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PREDICTIVE MODELING OF COVID-19 PANDEMIC IN BAHRAIN

TANIYA MUKHERJEE[1] AND JANAKI BOJIAH

ABSTRACT. The aim of this study is to trace the rate of spread of the COVID-19 pandemic and predict the end of the spread of COVID-19 in Bahrain. Though the term 'Corona virus' hit the headlines from 31 December 2019 and gradually started spreading in leaps and bounds right from January 2020 in Wuhan, China, Bahrain started witnessing cases only in February 2020. With a gradual increase in the number of cases and the number of deaths, the people in Bahrain are deprived of leading a normal routine anymore. With the suspension of educational institutes, imposed restrictions on businesses, and the enforced 'work from home' on the working class, the COVID-19 has played havoc in the lives of the people residing in Bahrain. Extracting the data from web site of Worldometers about the active cases, death cases and recovery cases in Bahrain, and devising a mathematical model, this study traces the spread of the virus for a specified period from 1 March 2020 to 20 September 2020 cumulatively and attempts to predict the rate of spread of the virus using polynomial regression method. The proposed prediction of the end of COVID-19 disease in Bahrain will help Bahrain prepare for the post-pandemic scenario keeping in mind the well-being of its residents.

1. INTRODUCTION

On 31 December 2019, a medical case of pneumonia with strange etiology was identified in Wuhan, China [1]. Following this, more than 40 cases with the similar

[1]*corresponding author*

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symptoms were reported which paved the way for intense examination. As a result, on 7 January 2020, China declared that to be an advanced type of coronavirus which is called severe acute respiratory syndrome coronavirus–2 (SARS-CoV-2), and the World Health Organization (WHO) proclaimed it to be the coronavirus disease 2019 (COVID-19). Believed to be transferred from animal to human, the name of the virus originates from the Latin word corona which implies crown. Though COVID-19 was only a topic of world news till January 2020, Bahrain started sensing the fear of the pandemic when the spread intensified throughout the globe. The index case of Bahrain was identified on 21 February 2020 and the government of Bahrain took immediate measures to start the battle to combat COVID-19. Since the first case was found, there has been meticulous medical testing procedure in place, especially on the citizens and residents returning to Bahrain from religious pilgrimages in Iran. Many specialized camps were set up to treat people coming from COVID-19 affected countries involving numerous healthcare professionals and volunteers. As per official statistics, till 20 April 2020, 89,225 people had undergone the corona virus test whereas 1907 confirmed cases and seven deaths, out of a global count of 2.48m infections and 170,000 fatalities were reported in Bahrain [2].

In addition to the bearing of the cost of salaries of three months for all the working Bahrainis, the government of Bahrain also waived off the expenses of electricity and water for the residents of Bahrain during the lockdown period from April 2020 for 3 months [3]. Further, to prevent transmission, BeAware Bahrain app was initiated on 31 March 2020 by the Information and eGovernment Authority (iGA). In addition to the provision of the global updates related to COVID-19, it helps you to track the nearby COVID-19 cases especially when the area has more confirmed cases or active cases by push notifications and SMS. This app was found to be successful in fighting against COVID-19, as by 17 April 2020, it had been downloaded 294,516 times. Following this, on 4 April 2020, the authorities provided electronic bracelets for people under quarantine to ensure their compliance with pandemic control measures which has helped Bahrain, a country with the third-highest rate of population density in the world, in controlling the spread of corona virus. Owing to border closures and political sensitivities, Bahraini government organized a series of charter connections from Mashhad in Iran to Bahrain's capital, Manama, to repatriate its nationals and by 7 April 2020, the government successfully brought 1200 citizens home.

Under the slogan, "Feena Khair," financial donations were collected from individuals, communities, and organizations to contribute to the COVID-19 national campaign [4]. Acquiring the insights from China and other affected countries, the ruling authorities of Bahrain announced the suspension of educational institutes, restricted procedures for businesses and directed the employees of all public and private sectors to work from home [5]. Gradually, the suspension of recreational activities, salons, movie theatres, shopping malls, public events and dining-in facility in the restaurants etc. came into picture. As a result, over the period of four months, with suspension of aviation from and to other countries, Bahrain witnessed thousands of jobless expats forcefully staying in Bahrain with agony. The perpetual spread of the virus across the globe in general and in Bahrain, in particular, has resulted in economic recession.

