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A Predictive Model for Confirmed Cases of COVID-19 in Nigeria

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ABSTRACT

Background and Objectives: COVID-19 pandemic globally remains a major problem affecting every aspect of human endeavours with Nigeria, not an exception. The number of confirmed cases of COVID-19 in Nigeria as at 8th May, 2020 was 3,912 this study builds an ARIMA model for forecasting the confirmed cases of COVID-19 in Nigeria based on Box-Jenkins methodology. **Materials and Method:** Data on confirmed cases of COVID-19 in Nigeria were obtained from the Nigeria Centre for Disease Control (NCDC). The stationarity of the data was determined using the Augmented Dickey-Fuller (ADF) test and stationarity was achieved after taking the natural log transformation and first differencing. Based on Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) plots, three ARIMA models were identified [ARIMA (2,1,0), ARIMA (0,1,2) and ARIMA (2,1,2)]. The fitness performance of these models was compared using R^2 and normalized Bayesian Information Criteria while the forecasting accuracy was compared using Root Mean Square Error (RMSE). **Results:** Results showed that among the ARIMA models, the ARIMA (2,1,0) outperformed other proposed models both in terms of fitness and forecasting accuracy and hence the ARIMA (2,1,0) was recommended for forecasting confirmed cases of COVID-19 in Nigeria. Hence, the ARIMA (2,1,0) model was then used to project the confirmed cases of COVID-19 in Nigeria for the next two weeks (9/05/2020 to 2/05/2020). The forecasts showed an upsurge in the confirmed cases of COVID-19 in Nigeria if the current relaxation of the lockdown continues. **Conclusion:** This finding has implication for the need for the Nigeria government to ensure that COVID-19 preventive measures such as social distancing, use of face mask, regular hand washing with soap and water or alcohol-based sanitizer as well as the restriction of movement are sustained to possibly hurt these projected increase in the confirmed cases of COVID-19 in Nigeria in order to prevent the collapse of health systems.

Keywords: COVID-19, Pandemic, ARIMA, Box-Jenkin, forecasting, Root Mean Square Error, Autocorrelation Function, Partial Autocorrelation Function. RMSE, ACF, PACF.

1 Introduction

The world-renowned pandemic, Corona Virus also commonly referred to as COVID-19 started at the end of December 2019 when the world was about to usher in a New Year in Wuhan, Hebei Province, China[1]. The global pandemic started when multiple unexplained cases of pneumonia were reported

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in the area. It was discovered that there is a severed human to human transmission and the cause of this was unraveled. The epidemiological finding showed that this was caused by a novel Corona Virus. By early 2020, about 59 cases of COVID-19 were reported in Wuhan[1]. After this pandemic was confirmed in Wuhan, China, the pandemic has spread to other countries of the world[2]. At least 146 countries have been infected with the virus with more than 164,000 people with more than 6400 deaths recorded[3]. Thereafter, the World Health Organization (WHO) formally declared COVID-19 a pandemic, named the virus as novel Corona (nCOV-19) or COVID-19 and the incubation period of the virus was 14 days[4] As at 4 May, 2020, more than 3.5 million have been confirmed in 187 countries and regions and has resulted to more than 248,000 deaths while more than 1.13 million people have recovered[5]. Just two months later, daily reports of outbreaks of waxing and waning infection and mortality rates continue to heighten anxiety, cause pain, and challenge the contours of our collective social and economic future. In this unprecedented reality, humans are witnessing the beginnings of a dramatic restructuring of the social and economic order, the emergence of a new era that humans consider the "next normal." The global humanitarian and economic crisis of COVID-19 has forced individuals and government to rapidly change how humans live and work. Many aspects of business and life are challenged; in some cases, the next normal may look very different as new ways of working are advance into the future.

