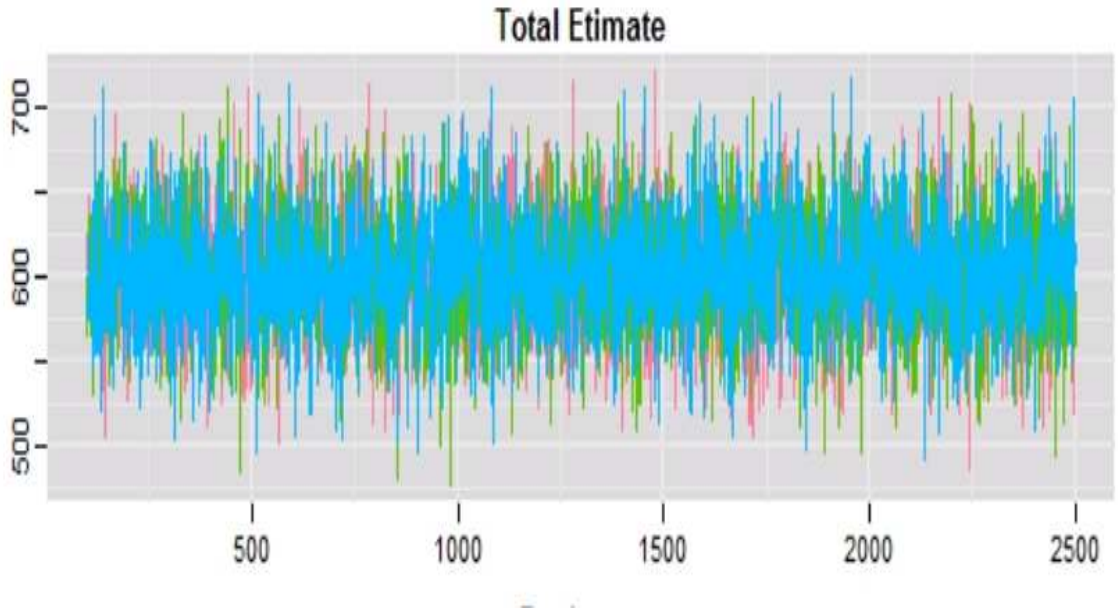


Figure 6: Trace plot

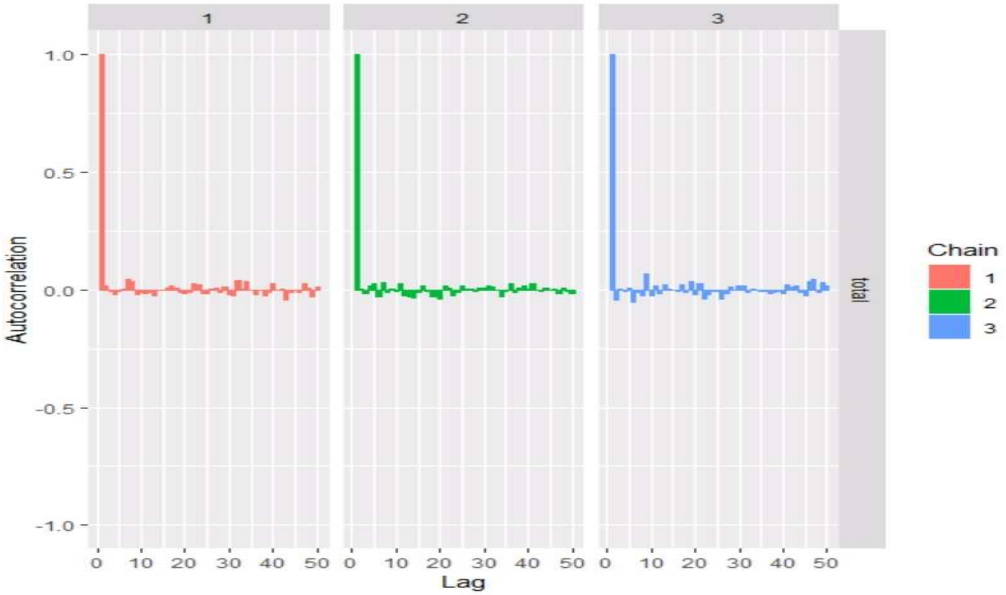


Figure 7: Autocorrelation plot

The predictor in Eq (1) gave an estimated number of COVID-19 carriers in Nigeria for July 31, 2020, as shown in Table 1. It was observed in Table 1 and Figure 8, that for each state, the estimated number of carriers is higher than confirmed cases tracked by the NCDC team without involvement of Statisticians. Thus, the NCDC team (medical personnel) were unable to capture all the carriers due to challenges they faced which could only be resolved by Statisticians.

Table 1: Estimated numbered COVID-19 carriers versus confirmed cases in Nigeria for July 31, 2020.

State	Estimated number of COVID-19 carriers	Confirmed COVID-19 cases
Abuja	126	93
Lagos	109	78
Oyo	71	47
Edo	18	7
Rivers	20	9
Kano	16	6
Delta	21	9
Kaduna	94	54
Ogun	24	9
Plateau	92	64
Ondo	52	32
Enugu	18	6
Bauchi	35	19
Nasarawa	15	5
Adamawa	40	23

Osun	3	1
Cross River	15	0
Zamfara	7	0
Yobe	7	0
Taraba	42	0
Ebonyi	21	0
Kwara	13	0
Katsina	21	0
Borno	7	0
Gombe	54	0
Abia	21	0
Imo	9	0
Benue	21	0
Bayelsa	7	0
Jigawa	7	0
Niger	74	0
Akwa Inom	27	0
Sokoto	7	0
Anambra	11	0
Ekiti	20	0
Kebi	7	0
Kogi	7	0

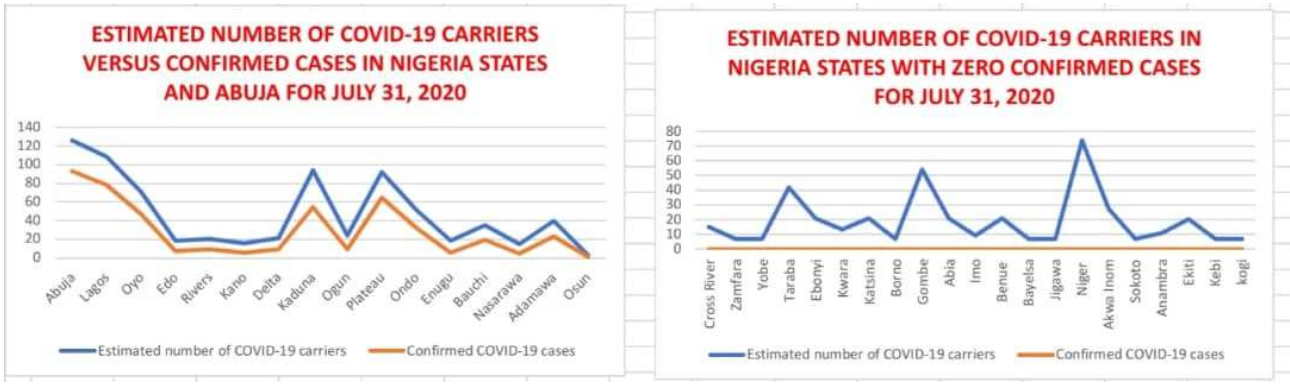


Figure 8: Estimated number of COVID-19 carriers versus confirmed cases

On July 31, 2020, estimated number of COVID-19 carriers in Nigeria was 1159 while confirmed cases was 462 as shown in Figure 9. This justified that contact tracing process by medical personnel is inefficient to capture carriers. It requires integration of Statistical techniques for carriers to be properly tracked and captured.

