Covid-19 Spread Model with Social Distancing

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ABSTRACT

Mr. Martin Armstrong report [1] that at normal behavior one person can infects 2.5 people in 5 days and infects 406 people in 30 days. If reducing 50% contact, then one person infects 1.25 people in 5 days and 15 people in 30 days. If reducing 75% contact than one person infects 0.625 people in 5 days and 2.5 people in 30 days. He wanted to stress on that social distancing can really reduce the spread of Covid-19. In this paper I want to create a mathematics model that can show that how the social distancing affects the spread of Covid-19.

Keywords: *SEIR model, Covid-19, Social Distancing, Vensim PLE*

1. Introduction

The worldwide pandemic of Covid-19 changes the normal life all over the world. School closed, public assemblies were cancelled, and most economic activities were reduced to minimal. Government placed shelter in places that limited everyone's normal behavior. All these policies want to keep social distancing that can smooth the spread of Covid-19 spread.

2. Research Model

From CDC documents, we learned that Covid-19 through interaction between virus carriers and susceptible people. Some carriers don't show symptoms and some of them show symptoms. Those who show symptoms are usually either in hospitals or self-isolated at special area. It means those carriers have

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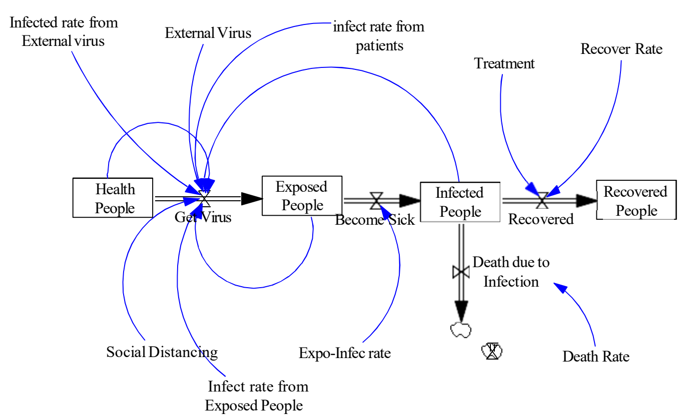

Fig 1 Model

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less chance to infect healthy people. The real problems are those carriers who don't show symptoms. Those carriers are actively interacted in the communities. They can un-intentionally spread virus in the air, and anything they touched. The infected rate from those carriers is higher than those carriers who show symptoms. This is a typical SEIR model. 'S' represents susceptible people (Healthy people); 'E' represents exposed virus but no symptom people; 'I' represents those carriers with symptoms; and 'R' represents those patients who got recovery through treatments.

The Fig 1 shows the mathematics model that I created through Vensim PLE.Four squares show four variables. Blue arrows show the relationship from one variable to the other variable. For example infected people get treatment and become recovered people with recovered rate r. Those variables without boxes are parameters. I assume that infected rate are inversely proportional to social distancing. People get infect can be through interaction with carriers or through unknown reason that I called it infected from external virus. Some exposed people will never show symptoms and will stay active in the communities. Those infected people show symptoms may die or get recovery through treatments. Recovered people will have ammunity and never become carriers.

Notation:

H: Healthy People (Susceptable people)

E: Exposed People without symptoms

I: Infected People with symptoms

R: Recovered People

re: Infected Rate from external virus

rp: infected rate from Exposed people

ri: infected rate from infected people

ei: rate of Exposed people become infected people

rd: death rate for infected people

rr: recovered rate due to treatment

The change of healthy people, $\frac{dH}{dt}$ is due to getting exposed covid-19. It can be getting from external virus such as touching mails from mailbox; filling gas from gas pumps, … etc., or interaction with infected people or with exposed people. Therefore

$\frac{dH}{dt}$= -re*H – rp*H*E -ri*H*I..(1)

The change of exposed people will be equal to the change of healthy people subtract those people start showing symptoms, and therefore

$\frac{dE}{dt}$ = re*H + rp*H*E +ri*H*I – ei*E..(2)

The change of infected people can be the death of infected people and people getting treatment and recovered. Therefore

$\frac{dI}{dt}$ = ei*E – rr*I – rd*I...(3)

Finally, the change of recovered people is from infected people who get recovered from the disease. Therefore,

