Modelling the Spreading Pattern and Prevention Strategies of COVID-19 in Nigeria

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Abstract - It is obvious that the World right now is in the stagnant position due to COVID-19. The problem of this pandemic is its mode of transmission from person to person on daily basis. This study aims at modelling the spreading pattern of the disease in Nigeria with a view to understanding how the spread can be curbed. Secondary data collected from Nigerian Center for Disease Control (NCDC) between 29th Feb 2020 and 30th May 2020 were used. These daily data were further grouped into 14 weekly data. Parameters like number of suspected persons, the number of people quarantined and the total number of active cases were used to develop the model thus; the undetected infected people were termed as Hidden nodes (d) defined as $d_i = x_i - q_i$, where: x_i is the suspected case of period i and q_i is the number of infected people that were isolated in period i. Each undetected infected person d (hidden node) can infect t several people in a given time (day, week or month), also those infected that show symptoms will also be fished out, tested and isolated if they were positive will be recorded as q. This model has established the maximum number of days to be spent in a lockdown period, given a certain number of confirmed cases to control the spread of the disease.

Keywords: Modelling, Hidden nodes, COVID-19, NCDC, pandemic, coronavirus

I. INTRODUCTION

It is no longer hearsay that Corona Virus Disease (COVID-19), an infectious disease caused by a newly discovered coronavirus has become a global tragedy. Nigeria, as a nation, is equally actively affected by this disease. Most people infected with this pandemic usually experience mild to moderate respiratory illness with the likelihood of chronic illness, which in most cases results in death.

The origin of the COVID-19 was traced to Wuhan, China on **31 Dec 2019,** where a novel coronavirus was first identified globally. However, the outbreak of the virus was recorded at the instance of the first Disease Outbreak News on **5 January 2020.** This was followed by an official confirmation of the first COVID-19 outside China recorded in Thailand on 13 January 2020.

This disease is termed the pandemic being a global disaster. The spread of COVID-19 has cut across many African countries as well with records of death and survival. The spread was confirmed in Africa on 14 February 2020. Among many other African countries, Nigeria confirmed her first case on 29 February 2020. This was mainly an initial experience of the disease in Nigeria, occasioned through importation by the arrival of infected persons, who returned to Nigeria. Lagos, being a hub of commercial and administrative activities of the country was first put on red alert of COVID-19, followed by Ogun State, the neighboring State. These two locations are the initial spreading point of the pandemic in the country. Worst still, the effects of the COVID-19 have paralyzed every public engagement, where all socio-economic activities have been put on hold, except essential services in both private and public sectors.

Meanwhile, COVID-19 is not the first recorded pandemic in Nigeria. Ebola pandemic was another recent contagious disease in the history of the country. It was as a result of the 2014 Ebola epidemic that Nigeria realized the need for a public health institute to be at alert in combating infectious disease. Hence, the creation of the National Centre for Disease Control (NCDC) in 2018. So far so good, Nigeria has improved on the structure it had during the 2014 Ebola outbreak to ensure that the incidence management system responds rapidly to public health emergencies not just at the national level but also at the state level.

As generally applied, the Nigerian Government has adopted several measures to combat the spread of the disease. The NCDC has been fully saddled with the responsibility to identify, monitor, and control all issues

around the plague of coronavirus; especially, devising the best way to prevent and slow down its transmission. This agency has, however, put up measures for daily sensitization of the public on the best way to protect themselves and others from infection by the washing of hands or using an alcohol-based rub frequently and not touching the face. Affected persons are regularly separated into an isolated center, where adequate monitoring is being given.

It must be noted that the spreading pattern of the COVID-19 across the Nigeria States is presently alarming, despite the interstate boundary lockdown at the national level, and the strategic total lockdown imposed on Lagos, Ogun, and Abuja by the government. The spreading mode of the disease is still worrisome. The observations during the lockdown and relaxed lockdown periods seemed not to return a positive response.

Presently, the observed figures of cases of COVID-19 in Nigeria is dwindling with the overall total of infected persons above 5000. More so, no literature is establishing the spreading pattern of the disease among the Nigerian States. This study, however, focused on modeling and predicting the spreading pattern of COVID-19 cases in Nigeria. The study stands to help in national policy formulation as relates to monitoring and controlling spreads of similar infectious disease in the future.

