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Using R-studio to examine the COVID-19 Patients in Pakistan Implementation of SIR Model on Cases

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***Abstract*—** This research is based on analysing the spread of COVID-19 in Pakistan. The exponential spread of virus fluctuates in Pakistan due to the implementation of smart lockdown. During smart lockdown implementing and utilizing Susceptible, Infectious and Removal (SIR) Model can help to analyse the growth rate or reproductive growth of virus (COVID-19). The value of Beta and Gamma obtained from SIR Model can help to predict the exponential growth of the virus. After running the SIR Model, the value of beta assumed as 0.41 and value of gamma value as 0.19 with *R0*=2.16. The value of beta and gamma is changing every day, with *R0* changes from 2.1 to 2.4, which still mean there is (rapid) exponential growth in COVID-19 cases. However, result predicts there will be a peak hit of infectious cases after August 25, 2020. Moreover, 67% of the total population will be infected.

Keywords— Compartmental Model, Epidemiological Model, COVID-19, SIR Model, Coronavirus

I. INTRODUCTION

A Novel Human Coronavirus (SARS-CoV-2) was spotted in the Wuhan district of China in the early days of December 2019. It was revealed in trace-back investigations that many of the patients who were infected by the virus had some link to seafood and wet animal market located in Wuhan; which highlighted the possibility of the virus spreading from animal-to-human [1]. However, the virus continued to spread through large chunks of the population, it was proved that many of the patients had no exposure to animal markets, which brought up the unpleasant possibility of the occurrence of person-to-person spread [2]. This virus was given the name Novel Coronavirus or known as COVID-19. Within days the virus causes complications in the respiratory tract of the infected person and causing an increase of austere fatal deaths [3].

The initial phase of the virus is more precarious, most of the infected patients do not show any affected symptoms of COVID-19 [4]. Likewise, the spread rate could be faster, if the individual himself is unaware of the infection [5]. On January 30, 2020, the World Health Organization (WHO) acknowledged COVID-19 as a pandemic due to its faster spread [5, 6]. Despite the on-going efforts of governments, the virus has spread almost everywhere in the world [7].

More than 15.8 million people across the world had infected by COVID-19 (respiratory complications) [8]. Over 630,222 of them have died and over 89 million have been recovered till July 23, 2020 [9].

On February 26, 2020, Pakistan's Prime Minister's Special Assistant on Health, Mr Zafar Mirza, specified clearly to the nation by confirming the first two registered cases of COVID-19 in Pakistan. These two patients travelled from Iran. They were treated according to proper clinical procedures [10]. However, due to the rapid spread of COVID-19 (coronavirus) March 24, 2020 lockdown was imposed official by all provinces of Pakistan [11].

The COVID19 brought numerous threats to society, economy and science numerous threats for society [12, 13]. Researchers around the globe initiated work in the direction to help their communities [14, 15]. Besides medicinal research, economists, business analysts, educators, Data scientists, everyone start their contribution to handling coronavirus efficiently [16-18].

Governments of various counties all over the world have gone on to impose very strict lockdown measures on their citizens to prevent the virus from spreading [18-20]. The strict measures have helped to regulate a huge spread of COVID-19, in turn, it had a destructive impression on the economies [21]. Furthermore, unemployment, depression or other factors holds identical negative impacts on economic growth [22]. However, governments are willing to enforce the measures for months to protect the lives of their citizens [6, 18].

Initially, a strict lockdown was imposed by the government of Pakistan [23]. However, a country like Pakistan faces various economic stability challenges. It was not possible to carry complete lockdown in cities of Pakistan [3, 24, 25]. So, the Government came up with strategies towards smart lockdown. Almost a month-and-a-half after imposing a nationwide lockdown, the Prime Minister of Pakistan - Imran Khan - announced gradual ease in lockdown restrictions. In the first phase, they allowed specific organizations to start their operations with assigned SOP's (Standard Operating Procedure). In the second phase, they allowed local business personnel and traders to start their operations with SOP's in a given time [26].