This lock down phase that insists on individuals to remain isolated and maintain social distancing [6] and [7], has brought in some complexities with respect to the social and mental fabric of the society [8] and [9]. With too many questions about future, hampered short term plans, budgeted lifestyle, 'not much to do' mental set up and staying indoors with family, there is a cold war building up in every family as familiarity breeds contempt [10]. This has thrown light into the need for socialization and rethink the importance of other people in our lives [11]. The government is leaving no stone unturned to ensure the health care as well as well-being [12] of the residents and the people resist breaching the rules pertaining to lockdown as well as pray for a corona free world. The medical scientists across the globe are involved in discovering a vaccine for the eradication of COVID-19 whereas the other researchers are trying their luck to predict the end of corona virus [13] in various parts of the world. This study too is such an effort to identify the rate of spread of COVID-19 in Bahrain devising a mathematical model and employing polynomial regression method.

2. Preliminaries

Since times immemorial, the pandemic hit has been witnessed in each century severely. To name a few: Great Plague of Marseille in 1720 which existed for three years and ended up killing nearly 30% of the population of Marseille. First Cholera Pandemic in 1820 that affected Indonesia, Thailand and the Philippines significantly resulted in the death of 1,000,000 people. Spanish Influenza or Flu

in 1920 which killed 100 million is the deadliest pandemic ever recorded till now historically. Novel Corona virus Disease in 2020 is the topic of the current era [14].

Corona, the novel virus, the merciless monster that is the threat to the world [15] was first discovered in December 2019 in Wuhan, China [16]. Ever since the outbreak of the severe acute respiratory syndrome (SARS) in 2003, Corona Virus Disease in 2019 abbreviated by WHO on 11 February 2020 as (COVID-19), has been the largest outbreak of atypical pneumonia [17]. To support this, [18] mentioned that the number of infected cases and deaths of COVID-19 has outnumbered those of SARS within the few initial weeks of its beginning of the spread. In addition, [19] clearly reported that the spread of each COVID-19 case will, in turn, result in 4 more new cases because of its high reproduction number which is nearly equal to 2.5 as observed by WHO.

With the symptoms that can be paralleled initially with any kind of common cold such as fever, coughing, throat pain, nasal congestion and problems in breathing - this was labelled to be Severe Acute Respiratory Syndrome- Corona Virus (SARS-CoV2) which was proclaimed by World Health Organization as pandemic on 11 March 2020 [20]. Like SARS, COVID-19, is identified to be a beta-coronavirus which can be transmitted to human through the animal intermediators like bats [21], but not all the patients tested with Corona positive had the recent past movement in the animal market or other related places. It was later when the medical professionals [22] were found to be COVID-19 positive, the possibility of transmission through virus-laden respiratory droplets was then brought forth.

Further, [23] discovered that the male members of the community were more affected than women; older men with less immunity and men with medical issues related to heart and kidney were quite likely to get affected badly. Later, [24] added that the infected cases of men with chronic cardiac or renal problems would be resulting in deaths. The investigative [25] notified that the average of the incubation period of the virus is 5.2 days amounting to significant variation amidst the patients with varying physical conditions and to add to this, a possibility of the asymptomatic spread was identified by [26]. The number of cases reported after 17 January 2020 had increased 21 times compared to the number of cases in the initial half of January 2020 [27].

In addition, [28], [29], [30], [31] in their studies, found out that the people had undergone intense emotional trials and tribulations owing to not only the

fear of the outbreak but also the enforced preventive measure called 'lock down.' Though 75.1% of the respondents of their study were satisfied with the amount of information given by the health care communities and the preventive measures taken by the government, it is noteworthy to find out that almost an equal percentage of people were bothered about their loved ones getting infected. The research pursuit of [32] confirmed that the awareness of the preventive measures of COVID-19 and the active implementation of the same can only help control the spread globally. A vaccine or specific drug combination to cure COVID-19 is yet to be found [33] and so it is better to be cautious. Let us try to adopt more regulations pertaining to prevention of the infection like washing the hands, wearing the face masks, refraining from having physical contact with others etc. and self-consciously contribute to combat COVID-19.

