

# Preliminary Estimation of the Basic Reproduction Number of SARS-CoV-2 in the Middle East

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## Abstract

Up to April 9, 2020, 142490 cases have been confirmed as COVID-19 infection including 5705 associated deaths in the Middle East. Most of the countries, such as Qatar, Bahrain, Iraq, Kuwait, United Arab Emirates (UAE), Oman, Lebanon, and Saudi Arabia have imported COVID-19 cases from Iran. Using the available data from WHO webpage, up to 9 April 2020, we traced epidemic curves and estimated the basic reproduction number ( $R_0$ ) of COVID-19 through the susceptible-infectious-recovered (SIR) model for the Middle East countries. Epidemic curves for Middle East countries and territory show similar trend as Iran, with a couple of weeks' delay in time. In SIR model,  $R_0$  ranged between 7.41 as in Turkey to lowest as 2.60 for Oman whereas basic reproduction number for Iran, Kuwait, Bahrain, Qatar, Saudi Arabia, United Arab Emirates (UAE), Oman, Jordan, Egypt, Lebanon, Syria, Israel, West Bank and Gaza Strip territory, and Cyprus were 4.13, 2.71, 3.39, 4.18, 4.45, 2.75, 2.60, 3.52, 3.35, 3.16, 4.99, 4.08, 2.89, and 4.05, respectively. This study indicates an important trend on an early outbreak of COVID-19 based on estimated  $R_0$  for the Middle East countries, mean  $R_0 = 3.76$  for COVID-19, with median = 3.51. and interquartile range (IQR) = 1.16. in the Middle East.

**Keywords:** Basic Reproduction Number ( $R_0$ ), COVID-19, Mathematical Model, SIR, Middle East.

## 1. Introduction

The COVID-19 infection, caused by the novel coronavirus SARS-CoV-2, is a contagious disease that can be transmitted through droplets, aerosols, and contact (Morawska and Cao, 2020; van Doremalen et al., 2020; Xu et al., 2020). The symptoms of COVID-19 infection appear after approximately 5.2 days (incubation period) (Li et al., 2020), which ranges from most common (fever, sore throat, cough, and fatigue) to variable ones (loss of smell, sputum production, headache, haemoptysis, diarrhoea, dyspnoea, and lymphopenia) (Huang et al., 2020; Li et al., 2020). In severe cases, infected cases may develop pneumonia, bronchitis, severe acute respiratory distress syndrome (ARDS), multi-organ failure, and death. The first confirmed COVID-19 case was detected in the Chinese city of Wuhan in late December 31, 2019, since then, the virus has spread worldwide. The World Health Organization (WHO) declared COVID-19 outbreak as a pandemic on March 11th, 2020 (WHO, 2020a). The reported cases of COVID-19 have since risen exponentially worldwide reaching more than 200 countries (Lewnard and Lo, 2020). As of April 9th, 2020, the outbreak has affected around 1521252 people

globally and 142490 confirmed cases in the Middle East. The number of cases reported only in Iran until April 9th, 2020 is 68192 which records the highest number of infected cases of coronavirus in the Middle East. Iran has quickly led to an infection chain that represents the second highest COVID-19 outbreak after Italy, the epicenter outbreak in Europe, with local cycles of transmission have occurred in more than eight countries after imported cases.

In the emergence of a new infectious disease outbreak, predicting the trend of the epidemic is of crucial importance to suggest effective control measures and estimate how contagious it is and how far it could spread (Viboud et al., 2018). Mathematical modelling plays a key role in understanding the transmission rates and prediction evaluation of infectious diseases and their control measures since the early 20th century (Hamer, 1906). Thus, it can provide insights into the epidemiological characteristic which help decision makers to implement restriction strategies and prepare the health system capacities in the course of pandemic (Lauro et al., 2020; Wenbao et al., 2020). Rapid research on the prediction and transmissibility of COVID-19 has been focused on Asian and European countries (Yuan, 2019), with less attention in Middle Eastern countries. Increasing number of COVID-19 cases in Middle East, urged us to estimate the prediction and transmissibility in the region to implement appropriate alternative control measures accordingly.

The basic reproductive number ( $R_0$ ) represents an indication of the initial transmissibility of the virus, i.e., the average number of secondary infections generated by each infected person. If this number is equal to one or less,  $R_0 \leq 1$ , it indicates that the number of secondary cases will decrease over time and eventually the outbreak will peter out. However, when  $R_0 > 1$ , the outbreak is expected as transmission to secondary cases increases that urges the implementation of control measures.

