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## Simulation of the evolution of the Covid-19 pandemic in the United Arab Emirates using the sir epidemical model

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### ABSTRACT

The Coronavirus Disease 2019 (COVID-19) is a pulmonary disease produced by the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) and has become a global pandemic March 2019. The aim of this research is to study a modelling approach on the spread of the COVID-19 pandemic utilizing analysis that is based on the well-known susceptible-infectious-removed (SIR) model. Since the declaration of the epidemic in Wuhan-city in China and other places around the world, several studies have addressed the development and evolution of the disease in different countries and have shown good stability of the use of such model. The United Arab Emirates is among the countries affected by the spread of the virus. Using collected data from 1 March 2020 to 31 August 2020 collected by John Hopkins University and the Federal Competitiveness and Statistics Authority (FCSA) in the UAE, we apply the SIR model to simulate the evolution of the virus in the United Arab Emirates. Our model predicts a peak in the daily infected cases on 19 May 2020, and the cumulative number of infected individuals to reach 100,000 cases by the end of October 2020.

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## 1. Introduction

The new coronavirus disease 2019 (2019-nCoV), known as COVID-19, was first addressed globally with a warning message from an ophthalmologist in Wuhan, China, to his colleagues about the existence of a new disease with symptoms similar to the acute respiratory syndrome (SARS) (Landry et al., 2020). Since its first outbreak in December, 2019 in *Wuhan city-China* (WHO, 1976), COVID-19 virus has spread rapidly throughout the world and declared as a global pandemic by the *World Health Organization (WHO)* in March 2020 (WHO, 2020a, 2020b). Scientists believe that several strains of COVID-19 have been found and warn that recovered people could be infected again (Gousseff et al., 2020). Though studies by international teams are yet to be peer-reviewed, the emergence of different strains of the virus has raised concerns about the nature of the virus and the environment in which the virus spreads. Estimating the infection rate that characterizes the pandemic spread peak of the infection, that is, at the edge, top and stabilizing peak of the pandemic spread, will be very important to analyze the evolution of the disease. Applying some advanced