History of COVID-19 in Nigeria
On 29th February 2020, a confirmed case of COVID-19 was reported and one patient was isolated by NCDC, the patient has been in contact with several people of the two states which are Lagos and Ogun. Lagos state was his port of arrival while Ogun state is his destination. NCDC workers in collaboration with the government of the two states were able to detect his contact and they were able to gather about 126 contacts follow up. 115 out of 126 were isolated due to symptoms shown and the remaining were released. These 111remaining patients might be possible carriers of the virus among them but they were released as they do not show any symptoms of the virus. Thus, these carriers are called Hidden nodes (undetected infected people). From 29th February to 5th March 2020, Nigeria records only one hidden node (undetected infected person) in these two states (Lagos and Ogun). A quick action (such as lockdown) should have been taken by the government to curve the spread of the disease to other parts of the country. On 6th March 2020, another suspected case was reported from 3 different states (Kano, Edo, and Abuja) making the number of states to 5 with a total of 26 suspected cases.

On 12th – 13th march, 2020 another state also reported a total of 17 suspected cases, the states were Rivers and Yobe making the suspect list 43 cumulatively including the previous records, with a total of 2 confirmed cases from Ogun state. We have already known that every state that has reported a suspected case, then, there might be an undetected infected people (Hidden active node). Thus, on

the 17th of March, 2020 Lagos state reported its first confirmed case of covid19, making the total of active cases to 3 for the whole nation, and the new total suspect list to 55 including Enugu state that reported 1 suspect. The following day that is 18th march, 2020 Lagos state reported another 4 confirmed cases making it 5 active cases for the state and 7 for the whole nation including two from Ogun. On 19th March 2020, the number of confirmed cases was 12 for the whole nation in which Lagos state recorded 9 patients, Ogun 2 and Ekiti 1, while the suspected number of patients has risen to 90 across the nation.

On 21st of March 2020, FCT Abuja joined the list of states with confirming cases of COVID 19 in which it recorded 3 patients and Lagos state also its cases reached 19 with Ogun state 3 and Ekiti state 1 confirmed patient, making the total of 25 for the whole nation.

On 22nd- 23rd march the total number of COVID-19 patients in Nigeria reached 36, whereas 6 from FCT, 25 from Lagos state, 2 from Ogun state, 1 from Edo state, 1 from Ekiti, and 1 from Oyo state and the total suspected cases were 158 people. Just between 24th March and 26th March NCDC reported the confirmed cases of COVID-19 patients have reached 65 with suspected cases of 847. subsequently, from 28th- 30th March the tally of Nigerians Covid-19 patients was 131 across the Nation, Lagos having highest number with 85 confirmed cases followed by FCT 25, Oyo 8, Kaduna 3, Ogun 3, Bauchi 2, Edo 2, Enugu 2, Osun 2, Benue 1, Ekiti 1, and Rivers also 1.

Nigeria is among countries with many Ethnic groups, but the main dominant ones are Hausa, Yoruba, and Igbo, and also it consists of subparts in are Northern part and Southern part, where River Niger and River Benue serves as the demarcation for the two parts. From the above diagram and the above discussion, it is easy to understand that up to 30th March 2020, there are only 5 confirmed cases in the northern part of the country out of 131 whereas all the remaining patients are in the southern part of the country, but suspected cases have already been recorded since 6th of march in Kano, and based on the theory of our propose model, if a state has a suspected case there might be a possible undetected infected person(s) called Hidden nodes, and assuming these Hidden nodes were performing their day to day activities within Kano state, contacting people and spreading the virus without their consent.

On 30th March around 10:00 pm, a lockdown was imposed instead on the entire Nation, but it was on the most infected states that are Lagos, Federal Capital Territory (FCT), and Ogun to be able to curve the spread of the disease. so, the rate of spreading the virus was reduced in the lockdown areas but in the other parts of the country where there is no lockdown the rate of infecting the virus is going up.

Also from the above explanation, it's obvious that up to 10th April there are only 72 confirmed cases of COVID 19 in the northern part of the country in which FCT having 56, Bauchi 6, Kaduna 6, and Katsina 4, but FCT was in the state of lockdown so, the infection rate in the state was already minimized instead of locking the whole nation but the federal government of Nigeria chose to lock only the states with the highest number of cases which fall in the southern part, leaving the other parts of northern Nigeria

not in lockdown which as the result much more Vulnerable to the spread of the virus.

