A Mathematical Model to Analyze Data on Coronavirus Cases

Santanu Basu
Sparkle Optics Corporation
Menlo Park, CA
sb201@sparkleoptics.com

ABSTRACT

A mathematical model is presented which is designed to be applicable to Coronavirus case data from any country and which can serve as a tool to carry out predictive analysis and sensitivity analysis with the goal of minimizing virus related deaths. The model has been successfully applied to Covid-19 case data in five countries – China, South Korea, Iran, Italy and the USA. The model is versatile and can be applied to other countries and regions as well.

Key words: Coronavirus, Covid 19, modelling, mathematical, infectious disease, data analysis

INTRODUCTION

Mathematical modelling of spreading of infectious diseases is a well-established field [1,2]. Many infectious diseases such as Hepatitis C, HIV and Lyme disease have been extensively studied using mathematical models. There have been a surge of recent efforts in modelling Coronavirus spreading as reported in the literature [3,4]. In this paper we present a mathematical model which analyzes Covid-19 case data (daily values of number of cases, deaths and recovered) from five countries with very different case outcomes. The model fits the Covid-19 case data for these countries very well. The model also enables the reader to make near term predictions and sensitivity analysis for any country.

The Covid-19 virus has spread rapidly through many countries in the world in the first three months of 2020 causing widespread deaths. The same virus with the same infectious and fatality properties however had different number of casualties in different countries. It is important to have a mathematical model that can explain the case data from various countries and that uses parameters which can be measured and which can be used to do sensitivity and what if analyses. This is the motivation behind the model presented in this paper.

METHODOLOGY

In this section we study the propagation of a new infectious disease through an isolated country's population. With some simple modifications, the procedure can be applied to recurring outbreak of the same virus and also to the normal state in which there is population movement among countries.

Let n be the number of days since the onset of virus infection.

Figure 1 is a schematic of our model.

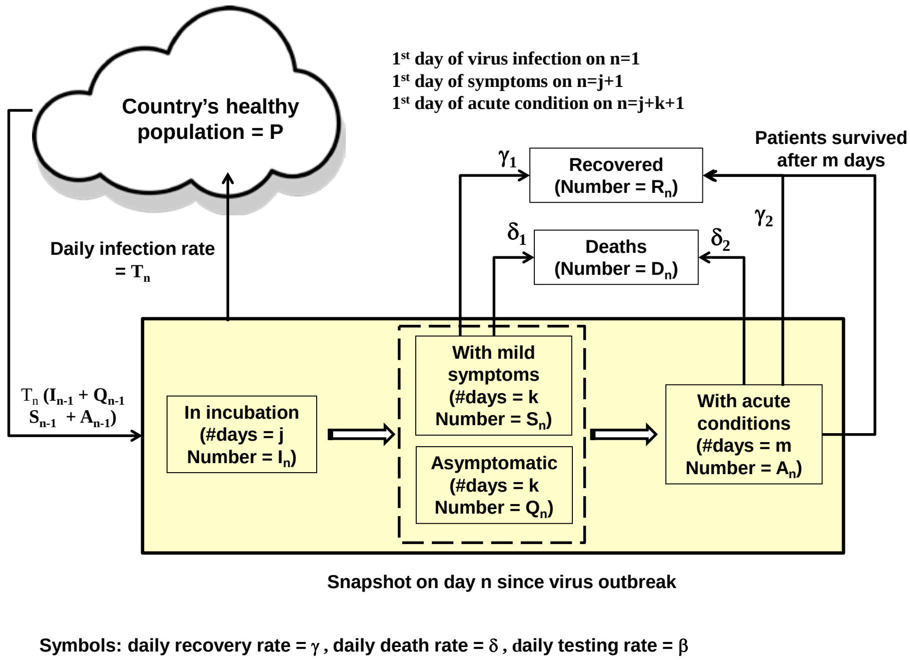


Figure 1. Schematic of the mathematical model for the virus infected cases

The entire population of virus infected people is classified in six categories:

I – people in whom the virus is in incubation

Q – people who are infected with the virus but who do not exhibit any symptoms

S – patients who exhibit mild symptoms of the viral infection

A – patients who are in acute condition

D – people who have died as a result of viral infection

R – people who have recovered from the viral infection

On any day n, the total number of people who have been infected with the virus is N_n, where

$$N_n = I_n + Q_n + S_n + A_n + D_n + R_n \tag{1}$$

We denote the incubation period for the virus in number of days by j. The model assumes each infected person spends j days in incubation. We assume that after the incubation period of j days, each infected person either is asymptotic but carries the virus for another k number of days, or shows mild symptoms of the disease for k number of days. For each patient during each day in this mild symptom phase, the probabilities of recovery and death are denoted by γ_1 and δ_1 per day. At the end of k number of days, the patients who have not recovered or died are assumed to enter the acute condition phase as shown in figure 1. We assume that the acute condition period lasts for m number of days. For each patient during each day in the acute condition phase, the probabilities of recovery and death are denoted by γ_2 and δ_2 per day. The patients who survive m days in acute condition are assumed to be fully recovered.