3. Data Formulation

The mathematical or the statistical analysis of COVID-19 is complex in nature. The data used for analysis may have some missing numbers as many cases may not have been registered. In addition, there are many asymptotic carriers of the virus who are not considered to be victims. The data set used in the analysis of the COVID-19 cases in Bahrain was derived from the GitHub portal of Center for Systems Science and Engineering (CSSE) at [34] as well as from [35]. This dataset includes details of confirmed cases, active cases, recovered cases, and death cases in Bahrain from 1 May 2020 to 20 Sep 2020. The data used is time series data which is defined as a type of data where a variable has a set of observations on values collected over different points of time. The data points are normally collected at fixed intervals such as daily, weekly, monthly, quarterly, or annually. Our analysis is based on values counted daily. The data used for analysis in this study has been filtered over a time interval reducing the number of attributes. It is nevertheless to mention that the basis of any analysis task is its data and obviously the data-preparation and its representation enrich the analysis. The dataset obtained from the portal has many variables irrelevant to our concerned area of study like hospital beds per thousand, diabetes prevalence, male smokers, female smokers and so the data-cleaning is performed. The concerned dataset has discrete numeric, positive values as the number of individuals affected by COVID-19 are considered and thus assumes the aggregate number of the total people having

COVID-19 for confirmed cases, active cases, death cases and recovered cases. The mean of the column values is not used to fill the missing values as the data value in this data set can remain constant or may increase on the very next day. That means for the next day for which the data are missing, the values remain constant. Here, the datum value is considered for each day in the time series starting from 1 May 2020 whereas the location or the continent remains constant.

4. Mathematical Model

The regression analysis is defined as a statistical tool to determine the relationship between a dependent variable and an independent variable, thus helping to estimate the probable change in one variable for the given amount of change in another and model their future relationship. Linear regression, multiple linear regression and non-linear regression are the various variations of regression analysis. The simple linear model is expressed by the equation:

$$Y = \beta_0 + \beta_1 x + \delta,$$

where β_0 is the intercept, β_1 is the slope and δ is the unobserved random error with mean zero conditioned on a scalar variable.

A polynomial regression which is also considered as a special case of multiple linear regression, can be summed up as a regression analysis in which the interrelationship between the dependent variable y and the independent variable x ismodelled as a nth degree polynomial in x. The general equation of polynomial regression is

$$Y = \beta_0 + \beta_1 x + \beta_2 x^2 + \beta_3 x^3 + \cdots + \beta_n x^n + \delta.$$

5. Methodology

In this section, our aim is to establish an interrelationship between the confirmed cases, active cases, death cases, and predict the rate of spread of the deadly pandemic in Bahrain. The data from the confirmed cases, active cases, recovered cases, and death cases have been combined to present the new dataset keeping the date and day as constant. Hence, the new data set contains three more columns of closed cases, active case % and closed case %. The closed cases are calculated as closed cases = death cases + recoveries each day. Closed cases = confirmed cases - active cases. Active cases represent the current number of people confirmed to be

infected with the virus. This represents a quantitative analysis and so regression models can be applied on these data sets.

The numbers represented in this data set are absolute numbers and not floating-point numbers. Since the absolute numbers in the data set are the cumulative sum of the past records, the absolute numbers are not considered to be effective measure to predict the current and correct status of the pandemic in the region. So, determining the vastness of the pandemic or the declining tendency of its spread cannot be forecasted based on the absolute numbers. Hence, active case% and closed case% are used in this respect. The correct estimation of the active case% will help in predicting the status of the pandemic in the region. The decreasing order of the active case% will certainly ensure an eradication of the pandemic from the region.

Active case % = (active cases/confirmed cases) x 100.