COVID-19 cases across the affected States of Nigeria

The total number of cases for each of the affected State in Nigeria from 29, February, 2020 to 30, May, 2020 were presented in Table 1. The major indices for monitoring the disease include, Total Confirmed Cases (TCC), Active Cases (AC), Discharged Cases (DC) and Deaths (D).

Table 1: Distribution of Covid-19 cases across the affected states of the federation

	States	Total confirmed cases	Active Cases	Discharged Cases	Deaths
1	Lagos	4755	3939	766	50
2	Kano	951	708	200	43
3	FCT	616	426	173	17
4	Katsina	364	282	68	14
5	Edo	284	202	69	13
6	Oyo	280	177	97	6
7	Borno	271	78	167	26
8	Jigawa	270	156	109	5
9	Ogun	259	104	146	9
10	Kaduna	244	80	157	7
11	Bauchi	236	15	214	7
12	Rivers	204	139	52	13
13	Gombe	156	30	122	4
14	Sokoto	116	6	96	14
15	Plateau	104	49	53	2
16	Kwara	87	49	37	1
17	Delta	80	57	16	7
18	Zamfara	76	0	71	5
19	Nasarawa	62	42	18	2
20	Yobe	52	21	24	7
21	Akwa Ibom	45	29	14	2
22	Osun	45	6	35	4
23	Ebonyi	40	32	8	0
24	Adamawa	38	14	20	4
25	Imo	34	20	14	0
26	Kebbi	33	0	29	4
27	Niger	30	20	9	1
28	Ondo	25	3	20	2
29	Ekiti	20	2	16	2
30	Taraba	18	8	10	0
31	Enugu	18	6	12	0
32	Bayelsa	12	4	7	1
33	Anambra	11	7	3	1
34	Abia	10	7	3	0
35	Benue	7	6	1	0
36	Kogi	2	2	0	0

Source: NCDC, 2020

The cases presented shows that all the States in Nigeria are affected by the spread of the disease. However, it was generally observed that Lagos state has been the leading point of the pandemic in Nigeria. This is because Lagos State is the most affected state with a total of 4755 followed by Kano state with 951 cases while Kogi state has the least number of 2 cases. Cross Rivers state is the only state yet to report a case as at 30, May, 2020.

Further, Table 1 also shows the active cases recorded by each affected states of Nigeria as at 30, May, 2020. Lagos state has the highest number of active cases with 3939

cases followed by Kano with 708 cases while Kogi state has the lowest number of active cases with only 2 active cases. However, Kebbi and Zamfara States had zero active case. This means, there was no corona virus in these two states as at 30, May, 2020.

COVID-19 cases across the six Geopolitical Zones in Nigeria

The overall spread of the disease is presented in Figure 1 based on identified cases with Total Confirmed cases, Active cases, Discharged cases and Death cases across the six Geopolitical zones in Nigeria. It could be deduced

from Figure 1 that South West zone has the highest number of Covid-19 cases followed by North West zone while South East zone has the lowest number of Covid-19 cases. It was equally observed that the number of Active, discharged and death cases increase as the Total cases increases.
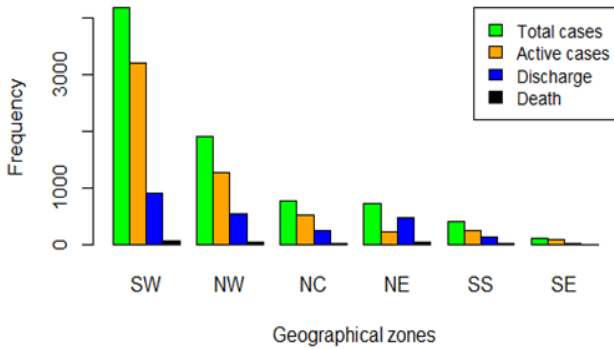