Let I_n be the total population of infected people who are still in the incubation period on day n. Let I_n^i be the population of those infected people in the incubation period on day n who have been infected for i number of days (i ranges from 1 to j).

$$I_n = I_n^1 + I_n^2 + \ldots..+I_n^j = \sum^i I_n^i \tag{2}$$

Let S_n be the total population of infected people who are showing mild symptoms of the disease on day n. Let S_n^i be the population on day n of those infected patients who have been showing mild symptoms for i number of days (i ranges from 1 to k).

$$S_n = S_n^1 + S_n^2 + \ldots..+ S_n^k = \sum^i S_n^i \tag{3}$$

Let Q_n be the total population of infected people who have gone through the incubation period and in whom the virus still lives for k number of days, but who are asymptomatic of the disease. Let Q_n^i be the population on day n of those asymptomatic people who have been carrying the virus for j+i number of days (i ranges from 1 to k).

$$Q_n = Q_n^1 + Q_n^2 + \ldots..+ Q_n^k = \sum^i Q_n^i \tag{4}$$

Let A_n be the total population of patients who are in acute condition on day n. Let A_n^i be the population on day n of those infected patients who have been in acute condition for i number of days (i ranges from 1 to m).

$$A_n = A_n^1 + A_n^2 + \ldots..+ A_n^m = \sum^i A_n^i \tag{5}$$

The total number of people who are currently infected on day n and who are able to transmit the virus is $(I_n + S_n + Q_n + A_n)$. Out of this population, only $(S_n + A_n)$ number of people show outward signs of the disease. Ironically in the beginning of the outbreak, when $(S_n + A_n)$ is small, the problem is sometimes underestimated without realizing that the disease is spreading exponentially everyday by the entire infected population $(I_n + S_n + Q_n + A_n)$. The time to take swift and decisive preventive measures is when $(S_n + A_n)$ is small.

We denote the rate of transmission of the virus from an infected person to a healthy person per day by T_n. Let N_0 be the number of infected people on the first day. For example, the numbers of infected people on the first two days of the outbreak are:

$$I_1 = N_0 \tag{6}$$

$$I_2 = N_0 (1+T_1) \tag{7}$$

In general, the number of newly infected people on day n is given by

$$I_n^1 = T_{n-1} (I_{n-1} + S_{n-1} + Q_{n-1} + A_{n-1}) \tag{8}$$

A fraction, f_a, of the newly infected people is asymptotic of the disease. An estimate of $f_a = 30\%$ has been given in reference [9], which has been used in this model calculations. The number of new patients with mild symptoms on day n is given by

$$S_n^1 = (1 - f_a) I_{n-1}^j \tag{9}$$

Similarly the number of new asymptotic patients on day n is given by

$$Q_n^1 = f_a I_{n-1}^j \tag{10}$$

The number of new patients with acute condition on day n is given by

$A_n^1 = (1 – \gamma_1 - \delta_1)\ S_{n-1}^k$ (11)

The numbers of patients who recover and die from mild symptoms on day n are given by $\gamma_1\ S_n$ and $\delta_1\ S_n$ respectively. Similarly the numbers of patients who recover and die from acute conditions on day n are given by $\gamma_2\ A_n$ and $\delta_2\ A_n$.

$S_n^{i+1} = (1 – \gamma_1 - \delta_1)\ S_{n-1}^i$ for $0 \le i \le k-1$, n>1 (12)

$Q_n^{i+1} = Q_{n-1}^i$ for $0 \le i \le k-1$, n>1 (13)

$A_n^{i+1} = (1 – \gamma_2 - \delta_2)\ A_{n-1}^i$ for $0 \le i \le k-1$, n>1 (14)

The number of deaths caused by the virus on day n is given by

$D_n = \delta_1\ S_n + \delta_2\ A_n$ (15)

The number of patients who recover from the disease on day n is given by

$R_n = \gamma_1\ S_n + \gamma_2\ A_n + (1 – \delta_2)\ A_n^m$ (16)

Before the first person showing symptoms of the disease caused by the new virus and shortly thereafter up to day n_1, the transmission rate T_n is assumed to be constant at an initial value T_0:

$T_n = T_0$ for $1 \le n \le n_1$ (17)

Typically the authorities take steps to prevent the spreading of the disease such as patient isolation, testing, contact tracing and social distancing. As a result T_n decreases with time. The model is capable of including actual time dependent transmission data, however at this time such data for the Coronavirus case is not available. A reasonable approximation is exponential decay of the rate of transmission T_n from infected persons to the general population. Let G be the number of days it takes for T_n to decrease by 63% of T_0, and let T_f be the long term steady state value of T_n.