Initially, WHO estimated the basic reproduction number for COVID-19 between 1.4 and 2.5, as declared in the statement regarding the outbreak of SARS-CoV-2, dated 23th January 2020. Additionally, several articles aimed to more precisely estimate the COVID-19  $R_0$ . Recently, (Liu, Y. et al, 2020) compared 12 published articles from January 1, 2020 to February 7, 2020 and they reported that mean and median estimates for  $R_0$  were 3.28 and 2.79, respectively. Furthermore, Korolev, I (Korolev, 2020), reported  $R_0$  to be 2 to 3 times higher for the US and Western countries than for Asian countries. Rahman, B. et al (Rahman et al., 2020) also reviewed 50 published articles which estimated 103  $R_0$  of COVID-19 with hovering between 0.32 and 6.47 in different countries including Italy, Iran, South Korea, Singapore, Japan, Israel, Algeria, Brazil and China. These differences are not surprising as transmission of COVID-19 multifaceted involving several changeable factors for deriving  $R_0$  estimates, such as methods for modelling, variables to be considered, conditions on the clinical parameters, and various estimation procedures.

Up to our knowledge, limited number of articles published on prediction and  $R_0$  of COVID-19 in Middle East. A group of researchers at Shahrekord University of Medical Sciences (Ahmadi et al., 2020), estimated  $R_0$  to be 4.7 at the beginning of the outbreak in Iran and now  $R_0$  has fallen below 2. Moreover, with three different scenarios estimated the prediction of confirmed cases by 3rd April 2020 at 19500, 27000, and 48830, with growth models of von Bertalanffy, Gompertz, and the least squared error, respectively. Authors concluded that the most ideal scenario is the Gompertz model. Current data from the WHO suggest more than a week ahead from Gompertz model prediction, with a reported number of 27017 cases by 25th March 2020. Muniz-Rodriguez K. et al (Muniz-Rodriguez et al., 2020), estimated  $R_0$  to be 3.6 and they recommended immediate social distancing in Iran. Sahafizadeh E. et al (Sahafizadeh and Sartoli, 2020), considered a basic SIR model by fitting the reported cases and observation for  $R_0$  COVID-19 in Iran which was 4.86 and later reduced to 4.29. Ghaffarzagdegan N. and Rahmandad H. (Ghaffarzagdegan and Rahmandad, 2020), developed SEIR epidemic model to predict a reliable figure of COVID-19, according to their trajectory prediction 1.6 million Iranian might get infected with 58000 death cases by the end of June 2020. (Wang J. et al, 2020) used SEIR model and estimated  $R_0$  to be 8.93 with a transmission rate of 0.638 in Iran. Lately, (Klausner Z. et al, 2020), estimated  $R_0$  to be 2.19 and presented deterministic compartment model with emphasizing quarantine and isolation policies. Their analysis showed that a single holiday changed the epidemic curve from flattened to exponential growth in Israel.

## 2. Method

Considering the daily data of the pandemic on the number of laboratory-confirmed cases reported from WHO situation reports, we employ an epidemic model SIR, a simple and widely used deterministic, that describes the flow of individuals through three mutually exclusive stages of infection: Susceptible (S), Infected (I) and Removed (R)

$$\begin{aligned}
 \frac{dS}{dt} &= -\frac{\beta SI}{N}, \\
 \frac{dI}{dt} &= \frac{\beta SI}{N} - \alpha I, \\
 \frac{dR}{dt} &= \alpha I, \\
 N &= S + I + R,
 \end{aligned}
 \tag{1}$$

where  $\beta$  is the parameter that controls the transition between  $S$  and  $I$  and  $\alpha$  which controls the transition between  $I$  and  $R$ . Removed compartment is a combination of both recovered and dead cases. In the absence of vaccine, the whole population assume to be susceptible,  $S \approx N$ , in this case infected population can be approximated to

$$\frac{dI}{dt} = \frac{\beta SI}{N} - \alpha I = (\beta - \alpha)I.
 \tag{2}$$

Works out as

$$I(t) = I_0 e^{(\beta - \alpha)t},
 \tag{3}$$

where  $I_0$  is the number of infectious individuals at the beginning of the outbreak. An epidemic occurs if the number of infected individuals increases, i.e  $\beta - \alpha > 0$  which is equivalent to  $\frac{\beta}{\alpha} > 1$ . According to the definition of  $R_0$ , the transmissibility of a virus is measured by the basic reproduction number, which measures the average number of new cases generated per typical infectious cases, can be estimated throughout system (1), we arrive at the following inequality,