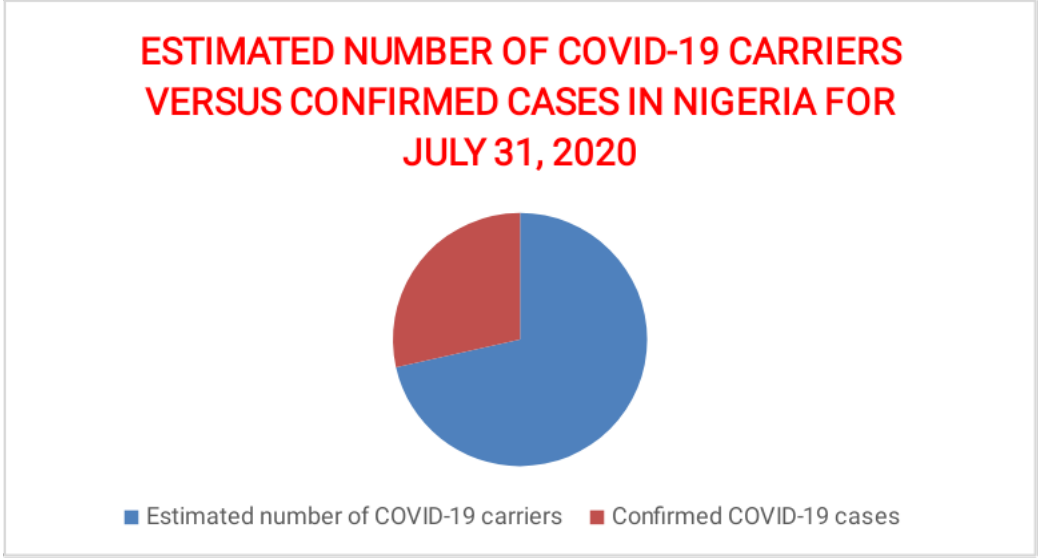


Figure 9: A pie chart showing estimated number of COVID-19 carriers versus confirmed cases in Nigeria

Figure 10 presents the distribution of estimated number of COVID-19 carriers among Nigeria states for July 31, 2020. It was classified into very high, high, moderate, low and very low. The highest number of COVID-19 carriers is in Lagos State and Abuja, while the least is from Osun State. Figure 11 shows that majorities of the states have zero confirmed cases and where there is confirmed cases, it is less than estimated number of carriers, hence present contact tracing process by medical personnel is inefficient to track COVID-19 carriers in Nigeria.

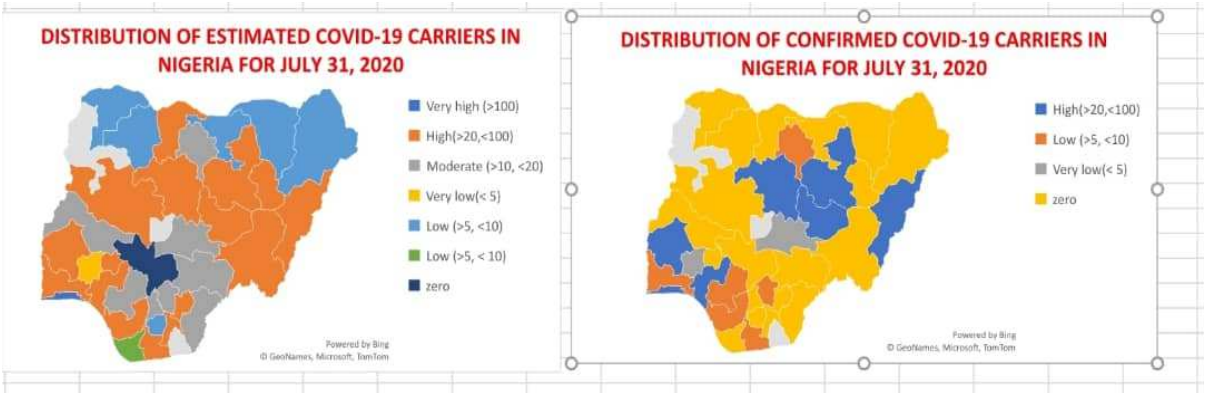


Figure 10: Distribution of Estimated COVID-19 Carriers in Nigeria for July 31, 2020

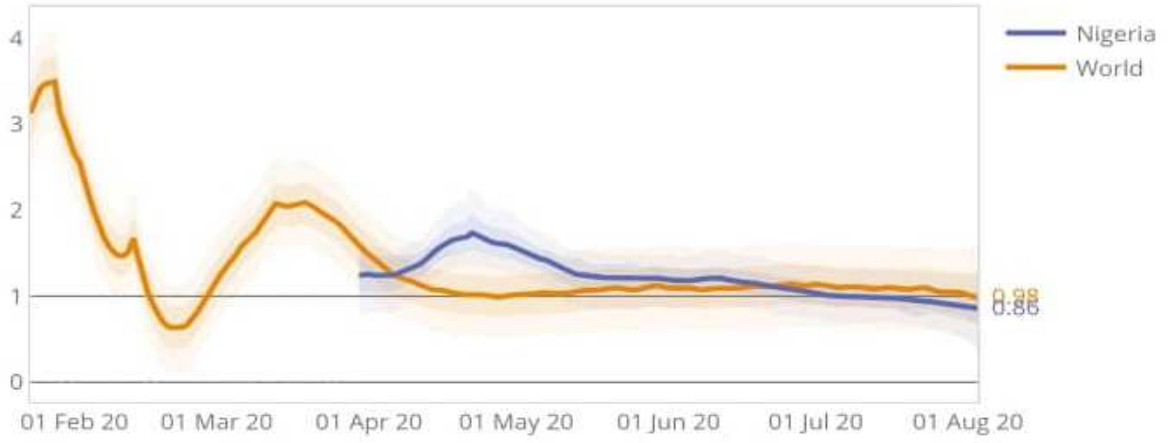
Figure 11: Distribution of confirmed COVID-19 cases in Nigeria for July 31, 2020.

Reproduction Rate (R) for COVID-19

Reproductive rate supposed to be computed based on the required data. In Nigeria the available data is not sufficient to compute the Reproduction rate (R). However, there is a software online called tracking R being used to determine R for all countries, which we are

still wondering on how they arrived at the parameter for its calculation.