Under such circumstances, various predictive models had been proposed by research to date. Data scientists are working on various predictive models to develop data-driven and effective solutions [27]. In this situation, the unassuming simple analytical model could support government-drafted policy formulation or reform. Such policies and strategies would be there to successfully advance mitigation strategies and use the national health service judiciously [2, 3, 28].

Section I contains the background and introduction of COVID-19 breakdown in Pakistan. Section II covers the related work based on the latest development in a theoretical and practical study based on COVID-19. Section III focused on methodological detail study based on SIR Model, using R-studio available packages helps to predict an increase in the number of COVID-19 cases in Pakistan, this section is divided into subsections (A) SIR Model, (B) Differential Equation, (C) Running SIR model in R- Studio. With detail SIR model charts and exponential growth chat, section IV comprehends on results and discussion.

II. RELATED WORK

Researchers, data scientists, economists and various-domain experts are expected to come up with a solution. COVID-19 made a significant shift around the world. Every individual is interested to know about COVID-19's post scenario. Countries are move through different phases. Moreover, no one knows where this virus will end. Researchers have implemented various models and techniques to aid their governments and economies.

Researchers applied different approaches including SIR Model, SEIR Model or Regression analysis to challenge the theories or hypothesis. Previous, studies are usually predicting about the first phase of COVID-19 in Pakistan
In this research, we attempt to use r-studio-related knowledge and run SIR model over available r packages. Thus, SIR model was established to predict the second phase of COVID-19's in Pakistan. We seek to concentrate on the probability of the second phase of COVID-19 after the ease of lock-down in Pakistan.

III. METHODOLOGY

This research use R-studio to analyse the COVID-19 data, we used available R- respiratory packages **"coronavirus"** and **"covid19.analytics"**. "Coronavirus" package was introduced on February 23, 2020 and package "covid19.analytics" was introduced on May 3, 2020 is available under the MIT license and support for R 3.0.2 and above. Among 202 countries, data for Pakistan was extracted from "**covid19.analytics"** respiratory. SIR Model is used to understand the details of available data with the implementation we will be able to predict the future of increase or decrease of COVID-19 cases.

A. *SIR Model*

SIR Model (Susceptible, Infectious and Removal Model) is also known as Compartmental Model or Epidemiological Model. SIR Model fundamentally practices for modelling of infectious diseases. Moreover, this model lies among one of the simplest models with essential inaccurate results. Total population (N) is compartmented in between following labels S, I and R.

$$N=S+I+R \quad (1)$$

N= Total Population
S= Susceptible = *Not infected yet, however, they have no immune so they will be infected*
I= Infectious = *generally infected with a disease*
R= Removal = *those people who had recovered or so deaths also included*

Figure 1: Basic SIR Model

Before entering the infectious (I) phase, all the individuals usually passes through susceptible (S) phase. After, they are infected only two possibilities occur. The two possibilities of removal phase are either individual recovered or die from virus or diseases.

B. *Differential Equation*

We assumed that initial lockdown prevents the fast growth of COVID-19 in Pakistan. For the sake of simplicity of the model, we assumed the sum of the total population of Pakistan as (N). Population size is 220 million throughout the epidemic situation. Hence, N is supposed to be constant. We used SIR model in figure 1 to present the susceptible, infectious and recovered cases. However, on the basics of assumption, we also considered the scenario that smart lockdown helps Pakistani's to control COVID-19 in general. Therefore, the possibility of increase of recovered cases brought a vital change in SIR model.