$T_n = T_f + (T_0 - T_f)\ \exp\ (- (n – n_1) / G)$ for $n_1 < n$ (18)

Three parameters n_1, G and T_f were found to significantly affect the number of cases from the virus. The data analyses carried out in this paper clearly showed that the actual case data for countries with smaller number of cases could be fit well with smaller G and n_1. In this paper, we will limit the analysis to the first outbreak of the virus. It may also happen that social distancing measures are lifted due to economic necessity before the virus is completely extinguished within the population, which would cause T_n to rise again and a possible recurrence. The recurrence can be modelled in future using the methodology given in this paper.

Let σ_n per day per person be the rate of testing of the entire population, P of the country including the infected people without symptoms ($I_n + Q_n$) on any day n. Let β_n per day per person be the testing rate of patients with symptoms. The active number of infected cases which are confirmed by testing and reported can be expressed as:

$B_n = \sigma_n\ (I_n + Q_n) + \beta_n\ (S_n + A_n)$ (18)

Total cumulative number of reported cases, C_n is given by

$C_n = B_n + \sum^i \beta_i\ (D_i + R_i)$ for $1 \le i \le n$ (19)

In the model, the testing rates σ_n and β_n are considered time dependent as follows:

$\beta_n = 0$ for $1 \leq n \leq j$ (20)

$\beta_n = \beta_0$ for $j+1 \leq n \leq n_2$ (21)

$\beta_n = \beta_0 + ((1 - \beta_0)(n - n_2) / n_\beta)$ for $n_2 \leq n \leq n_2 + n_\beta$ (22)

$\beta_n = 1$ for $n > n_2 + n_\beta$ (23)

and, $\sigma_n = 0$ for $1 \leq n \leq n_2 + n_\beta$ (24)

$\sigma_n = \sigma_f ((n - (n_2 + n_\beta)) / H)$ for $n_2 + n_\beta \leq n \leq n_2 + n_\beta + H$ (25)

$\sigma_n = \sigma_f$ for $n > n_2 + n_\beta + H$ (26)

The rationale for choosing different testing rates is as follows. During the first j number of incubation days of the outbreak there is no testing and $\beta_n = 0$. During the first outbreak of the virus, it takes several days to identify the new virus and to develop an initial test, during which time, the testing rate of the patients showing symptoms is low, denoted by β_0. Let n_β be the number of days to ramp up the testing of the patients with symptoms to 100% final testing rate. The testing rate σ_n for the general population including those who are infected and not showing symptoms is assumed to be zero until $n = n_2 + n_\beta$ during which time testing rate is being ramped up for those showing symptoms. Let H be number of days it takes to build up the testing capability to test the general population at a final rate of σ_f . This recognizes that large scale production of testing supplies and development of infrastructure and resources for administering of tests in large numbers take time.

It is to be noted that there is daily variation and probability distribution function for each of these model parameters. The time dependent data on these parameters for the new Coronavirus in each country are not available yet. When the values of these parameters become available on a later date, these can be inserted in the model. For near real time analysis of the case data, we make realistic initial assumptions as described in detail in this section and then numerically iterate on them to fit the published data on Covid-19 infected cases for each country.

Model parameters

We test this model to explain the number of Covid-19 cases in a small number of countries at first – China, South Korea, Iran, Italy and USA. We collected the data on number of cases, deaths and number of recovered people from reliable sources [5-8] for the period January 1st, 2020 to March 31st, 2020. The actual data used in this paper is included in table I in the appendix.

There are seventeen variable parameters in the model description. These are j, k, m, N_o, T_o, T_f, n_1, G, β_0, n_2, n_β, γ_1, γ_2, δ_1 and δ_2, σ_f and H. We start with reasonable assumptions for each parameter and then use the published data on total number of cases, total number of deaths and total number of recovered patients for each country to iteratively optimize the parameter values using the mathematical model. We also make sure that the values for the parameter are reasonable. For example, for j, k and m, we make use of the information presented on the WHO website [5], which states *"Most estimates of the incubation period for COVID-19 range from 1-14 days, most commonly around five days. These estimates will be updated as more data become available."* Another such source of information is a published study done at the World Health Organization, *"Using available preliminary data, the median time from onset to clinical recovery for mild cases is* *approximately 2 weeks and is 3-6 weeks for patients with severe or critical disease. Preliminary data suggests that the time period from onset to the development of severe disease, including hypoxia, is 1 week. Among patients who have died, the time from symptom onset to outcome ranges from 2-8 weeks."*[6].

We carry out multivariate optimization to fit the data for each country between Jan 1 and Mar 31 of 2020. Starting with reasonable initial conditions in the model, iterations are made in the algorithm until the residual errors in fitting the published data during Jan 1 and Mar 31, 2020 for each country are minimized. At that point the final values of all parameters for this predictive model for each country become available. This can be considered as the training set. Once the optimization is completed, the country-specific parameters are determined and the model becomes powerful to yield information such as (1) predicted number of future cases in a country or (2) sensitivity analysis such as the effect on number of casualties on days to implement social distancing. The model can also be used to quantify if there is a recurrence of the disease once social distancing measures are lifted. We discuss the results in the next section.