$\frac{dR}{dt}$ = rr*I...(4)

Equations (1), (2), (3), and (4) form a system of differential equations. It is very tedious to use algebraic procedures to find numerical solutions. I use difference equations to approximate differential equations. As an example, $\frac{dH}{dt}$ is the limit of $\frac{H(t+h)-H(t)}{h}$ when h approaches zero. We use $\frac{H(t+h)-H(t)}{h}$ with a small h to approximate $\frac{dH}{dt}$. The equations (1), (2), (3), and (4) can be approximated by

$\frac{H(t+h)-H(t)}{h}$ = -re*H – rp*H*E -ri*H*I (a)

$\frac{E(t+h)-E(t)}{h}$ = re*H + rp*H*E +ri*H*I – ei*E (b)

$\frac{I(t+h)-I(t)}{h}$ = ei*E – rr*I – rd*I (c)

$\frac{R(t+h)-R(t)}{h}$ = rr*I (d) respectively.

H(t +h) = H(t) + h*(-re*H – rp*H*E -ri*H*I) (e)

E(t + h) = E(t) + h*(re*H + rp*H*E +ri*H*I – ei*E) (f)

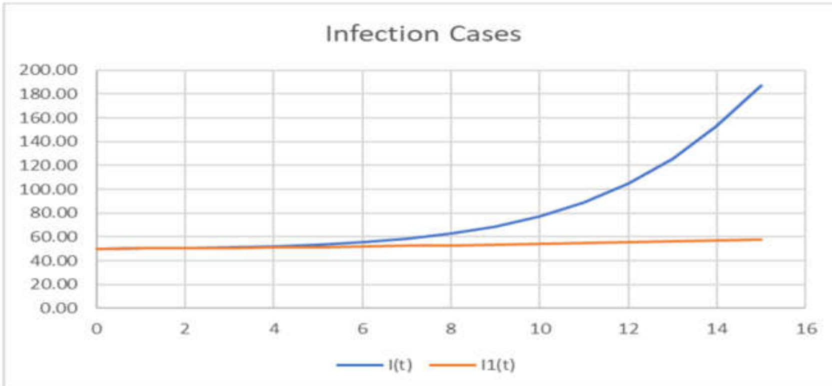
I(t+ h) = I(t) + h* (ei*E – rd*I – rr*I) (g)

R(t + h) = R(t) + h* (rr*I) (h)

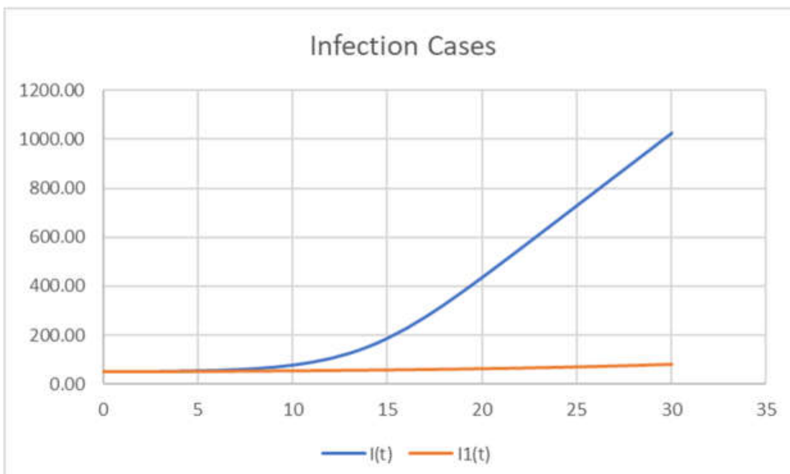
The last four equations (e), (f), (g) and (h) are the formula we want to enter to our Excel worksheet. Since social distancing may change infected rate. We have another parameter s which is the distance we want to keep between any two people while people are outside interacting with other people. We assume the infection rates are inversely proportional to s. As an example, when s = 6, the new rp = rp/6.