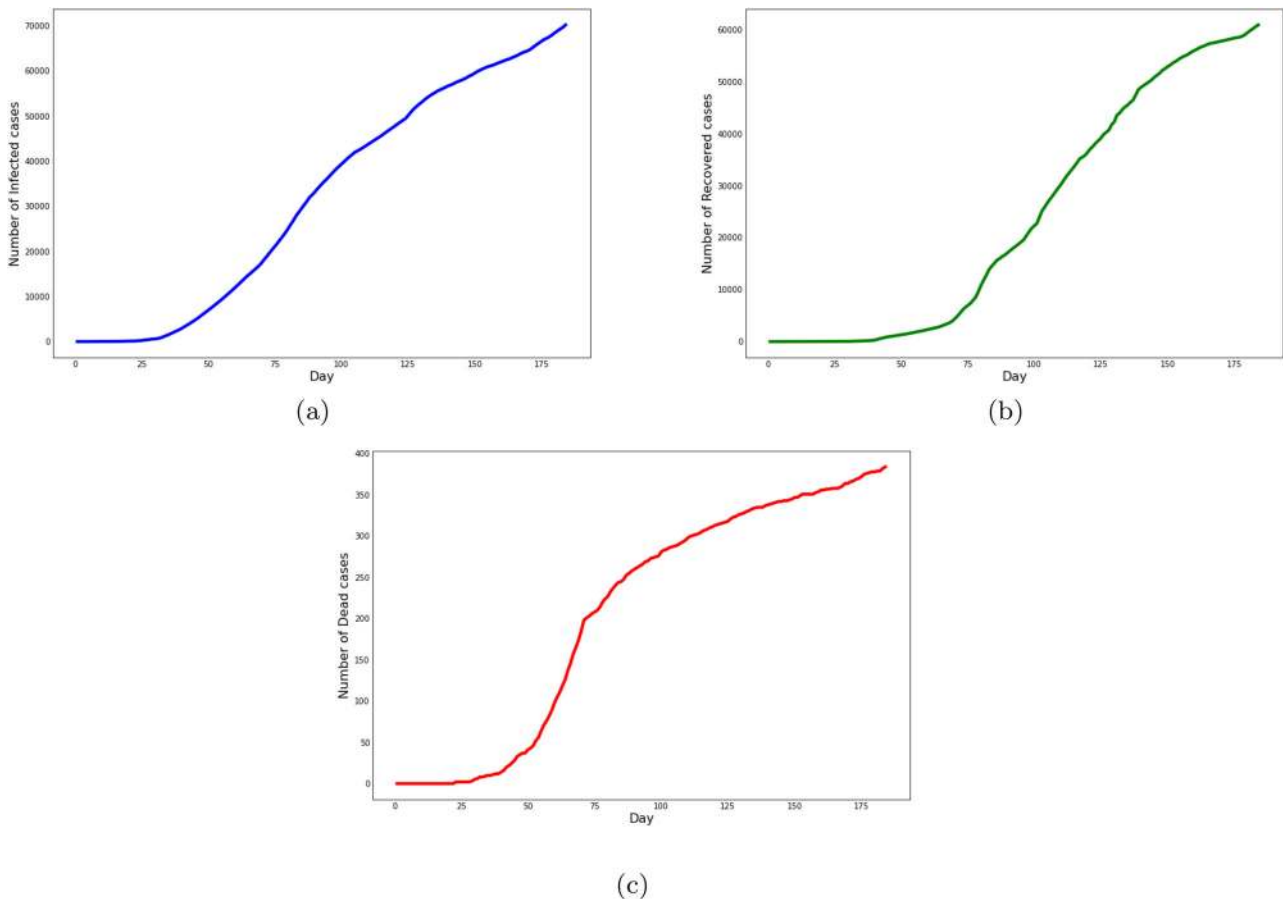
mathematical tools on these parameters would help in understanding the efficacy of restrictions and its impact on the evolution of the virus (Burdick et al., 2020; Din, Khan, & Baleanu, 2020; Din, Khan, et al., 2020; 2020; Din & Li, 2020; Wang, Zheng, Li, & Zhu, 2020; Wang & Xinqi, 2020). Such models can predict certain patterns of the future of the pandemic and determine the relationship with the factors of the initial conditions that produce such patterns. This approach is very useful to provide the necessary theoretical basis for evaluating the relative importance of various factors that can have an influence on the outcome of the pandemic. Therefore, the investigation of the correlation between the infection and recovery rates at different areas and stages could help specifying the nature of this pandemic.

Data analysis can then provide a powerful tool to investigate different environmental parameters that affect the rapid spread of this pandemic. Using data-based models will also help to extend public awareness to forecast various virus evolution scenarios. In order to develop vaccines or suggest precautionary measures to reduce the spread of the virus, it is extremely relevant that we understand the biological characteristics involved in the COVID-19 pandemic.

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**Figure 1.** Number of accumulated infected (a), and recovered (b), and dead individuals (c) due to the COVID-19 pandemic, in the period of 1 March 2020 to 31 August 2020.

An accurate prediction of the infection rate helps us to develop and implement the necessary preventive measures to reduce the biological impact on health and well-being.

As the pandemic continues to spread quickly, more precautionary and preventive measures have to be implemented, and their impact has to be frequently evaluated. However, the impact and dependence on other restrictions can not be directly predicted. Therefore, the use of mathematical approaches can be very useful to examine, evaluate, and predict the evolution of the virus. Such studies depend on the location, size of the spread of the virus, and the number of measures. The United Arab Emirates was one of the first countries to apply restrictions and measures to slow down the spread rate of the virus. The ministry of health and prevention reported the first confirmed case on 29 January 2020, and the number of daily infections continued to rise steadily, reaching 994 cases on 22 May 2020 (Dong, Hongru, & Gardner, 2020; FCSA, 2020).

This article aims to investigate the use of the mathematical susceptible-infectious-recovered (SIR) model in predicting the development of the epidemic in the United Arab Emirates, and discuss the effect of the applied measures and restrictions by the United Arab Emirates authority to control the

spread of the virus. It is important to mention that this study assumes the same measures and restriction by the United Arab Emirates will hold during the predicted period, including closing schools and remote learning, quarantine, and other lockdown rules.