For the specified dates in Figure 12, reproductive rate values of 0.86 and 0.98 were obtained for Nigeria and world respectively. The values for R show that the spread is declining, indicating that some measures put in place to reduce the spread of COVID-19 were effective. Nevertheless, a closer value to zero is required. More efforts still need to be put in place. The R value for Nigeria is misleading because confirmed cases is increasing on daily basis and US and UK government are emphasizing that people should avoid travelling to Nigeria.



Source: Tracking R [15]

Figure 12: Graph showing the Reproductive Rates of COVID-19 in Nigeria versus World

Conclusion

WHO in 2015 had suggested involvement of Statisticians in contact tracing team. In Nigeria, NCDC team members (medical personnel) are solely responsible for contact tracing, which made their effort inefficient to capture all carriers. This study integrated the use of a Model and Adaptive Cluster Sampling techniques in contact tracing to estimate and capture hidden COVID-19 carriers in Nigeria. The proposed methodology suggested Statisticians to be part of the NCDC team to make its effort effective to curb the spread of COVID-19 cases in Nigeria.

Recommendation

Based on the finding from this study; that the present approach is inefficient to track all COVID-19 carriers and computation of COVID-19 spread rate in Nigeria due to lack of involvement of Statisticians, we hereby present the following recommendations for effective tracking of the COVID-19 carriers in Nigeria.

1. Implementation of the Integrated Contact Tracing Approach with involvement of Statisticians

The model in Eq(1) will guide statisticians to know the estimated number of COVID-19 carriers within a population together with appropriate sample to be selected strategically and adaptively such that all carriers would be captured. Immediately a carrier or carriers is/are identified, contact tracing will commence by the team of medical personnel with statisticians. All selected samples by contact tracing process and Adaptive Cluster Sampling would be subjected to isolation for 14 days or test depending on availability of the test equipment. These samples would be observed for 14 days and any one with the symptom of

COVID-19 would be tested. If positive, admit and treat and if negative discharge. After 14 days, others without the symptoms would be discharged. The proposed procedure is presented in a flow chart in Figure 13

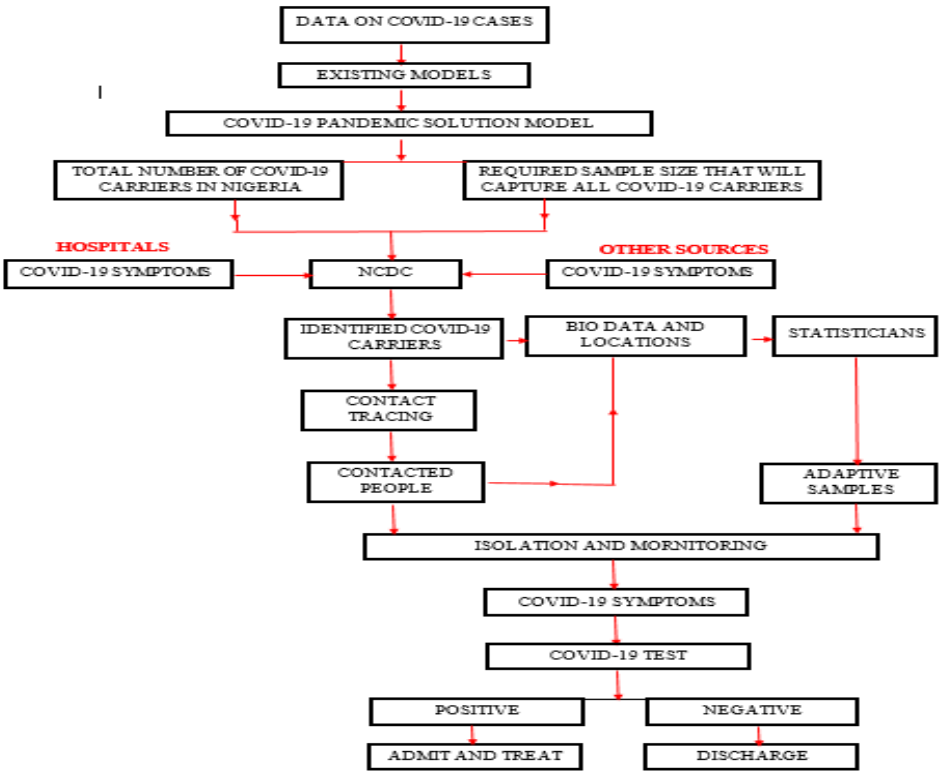


Figure 13: Flow chart for integrated contact tracing Approach

2. Computation and Interpretation of Reproduction Rates (R) of COVID-19

Involvement of Statisticians in contact tracing will help to get appropriate data for computation of R, which will guide policy makers about the spread rate of the virus. R is a way of rating disease's ability to spread. It is the number of people one infected person will pass the virus on to, on average. If R > 1, it implies the number of cases increases exponentially
If R < 1, it implies the number of cases will eventually decline, and if R = 1, the spread neither increases nor decreases.

Recommended computation procedure of the Reproduction Rate, R, is as follow
Let:
n = number of COVID-19 carriers
m = number of locations of carriers
T = Contact Tracing process
A = Adaptive Cluster Sampling
g = number of priority groups
n_{ijT} = number of confirmed cases from carrier i contacts at location j captured by contact tracing process
$C_{g_{ij}A}$ = number of confirmed cases from priority group i at location j captured by Adaptive Cluster Sampling,

Then,

$$R = \frac{\sum_{i=1}^{n}\sum_{j=1}^{m} C_{iJT} + \sum_{i=1}^{g}\sum_{j=1}^{m} C_{g_{ij}A}}{\sum_{j=1}^{m} C_{J}} \quad \text{----------} \quad (2)$$

Figure 14 represents recommended integrated contact tracing technique which comprises Statisticians in NCDC team. The inner circle is the focus of contact tracing by NCDC team. In this region, as the medical personnel is tracing the contact to carriers, statisticians in their midst will adopt their professional skills to handle all challenges of not at home, hard to reach, non- response due to sensitive issues, hard core, lack of knowledge of the estimated number of COVID-19 carriers and lack of appropriate strategy for sample selection.

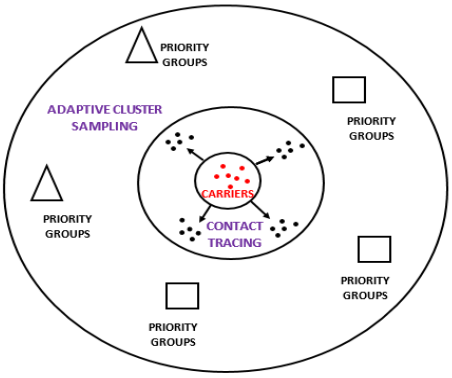


Figure 14: Contact tracing

The outer circle which, comprises of the priority groups, such as big Supper Markets, Churches, Mosques, major car park etc, will be the focus of Statisticians. Statisticians will adopt Adaptive Cluster Sampling to strategically and randomly select adaptive samples from priority groups in the vicinity of identified COVID-19 carriers. Combination of samples from contact tracing and adaptive samples would be subjected to isolation or test depending on availability of test equipment. With this process, required data for computation of R in Eq (2) would be generated and the value of R would be determined and interpreted for policy makers to monitor the spread rate of COVID-19 and for making appropriate decisions.