RESULTS AND DISCUSSION

We used the data on number of cases, deaths and number of recovered people from reliable sources [5-8] for the period January 1st, 2020 to March 31st, 2020. The actual data used in this paper is included in table I in the appendix. The results are shown for China, South Korea, Iran, Italy and USA in figures 2-6. The same model fits the data for five countries in three continents remarkably well as shown in the figures. As stated before, we have done multivariable optimization and iterated on seventeen parameters to obtain the best fit between the model prediction and the actual data for each country.

Figure 2 shows the comparison of the actual data and the model predictions for China in five categories: (a) total cases, (b) total deaths, (c) total recovered, (d) daily new cases and (e) daily deaths. In the literature [5,6,8], the daily case data for China became available since Jan 22, 2020. Before that time, the data has been scarce. On Dec 19, 40 cases were reported in China, 59 cases were reported on Jan 9, 200 cases were reported on Jan 20 and 571 cases were reported on Jan 22. The 1st death was reported on Jan 11, a total of 2 deaths were reported on Jan 17 which increased to 3 on Jan 20 and to 17 on Jan 22.

We used the mathematical model to best fit the case data for China between Jan 1 and Mar 31, 2020 and to obtain the values for parameters used in the model for China. For example, the best fit for the data with minimum least squares error was obtained by using initial number of infected people, $N_0 = 10$, initial transmission factor $T_0 = 0.54$, Jan 15 start date for transmission factor decrease and a transmission decay rate of $1/G$, where $G = 6$ days. The spike in the actual daily case on Feb 12 could not be fitted with model, as it was a one-time event in the actual data set. It should also be mentioned that the case data from China was revised on April 17th which is outside the data set used in this paper.

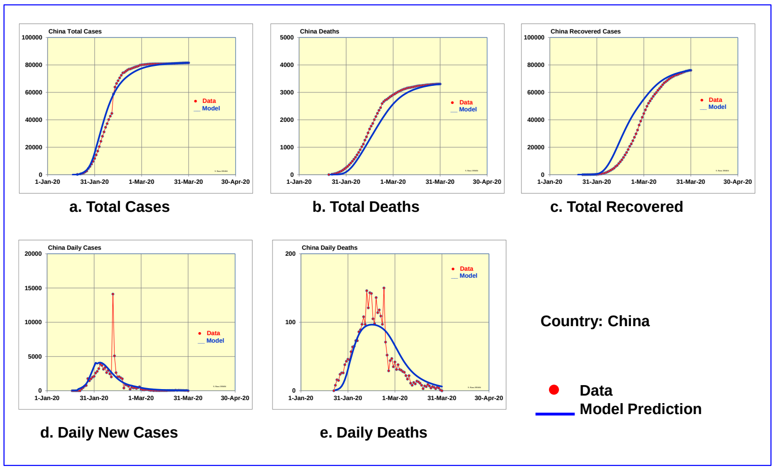


Figure 2. Data and model predictions for Covid-19 cases in China

Figure 3 shows the comparison of the actual data and the model predictions for South Korea. The daily case data for South Korea has been available in literature [5,6,8] since Feb 15. There were 28 total cases on Feb 15 and the first Covid-19 death was on Feb 20. The model fitted the South Korea case data with minimum error with N_0 = 3, T_0 = 0.47, Feb 12 start date for transmission factor decrease and a transmission decay rate of 1/G, where G= 6 days. Swift action to reduce the transmission factor when the infected population was small is what we believe to be the primary reason for very low Covid-19 deaths in South Korea and which is supported by the model.

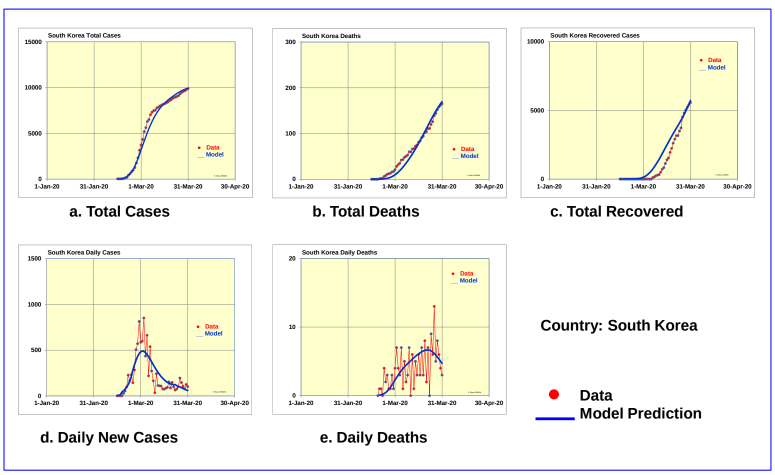


Figure 3. Data and model predictions for Covid-19 cases in South Korea

Figure 4 shows the comparison between the model prediction and the actual data for Iran. The daily case data for Iran has been available in [5,6,8] since Feb 19. There were 2 total cases and equal number of deaths on Feb 19. The model fitted the Iran Covid-19 case data with T_0 = 0.31, Feb 20 start date for transmission factor decrease and a transmission decay rate of 1/G, where G= 15. For Iran with higher number of casualties than South Korea, the transmission rate decay factor, G is higher (15 as compared to 6). Figure 6 shows the model predicting (solid curve in figure 4(d)) the number of daily new cases to level off at the end of March 2020 timeframe.