Figure 1: Distribution of Covid-19 cases across the six Geopolitical zones

Recovered cases of COVID-19

The distribution of the number of recovered cases for each of the affected states in Nigeria was presented in Figure 2. It was generally observed that Lagos State has the highest number of recovered patient having reported 766 followed by Kano State with a reported recovery of 200 patients, while Kogi State is yet to report recovery cases as of 30, May, 2020.
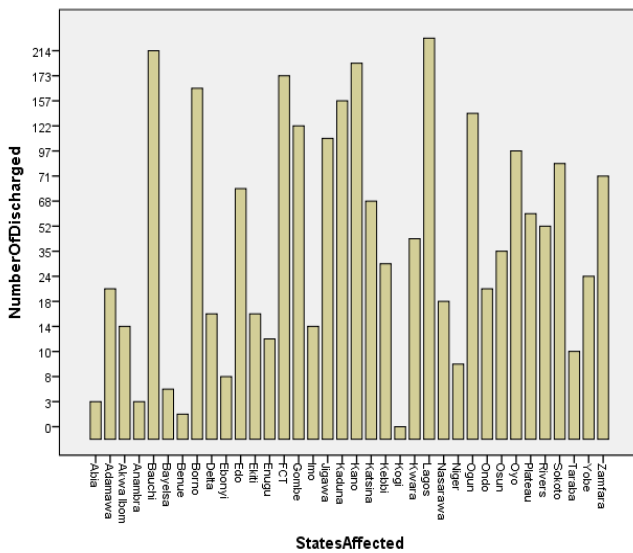

Figure 2: Recovered cases for each of the affected states in Nigeria

Death cases of COVID-19 between February 29th and May 30th

Figure 3, shows the distribution of the number of reported death in each of the affected states of the federation. It was observed that Lagos state has reported more death than any other state with a total of 50 reported death cases followed by Kano with 43 death cases while Ebonyi, Imo, Taraba,

Enugu, Abia, Benue and Kogi States have not reported any death cases as of 30, May, 2020.
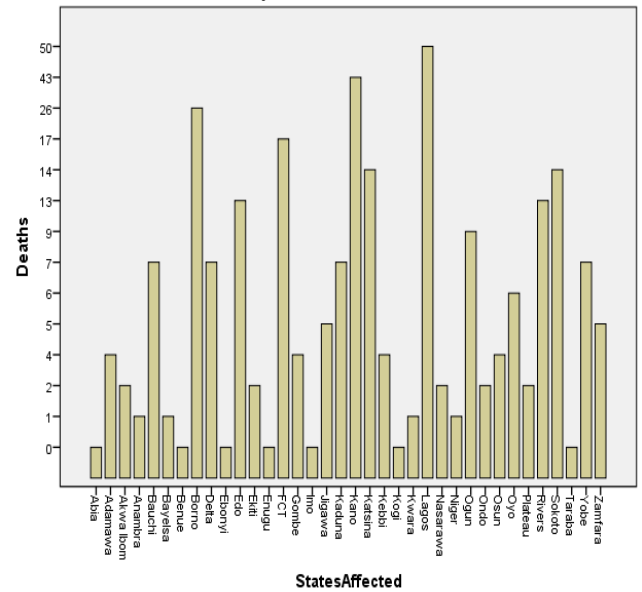

Figure 3: Distribution of Death cases in each of the affected states in Nigeria

II. LITERATURE REVIEW

According to research conducted on the early dynamics of transmission and control of COVID-19. He used four datasets from inside and outside of Wuhan combined with a mathematical stochastic model of severe SARS-CoV-2 transmission, and predict the variation of transmission between December 2019 and February 2020 in Wuhan. The predicted variation values give the probability that the other areas might encounter an outbreak due to newly introduced cases [1]. Based on research conducted by, proposed a new model for the spread of COVID-19; where he used three countries India, USA, and Italy as his study case and tried to predict the new cases of each country to help fight the pandemic. His result turns out to be that the USA and Italy are both in the third stage whereas India is in the second stage and also he discussed the effect of Lockdown in eradicating the spread of COVID-19 [2]. An infectious disease dynamic and time series model was developed to estimate the trend of COVID-19 transmission based on its transmission mechanism and the control measures. The result shows that the forecasted number of infected people in china mainland can reach 36,343 within one week and the total cases will have reached up to 87,701 within one month [3].

The statistical model for the spread of COVID-19 within a cluster was proposed. The research study finds out that the chance of a person getting infected with the disease is high if he is closed to the source and the chance of more people getting infected will be less if measures like lockdown and social distancing are imposed [4]. During the pandemic, a lot of researchers have focused on studying the spread of diseases for different cities and countries. For example, a researcher applied a statistical model on data obtain from

NCDC to study the spread of COVID-19 in Nigeria. A forecast has been made using (ARIMA) model and the result showed an increasing tendency from day-to-day [5]. Using a practical scenario in India help to discover that lockdown and isolation play a vital role in curbing the spread of COVID-19 and also a proposed mathematical model was developed based on the effect of lockdown and isolation to predict the total infected cases or new cases. The research also considered a tree-based model in which it takes into account the knowledge of hidden nodes (symptoms not shown, hidden travel history, etc.) and concludes that lockdown and isolation are good techniques of reducing the rate of infection of COVID-19 [6].