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Figures

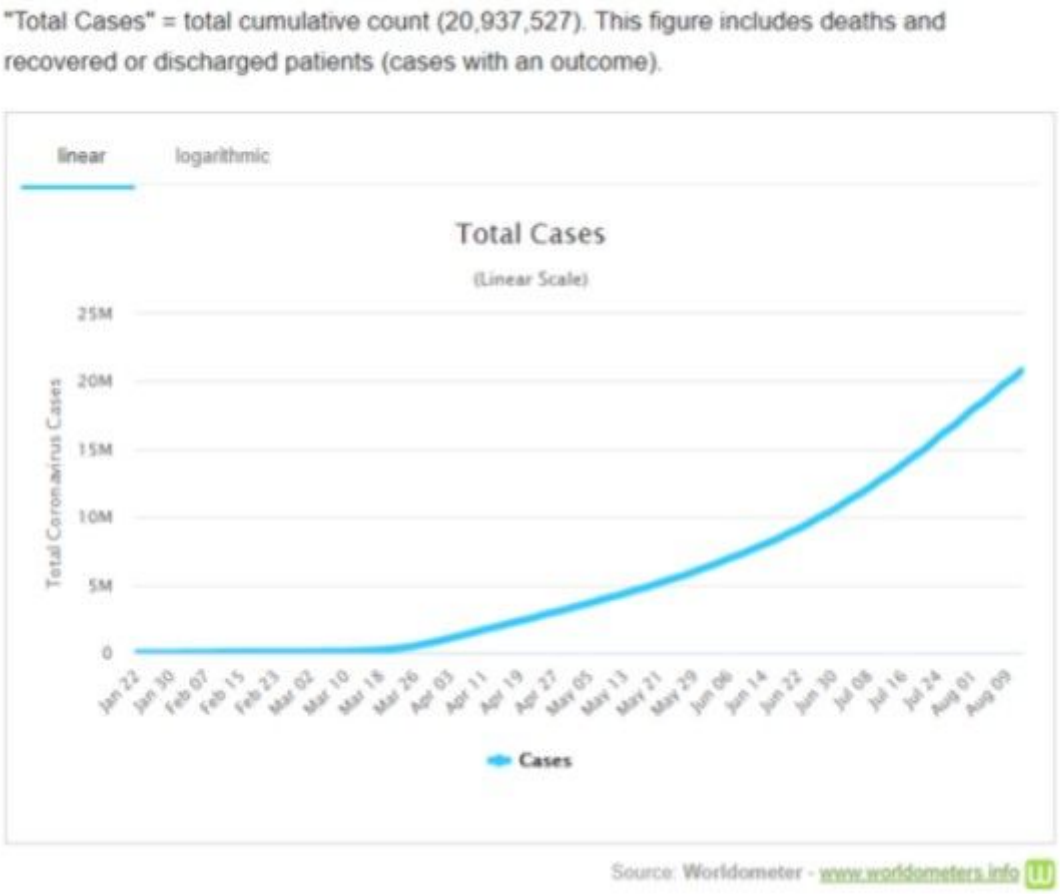


Figure 1

Total confirmed cases in the world

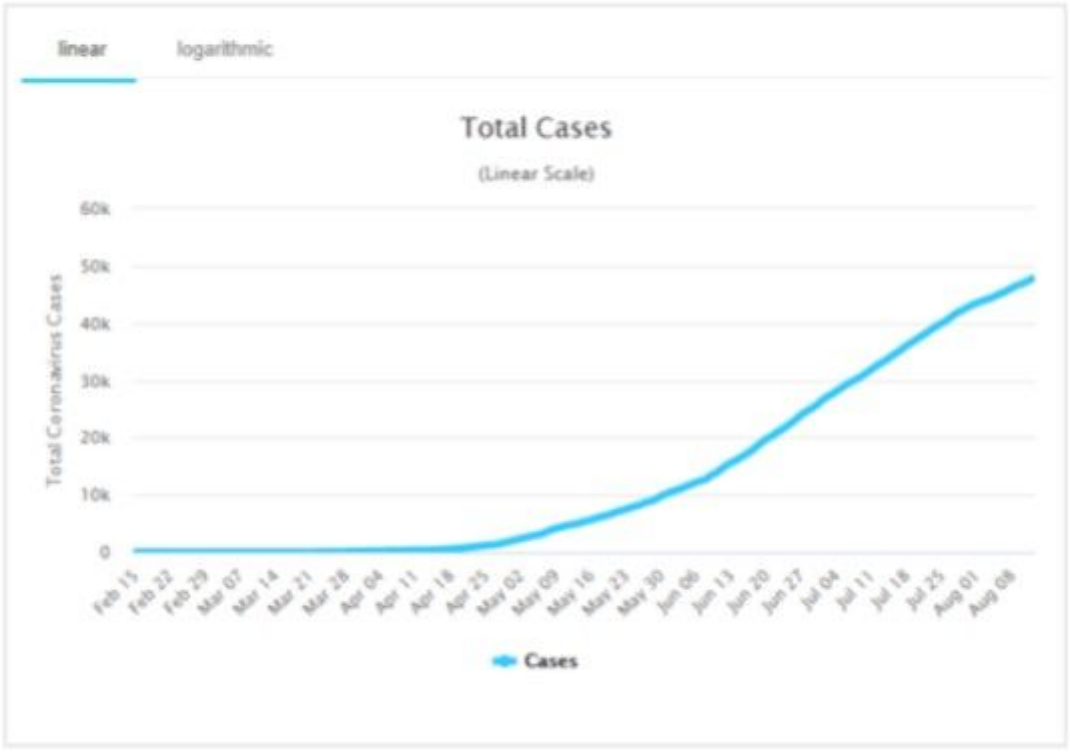


Figure 2

Total confirmed cases in Nigeria

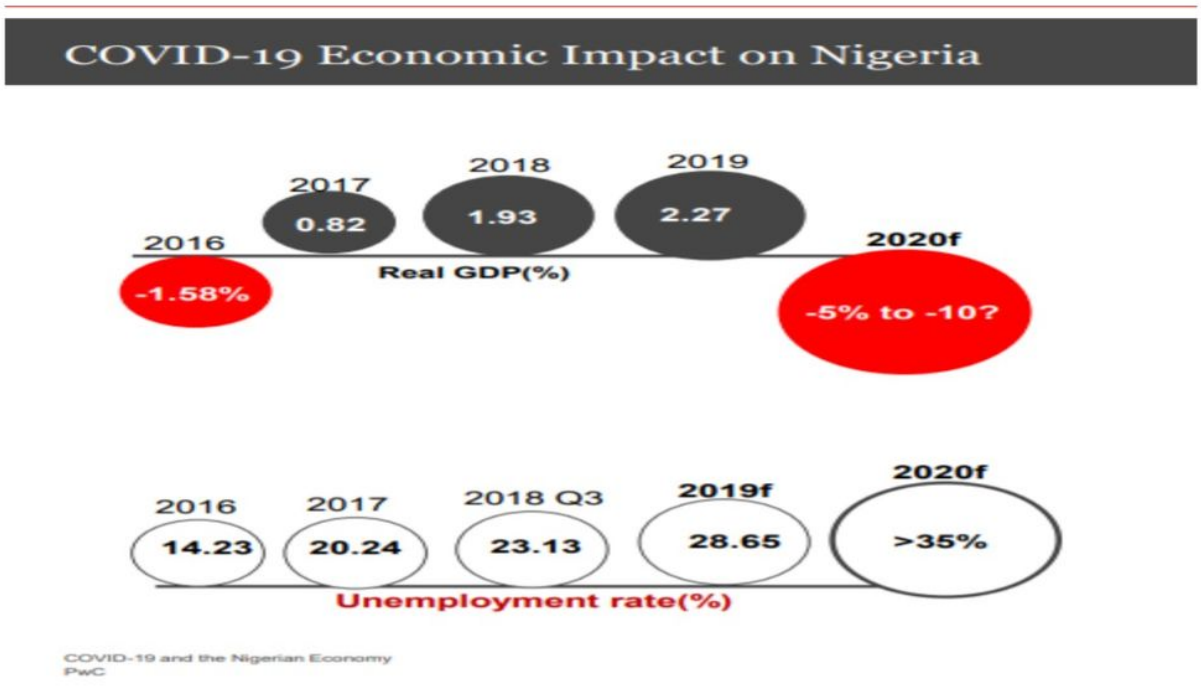


Figure 3

Graph showing economic impact of COVID-19 on Nigeria's GDP and Unemployment.

(source: investing.com)

