BIO Capstone

Research Question

What is the effect of social distancing (average count of people met per day) on the duration of the infection (measured in days to end of epidemic) and on the total death toll?

The Model

Mathematical Representation

The SIRD model can be represented by the following equations:

$$N = S(t) + I(t) + R(t) + D(t)$$

$$\frac{dS}{dt} = -\beta I$$

$$\frac{dI}{dt} = \beta I - \gamma I - \mu I$$

$$\frac{dR}{dt} = \gamma I$$

$$\frac{dD}{dt} = \mu I$$

$$\beta = a \times b \times \frac{S}{N-D} = \frac{abS}{N-D}$$

Independent Variables

b is the number of people an infected person can contact each day.

Controlled Variables

N is the total population at the beginning of the pandemic. (World population)

γ is the recovery rate of this disease. $\gamma = 1/D = 1/7.5$ Source of 7.5 day recovery

μ is the mortality rate of this disease. 5.3%

a represents the probability a susceptible person is infected after close contact. on average 7% of close contacts becoming infected

Dependent Variable

The dependent variable is the peak of I(t).

Mathematical Functions Explained

S(t) is the population susceptible to the new disease at given time t. The initial value is the current estimates of susceptible population.

I(t) is the population infectious with the new disease at given time t. This initial value is based on current extrapolation of the population that has been tested.

R(t) is the population no longer susceptible to the new disease at given time t due to immunity. 154000 recovered

D(t) is the population no longer susceptible to the new disease at given time t due to death. This is the current reported death toll.

Methodology

The methodology is to use the constants and the independent variable to estimate the separate functions. The functions will be estimated using Euler's method with an interval of 1 (day). The resulting function graph will be used to find the dependent variable.

A python script written in Python 3.8 would be used to do the calculations above for different values of the independent variable and print the output in CSV format. A copy of the script can be found in the Appendix 1