$$R_0 = \frac{\beta}{\alpha} > 1.
 \tag{4}$$

It is obvious that the basic reproduction number  $R_0$  is dependent on both infection rate  $\beta$ , and removal rate  $\alpha$ , which is the inverse of infectious period. As reported in the WHO-China joint mission on COVID-19 (Report of the WHO-China Joint Mission on Coronavirus Disease COVID-19, (2019)), in our simulation, we assume susceptible individual with COVID-19 takes an average of 7 days to be infected and takes an average of 14 days from infected to removed, yields  $\alpha = \frac{1}{14}$ . Next, we used estimation procedure (least-square fitting) like Method 2 in (Chowell et al., 2007), and compute the residual sum of squares for the reported cases, given by

$$RSS(B) = \sum_{t=1}^n (RD(t) - FD(t, \beta))^2,
 \tag{5}$$

where  $RD$  stands for real data, and  $FD$  is a fitted data, that is the value of data  $t$  on the fitted curve, which can be predicted by SIR model,  $n$  is the number of daily reported cases of COVID-19. We then estimate the infection rate  $\beta$  by minimizing the  $RSS$ .

### 3. Results and Discussion

The COVID-19 pandemic spread rapidly, and crossed borders reaching almost every corner of world and took more than two hundred thousand lives. The current economic and social impact of this pandemic is just the tip of iceberg. Due to lack of population immunity and an effective vaccine, the spread of COVID-19 is still expanding exponentially in many countries. Therefore, evaluating the effectiveness of implemented controlling measures like traffic restriction, lockdown, and social distancing are critical to stop the spread of the COVID-19 and save lives of thousands of people. Here we report the  $R_0$  of all Middle East countries based on SIR model (Figure 1 and Table 1). Interestingly, it was found that Middle East countries seem to follow Iran's trend with just a few week delays in time.

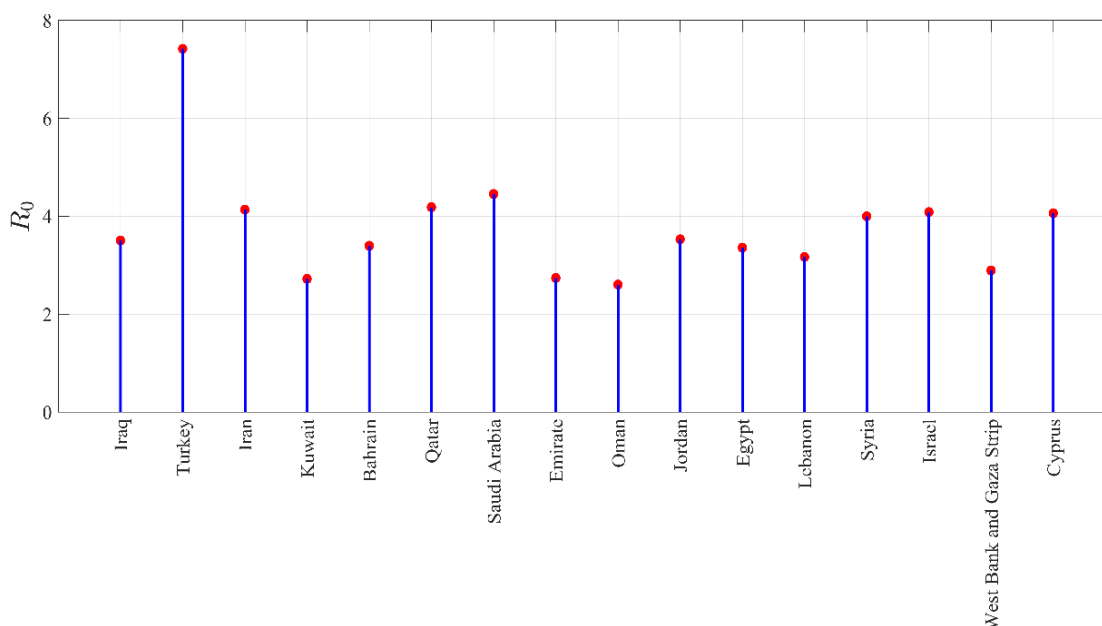


Figure 1. Dot Chart Showing the Estimated  $R_0$  in the Middle Eastern Countries and Territory.