The first confirmed case of COVID-19 was reported in Nigeria by the Nigeria Centre for Disease Control on 27 February 2020. This first case was an Italian citizen who works in Nigeria and returned from Milan, Italy to Lagos, Nigeria on the 25th of February; 2020. The first index case was confirmed by the Virology Laboratory of the Lagos University Teaching Hospital (LUTH), Lagos. This Laboratory is part of the Laboratory Network of the Nigeria Centre for Disease Control (NCDC). As at 8 May, 2020, the total confirmed cases of COVID-19 in Nigeria was put at 3,912[5] while in India, the total of 10,453 were confirmed as at 13, April 2020[5]. Though, the novel coronavirus disease, COVID-19, has not progressed in low and middle income countries as predicted. Meanwhile, the total confirmed cases of the virus in other countries were as follows: in Iran, it was 97,424 cases as at May 04, 2020[6], 124,633 cases in Italy between February 20, 2020 and April 4, 2020 with the highest cases of infection reported in US and abrupt rising in other countries like Spain, Italy, France and Germany[3]. Compared to other African countries, confirmed cases of COVID-19 in Nigeria is lower than that of South Africa with 8,895 cases as at 8 May, 2020 and higher than that of Ghana and Kenya with 4,012 cases and 621 cases respectively[3]. Based on this statistics, Nigeria is not the worst hit in Africa as far the issue of COVID-19 pandemic is concerned.

After the announcement of this first case of COVID-19, one of the giant steps taken by the NCDC was the activation of the National Emergency Operation Centre. Several policies were formulated to curtail the spread of the disease in Nigeria which include hand washing, use of sanitizer, social distancing, markets were closed and any forms of social and religious gatherings including churches and mosques were prohibited[8,9]. The total lockdown was announced by the federal government of Nigeria in Ogun state, Lagos state, and Federal Capital Territory. Thereafter, many state governors declared total lockdown. But despite these efforts, there has been an upsurge in the confirmed cases of COVID-19 in Nigeria and at present, the future trend of this pandemic in Nigeria seems to be unknown. Precisely, between 27th February 2020 and 8th May 2020, the total confirmed cases of COVID-19 in Nigeria have increased from 1 to 3,912 cases with the highest new cases within this period reported on the 8th May 2020 with 386 new cases.

Developing a predictive model for the pandemic is very crucial in policy formulation which will help in controlling the spread of COVID-19 pandemic. This is one of the reasons why several time series based models have been proposed to predict the evolution of the pandemic[1, 2, 5, 7]. Though, there are no enough studies that focused on predicting the COVID-19 pandemic given the fact that the disease just emerged, yet the use of time series models in forecasting the dynamics of this pandemic has gained popularity[5, 7]. Given the way the pandemic is ravaging the lives of Nigerians, it was therefore imperative to propose a predictive model for this pandemic in Nigeria.

2 Materials and Methods

Study Area: This study was carried out in Nigeria located in the western coast of Africa. Nigeria borders Niger in the north, Chad in the northeast, Cameroon in the east and Benin in the west. The southern coast of Nigeria is on the Gulf of Guinea in the Atlantic Ocean. The federation comprises 36 states, divided into six geopolitical zones and with one Federal Capital Territory.

Source of Data and Test of Stationarity using Augmented Dickey-Fuller test: Data used in this study were the confirmed cases of COVID-19 in Nigeria between 27th February 2020 and 8th May 2020 as obtained from the Nigeria Centre for Disease Control (NCDC). The stationarity of the series was determined using the Augmented Dickey Fuller (ADF) test.

ARIMA Model Building Methodology: The following five principals' steps are required in the ARIMA model building using Box- Jenkin's methodology namely: model identification, model estimation and selection, model diagnostic checking, model validation, and model use[10]. To identify the appropriate model, the Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) of the data were plotted. Autoregressive Integrated Moving Average model [ARIMA (p,d,q)] in terms of B operator can be expressed mathematically as:

$$\phi_p(B)(1-B)^d y_t = \theta_q(B)\varepsilon_t \quad (1)$$

where,

$$\phi_p(B) = 1-\phi_1 B-\phi_2 B^2 - \ldots - \phi_p B^p \quad (2)$$

$$\theta_q(B) = 1-\theta_1 B-\theta_2 B^2 - \ldots - \theta_q B^q \quad (3)$$

where, p is the order of autoregression while d and q are the orders of non- seasonal differencing and moving average respectively.