Figure 4

Graph showing economic impact of COVID-19 on NSE

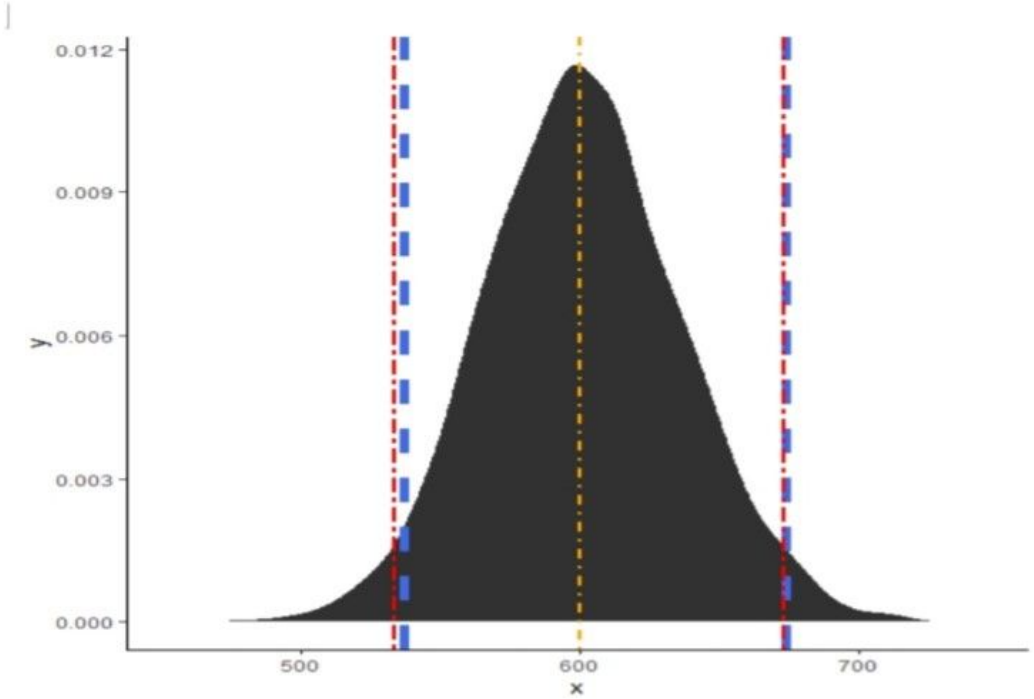


Figure 5

95% Credible Interval for Posterior Total Estimation for COVID-19 carriers

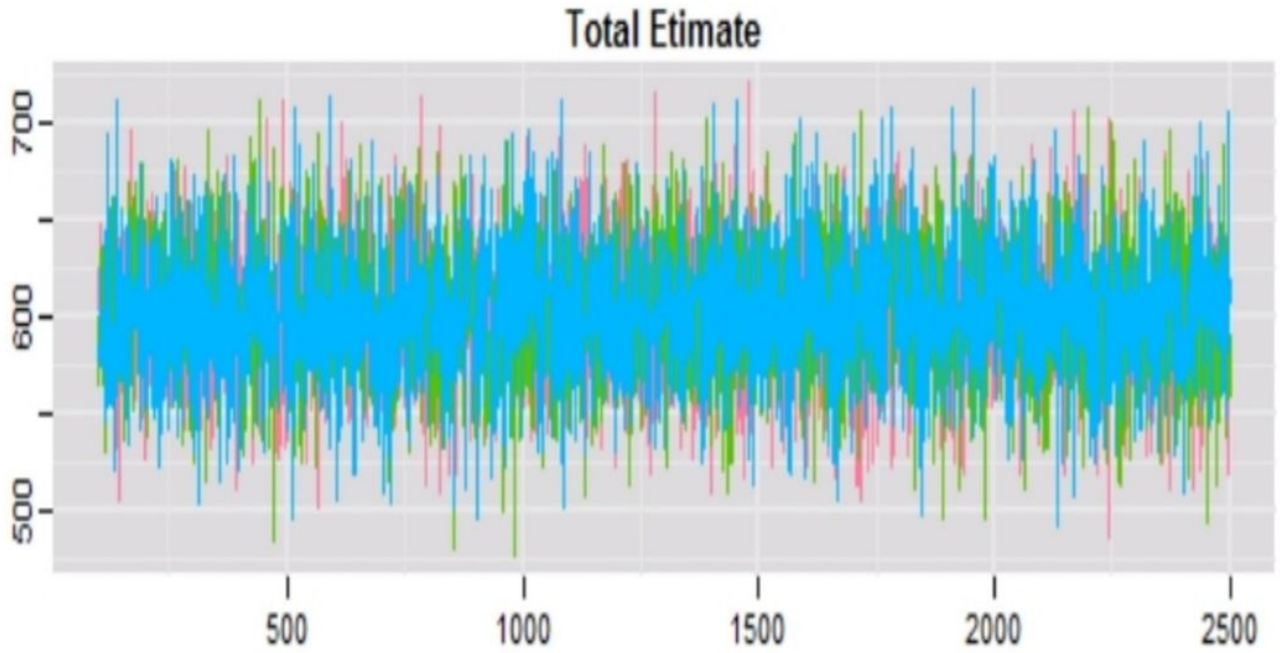


Figure 6

Trace plot

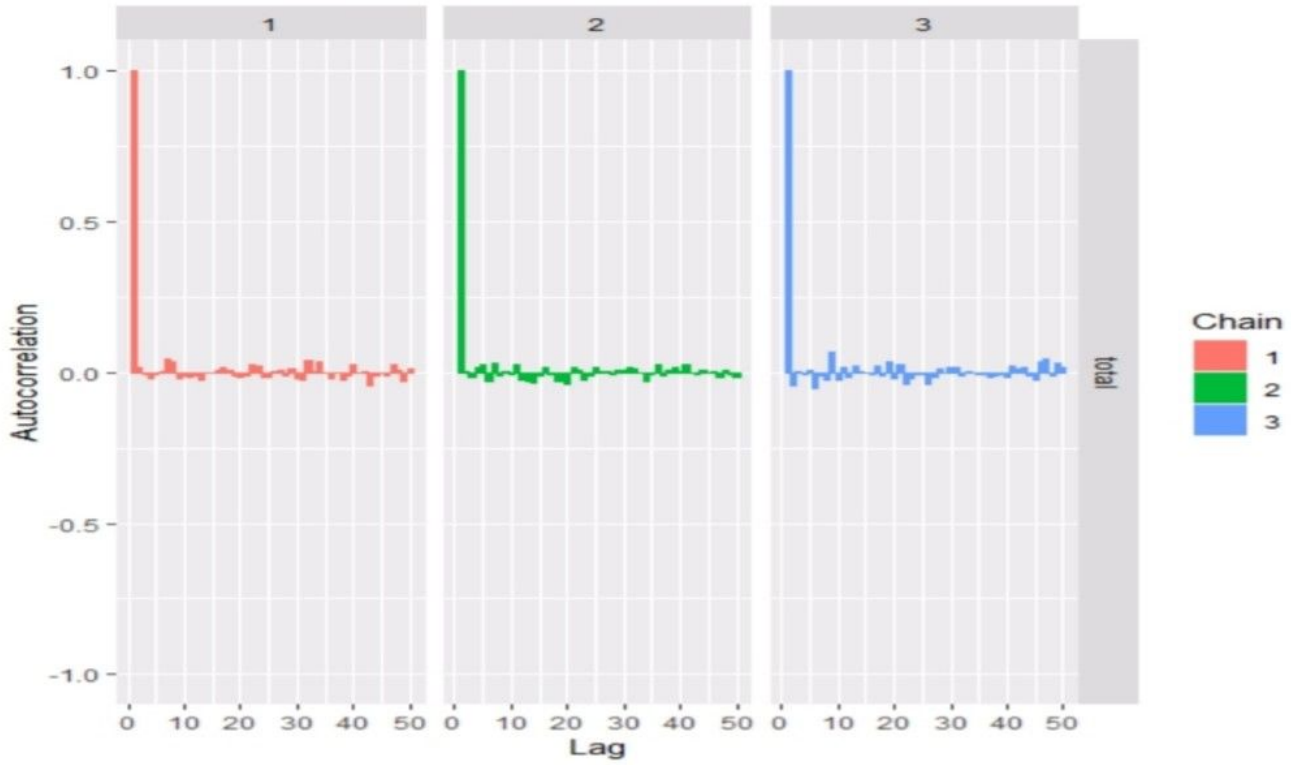