It was found out that temperature plays a good role in the pathogen incubation period in Covid-19, by the use of correlation among the three factors (infections, deaths, and recoveries) in which the k-means clustering approach was applied to the data [7]. A study conducted titled "Covid-19 Cases and Recovery Previsions with Deep Learning Nested Sequence Prediction Models with Long Short-Term Memory (LSTM) Architecture" used 12 variable data based on 79 countries affected with Covid-19 to build a Deep Learning nested sequence-based model with Long Short-Term Memory (LSTM) [8].

In this literature, it is evident that researchers are making all-round efforts in studying the spreading pattern of COVID-19 using different countries. This current study focuses on considering the same trend of spreading patterns of this disease in Nigeria.

III. MATERIALS AND METHODS

This study is aimed at modelling and predicting spreading pattern of COVID-19 Cases in Nigeria. Secondary data source was used in gathering data for this study. Data on daily confirmed cases, discharged and deaths were sourced from the National Centre for Disease Control (NCDC) in Nigeria in year 2020. This study assumed that the Covid-19 patient spread the disease to t number of people later testing and tracing of suspected people began and the confirmed cases that were found and isolated denoted as q, this will minimize the spread to other people. But there might be possible contacts with the infected person, which the NCDC could not able to trace and remove from the society. This undetected infected people were termed as Hidden nodes (d). Defined as $d_i = x_i - q_i$, where: x_i is the suspected case of period i and q_i is the number of infected people that were isolated in period i. Each undetected infected person d (hidden node) can infect t several people in a given time this time can be (day, week or month), also those infected that show symptoms will also be fished out, tested and isolated if they were positive as q. This process keeps on going like this repeatedly, hidden active nodes keep infecting people and also those that show symptoms will be tested and get isolated if found positive while those that didn't continue to stay in the society irrespective of their condition, these people

increase the number of hidden nodes (undetected infected people). Due to nature of the virus some people show no symptoms or hide their traveled history and also they might be a carrier of this disease, such kind of people were termed as c that is constant number which increases the number of Hidden nodes (undetected infected people) by unit time. The number of hidden nodes is increased by $d + c, d + 2c, d + 3c$ ... subsequently in a unit time. This repetition gives the total number of cases as:

$$\beta_{cases} = 1 + t + \{dt + (d+c)t + (d+2c)t + (d+3c)t + \ldots\} \qquad (1)$$

With the exception of the first two terms, equation (1) is an arithmetic progression with common difference of ct. Hence the sum of nth term of the series in (1) becomes:

$$\beta_{cases} = 1 + t + \frac{(N-2)[2dt + (N-3)Ct]}{2} \qquad (2)$$

Where: $x_i = number\ of\ suspect$

$\quad q_i = number\ of\ infected\ people\ that\ were$
$\quad\quad\quad isolated\ in\ period\ i$

$d_i = number\ of\ hidden\ nodes$
$N = Required\ number\ of\ weeks\ to\ be\ in\ lockdown$

$\beta_{cases} = total\ number\ of\ confirmed\ cases$

This gives an estimate of the total number of cases in the country. This means that the total number of cases increases with the increase in d (the Hidden node) and N (the period of lockdown).

The spread of COVID-19 was examined as part of the researchers' efforts to ascertain its spreading pattern in Nigeria based on data collected from Nigerian Center for Disease Control (NCDC) daily reports, between 29th February, 2020 and 30th May, 2020. However, these daily data were merged on weekly basis, with the total of 14 weeks.

The cumulative of covid-19 cases for the 14 weeks indicates that the pandemic is at its 14th week in the Nation. Whereas, the Betas indicates cumulative cases that were recorded daily by NCDC. As at the beginning of the pandemic, many people have been a suspect of the disease, x_i is telling us the number of suspects we have in each week, q_i is the no of active cases or infected people that were isolated in each week, d_i is the number of Hidden nodes of each week. As already stated in the research methods, d_i was obtained by subtracting the number of infected from the number of suspected. Using these parameters in our model given by (2)

The required days needed to be in lockdown so that the total cases become zero so as to stop the spread of the virus by these hidden nodes were calculated.