Closed case %= (100 - active case%)

As mentioned in the previous section, regression analysis helps in establishing the relationship between the dependent or outcome variable and independent variables [36], [37] and [38]. In this study, polynomial regression is applied to set up a pattern of interrelationship between the confirmed cases, active cases as well as number of deaths in Bahrain and to predict the rate of spread of the pandemic in the coming weeks. R^2 and RMSE will be the two-evaluation metrics or parameters. Root mean square error is the standard deviation of the residuals,measuring how far the data points are from the regression line while R-squared (R^2) tells about the closeness of the predicted data and real data points. It is also an important factor for determining the goodness of fit of a regression model. A model is considered to have good accuracy if the RMSE values decrease and R^2 values increase.

6. Results

The mean (μ) value of each of the confirmed cases, active cases, death cases and recovered cases is greater than 1. Thus, the reciprocal of mean will also be positive. As per the trend and the conclusion of the Table 1 and the graphs in Fig. 1 and Fig. 2, it can be concluded that the total cases, confirmed cases, death cases and recovered cases data are distributed exponentially.

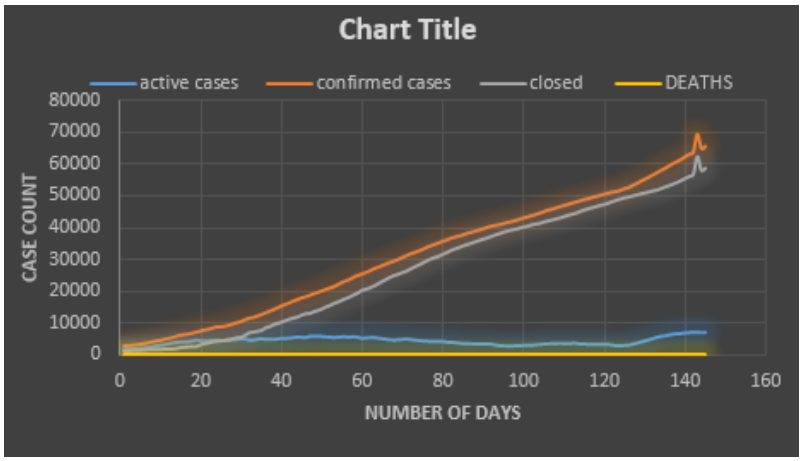

FIGURE 1. Exponential graph of total cases, closed cases, active cases, and deaths of COVID-19 in Bahrain.

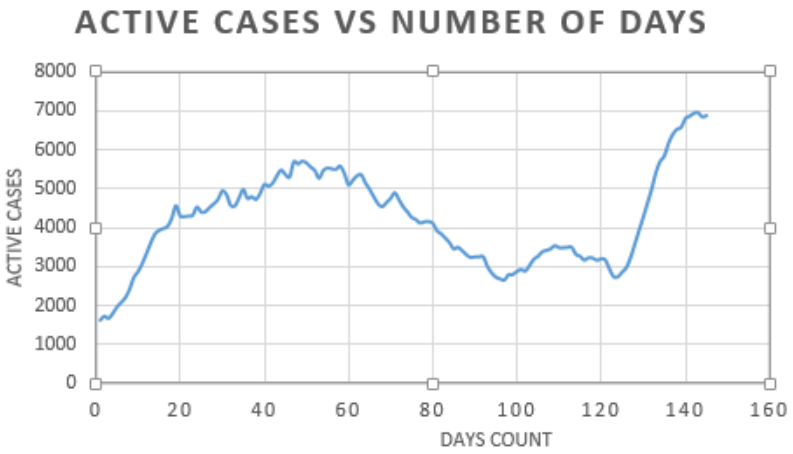

FIGURE 2. Trend of active cases of COVID-19 pandemic in Bahrain.