Table 1. The Basic Reproduction Numbers and the Corresponding Key Parameters.

Countries/Territory	Population	$n$	$\beta$	$R_0$
Iraq	40,222,000	46	0.25012	3.50168
Turkey	83,200,000	30	0.52979	7.41706
Iran	82,914,000	50	0.2952	4.1328
Kuwait	4,700,000	46	0.19422	2.71908
Bahrain	1,443,000	46	0.2425	3.395
Qatar	2,839,000	40	0.29878	4.18292
Saudi Arabia	34,140,000	39	0.31805	4.4527
UAE	9,680,000	50	0.19549	2.73686
Oman	5,107,000	45	0.18585	2.6019
Jordan	10,458,000	39	0.25188	3.52632
Egypt	100,388,000	50	0.23971	3.35594
Lebanon	6,825,000	48	0.22622	3.16708
Syria	17,070,000	18	0.28549	3.99686
Israel	8,972,000	49	0.29162	4.08268
West Bank & Gaza Strip	5,101,000	36	0.20647	2.89058
Cyprus	1,207,000	31	0.28999	4.05986

The control and delay in spreading of COVID-19 infection strongly rely on the capabilities of a country's health system. The health system of many developing countries in the Middle East is below the world's standards (Ghsindex, 2020) that make these countries vulnerable to a rapid spread of COVID-19 with higher rate of fatality as a result of current pandemic. It is worthy to note that, current official cases in the region is far behind those in the US, Italy, and Spain.

The overall timeline of the outbreak has provided countries with a window of opportunity for the early implementation of preventive interventions. Thereby, the before math intervention introduced in some Gulf countries play a considerable role in slowing down the number of confirmed cases, or "flattening the curve" of the virus' growth (Vatanka et al., 2020). A recent article illustrates that the government response and population demography in Iraq have a significant role in flattening the epidemiological curve (Jebril, 2020). We suggest all countries need to consider the Chinese and Italian

lessons and implement immediate and more powerful control measures in order to stop the spread and break the chain of transmission.

Regarding the used parameters by SIR model for the prediction, the  $R_0$  values shown in Figure 1, is relatively consistent with several mathematical models that have been used so far. Estimated the COVID-19  $R_0$  varies from 1.69 to 6.47 (Muniz-Rodriguez et al., 2020). A review written by (Liu et al, 2020) compared 12 published articles from the 1st January to the 7th of February 2020 which estimated for the  $R_0$  for COVID-19 a range of values between 1.5 and 6.68. In a recent article, (Jiang, S et al, 2020)(Wang et al., 2020), estimated  $R_0$  to be 6.66, 5.03, 5.60, and 8.93 for the four main epicenters Wuhan, Korea, Italy and Iran respectively. (Sardar, et al, 2020), estimated  $R_0$  in different Indian states (Maharashtra, Delhi, Tamil Nadu) and overall, India ranged between 1.46 to 8.44. By comparing the various investigation, these different basic reproduction number arise for many reasons: the virus is shed before symptoms begin, it is hard to identify the incubation period, the proportion of infected cases missed at the tracing and control procedures and the effectiveness of current strategies to prevent the spreading of the infection (Viceconte and Petrosillo, 2020).

Based on current model, the trend falls into three different curves which are exponential, sub-exponential, and polynomial (Figure 2) and number of cases in each country shown in (Figure 3). In Iran, Turkey, Saudi Arabia, and Israel, the confirmed cases rise exponentially; in Qatar, UAE, and Egypt increase sub-exponentially; in Iraq, Kuwait, Bahrain, Oman, Jordan, Lebanon, Syria, West Bank and Gaza Strip, and Cyprus grow polynomially. These countries have exponential curves recorded the highest  $R_0$  ranging from 4.08 to 7.41, while countries and territory with polynomial curves reported the lowest ranging between 2.60 to 4.05.