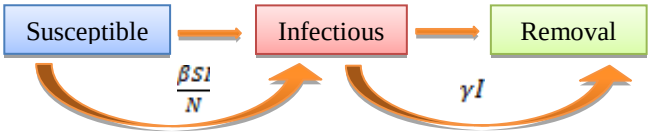

Figure 2: Implementation of the differential equation on SIR Model

i. $\frac{dS}{dt}$ the rate of the first transition is proportional to both S and I.

$$\frac{dS}{dt} = -\frac{\beta SI}{N} \quad (2)$$

ii. $\frac{dI}{dt}$ the rate of the second transition is only proportional to I.

$$\frac{dI}{dt} = \frac{\beta SI}{N} - \gamma I \quad (3)$$

iii. $\frac{dR}{dt}$ the more people infected to they will also recover or die.

$$\frac{dR}{dt} = \gamma I \quad (4)$$

The first transition is proportional to S because of increase in socializing. Furthermore, escalation of S to I would cause in the second transition. Therefore, the increase of R is directly proportional to the increase of S and I.

Keeping a basic assumption of SIR model following equation present in any given period:

$$S(t)+I(t)+R(t)=N \quad (5)$$

In this scenario, the value of the basic reproduction number (R_0) is considered as the ration between susceptible (beta) and recoveries (gamma). R_0 carries significant role to shape the infectiousness of a certain virus. Therefore, any change in infected person will hold is directly impact on the R_0:

$$R_0 = \frac{\beta}{\gamma} \quad (6)$$

C. Running SIR Model in R-Studio

As mentioned before, all the data about confirmed cases, deaths, recovered cases and active cases around the globe was retrieved from **"covid19.analytics"** package. Data from February 26, 2020 to July 30, 2020 was used to retrieve results.

According to global registered cases, Number of confirmed cases in Pakistan was still below 1 million. Keeping this in mind, we clearly distinguish the *S*, *I* and *R* compartments. By using available data from r respiratory for Pakistan with a time interval of 150 days, the initial fatality rate reached 2.1% with 220,600,000 and a 9.8% increase in confirmed cases. Moreover, a 74% increase in the recovery rate.

In the case of COVID-19, R_0 is relatively higher. According to equation (6), the value of R_0 is equal to 2.16. Hence, the value of $\gamma = 0.19$ and the value of $\beta = 0.41$.

Forecasting method was implemented on r-package to predict the next 28 days data till August 27, 2020. It is predicted that their will rapid increase in the number of cases after August 25, 2020 in Pakistan. The main reason can be ease in lockdown on Eid-ul-Adha festival and Independence Day.

IV. RESULTS AND DISCUSSION

So, the result obtained after running the SIR model on available data. We came to know about the value of beta and gamma. The beta value is 0.41 and the gamma value is 0.19 with R_0 equals to 2.16. The value of beta and gamma is changing every day, with R_0 changes from 2.14 to 2.46, which still mean there is (rapid) exponential growth.

Following figure 3, describes the positive confirmed cases are gradually increasing. However, it also shows the parallel increase in Recovered cases. The outbreak started from 2 cases and on day 148 reached above 250000 cases. X-axis clearly defines the total number of days and Y-axis mention about the total number of population.

The exponential growth of COVID-19 varies day by day. Figure 4 graph shows the exponential growth pattern for the 151 days. We can observe the growth after 31 days and shows a spike of around 121 days. Moreover, after 133 days there is a gradual decrease in exponential values. There is a possibility that the number of unreported cases of asymptomatic cases can generate gaps in exponential values. In figure 4, X-axis links to the total number of observed days, whereas the Y-axis corresponds to the total number of recorded cases.