For ARIMA (2, 1,0), p =2, d=1 and q=0.

$$\left(1-\phi_1 B-\phi_2 B^2\right)(1-B) z_t = \varepsilon_t \quad (4)$$

Where, ϕ_1, ϕ_2 are the parameters of the model in equation (4), $z_t = \log(y_t)$ and y_t is the confirmed cases of COVID-19 at day t, $Bz_t = z_{t-1}$

For ARIMA (0,1,2),

$$(1-B) z_t = \left(1-\theta_1 B-\theta_2 B^2\right)\varepsilon_t \quad (5)$$

Where, θ_1 and θ_2 are the parameters of the ARIMA (0,1,2).

For ARIMA (2,1,2)

$$\left(1-\phi_1 B-\phi_2 B^2\right)\left(1-B\right)z_t=\left(1-\theta_1 B-\theta_2 B^2\right)\varepsilon_t \tag{6}$$

Where, ϕ_1, ϕ_2, θ_1 and θ_2 are the parameters of ARIMA (2,1,2).

Model estimation and selection: The estimation of the parameters of these ARIMA models was carried out using the Statistical Package for Social Sciences (SPSS version 20.0). Among these proposed ARIMA models, the selection of the best fitting models was based on the coefficient of determination (R^2), Normalized Bayesian information criteria, and Root Mean Square Error (RMSE). The coefficient of determination (R^2) and Normalized Bayesian information criteria was used to assess the performance of the ARIMA models in terms of fitness while Root Mean Square Error (RMSE) assesses the forecasting accuracy of the models.

$$R^2=\frac{(n-1)\sum_{t=2}^{n}\left(y_t-\hat{y}_t\right)^2}{p\sum_{t=2}^{n}\left(y_t-\bar{y}_t\right)^2} \tag{7}$$

$$BIC=-2\log\left(L\right)+k\left\{\log\left(n\right)\right\} \tag{8}$$

$$RMSE=\sqrt{\frac{\sum_{t=2}^{n}\left(y_t-\hat{y}_t\right)^2}{n-1}}, \tag{9}$$

where y_t is the actual confirmed cases of COVID-19, $\hat{y}_t$ is the estimated confirmed cases, n is the number of observations, L is the likelihood, and k is the number of parameters in the model and p is the number of parameters in the model excluding the constant term. The model with the highest R^2 and least normalized BIC is the best model in terms of fitness while model with the least RMSE is the best model in terms of forecasting accuracy.

Model diagnostic checking: The diagnostic check is a procedure that is used to check residuals[11]. In this study; the Ljung-Box test statistic was used. The Ljung-Box test statistic was used for testing the independency of the residuals.

The null hypothesis is:

H_0: the model does not exhibit lack of fit.

versus the alternative hypothesis:

H_1: the model exhibits lack of fit.

$$Q(m)=\frac{n(n+2)\sum_{k=1}^{m}r_k^2}{n-k} \tag{10}$$

where, n = length of the time series, r_k is the estimated autocorrelation of the series at lag k and m is the number of lags tested. The null hypothesis is rejected if

$$Q(m)>\chi^2_{1-\alpha,h} \tag{11}$$

where, $\chi^2_{1-\alpha,h}$ is the Chi-square distribution table value with h degrees of freedom and α level of significance.

3 Results

Figures 1 shows the plot of the confirmed cases of COVID-19 in Nigeria with an upwards trend in the reported confirmed cases of the pandemic in Nigeria. This observed trend shows that the confirmed cases of COVID-19 in Nigeria are not stationary. Result of the test of stationarity using Augmented Dickey Fuller (ADF) test is presented in Table 1. From Table 1, it can be deduced that at level (p = 0.6746), the series was not stationary but after natural logarithm transformation and first differencing stationarity was achieved (p= 0.0159). The plots of the Autocorrelation Function (ACF) and Partial Autocorrelation Function (APCF) show that both the ACF and PACF at lag 2 exceeded the significance limits while other lags were within the significance limit (Figures 2 and 3). Hence, three ARIMA model [ARIMA (2,1,0), ARIMA (0,1,2) and ARIMA (2,1,2)] were suspected as been suitable for COVID-19 prediction in Nigeria.