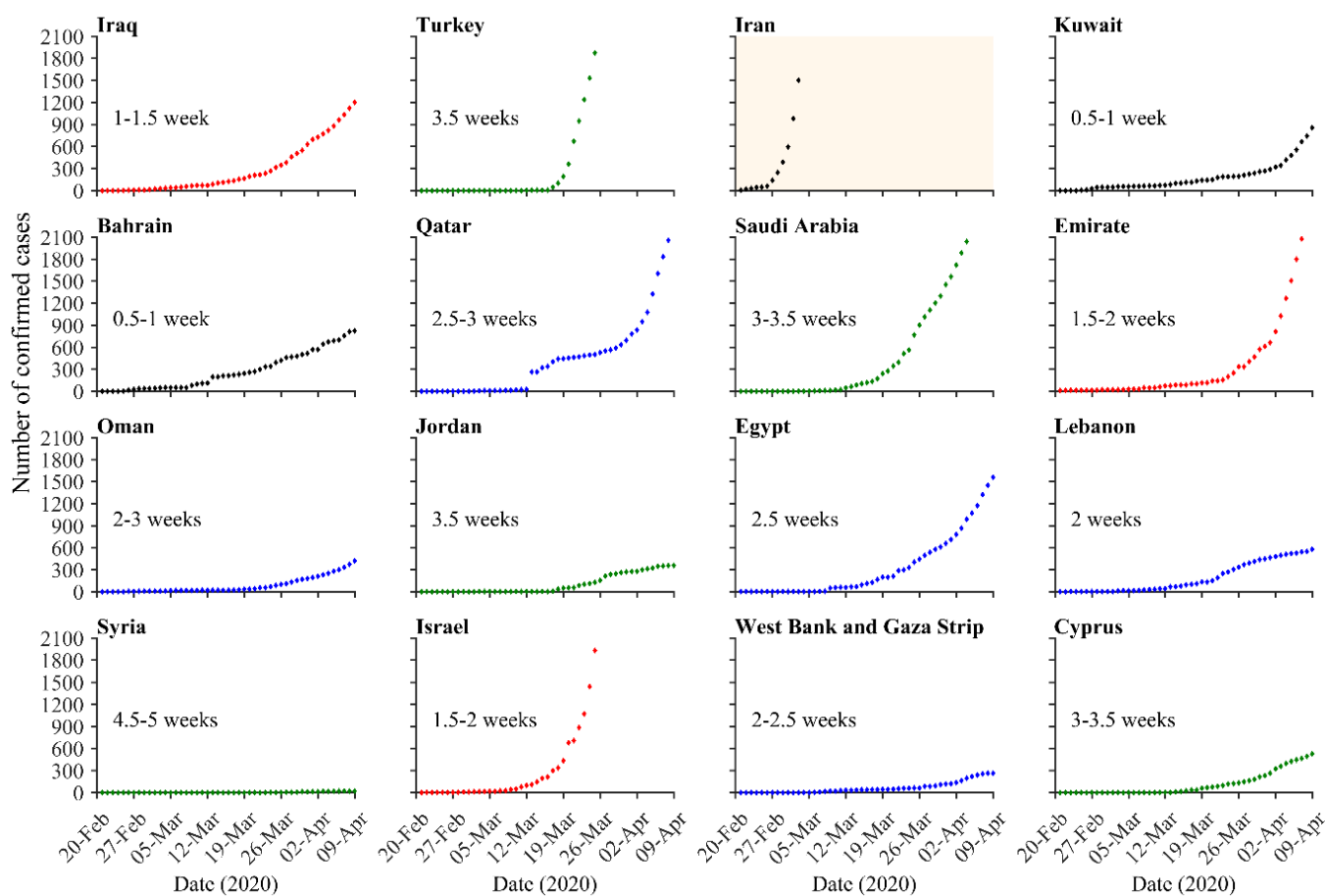


Figure 2. Cumulative of Confirmed Cases for Middle East Countries and Territory, with Estimated Delay in Time from Iran's Situation, as of 9th April 2020. Black dots are for countries with less than 1 week delay in time from Iran; red is for countries with 1–2 weeks delay in time; blue is for countries and territory with 2-3 weeks delay in time; and green is for countries with more than 3. The Iranian and Turkish data curves are cut at 2100 cases in order to compare delay in time with other countries. (WHO, 2020)