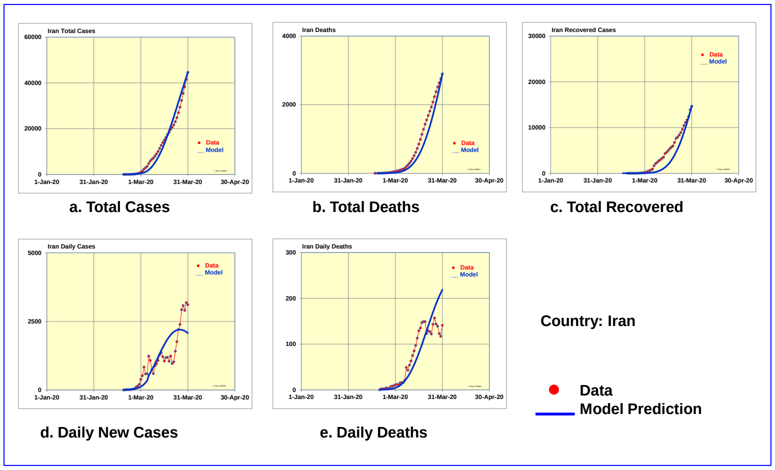


Figure 4. Data and model predictions for Covid-19 cases in Iran

Figure 5 shows the comparison between the Covid-19 case data and the model prediction for Italy. The first reported Covid-19 case in Italy was on Feb 15, at nearly the same time as South Korea and Iran. There were 3 total cases on Feb 19 and the first death was on Feb 21. The model fitted the Italy Coronavirus case data with $T_0 = 0.38$, Feb 16 start date for transmission factor decrease and a transmission decay rate of 1/G, where G= 16. Comparing case data for Italy and South Korea, we find that the model parameter, G is 16 for Italy as compared to G=6 for South Korea. Transmission containment actions were swifter in South Korea. As shown in figure 7, the model predicts the number of daily new cases reaching a maximum at the end of March 2020 timeframe (solid curve in figure 5(d)).

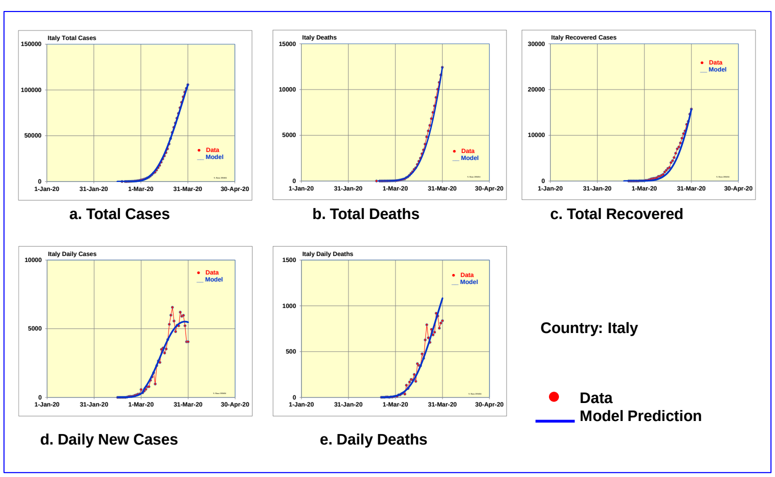


Figure 5. Data and model predictions for Covid-19 cases in Italy

Figure 6 shows the comparison of the actual data and the model predictions for USA. The daily case data for USA was obtained from references [5-8]. The first reported Covid-19 case in the USA was on January 22, 2020. The model fitted the USA Coronavirus case data with minimum error using the following parameters: T_0 = 0.22, Mar 13 start date for transmission factor decrease and a transmission decay rate of 1/G, where G= 9. In the USA different measures were taken in different states with population migration among states, the data on which is not fully available at this time. In future it will be possible to extend this mathematical model to the Coronavirus cases in each state separately and then combining to generate a composite model for the country as a whole. The values of the parameters which fit the USA case data in this paper in figure 6 may be considered average values in the country.