Figure 7

Autocorrelation plot

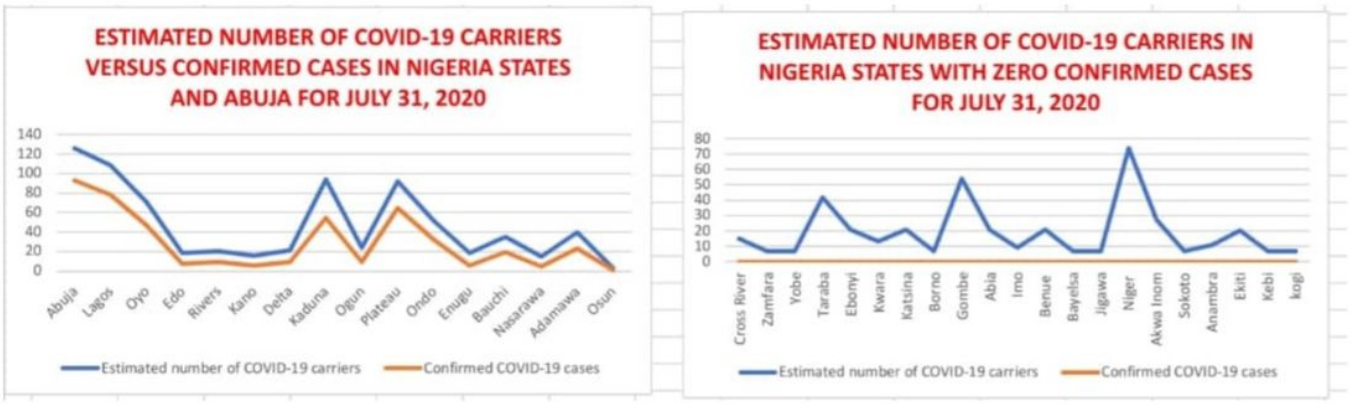


Figure 8

Estimated number of COVID-19 carriers versus confirmed cases

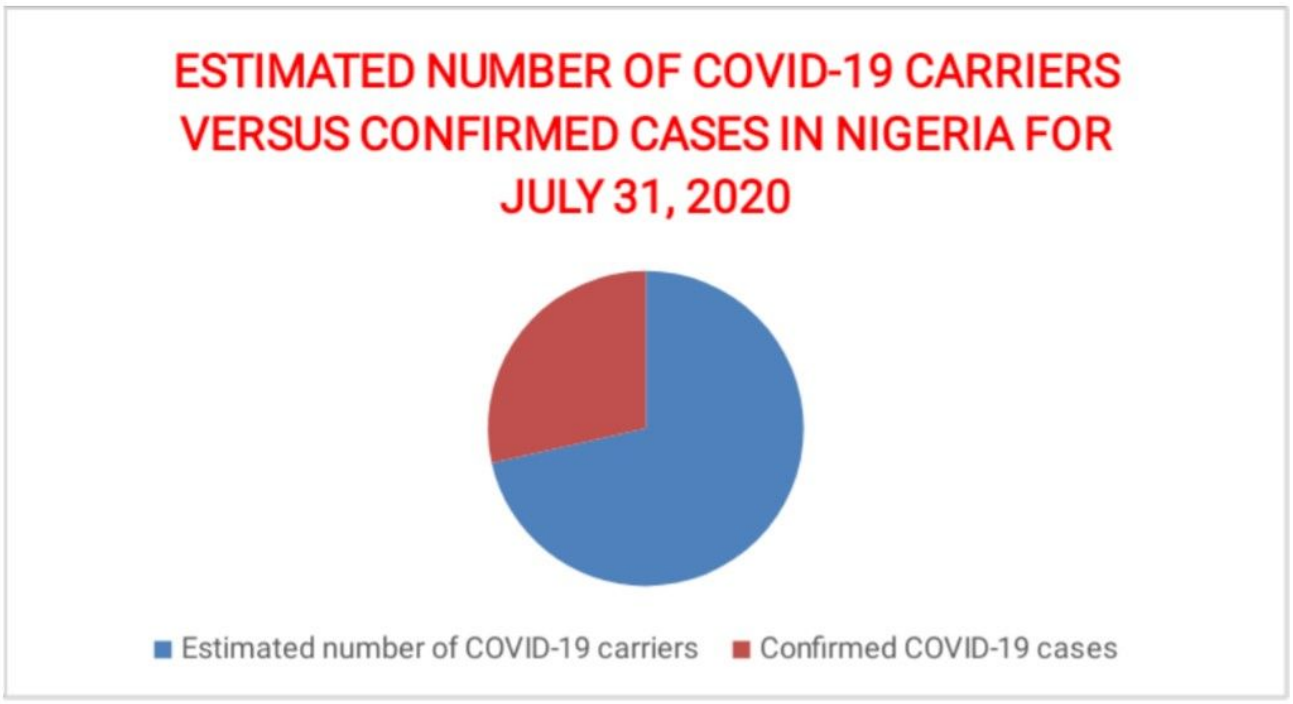


Figure 9

A pie chart showing estimated number of COVID-19 carriers versus confirmed cases in Nigeria