TABLE 1. Mean (μ) of each category

Recovered cases	566.023
Active cases	436.239
Death cases	1.4055

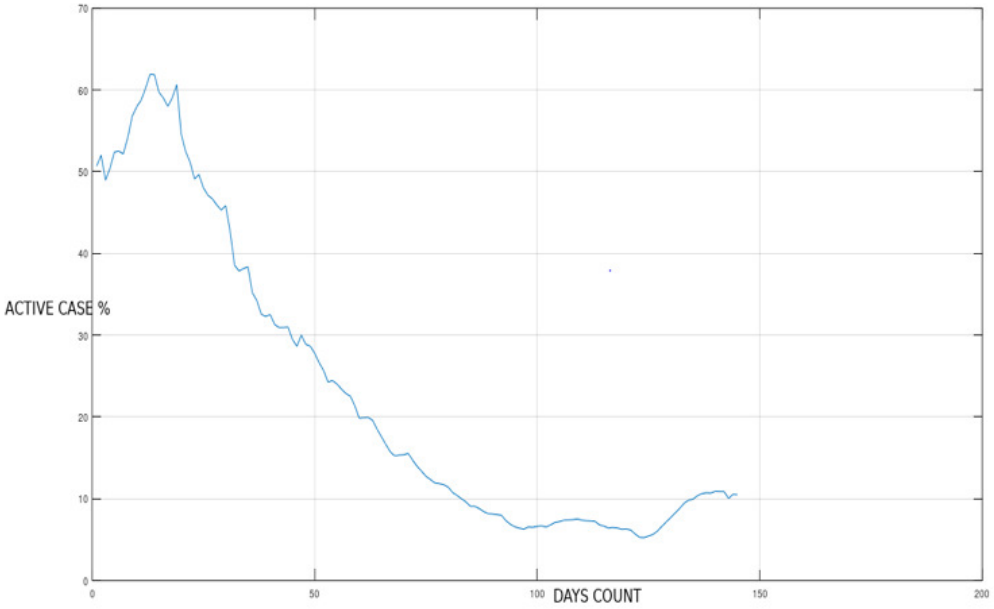

FIGURE 3. Trend of the active cases (%) in Bahrain using OCTAVE

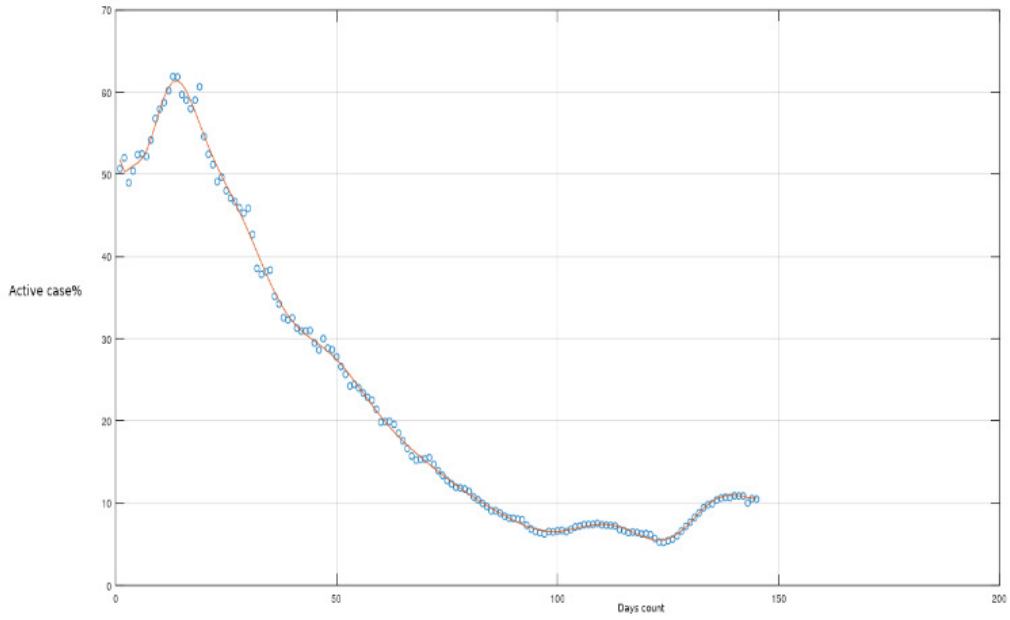

FIGURE 4. Best fit curve for active cases (%)

From the Fig. 4 and Fig. 6 it is evident that for the degree level equals to 22, the polynomial regression fits best in the study. For degree level 22, the result for the polynomial regression model is consolidated in Table 2 and Table 3.