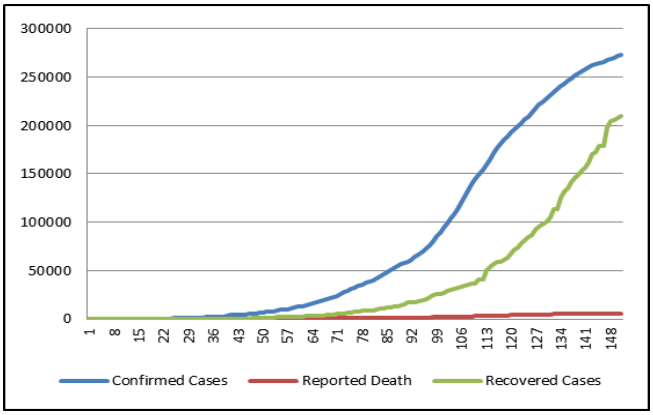

Figure 3: COVID-19 Registered Cases in Pakistan

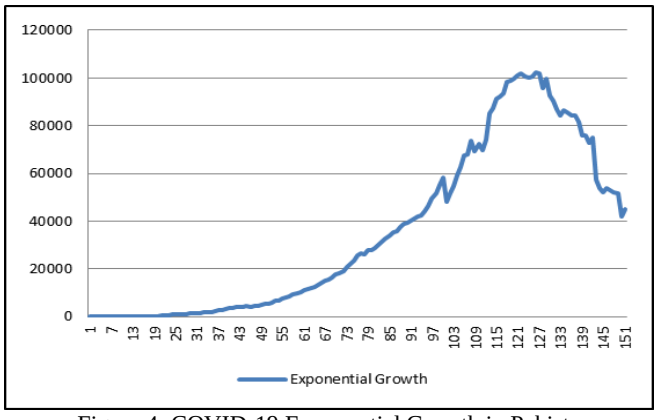

Figure 4: COVID-19 Exponential Growth in Pakistan

According to the SIR model after 75 days the first spike was predicted. Likewise in April, the maximum number was supposed to be observed in Pakistan. For the second prediction after 160 days peak maximum cases are supposed to be observed. August is highlighted for the second wave of COVID-19 in Pakistan mentioned in figure 5 and 6. During this period the fatality rate would increase from 0.02 % to 2.1%. 89,213.004 cases out of 220,600,000 susceptible cases will be confirmed as infectious cases. More or less 67% of the population will be affected by 250 days. This prediction is based on the most recent values of beta and gamma. In figure 5 and 6, graphical results indicate the change of beta and gamma values.

In figure 7, we can see the contradiction among actual and predicted values. According to the system, the predicted value was supposed to be 29, 1769 confirmed cases in Pakistan. However, actual registered confirmed cases were 27, 7402 on July 30, 2020. Therefore, we cannot completely depend on models and predicted values.