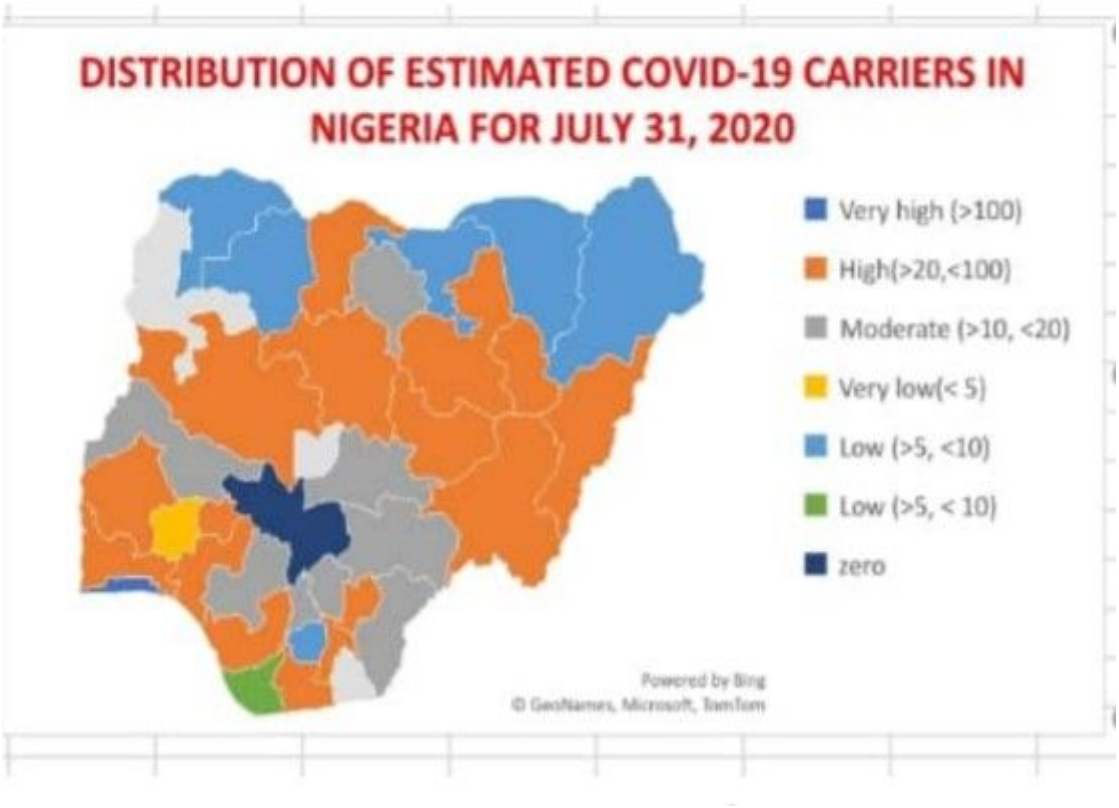


Figure 10

Distribution of Estimated COVID-19

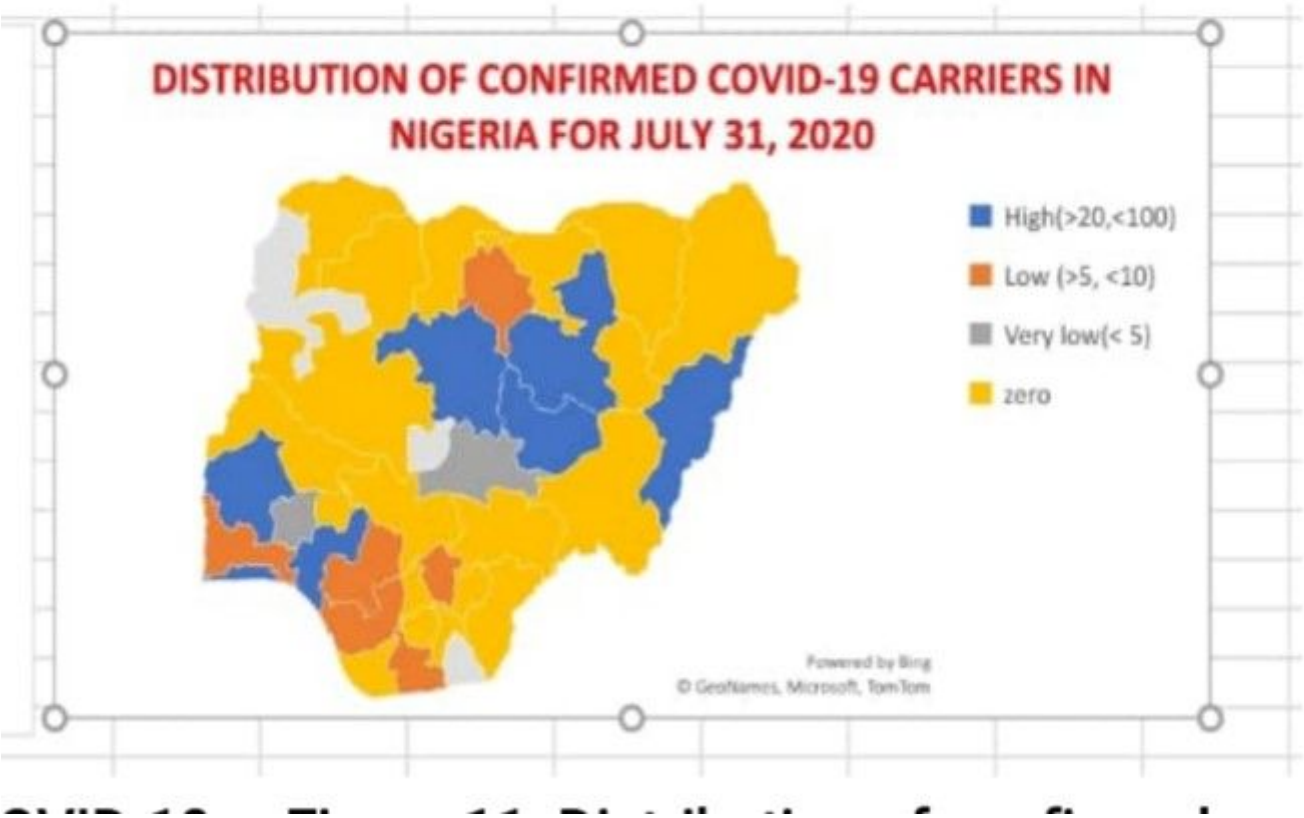
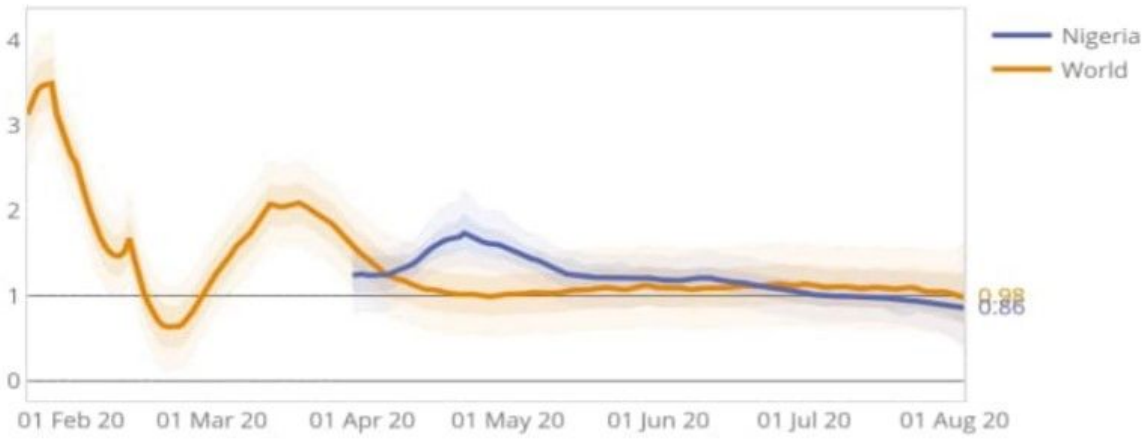


Figure 11

Distribution of confirmed COVID-19 cases



Source: **Tracking R [15]**