Result in Table 2 shows the estimates of the three proposed predictive models and their performances. Results shows that among the proposed models, ARIMA (2,1,0) and ARIMA (2,1,2) have the highest coefficient of determination (R^2) of 0.998 meaning that the models accounted for 99.8% of the variation in the data set. The ARIMA (2,1,0) gave the least Root Mean Square Error of 38.609 compared with other models. Based on the least Root Mean Square Error, the ARIMA (2,1,0) was adjudged the best of the three proposed models for predicting confirmed cases of COVID-19 in Nigeria. The Autoregressive terms of orders 1 and 2 for the best models values of 0.082 and 0.519 were obtained meaning that confirmed cases at lag 1 (a day before) and lag 2 (two days before) have positive effect on the present day confirmed cases of the pandemic. This also shows an upwards trend in the confirmed cases of COVID-19 in Nigeria. Table 3 shows the result of the model diagnostic checking and the result shows that the three models had p-values greater than 0.05 indicating that the three models fitted the data well.

To validate the model, the graph of the actual and predicted confirmed cases were plotted and the figure reveals that the actual and the predicted confirmed cases based on the ARIMA (2,1,0) followed the same pattern (Figure 4).

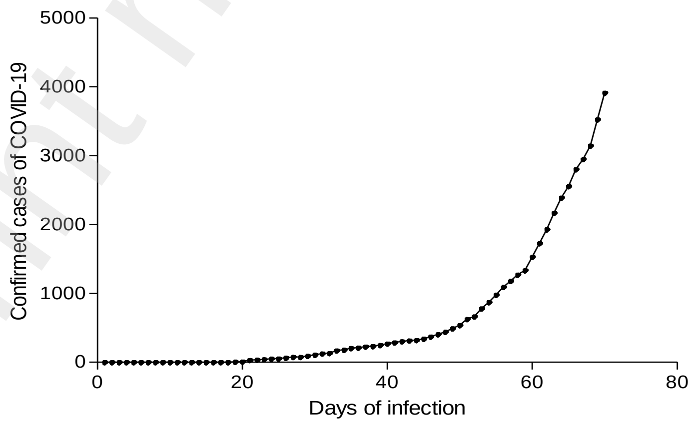

Fig 1: Trend in the confirmed cases of COVID-19 in Nigeria between 27th February, 2020 and 8th May, 2020.

Table 1: Summary of the stationarity for confirmed cases of COVId-19 using Augmented Dickey Fuller test.

		t-Statistic	Prob.*	Remarks
At level	Augmented Dickey-Fuller test statistic	-1.189124	0.6746	Not stationary at level
After first differencing	Augmented Dickey-Fuller test statistic	-3.362097	0.0159	Stationary after first differencing

Prob. = probability value, p-value less than 0.05 ($p<0.05$) indicates that the series is stationarity.

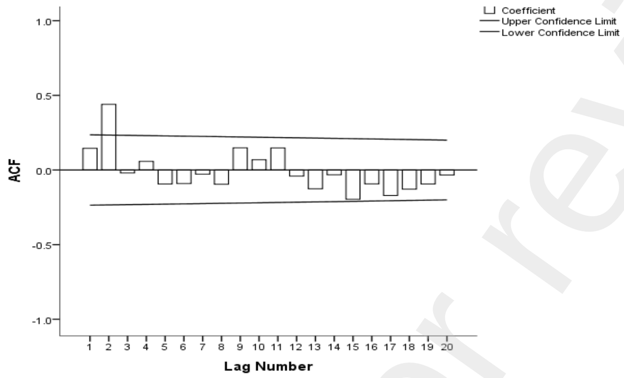

Fig 2: Autocorrelation function (ACF) plot after natural log transformation and first differencing for the confirmed cases of COVID-19 in Nigeria.

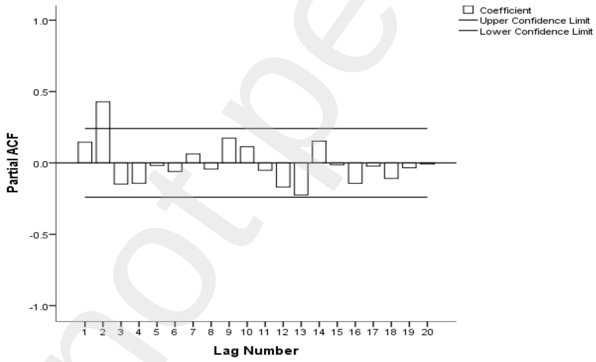

Fig 3: Partial Autocorrelation Function (PACF) plot after taking log transformation and first differencing for the confirmed cases of COVID-19 in Nigeria.