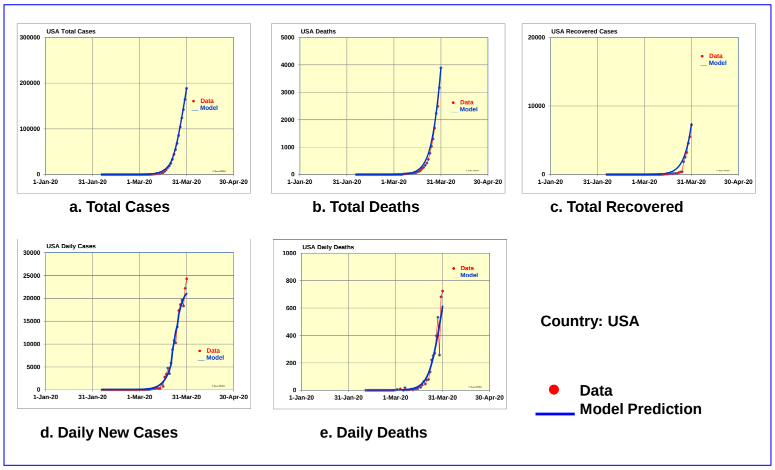
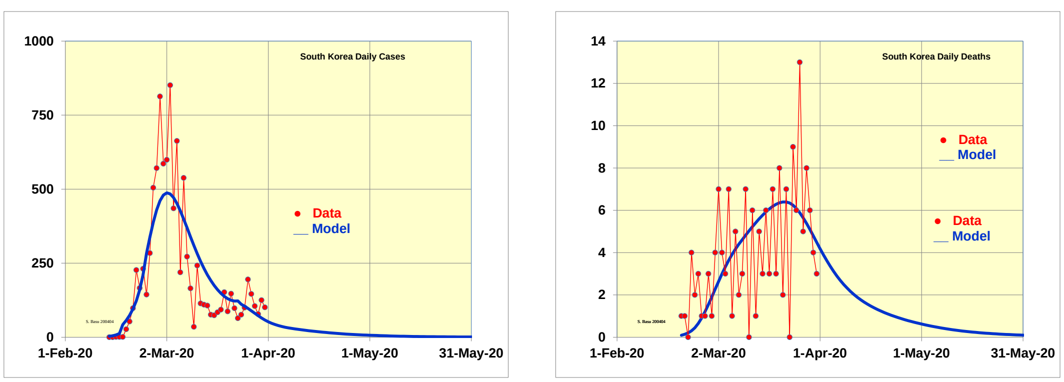


Figure 6. Data and model predictions for Covid-19 cases in USA

Predictive capability

One of the uses of this model is to be able to predict the course of the outbreak so that corrective actions may be taken to minimize casualties.



a. Projected Daily Cases

b. Projected Daily Deaths

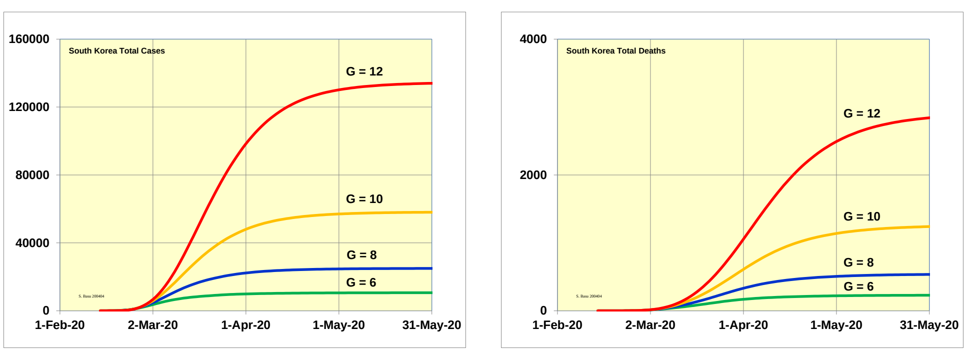
Figure 7. Predicted daily cases and deaths with the Covid-19 data from South Korea for the next two months

Figure 7 shows the predictions for Covid-19 related daily cases and daily deaths in South Korea for two months (Apr 1 - May 31, 2020) beyond the date range of the used data set. The model is based on the actual case data until Mar 31st. Without any change in the model parameters in the next two months, the model predicts 741 additional cases and 64 additional deaths. A few comments are in order. The conditions within a country vary daily due to large number of factors which make the model parameters change unpredictably with time. The model predictions are to be considered best estimates with some amount of implied uncertainty. The predictions are only valid for a short period of time in the future. Also for a country such as South Korea, in which the peak of the outbreak has passed, the model should give better predictions than for a country such as India in which the daily number of cases is rising.

One utility for this predictive model is one can take corrective action by knowing what to expect in two weeks from the present by using the model and then adjusting containment strategies by comparing with the actual data.