IV. RESULT AND DISCUSSION

Table 2: Weekly distribution of Covid-19 cases in Nigeria

Period(Weeks)	x_i	q_i	$d_i = x_i - q_i$	N(weeks)	β_{cases}
29th Feb (1)	30	1	29	0.6	1
7th March(2)	53	1	52	1	1
14th March(3)	101	2	99	1.6	2
21st March(4)	234	23	211	2	25
26th March(5)	1080	61	1019	2.3	65
30th March(6)	2231	128	2103	3	139
7th April (7)	4071	204	3867	3.6	254
14th April (8)	5975	263	5712	4	373
21st April (9)	12519	560	11959	4.6	782
28th April(10)	24519	1233	23286	5.3	1532
5th May (11)	47207	2371	44836	5.9	2950
12th May (12)	76599	3670	72929	6.6	4787
21st May (13)	112263	4898	107365	7	7016
30th May (14)	157687	6726	150961	7.3	9855

Considering Table 2, it was obvious that the first week was noted with only 30 suspected cases, 1 infected person, 29 hidden nodes, and the total case was 1. Putting these values into the model, we got N=0.6. This simply connotes that as of 29th Feb 2020 only total lockdown of 4 days was enough to stop the spread of the virus across the nation. However, no lockdown was imposed, which necessitate an increase in the hidden nodes and the continuous spreading of the virus.

Also, the input of data for the subsequent week based on the values of cases into the model depicts N=1. The model suggests that a 1week lockdown was sufficient to stop the spread of the disease at that time. In week three, also happened to be not in the state of lockdown even though the number of suspected cases has passed 100. Based on the available data the model predicted a lockdown of 1 week 4 days was sufficient to tackle the virus spread. Likewise, in week four (4) and five (5), there were 211 and 1019 Hidden nodes respectively and the total confirmed cases have reached 25 and 65 as at the end of the fourth and fifth week respectively. Total lockdown of 2 weeks and 2weeks 2 days by the fourth and fifth weeks could have halted the spread of the disease. In the 6th week, the Federal Government of Nigeria imposed a lockdown rule on some of the states of the federation with an effort at reducing the spread of the virus. However, new cases emerged from those states that were on lockdown, with total confirmed cases of 139. The suspected cases at this time were 2231 and the Hidden node number was 2103. With this, the model predicted that a total lockdown of 3 weeks was enough to control the spread of the pandemic provided that all the necessary measures, good health care facilities, awareness policy are given optimum concern.

The number of Covid-19 cases keeps on increasing day by day despite the lockdown rule imposed by the Federal Government on the most affected states. As of 30, May 2020 the total number of Covid-19 patients was 9855, the number of suspected patients was 157687. Based on these parameters, the model suggests that the number of days

required to be in a state of lockdown so that the total case becomes zero is 51 days. The increase in the number of reported cases occurred due to the increase in the number of Hidden nodes. It is adequate to note that most people who are already infected with the disease keep on mingling with people, which as a result, numbers of the infected people keep increasing. A total lockdown rule should be imposed by the federal government to curb the spread of the virus. This is in support of [9] who used practical scenarios in India and discovered that lockdown and isolation play a vital role in curbing the spread of COVID-19. An increase in the number of cases is observed in some part with no lockdown rule as some people who might be infected tends to travel from areas observing total lockdown to the areas with easing lockdown or no lockdown rule. This study is in agreement with the work of [7], who proposed a statistical model for the spread of COVID-19 within a cluster. He finds out that the chance of a person getting infected with the disease is high if he is closed to the source and the chance of more people getting infected will be less if measures like lockdown and social distancing are imposed.

V. CONCLUSION

This study aims at modeling the spreading pattern of COVID-19 in Nigeria to understand how the spread can be curbed. Results from table (2), shows that an increase in the number of cases is observed in the country when there is no lockdown rule. This may be because some people who might be infected tend to travel from areas observing total lockdown to the areas with easing lockdown or no lockdown rule. This study has developed a model that suggested maximum number of days to be spent in a lockdown period, given a certain number of confirmed cases to control the spread of the disease in the country.

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