Table 2: Summary of the model estimation

	AR1 terms	AR 2 term	MA 1 term	MA (2) term	Model fitness criteria		RMSE
Models	Coefficient (p-value)	Coefficient (p-value)	Coefficient (p-value)	coefficient (p-value)	R^2	BIC	
ARIMA (2,1,0)	0.183 (0.082)	0.519 (0.000)	-	-	0.998	7.430	38.609
ARIMA (0,1,2)	-	-	-0.182 (0.092)	-0.507 (0.000)	0.997	8.131	54.836
ARIMA (2,1,2)	0.141 (0.528)	0.464 (0.036)	-0.079 (0.7470)	-0.1180 (0.595)	0.998	7.643	40.405

ARIMA- Autoregressive Integrated Moving Average, AR 1 – Autoregressive of order 1, AR 2 – Autoregressive of order 2, MA 1- Moving Average of order 1, MA 2- Moving Average of order 2, p-value – probability value, R^2 - coefficient of determination, BIC- Bayesian Information Criteria, RMSE- Root Mean Square Error.

Table 3: Model diagnostic checking using Ljung- Box statistic

	Ljung- Box statistic		
Models	Test statistic	df	p-value
ARIMA (2,1,0)	18.480	16	0.297
ARIMA (0,1,2)	15.446	16	0.492
ARIMA (2,1,2)	16.703	14	0.272

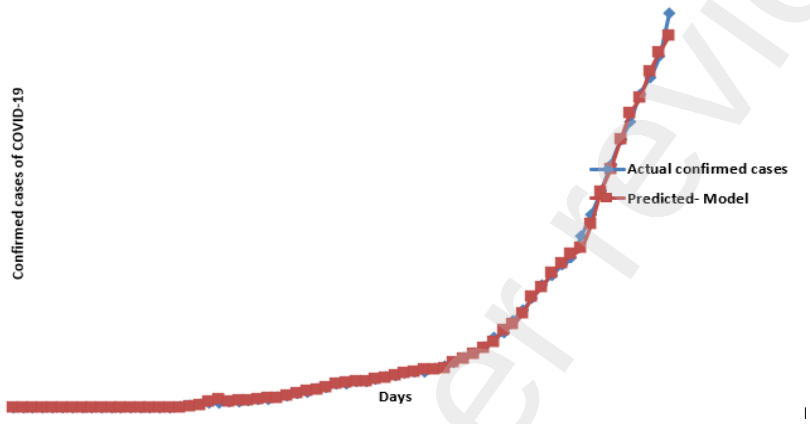

Fig 4: Graph showing the actual and predicted cases of COVID-19 based on ARIMA (2,1,0).

The model equation for ARIMA (2,1,0) is therefore given as follows:

$$\left(1-0.183B-0.519B^2\right)\left(1-B\right)z_t=\varepsilon_t \text{, where } z_t=\log\left(y_t\right)$$

The following predictions provided in Table 4 with 95% LCL and UCL were made for the confirmed cases of COVID-19 in Nigeria between 9/05/2020 and 22/05/2020.

Table 4: Two weeks prediction for confirmed cases of COVID-19 using ARIMA (2,1,0) 9/05/2020 to 22/05/2020

S/N	Date	Predicted	LCL	UCL
1	9/05/2020	4297	2976	6015
2	10/05/2020	4702	2627	7812
3	11/05/2020	5197	2107	10831
4	12/05/2020	5761	1725	14483
5	13/05/2020	6463	1374	19533
6	14/05/2020	7292	1104	25815
7	15/05/2020	8305	882	33907
8	16/05/2020	9515	710	43878
9	17/05/2020	10978	572	56232
10	18/05/2020	12726	464	71200
11	19/05/2020	14826	378	89269
12	20/05/2020	17334	310	110795
13	21/05/2020	20336	256	136293
14	22/05/2020	23920	212	166223