According to Georgia Department of Public Health COVID-19 Daily Status Report [2] on April 18, 2020, there are 17841 infected cases and 677 death cases. Approximately the infection rate is 17841/3990668, where 3990668 is the Georgia real time population up to April 18, 2020 according to

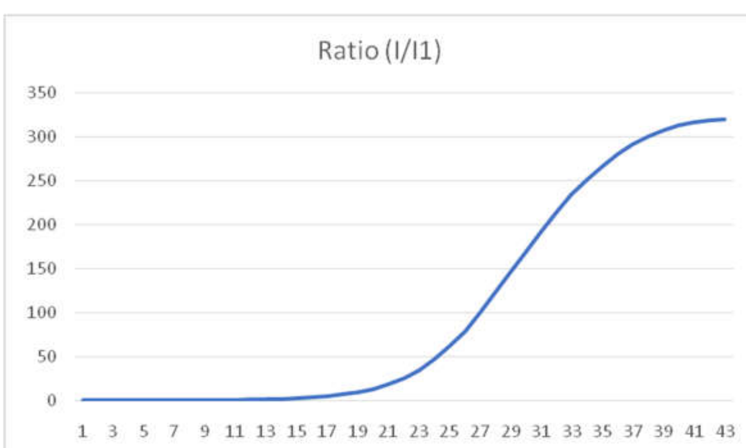
Worldometers [3]. Since we have no information about Exposed people, we assume that exposed people count is 10 times of infected people. Furthermore, we assume initially there are 100,000 healthy people, 50 infected people, 500 exposed people then we have the following gra phic models.



The above graph blue curve shows the infected cases while people behavior normally, and the orange curve shows the infected cases while people following strict social distancing code for 14 days. If we continue this model for 30 days, the difference is more significant.



The orange color curve of shows infected people under strict social distancing enforcement and blue color curve shows infected people with normal behavior. If we look at the ratio of Infected people (I) with normal behavior to the infected people (I1) under strict social distancing enforcement. We can see how social distancing can reduce the infected cases.



3. Appendix

Partial of Excel Worksheet insert here.

Time	H(t)	E(t)	I(t)	R(t)	H1(t)	E1(t)	I1(t)	R1(t)	Ratio (I/I1	Parameters	h =	0.001
0	100000.00	500.00	50.00	0.00	100000.00	500.00	50.00	0.00	1.0	s =	6	
1	99753.67	746.03	50.27	0.03	99958.57	541.13	50.27	0.03	1.0	re =	0.004471	0.004471
2	99398.09	1101.16	50.69	0.05	99914.08	585.30	50.57	0.05	1.0	rp =	0.004471	0.000745
3	98885.79	1612.80	51.33	0.08	99866.29	632.73	50.90	0.08	1.0	ri =	0.004471	0.000745
4	98149.66	2347.96	52.27	0.10	99814.98	683.67	51.25	0.10	1.0	ei =	0.6	0.6
5	97096.01	3400.21	53.65	0.13	99759.87	738.36	51.63	0.13	1.0	rd =	0.03	0.03
6	95596.31	4897.87	55.66	0.15	99700.70	797.09	52.05	0.15	1.1	rr =	0.5	0.5
7	93478.84	7012.40	58.57	0.18	99637.18	860.14	52.50	0.18	1.1	Initial Condition		
8	90523.36	9963.67	62.75	0.21	99568.98	927.82	52.99	0.20	1.2	H(0) =	100,000	
9	86465.26	14015.80	68.69	0.24	99495.76	1000.48	53.51	0.23	1.3	E(0) =	500	
10	81020.39	19452.25	77.07	0.28	99417.18	1078.46	54.09	0.26	1.4	I(0) =	50	
11	73946.19	26514.78	88.70	0.32	99332.84	1162.15	54.71	0.28	1.6	R(0) =	0	
12	65151.03	35294.03	104.56	0.36	99242.33	1251.96	55.37	0.31	1.9			
13	54840.21	45583.68	125.68	0.41	99145.21	1348.33	56.10	0.34	2.2			
14	43633.26	56763.27	152.96	0.47	99041.02	1451.72	56.87	0.37	2.7			
15	32530.40	67832.14	186.94	0.55	98929.25	1562.62	57.72	0.40	3.2			
16	22638.03	77683.96	227.54	0.64	98809.37	1681.56	58.62	0.43	3.9			
17	14752.71	85522.92	274.03	0.76	98680.80	1809.11	59.60	0.45	4.6			

References

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3. Worldometer April 18, 2020. https://www.worldometers.info/world-population/georgia-population/