### Middle East Coronavirus Cases

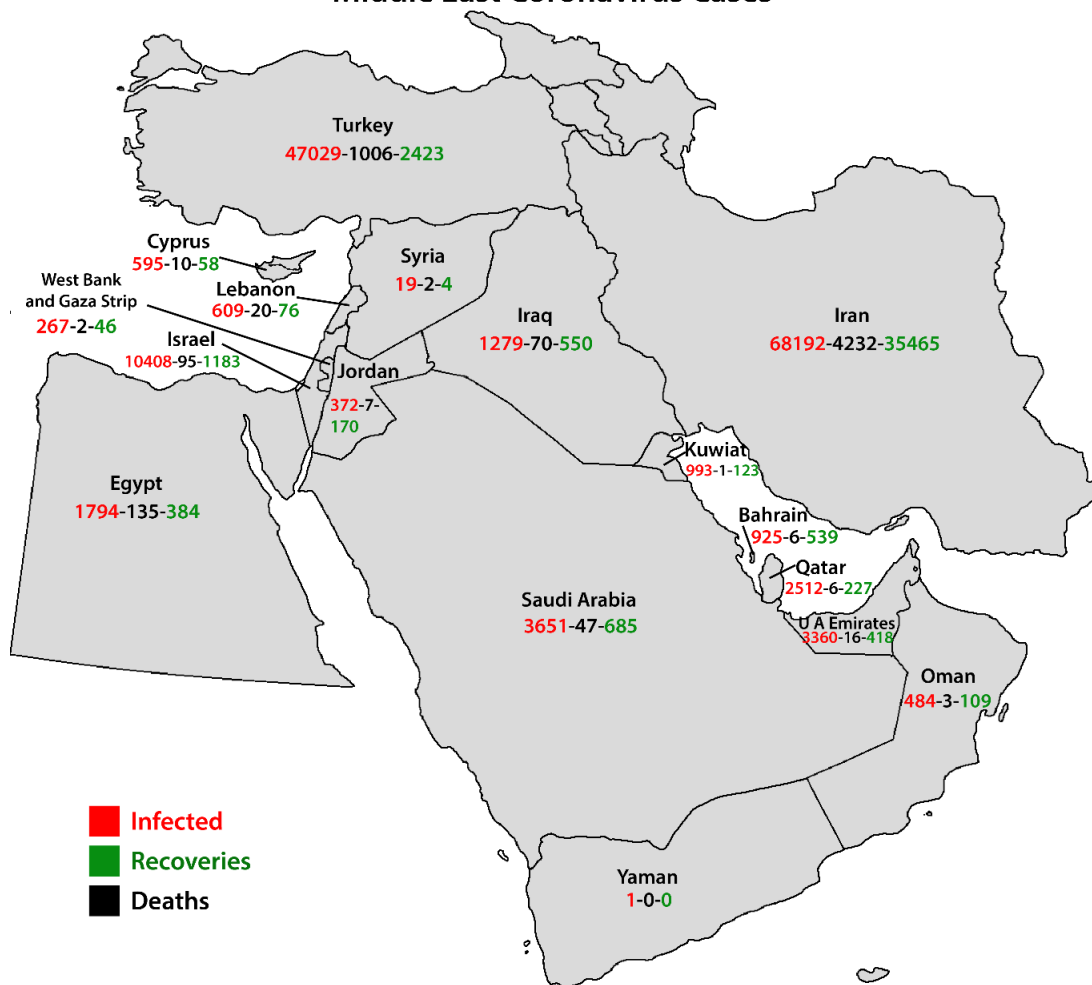


Figure 3. Infected, Recoveries and Deaths Cases in the Middle Eastern Countries and Territory.

#### 4. Conclusions

Basic reproduction number of COVID-19 is crucial parameter during a pandemic which is used to estimate the risk of COVID-19 outbreak and evaluate the effectiveness of implemented measures. For the first time, we report estimates of the basic reproduction number  $R_0$  of COVID-19 outbreak in the Middle East countries and territory together using SIR model by fitting the model to official reported data from WHO. It is also observed the Middle East countries epidemic curves is just a couple of weeks behind Iran. According to the result Turkey has the highest  $R_0$  and Oman has the lowest. This study also found that the estimated mean  $R_0$  for COVID-19 is around 3.76, with a median of 3.51 and IQR of 1.16. This mean  $R_0$  is close to the two recent review articles by (Liu et al, 2020 and Alimohamadi, Y. et al, 2020) which estimated  $R_0$  to be 3.38 and 3.28 respectively. Due to short onset time, current estimates of  $R_0$  for COVID-19 in the Middle East might be biased. Moreover, the basic reproduction number is continuously modified during a pandemic by accurate assumptions introduced and becomes more reliable  $R_0$  as more data and information come to light. The limitations of this study as it is applied to all other similar studies, due to limited number of tests in the whole population, the number of asymptomatic cases which may account about 25% of the population have been excluded and the reported confirmed cases are believed to be lower than the actual cases.