Data Collected

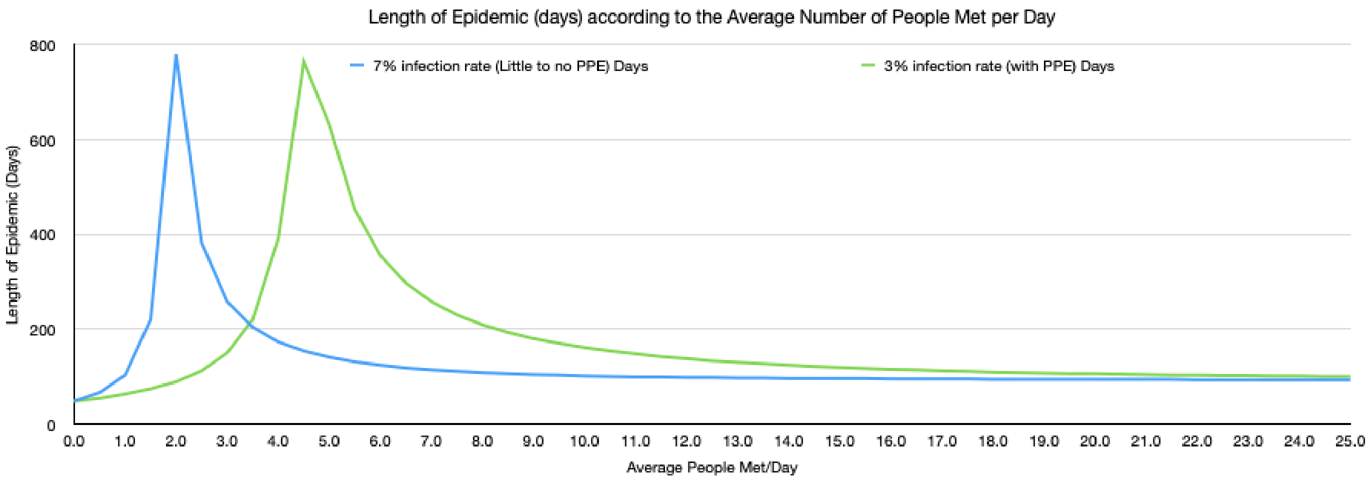
	7%	3%

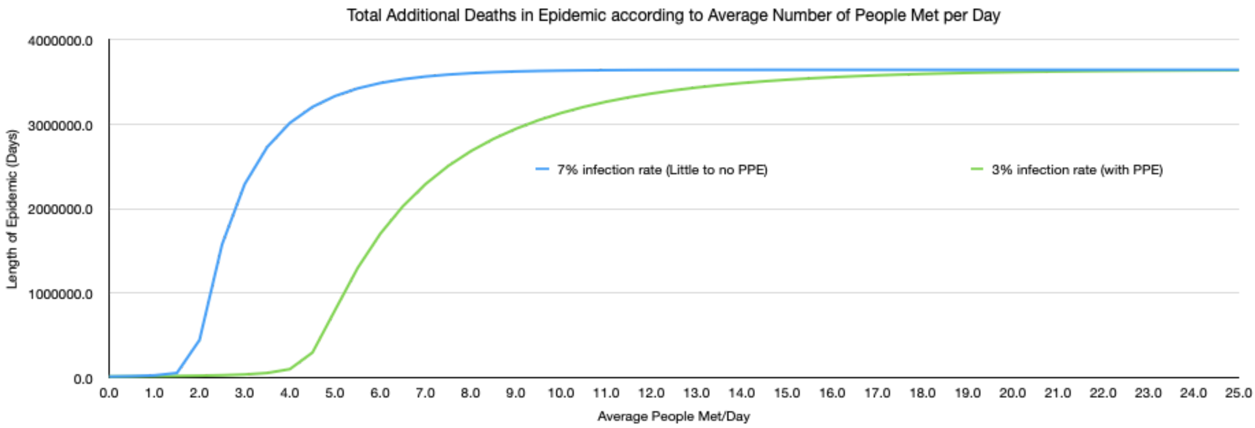
Avg. People Met/Day	Days	Deaths	Days	Deaths
0.0	48	12448.0	48	12448.0
0.5	66	16788.0	54	13997.0
1.0	103	25724.0	63	15990.0
1.5	220	54389.0	74	18639.0
2.0	779	444470.0	89	22332.0
2.5	382	1577075.0	112	27842.0
3.0	258	2289605.0	150	36894.0
3.5	204	2729829.0	220	54389.0
4.0	173	3013699.0	391	100172.0
4.5	154	3202930.0	764	296709.0
5.0	141	3332200.0	631	799726.0
5.5	131	3422121.0	452	1297268.0
6.0	124	3485471.0	355	1702279.0
6.5	118	3530482.0	297	2027285.0
7.0	114	3562658.0	258	2289605.0
7.5	111	3585732.0	230	2503147.0
8.0	108	3602288.0	209	2678455.0
8.5	106	3614147.0	193	2823482.0
9.0	104	3622620.0	180	2944270.0
9.5	103	3628656.0	170	3045499.0
10.0	101	3632923.0	161	3130766.0
10.5	100	3635919.0	154	3202930.0
11.0	99	3638005.0	148	3264235.0
11.5	99	3639443.0	142	3316519.0
12.0	98	3640423.0	138	3361238.0

Avg. People Met/Day	Days	Deaths	Days	Deaths
12.5	98	3641083.0	133	3399593.0
13.0	97	3641519.0	130	3432558.0
13.5	97	3641803.0	127	3460963.0
14.0	96	3641985.0	124	3485471.0
14.5	96	3642097.0	121	3506633.0
15.0	96	3642169.0	119	3524941.0
15.5	96	3642214.0	117	3540797.0
16.0	95	3642233.0	115	3554535.0
16.5	95	3642244.0	114	3566447.0
17.0	95	3642256.0	112	3576775.0
17.5	95	3642260.0	111	3585732.0
18.0	94	3642257.0	109	3593501.0
18.5	94	3642256.0	108	3600244.0
19.0	94	3642257.0	107	3606090.0
19.5	94	3642257.0	106	3611153.0
20.0	94	3642257.0	106	3615536.0
20.5	94	3642259.0	105	3619340.0
21.0	94	3642257.0	104	3622620.0
21.5	94	3642261.0	103	3625469.0
22.0	93	3642257.0	103	3627914.0
22.5	93	3642260.0	102	3630030.0
23.0	93	3642260.0	102	3631857.0
23.5	93	3642260.0	101	3633420.0
24.0	93	3642255.0	101	3634761.0
24.5	93	3642263.0	100	3635919.0

Avg. People Met/Day	Days	Deaths	Days	Deaths
25.0	93	3642262.0	100	3636911.0

Graphs





Appendix 1

```
import array

 #total population
N = 328200000
#initial Infectious population
initialInfectious = 1470000-260000-88199
#initial Recovered population
initialRecovered = 260000
#Probability at which people recover each day. Symptoms end on average after
7.5 days with a (1 - 5.3%) chance of recovery
gamma = 1/7.5
#Probability at which people die each day. Symptoms end on average after 7.5
days with a 5.3% chance of death
mu = 0.0599/40
#Probability person gets infected after close contact
a = 0.03

def sim(b_input,N,initialInfectious,initialRecovered,gamma,mu,a):
    Susceptible = array.array('d', [N-initialInfectious-initialRecovered])
#Initial Population of succeptible persons
    Infectious = array.array('d', [initialInfectious])
    Recovered = array.array('d', [initialRecovered])
    Deceased = array.array('d', [0])
    days=0
    #simulate a day of interactions if the count of Infectious population >= 1
    for i in range (1,1460):
        #calculate changes in each population
        beta = (a * b_input * Susceptible[len(Susceptible)-1] / (N -
Deceased[len(Deceased)-1]) )
        newSusceptible = Susceptible[len(Susceptible)-1] - round(beta *
Infectious[len(Infectious)-1])
        newRemoved = round(gamma * Infectious[len(Infectious)-1]) + round(mu *
Infectious[len(Infectious)-1])
        newInfectious = Infectious[len(Infectious)-1] + round(beta *
Infectious[len(Infectious)-1]) - newRemoved
        newRecovered = Recovered[len(Recovered)-1] + round(gamma *
Infectious[len(Infectious)-1])
        newDeceased = Deceased[len(Deceased)-1] + round(mu *
Infectious[len(Infectious)-1])



        #record resulting statistic of each population of that day
        Susceptible.append(newSusceptible)
        Infectious.append(newInfectious)
        Recovered.append(newRecovered)
        Deceased.append(newDeceased)
```

```
        if(Infectious[len(Infectious)-1]>1000):
            days=days+ 1
        else:
            print( str(b_input) + "," + str(days) + ","+
str(round(Deceased[len(Deceased)-1],0)) )
            break

#print(Susceptible[len(Susceptible)-1],Infectious[len(Infectious)-1],Recovered[
len(Recovered)-1],Deceased[len(Deceased)-1])

#print the contact/day, total days until infection ends, maximum infectious
population, deceased population increase in CSV format


#simulate contact/day from 0 to 500 per day

for i in range(0,51):
    sim(i,N,initialInfectious,initialRecovered,gamma,mu,a)
```