## 2. Data collection

The first infected case in the United Arab Emirates was reported on the 29<sup>th</sup> of January 2020. Since then, the number of cases, as reportedly announced, evolve frequently. In the following, the officially reported data for the period from 1<sup>st</sup> March 2020 to 31<sup>st</sup> August 2020, identified currently as the first wave of pandemic spread, will be included in this analysis. Such data can be freely accessed and downloaded from the John Hopkins University Center for system science and engineering (Dong et al., 2020), and also indicated by the Federal Competitiveness and Statistics Authority (FCSA) in the UAE (FCSA, 2020). Figure 1 shows a graphical presentation of the recorded infections, recovered, and dead individuals due to the COVID-19 pandemic in the UAE. From the graph, it can be seen that the spread of the virus is steady in the first month above which an exponential increase of the reported cases takes



**Figure 2.** Diagram of the SIR model for COVID-19.

place. On the other hand, the recovery rate in the UAE is indicated to be high, which in combination with country internal restrictions, reduces the number of active cases. In fact, the lockdown and strict internal measures applied by the UAE authorities to target clusters of human gatherings such as educational processes and outdoor activities led eventually to systematic control of the pandemic spread. Additionally, large number of daily tests has been performed by the UAE authorities allowing an early detection of positive cases at an early stage. The latter led to a positive impact on complete isolation which is in combination with adherence to internal measures, resulted in high recovery rate, reaching a number of 50k recoveries within a period of 100 days, as shown by Figure 1(b). Besides, Figure 1(c), indicates relatively small death rate of 380 cases in a period of 145-150 days of pandemic evolution. As such rate apparently stabilizes at this value, the UAE internal regulations and lockdown measures are regarded to be of the top successful procedures worldwide that led eventually on systematic control of the pandemic evolution.

### 2.1. The SEIR model (susceptible-exposed-infected-recovered)

The susceptible-exposed-infected-recovered “SEIR” model, first presented by Kermack and McKendrick in 1927 (Kermack & McKendrick, 1991), is a theoretical contagious disease framework that has been widely investigated and developed to study various other virus diseases such as; SARS (Ng, Turinici, & Danchin, 2003; Zhou, Ma, & Brauer, 2004), Ebola (Nazir et al., 2020), and MERS (Chang, 2017). In addition, the SIR model was used to predict the evolution of the COVID-19 pandemic in Saudi Arabia, using reported cases between 2 March and 15 May 2020 (Alboaneen, Pranggono, Alshammari, Alqahtani, & Alyaffer, 2020). The model showed that the number of infections decreases in June 2020, reaching an ending phase on 24 June 2020. In another case study (Ifguis, Ghazliani, Ammou, Moutcine, & Abdellah, 2020), the SIR model was used to optimize the size of the COVID-19 pandemic in the Kingdom of Morocco. The study used the reported data in March 2020, and predicted the total number of infected cases at the end of the pandemic to reach 1446 on 26 April 2020.

The SIR model divides the population into three main categories:

1. *The number of susceptible people (S):* This group refers to people who are not infected, but are vulnerable to infection.
2. *The number of infected people (I):* It contains all individuals who have already been infected by the virus and can spread it to the first group.
3. *The number of people who have recovered (R):* This group is for people who have recovered from the disease and are likely to be immune from the disease.

The rates of change of the three groups are represented by the following non-linear differential equations:

$$\frac{dS}{dt} = -\beta SI, \quad (1)$$

$$\frac{dI}{dt} = (\beta SI - \gamma)I, \quad (2)$$

$$\frac{dR}{dt} = \gamma I. \quad (3)$$

In these equations,  $\beta$  is the probability of transmission of the disease (the infection rate),  $\gamma$  is the rate of recovered or removed individuals.  $S(t)$  refers to the number of susceptible individuals at time  $t$ , while  $I(t)$  is the number of infected people at time  $t$ , and  $R(t)$  represents the number of recovered individuals at time  $t$  (Figure 2).