In summary, this study provides important findings on an early outbreak of COVID-19 in the Middle East. In theory, most the Middle East countries are in better positions than many other countries to react to the current outbreak. Nevertheless, health care system in some countries and territories of Middle East may face serious challenges as COVID-19 cases overwhelm hospitals, therefore, governments should work closely with the WHO to visit countries in need to provide recommendations, support control and prevention efforts. In the meantime, the Middle East countries and

territory should continue to prepare for and respond to COVID-19 and learn from China on relevant preventive and control measures.

## References

- Ahmadi, A., Shirani, M., and Rahmani, F. (2020). Modeling and Forecasting Trend of COVID-19 Epidemic in Iran. *MedRxiv*, 2020.03.17.20037671. DOI: <https://doi.org/10.1101/2020.03.17.20037671>
- Chowell, G., Nishiura, H., and Bettencourt, L. M. A. (2007). Comparative estimation of the reproduction number for pandemic influenza from daily case notification data. *Journal of the Royal Society, Interface*, 4(12), 155–166. DOI: <https://doi.org/10.1098/rsif.2006.0161>
- Ghaffarzadegan, N. and Rahmandad, H. (2020). Simulation-based Estimation of the Spread of COVID-19 in Iran. *MedRxiv*, 2020.03.22.20040956. DOI: <https://doi.org/10.1101/2020.03.22.20040956>
- Ghsindex. (2020). Global Health Security Index. Retrieved 24 March 2020 from URL <https://www.ghsindex.org/>
- Hamer, W. H. (1906). *The Milroy Lectures on Epidemic Diseases in England: The Evidence of Variability and of Persistency of Type; Delivered Before the Royal College of Physicians of London, March 1st, 6th, and 8th, 1906*. Bedford Press.
- Huang, C., Wang, Y., Li, X., Ren, L., Zhao, J., Hu, Y., Zhang, L., Fan, G., Xu, J., Gu, X., Cheng, Z., Yu, T., Xia, J., Wei, Y., Wu, W., Xie, X., Yin, W., Li, H., Liu, M., ... Cao, B. (2020). Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. *Lancet (London, England)*, 395(10223), 497–506. DOI: [https://doi.org/10.1016/S0140-6736\(20\)30183-5](https://doi.org/10.1016/S0140-6736(20)30183-5)
- Jebril, N. M. T. (2020). *Distinguishing epidemiological curve of novel coronavirus disease ( COVID-19 ) cases in Iraq : How it does not follow the epidemic curve of China*.
- Korolev, I. (2020). *Identification and Estimation of the SEIRD Epidemic Model for COVID-19*. 1–27.
- Lauro, F. Di, Kiss, I. Z., and Miller, J. (2020). The timing of one-shot interventions for epidemic control. *MedRxiv*, 2020.03.02.20030007. DOI: <https://doi.org/10.1101/2020.03.02.20030007>
- Lewnard, J. A. and Lo, N. C. (2020). Scientific and ethical basis for social-distancing interventions against COVID-19. *The Lancet Infectious Diseases*. DOI: [https://doi.org/https://doi.org/10.1016/S1473-3099\(20\)30190-0](https://doi.org/https://doi.org/10.1016/S1473-3099(20)30190-0)
- Li, Q., Guan, X., Wu, P., Wang, X., Zhou, L., Tong, Y., Ren, R., Leung, K. S. M., Lau, E. H. Y., Wong, J. Y., Xing, X., Xiang, N., Wu, Y., Li, C., Chen, Q., Li, D., Liu, T., Zhao, J., Liu, M., ... Feng, Z. (2020). Early Transmission Dynamics in Wuhan, China, of Novel Coronavirus–Infected Pneumonia. *New England Journal of Medicine*, 1–9. DOI: <https://doi.org/10.1056/nejmoa2001316>
- Liu, Y., Gayle, A. A., Wilder-Smith, A., and Rocklöv, J. (2020). The reproductive number of COVID-19 is higher compared to SARS coronavirus. *Journal of Travel Medicine*, 27(2), 1–4. DOI: <https://doi.org/10.1093/jtm/taaa021>
- Morawska, L. and Cao, J. (2020). Airborne transmission of SARS-CoV-2: The world should face the reality. *Environment International*, 139, 105730. DOI: <https://doi.org/10.1016/j.envint.2020.105730>
- Muniz-Rodriguez, K., Fung, I. C.-H., Ferdosi, S. R., Ofori, S. K., Lee, Y., Tariq, A., and Chowell, G. (2020). Transmission potential of COVID-19 in Iran. *MedRxiv*, 2020.03.08.20030643. DOI: <https://doi.org/10.1101/2020.03.08.20030643>
- Rahman, B., Sadraddin, E., and Porreca, A. (2020). The basic reproduction number of SARS-CoV-2 in Wuhan is about to die out, how about the rest of the World? *Reviews in Medical Virology*, e2111. DOI: <https://doi.org/10.1002/rmv.2111>
- Sahafizadeh, E. and Sartoli, S. (2020). Estimating the reproduction number of COVID-19 in Iran using epidemic modeling. *MedRxiv*, 2020.03.20.20038422. DOI: <https://doi.org/10.1101/2020.03.20.20038422>
- van Doremalen, N., Bushmaker, T., Morris, D. H., Holbrook, M. G., Gamble, A., Williamson, B. N., Tamin, A., Harcourt, J. L., Thornburg, N. J., Gerber, S. I., Lloyd-Smith, J. O., de Wit, E., and Munster, V. J. (2020). Aerosol and Surface Stability of SARS-CoV-2 as Compared with SARS-CoV-1. *The New England Journal of Medicine*, 382(16), 1564–1567. DOI: <https://doi.org/10.1056/NEJMc2004973>
- Vatanka, A., Slim, N. A.-D. R., Lister, C., Tol, M. F. M. M. G. W. G., Elgindy, G. M. F. K., Pack, J., Lawrence, W., Ford, R. S., and Salem, P. (2020). COVID-19 and the Middle East. Retrieved 18 March 2020 from URL <https://www.mei.edu/blog/covid-19-and-middle-east>.
- Viboud, C., Sun, K., Gaffey, R., Ajelli, M., Fumanelli, L., Merler, S., Zhang, Q., Chowell, G., Simonsen, L., and Vespignani, A. (2018). The RAPIDD ebola forecasting challenge: Synthesis and lessons learnt. *Epidemics*, 22, 13–21. DOI: <https://doi.org/https://doi.org/10.1016/j.epidem.2017.08.002>
- Viceconte, G., and Petrosillo, N. (2020). *COVID-19 R0: Magic number vidual affected by a transmittable disease is or conundrum?* 12, 12–13. DOI: <https://doi.org/10.4081/idr.2020>