4 Discussion

The Covid-19 pandemic is a world-changing event which has affected all forms of activities both nationally and internationally. The coronavirus is not only a health crisis of immense proportion; it's also an imminent restructuring of the global economic order. The society that emerges in the wake of COVID-19 will be different. People's behavior and values will change in ways we can't predict. Health systems will be fundamentally altered. A key question is whether these impacts will result in permanent changes in behavior, when the crisis ends. Disruptions can be a catalyst for shifts towards more sustainable activities, but avoiding a return to pre-crisis behaviours requires decisive action from governments. As lockdowns are lifted, policy will be crucial in determining whether mobility changes triggered by the pandemic are positive or negative in terms of their impacts on society, safety and long-term environmental and health outcomes. Government responses to the Covid-19 crisis will ultimately determine what happens this year and beyond. While, this study examined the performance of three ARIMA models for predicting the confirmed cases of COVID-19 in Nigeria. Finding shows that among the proposed model, ARIMA (2,1,0) outperformed other proposed models. Finding based on ARIMA (2,1,0) shows that there will be an increase in the confirmed cases of the pandemic in Nigeria as shown by the 14 days' predictions. This projected increase could be as a result of the relaxation of the total lockdown in Nigeria and reopening of places of worship centres in some states in Nigeria. Another possible explanation for this finding is that many people in Nigeria are yet to come into term with the reality of COVID-19 pandemic and hence many are not ready to obey COVID-19 preventive measures as stated by the Nigeria Centre for Disease Control (NCDC). Some of these preventive measures include no gathering of any kind, use of face mark, social distancing, hand washing with soap and water or any other alcohol-based sanitizers among others. Therefore, to hurt this projected upsurge in the confirmed cases of COVID-19 in Nigeria, there is a need for more enforcement of all the rules on COVID-19 preventive measures. This finding agrees with that of the findings carried out in China by Wu and Leung[17] where confirmed cases of COVID-19 were observed to be growing exponentially. The finding is corroborated by that of the finding in other countries[1, 2, 5, 7, 12-15] where an upward trend in the confirmed cases of COVID-19 were predicted**.** This finding is also corroborated by that of the findings by Cheng and Shan[16] in China where the infections was reported to be spreading at an exponential rate with a doubling periods of 1.8 days. These similarities in these findings indicate that the COVID-19 is contagious. This finding is not in line with that carried out by Benvenuto *et al.*[18] where a slight decline in the pandemic was projected. This disparity may be due to the difference in the area and the periods where these studies were conducted and the way COVID-19 guidelines like social distancing, washing hand with soap and water among other measures are obeyed. This disparity in result could also be due to the fact that many Nigerian are yet to come into terms with the realities of COVID-19 pandemic and many believe that it is scam. Although more data are needed, this study has made projection with regards to COVID-19 pandemic in Nigeria, these predictions are subject to others factors like government policy, strange change in the spread of the virus, adherence to COVID-19 safety measures by the public, increase in COVID-19 testing capability, innovations in biotech, discovery of COVID-19 drugs, vaccine development, and the regulatory regimes that govern drug development, so that treatments can be approved and tried faster among other factors. There is also need for more elaborate studies on COVID-19 pandemic using other models aside time series models. These models could include negative binomial regression, Poisson regression and other discrete regression models.

5 Conclusion

This study proposed ARIMA models for predicting the confirmed cases of COVID-19 in Nigeria. Three different ARIMA models were suspected after plotting the ACF and PACF of the data. These models were ARIMA (2,1,0), ARIMA (0,1,2), and ARIMA (2,1,2) but among these proposed models, ARIMA (2,1,0) outperformed other proposed ARIMA models both in terms of fitness and forecasting accuracy. Therefore, an ARIMA (2,1,0) was recommended for forecasting the confirmed cased of COVID-19 in Nigeria.

SIGNIFICANCE STATEMENT

This study discovered that there will likely be an increase in the confirmed cases of COVID-19 pandemic in Nigeria. This finding can be beneficial to government and the public. It will be beneficial to the government in the area of policy formulation that will help hurt the spread of the pandemic and adopting strategies such as quarantine for a large part of the population, as this will be the is most appropriate measure to minimize the number of infected people as much as possible and prevent the collapse of health systems in the country while the public will see the need to practice all the safety measures put in place. This study will help the researchers to uncover the critical areas of COVID-19 pandemic modeling and forecasting.

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