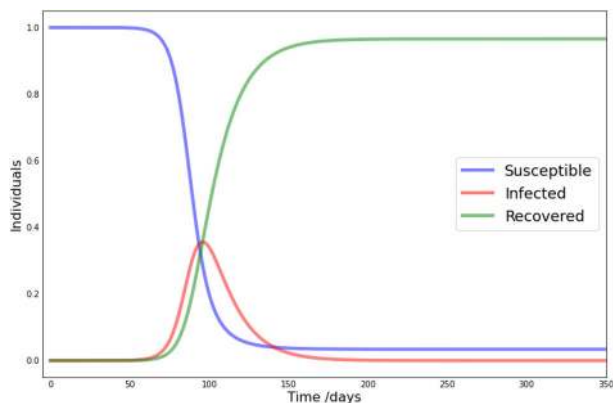
The model has a basic assumption that birth and death rates in the country are negligible compared to the living population. Therefore, the total population  $N = S + I + R$  is constant:

$$\frac{dS(t)}{dt} + \frac{dI(t)}{dt} + \frac{dR(t)}{dt} = 0. \quad (4)$$

Furthermore, the model also assumes that, once recovered, individuals will become immunized, and will not acquire the virus for a second time, and that is the only way to leave the category of infected people ( $I$ ). Additionally, the infection probability is independent of age, race, gender, or social status (Miller, 2017).

## 3. Results and discussion

In this paper, the SIR model was used as a framework to estimate the evolution of the COVID-19 pandemic in the United Arab Emirates over a period of



**Figure 3.** A typical behavior of the three categories, susceptible ( $S$ ), infected ( $I$ ), and recovered ( $R$ ) in the SIR model. Initial numbers of this simulation are:  $\beta = 0.25$ ,  $\gamma = 0.071$ ,  $I_0 = 1$ , and  $R_0 = 0$ .

six months (between March 1<sup>st</sup> 2020 and August 31<sup>st</sup> 2020). The simulation, fitting and prediction of the evolution of the disease were run using a Python program (Van Rossen & De Boer, 1995).

A simulation of the typical behavior of the three categories of the SIR model is modeled over a period of 350 days (Figure 3). Within the latter, the susceptible individuals is shown to decrease as the infected group increases to the maximum. Meanwhile, the number of recovered individuals increases to a maximum as the internal restrictions and measures begin to weaken the spread of the pandemic, which reported to be within day 40 from the start of pandemic spread.

Before running the numerical analysis, we give the parameters some initial values. According to the SIR model, the change in the population is described in terms of infection rate  $\beta$  and recovery rate  $\gamma$ . The infection rate  $\beta$  is given a value of 0.25, assuming one infected case will be in contact with 25 individuals, with a transmission rate of 10%. The recovery rate  $\gamma = 0.1$ , assuming ten days as the period during which an infected person remains infectious and can spread the virus. The model starts the simulation with one infected individual, zero recovered cases, and the rest of the population is considered as susceptible individuals. Furthermore, the reproductive number  $R_0$  is also considered as another important epidemiological parameter to analyze the evolution of the pandemic.  $R_0$  is the average number of secondary infections produced by a primary infected individual in a complete susceptible population. The equation is given as:

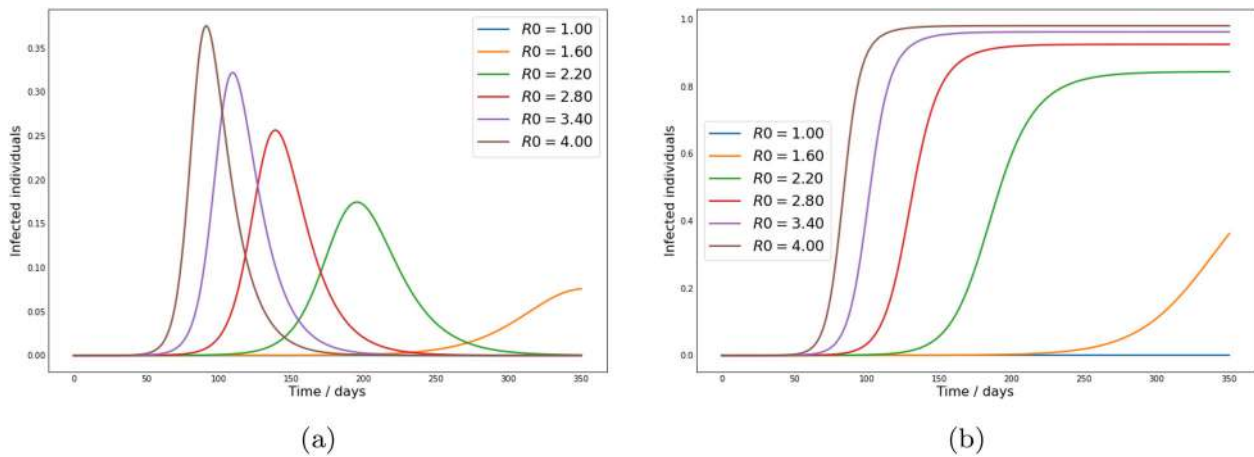
$$R_0 = \frac{\beta}{\gamma}. \quad (5)$$