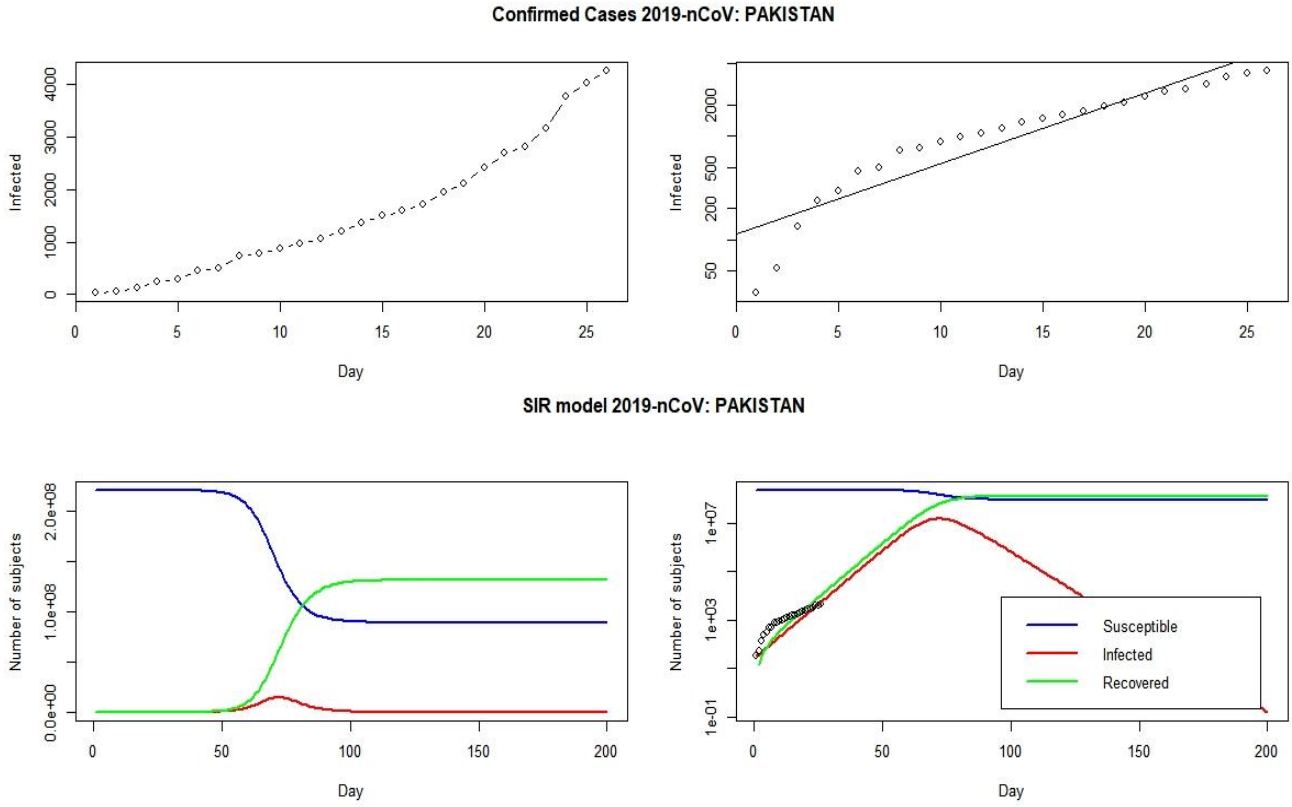

Figure 5: SIR model for COVID-19 Pakistan (First predicted model)

Hence, mentioned before that R_0 plays a vital role in the increase and decrease of infected cases. A decrease in gamma is possible by wash hands, stay at home, no public gathering or most favourable "Lockdown". Government of Pakistan imposed smart lockdown so we can clearly distinguish the change in the number of recovered cases.

The decrease in *S* can be only possible if "Vaccines" are available. If susceptible cases get vaccination on time, this can reduce the chances of a pandemic breakout. Hence, the reduction of *S* is directly linked to an increase in beta. Under current scenario antibiotics and vaccines are under development phase. Therefore, controlling *S* and increasing beta is challenging.

According to epidemiology, mathematical models can help in predicting significant growth or reduction in cases. Such model assists government and policymakers to execute their task accordingly. However, if vaccines are not existing and the total population is not ready to take precautionary measures; there is a possibility that the total population likely to become infected. Once all the susceptible passes to the infectious and removal phase; there will be only survivability for an individual with a good immune system.

Unfortunately, Pakistan has not yet fully recovered from COVID-19. Consequently, the Pakistani Government again imposed a strict lockdown for Eid-ul-Adha with different strategies. However, they need to review their strategies and policies for the lockdown to control Covid-19.