Sensitivity analysis and what if exercise

Another use of the model is to be able to carry out sensitivity analysis to see the effects of preventive measures on the outcome. One of the best examples of Covid-19 containment is South Korea with only 9887 cases and 165 deaths until Mar 31st, 2020. As explained in the results section, the model fitted the South Korea case data with transmission decay rate 1/G, where G = 6 days. Figure 8 shows the model predictions for Covid-19 for four different scenarios G = 6, 8, 10 and 12 days in South Korea. It can be seen that taking 2 days longer to reduce the transmission factor by 63% (G=8 as compared to G=6) would have increased the number of deaths by more than a factor of two, from 230 to 541. By doubling the number of days to slow down (from G= 6 to G=12) would have increased the number of cases by 12 times from 10,639 to 134,486 and the number of deaths from 230 to 2,911.



a. Total Cases **b. Total Deaths**

Figure 8. Sensitivity of the total cases and total deaths to the virus transmission reduction factor G using the Covid-19 case data for South Korea

These numbers need to be taken with caution since conditions change daily during a viral outbreak in any country and these have uncertainties associated with them. But the lesson in general is valid which is a great number of deaths in any country can be prevented by taking swift, strict and uniform action throughout the country to prevent person to person viral transmission.

In conclusion, we have developed a general mathematical model that provides insight into the Covid-19 viral outbreak cases in any country. The model fits the data reported until Mar 31, 2020 in five countries China, South Korea, Iran, Italy and USA with different levels of cases and casualties. The fit is good as seen in figures 2-6. The model is transparent and is based on parameters which are measurable. This allows the model calculations to be updated as the actual data of the parameters become available. One can also use the model parameters as a basis of comparison between the effectiveness of disease containment strategies in different countries. We presented some early results on prediction and sensitivity analyses. In future, we will apply the model to data for other countries. We will also expand the technique to study various cases such as effects of population migration and recurrence of the disease.

Additional Information

Correspondence and requests for materials should be addressed to the author.

References

1. Anderson, R.M. and May, R.M., *Infectious diseases of humans: dynamics and control* (Oxford University Press, Oxford, 1991)
2. Hethcote, H.W. "The mathematics of infectious diseases" *Society for Industrial and Applied Mathematics* **42**, 599–653 (2000)
3. Lin, Q., Zhao, S. et al, "A conceptual model for the coronavirus disease 2019 (COVID-19) outbreak in Wuhan, China and individual reaction and governmental action" *International journal of infectious diseases*. **93**, 211-216 (2020)
4. Kucharski, A.J., Russell, T.W. et al, "Early dynamics of transmission and control of COVID-19: a mathematical modelling study", www.thelancet.com/infection Published online March 11, 2020 https://doi.org/10.1016/S1473-3099(20)30144-4
5. World Health Organization website https://www.who.int/emergencies/diseases/novel-coronavirus-2019
6. World Health Organization website https://www.who.int/docs/default-source/coronaviruse/who-china-joint-mission-on-covid-19-final-report.pdf
7. U.S. Center for Disease Control and Prevention website https://www.cdc.gov/coronavirus/2019-ncov/index.html
8. https://www.worldometers.info/coronavirus/
9. Nishiura, H., Miyama, T. et al, "Estimation of the asymptotic ratio of novel coronavirus infections (COVID-19)", to appear in International journal of infectious diseases (2020).