If the number of secondary infections from a primary infected individual is greater than one ( $R_0 > 1$ ), the spread of the virus will increase. On the other hand, if the number of secondary infections is less

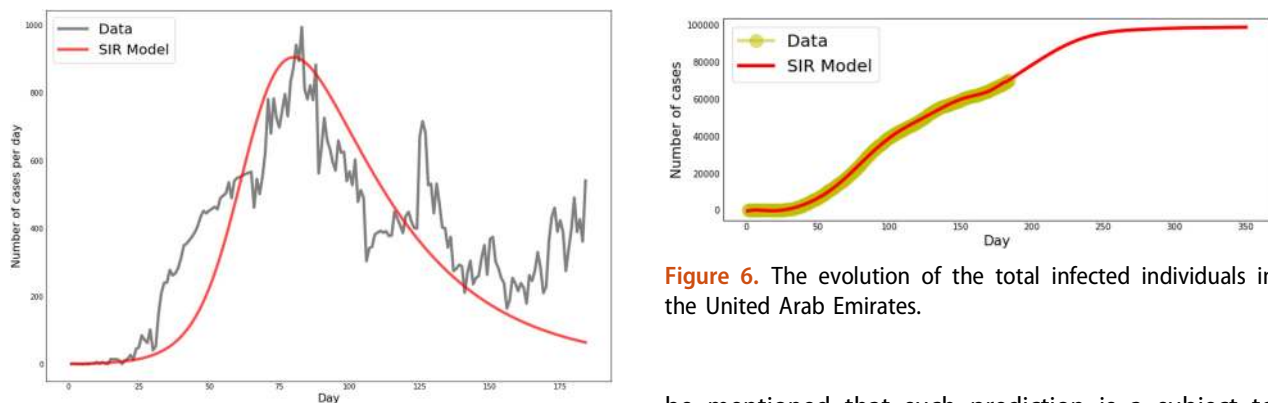
than 1 ( $R_0 < 1$ ), the risk of the pandemic will decrease. In addition. The reproductive number changes from day to day based on the number of reported cases every day. Figure 4 shows a simulation of different scenarios of the reproductive epidemiological parameters between 1.00 – 4.00. As can be inferred, for fraction of population, Figure 4(a) indicates that the peak of infected individuals changes for different reproductive numbers, reaching the maximum for the largest  $R_0$  of 4.00. The worst-case scenario of the simulation is shown for  $R_0 = 4$  (the brown distribution), where the probability of transmission of the disease is high and, consequently, the number of infected individuals has the maximum peak. Decreasing the reproductive number to  $R_0 = 2.2$  results in a sizable increase in the number of infected individuals (shown in green), and the best-case scenario is obtained when the transmission rate is equal to the recovery rate ( $R_0 = 1$  for the blue distribution), outside the range of the current period focus. An important fact to notice from Figure 4, is the time dependent of the infection rate development according to the different scenarios related to the different epidemiological parameters. The latter results have also been confirmed for the cumulative distribution of cases, Figure 4(b).

In order to solve the SIR model, the numerical simulation is performed using python (Van Rossen & De Boer, 1995) by comparing the simulated number of daily cases to actual daily data. The process runs a maximum likelihood optimization algorithm to search for the optimal values of the parameters in such a way that the difference between the simulation and data is at minimum. It is important to keep in mind that the model assumes during the process that new birth and death rates are negligible that the total population remains constant.