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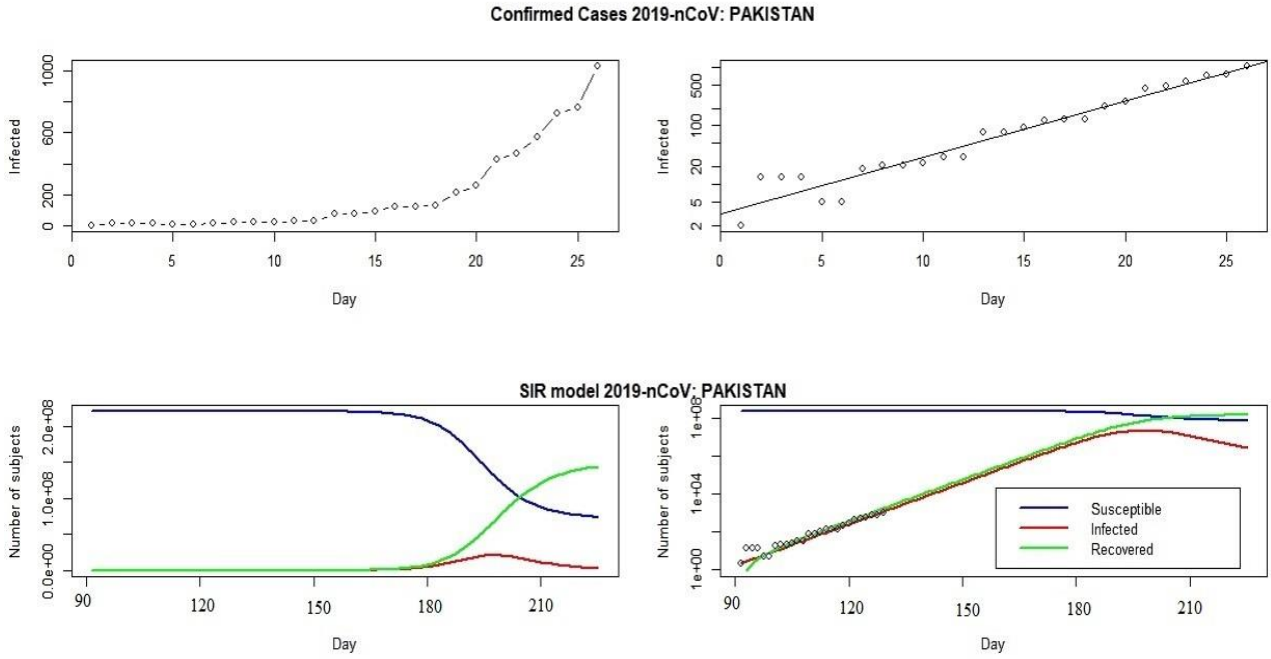

Figure 6: SIR model for COVID-19 Pakistan (Second predicted model)

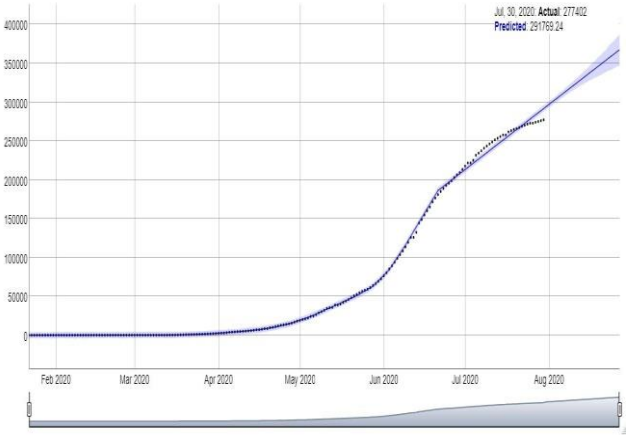

Figure 7: Predicted and Actual COVID-19 Cases

V. CONCLUSION AND FUTURE SCOPE

This research is conducted under the consideration of analyzing and predicting COVID-19 cases in Pakistan. Using SIR model, the exponential growth of COVID-19 has been measured. Due to smart lockdown government could manage to decrease in positive cases. However, it's due to Eid-ul –Adha and independence day it is assumed that an increase of social gathering will increase the COVID-19 infected cases. This increase can generate a high spike of cases after August 25, 2020.

SIR model is considered best for any epidemic or pandemic situation. However, data scientists use other models to make predictions and calculations. Therefore, for Removal (*R)* compartment in the SIR model, some researcher considered *R* as recovered cases and some take death as removal. In this research, we considered R as Recovered cases. By using real-time data, we observed that *R* hold great influence upon SIR model prediction.

In future, we can add the mortality rate in the model and make other assumptions. Rising numbers of cases could only predict about pandemic duration, the period having the highest spikes. Due to a change in everyday data, there were high possibilities of a misleading or wrong prediction. Furthermore, due to unreported or asymmetric cases, we still have deficiencies of inaccurate data.

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