- Wang, J., Distric, J., Jiang, S., Jiang, S., Li, Q., Li, C., He, X., Wang, T., Li, H., Corpe, C., Zhang, X., Xu, J., and Wang, J. (2020). Mathematical models for devising the optimal SARS-CoV-2 eradication in China , South Korea , Iran , and Italy. *The Lancet Global Health*.
- Wenbao, W., Yiqin, C., Qi, W., Ping, C., Ye, H., Shanwen, H., Yan, W., Zuxiong, H., and Wenxiang, W. (2020). Transmission dynamics of SARS-COV-2 in China: impact of public health interventions. *MedRxiv*, 2020.03.24.20036285. DOI: <https://doi.org/10.1101/2020.03.24.20036285>
- WHO (2019). *Report of the WHO-China joint mission on Coronavirus disease COVID-19 (2019)*.
- WHO (2020a). *Emergency Committee regarding the outbreak of Coronavirus disease 2019 (COVID-19)*. Retrieved 11 March 2020 from URL <https://www.who.int/dg/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19>.
- WHO (2020b). *Emergency Committee regarding the outbreak of novel coronavirus 2019 (n-CoV)*, Accessed 23rd January 2020. [https://www.who.int/news-room/detail/23-01-2020-statement-on-the-meeting-of-the-international-health-regulations-\(2005\)-emergency-committee-regarding-the-outbreak-of-novel-coronavirus-\(2019-ncov\)](https://www.who.int/news-room/detail/23-01-2020-statement-on-the-meeting-of-the-international-health-regulations-(2005)-emergency-committee-regarding-the-outbreak-of-novel-coronavirus-(2019-ncov)).
- Xu, R., Cui, B., Duan, X., Zhang, P., Zhou, X., and Yuan, Q. (2020). Saliva: potential diagnostic value and transmission of 2019-nCoV. *International Journal of Oral Science*, 12(1), 11. DOI: <https://doi.org/10.1038/s41368-020-0080-z>
- Yuan, J., Li, M., Lv, G., and Lu, Z. K. (2020). Monitoring Transmissibility and Mortality of COVID-19 in Europe. *International Journal of Infectious Diseases*. DOI: <https://doi.org/10.1016/j.ijid.2020.03.050>