TABLE 2. Evaluation of the polynomial regression model for active cases (%).

Polynomial Regression Model ::::	
RMSE	0.7476
R -SQUARED	0.9983

TABLE 3. Evaluation of the polynomial regression model for death rates.

Polynomial Regression Model ::::	
RMSE	0.005
R-SQUARED	0.9959

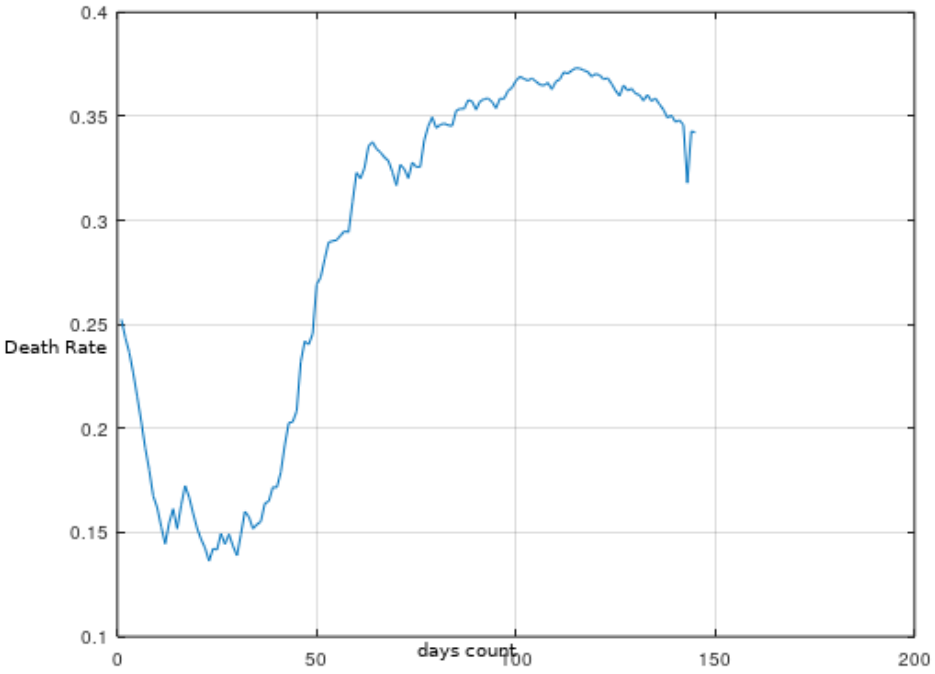

FIGURE 5. Trend of death rate in Bahrain using OCTAVE

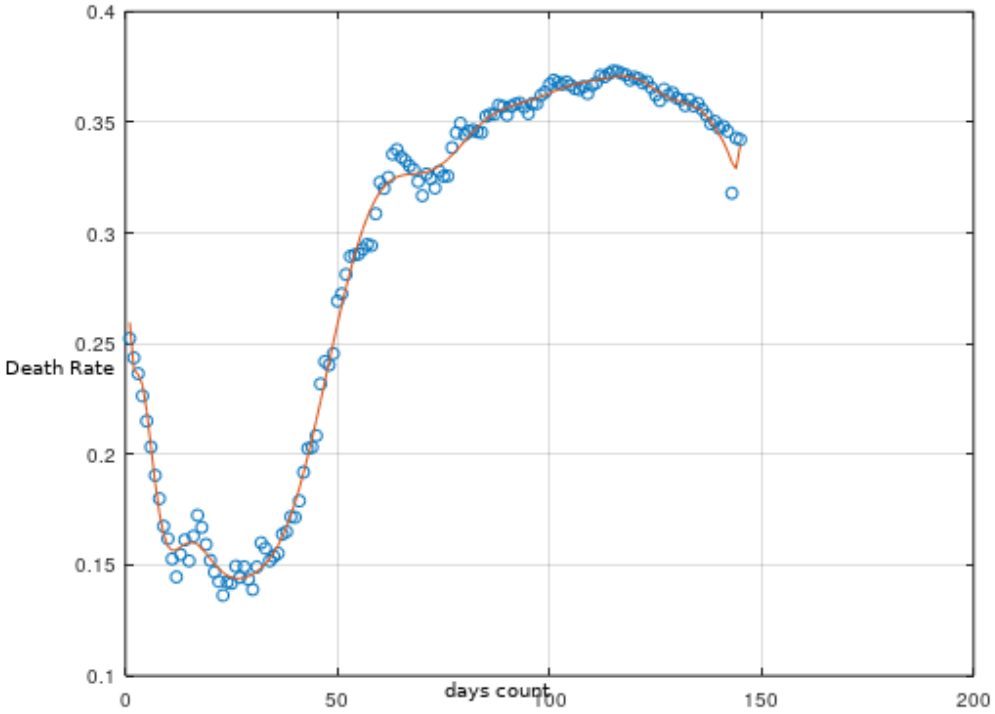

FIGURE 6. Best fit curve for death rates

TABLE 4. Representation of the active case% and death rate

08-10-2020	6.37849023138319	0.35473
09-10-2020	5.58776382580818	0.36200
10-10-2020	5.58662186034774	0.3626
11-10-2020	5.40905123389848	0.36368
12-10-2020	5.24042766103123	0.36867
13-10-2020	5.01232431298511	0.37366

The graphical representation of the results of this study as shown in Fig. 3 and Fig. 5 shows a gradual drop in the active cases out of every 100 confirmed cases (i.e. active cases percent) or explained otherwise, a gradual rise in resolved (closed) cases' percentage. After this whole statistical analysis from Table 2, Table 3 and Table 4, it is clear enough that Bahrain's decision of partial lockdown of businesses, working from home culture and closure of educational institutions,

sport facilities, wearing mask in public places seems to be successful in controlling the growth of the disease in its region.

7. Discussion

As per the results, it can be stated that the percentage of recoveries is greater than those of the (i.e. active cases) or confirmed cases recently. The death rate in Bahrain is 0.37% while the recoveries are nearly 81.4% asserting an improvement in the situation and a positive environment. Needless to mention that failing to adhere to the strict rules of maintaining safe social distance would result to a sudden increase in the daily active case count which was observed after the religious gatherings in the late August. However, from the recent gradual drop, it can be stated that the pandemic can be controlled