APPENDIX

Date	# days (n)	China			South Korea			Iran			Italy			USA		
		Total cases	Total deaths	Total recovered	Total cases	Total deaths	Total recovered	Total cases	Total deaths	Total recovered	Total cases	Total deaths	Total recovered	Total cases	Total deaths	Total recovered
31-Dec-19	0	40														
09-Jan-20	9	59														
11-Jan-20	11															
17-Jan-20	17															
18-Jan-20	18															
19-Jan-20	19															
20-Jan-20	20	200	3													
21-Jan-20	21															
22-Jan-20	22	571	17	24										1		
23-Jan-20	23	830	25	58										1		
24-Jan-20	24	1287	41	62										2		
25-Jan-20	25	1975	56	73										2		
26-Jan-20	26	2744	80	75										5		
27-Jan-20	27	4515	106	84										5		
28-Jan-20	28	5974	132	127										5		
29-Jan-20	29	7711	170	148										5		
30-Jan-20	30	9692	213	195										5		
31-Jan-20	31	11791	259	267										7		
01-Feb-20	32	14380	304	352										8		
02-Feb-20	33	17205	361	499										8		
03-Feb-20	34	20438	425	656										11		
04-Feb-20	35	24324	490	916										11		
05-Feb-20	36	28018	563	1177										11		
06-Feb-20	37	31161	636	1564										11		
07-Feb-20	38	34546	722	2074										11		
08-Feb-20	39	37198	811	2673										11		
09-Feb-20	40	40171	908	3305										11		
10-Feb-20	41	42638	1016	4020										11		
11-Feb-20	42	44653	1113	4773										12		
12-Feb-20	43	58761	1259	5935										12		
13-Feb-20	44	63851	1380	6747										13		
14-Feb-20	45	66492	1523	8120										13		
15-Feb-20	46	68500	1665	9443	28						3			13		
16-Feb-20	47	70548	1770	10868	29						3			13		
17-Feb-20	48	72436	1868	12576	30						3			13		
18-Feb-20	49	74185	2004	14400	31						3			13		
19-Feb-20	50	74576	2118	16181	58			2	2		3			13		
20-Feb-20	51	75465	2236	18332	111	1		5	2		4			13		
21-Feb-20	52	76288	2345	20683	209	2		18	4		21	1		15		
22-Feb-20	53	76936	2442	22425	436	2		29	6		79	2		15		
23-Feb-20	54	77150	2592	24758	602	6		43	8		157	3		15		
24-Feb-20	55	77658	2663	27254	833	8		61	12	1	229	7	1	15		
25-Feb-20	56	78064	2715	29773	977	11		95	16	3	323	11	2	15		
26-Feb-20	57	78497	2744	32519	1261	12		139	19	25	470	12	3	15		
27-Feb-20	58	78824	2788	36141	1766	13		245	26	54	655	17	45	16		
28-Feb-20	59	79251	2835	39026	2337	16		388	34	73	889	21	46	16		
29-Feb-20	60	79824	2870	41849	3150	17		593	43	123	1128	29	50	24	1	
01-Mar-20	61	80026	2912	44522	3736	21		978	54	175	1701	41	83	30		
02-Mar-20	62	80151	2943	47228	4335	28		1501	66	291	2036	52	149	53	6	
03-Mar-20	63	80270	2981	49890	5186	32		2336	77	435	2502	79	160	80		
04-Mar-20	64	80409	3012	52068	5621	35		2922	92	552	3089	107	276	98	11	
05-Mar-20	65	80552	3042	53750	6284	42		3513	108	739	3858	148	414	164		
06-Mar-20	66	80651	3070	55426	6503	43		4747	124	913	4636	197	523	214		
07-Mar-20	67	80695	3097	57089	7041	48	118	5823	145	1669	5883	233	589	279	19	
08-Mar-20	68	80738	3119	58624	7313	50	166	6566	194	2134	7375	366	622	423	22	15
09-Mar-20	69	80755	3136	59922	7478	53	247	7161	237	2394	9172	463	724	647	26	15
10-Mar-20	70	80783	3158	61493	7513	60	288	8042	291	2731	10149	631	1004	937	30	15
11-Mar-20	71	80796	3169	62802	7755	60	333	9000	354	2959	12462	827	1045	1215	38	15
12-Mar-20	72	80814	3177	64118	7869	66	510	10075	429	3276	15113	1016	1258	1629	41	31
13-Mar-20	73	80824	3189	65543	7979	67	714	11364	514	3529	17660	1266	1439	1896	49	41
14-Mar-20	74	80844	3199	66912	8086	72	834	12729	611	4339	21157	1441	1966	2234	57	56
15-Mar-20	75	80860	3213	67754	8162	75	1137	13938	724	4590	24747	1809	2335 d	3487	68	73
16-Mar-20	76	80881	3226	68690	8236	81	1401	14991	853	4996	27980	2158	2749	4226	93	74
17-Mar-20	77	80894	3237	69614	8320	84	1540	16169	988	5389	31506	2503	2941	7038	115	106
18-Mar-20	78	80928	3245	70420	8413	91	1947	17361	1135	5710	35713	2978	4025	10442	154	108
19-Mar-20	79	80967	3248	71150	8565	94	2233	18407	1284	5979	41035	3405	4440	15219	218	121
20-Mar-20	80	81008	3255	71740	8652	102	2612	19644	1433	6745	47021	4032	5129	18747	264	147
21-Mar-20	81	81054	3261	72440	8799	104	2909	20610	1556	7635	53578	4825	6072	24583	340	176
22-Mar-20	82	81093	3270	72703	8897	111	3166	21638	1685	7913	59138	5476	7024	33404	419	178
23-Mar-20	83	81171	3277	73159	8961	111	3166	23049	1812	8376	63927	6077	7432	44183	553	295
24-Mar-20	84	81218	3281	73650	9037	120	3507	24811	1934	8913	69176	6820	8326	54453	775	378
25-Mar-20	85	81285	3287	74051	9137	126	3730	27017	2077	9625	74386	7503	9362	68203	1027	394
26-Mar-20	86	81340	3292	74588	9332	139	4528	29406	2234	10457	80589	8215	10361	85520	1297	1868
27-Mar-20	87	81394	3295	74971	9478	144	4811	32332	2378	11133	86498	9134	10950	104142	1695	2522
28-Mar-20	88	81439	3300	75448	9583	152	5033	35408	2517	11679	92472	10023	12384	123750	2227	3231
29-Mar-20	89	81470	3304	75700	9661	158	5228	38309	2640	12391	97689	10779	13030	142070	2484	4559
30-Mar-20	90	81518	3305	76052	9786	162	5408	41495	2757	13911	101739	11591	14620	164253	3165	5506
31-Mar-20	91	81518	3305	76052	9887	165	5567	44605	2898	14656	105792	12428	15729	188530	3889	7251

Table I. Covid-19 case data for China, South Korea, Iran, Italy and USA (Jan 1- Mar 31, 2020)