Figure 5 presents a comparison between the actual numbers of infected cases in the United Arab Emirates fitted with SIR model. The number of infections increases exponentially after the first month of the selected period, reaching a peak of reported cases at 22<sup>nd</sup> of May 2020. Starting from March 2020, as a result of the lockdown and implemented measures in the country, the number of infections starts to decrease, reaching its minimum at 3 August (day 153). On the other hand, the maximum number of infected individuals corresponding to the optimized SIR model is found on 19 May (day 80), which indicates a good agreement between the reported data and the simulation results. Furthermore, the reported data seems to have a notable increase at the end of the selected period, which could indicate the start of a second wave of the pandemic that cannot be predicted with the current settings of the SIR model. However, more advanced simulations and



**Figure 4.** Simulation of the time scale of infected population with different assumptions of the reproductive number  $R_0$ . Left: cases as a fraction of population, Right: cumulative distribution of cases.



**Figure 5.** Daily number of reported cases, compared to simulation based on the SIR model.

**Figure 6.** The evolution of the total infected individuals in the United Arab Emirates.

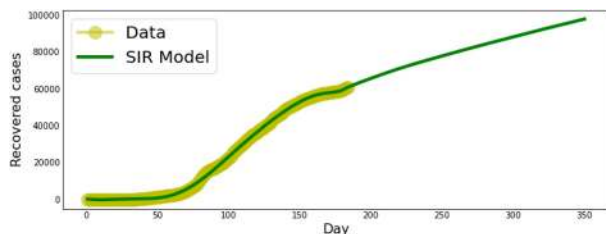
investigations of such expected scenario are still ongoing.

A prediction of the evolution of the overall spread of the pandemic, using the SIR model, is presented in Figure 6, and compared to the actual numbers of infected cases between March and August 2020. The cumulative number of reported cases continues to increase until the end of the selected period, reaching about 70 K at the end of August. The comparison shows that the model can describe the actual data in the selected period. In addition, the prediction of the evolution of the epidemic in the coming month shows that the cumulative number of infected cases will continue to increase, reaching nearly 100 thousand by day 225 (corresponding to 20 October 2020). After this period, the simulation outcomes predict stability of the daily infected cases, which in combination with continuous observation of the internal measures, might lead to gradual decrease of infected cases, indicating a possible end of the pandemic. On the other hand, the prediction of the number of recovered cases in Figure 7 shows a steady increase, reaching a maximum number at the end of the prediction period (around 98 K). It should

be mentioned that such prediction is a subject to other different parameters that are not considered in the current simulations such as evolving strains of the virus and tidiness of the internal restrictions. The coefficient of determinations  $R^2$  is evaluated to present the goodness of the fit procedure. The  $R^2$  is equal to 0.91 and 0.89 for the prediction of infection and recovery rates, respectively. However, other statistical indicators can be also presented for the development of new mathematical models.

#### 4. Conclusion

In conclusion, the prediction of the evolution of the final size of the COVID-19 pandemic in the United Arab Emirates is studied using the SIR model. The procedure allowed to simulate the peak of infected individuals in the UAE. Assuming the implemented precautionary measures and restriction will hold to the end of the selected period, the SIR model predicts that by the end of October 2020, the spread of the COVID-19 pandemic in UAE will cease, reaching approximately 100k infected cases. In addition, the model predicts the number of recover cases to increase, reaching approximately 98 K at the end of October. Nevertheless, further investigations with extended data and other mathematical models, such as the susceptible-exposed-infectious-recovered (SEIR) model (Haider Ali, Luís, & Pinho, 2014), the



**Figure 7.** The evolution of the total recovered individuals in the United Arab Emirates.

susceptible-infectious-recovered-deceased (SIRD) model (Maba, 2014), and aggregation functions (Jwaid, Meyer, Ismail, & Baets, 2021) maybe worthwhile to explore the emergence of the currently known as second pandemic wave spread. While keeping an eye on the commencement of a second wave of the pandemic, authorities have already increased the testing capacity in order to identify the infected cases at earlier stages, which could help in increasing the recovery rate.

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### Disclosure statement

No potential conflict of interest was reported by the authors.

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