to a satisfactory level within the next 2 months namely October and November. This conforms that Bahrain has applied smart strategies, taken measured risks in this pandemic management, and brought in applaudable initiatives to assure the health and welfare of its residents. The Bahrain model could be a role model to combat against COVID-19 and should be recommended for adoption to other affected countries of the similar geographic and demographic setting.

8. Conclusion

As there is a probability of unreported cases, hidden cases or asymptomatic cases, the data used in this study may not be accurate. The prediction is based on the available official data, the mathematical model devised, and the methodology employed; however, it is a matter of common knowledge that the affairs of nature could not be predicted or controlled completely. The study has been carried out in a rush to contribute towards the nation's fight against COVID-19, so there is a possibility of the improvement of this document qualitatively and quantitatively. The pandemic behavior is liable to change in accordance with the government initiatives and people's abiding behavior towards such initiatives. Hence, an accurate prediction could be impossible.

Longitudinal research should be initiated in future to clarify whether the pandemic ended as per the prediction. Comparing the Bahrain model with other countries can also facilitate more interpretations in this regard. Applying the same

mathematical model and the polynomial regression method for predicting the rate of spread of COVID-19 in other countries could bring in more valuable studies.

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DEPARTMENT OF GENERAL SCIENCE
COLLEGE OF ENGINEERING
GULF UNIVERSITY, KINGDOM OF BAHRAIN
Email address: Taniya.mukherjee@gulfuniversity.edu.bh

DEPARTMENT OF GENERAL SCIENCE
COLLEGE OF ENGINEERING
GULF UNIVERSITY, KINGDOM OF BAHRAIN
Email address: dr.janaki.bojiah@gulfuniversity.edu.bh