Figure 12

Graph showing the Reproductive Rates of COVID-19 in Nigeria versus World

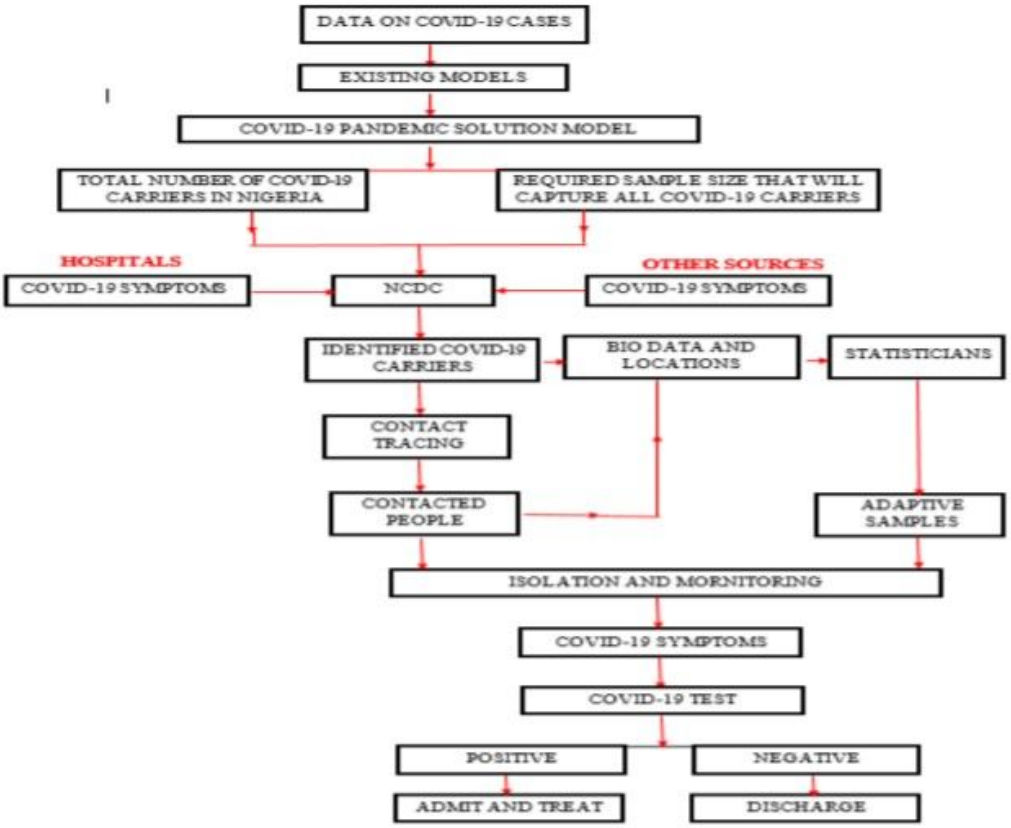


Figure 13

Flow chart for integrated contact tracing Approach

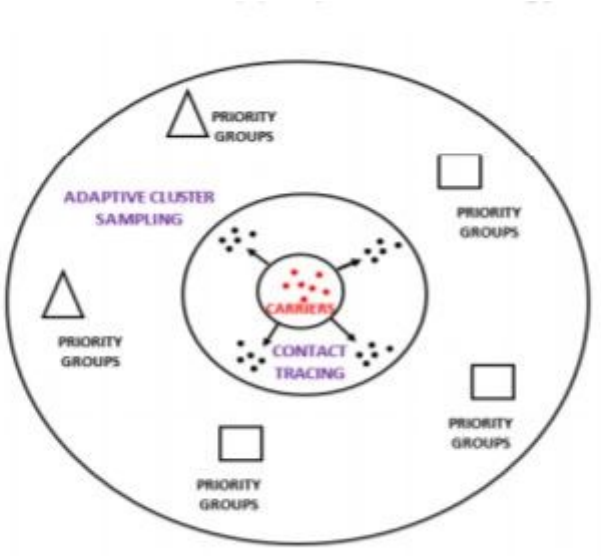


Figure 14

Contact tracing