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CORONAVIRUS: A CASE STUDY

Covid-19, a branch of virus from the coronavirus family, originated from the city of Wuhan in China. It quickly became the biggest concern in almost every country's agenda. Even when the number of infected people were very few, strict restrictions were ordered. This was because the virus had an exponential transmission property. It had the potential of quickly overwhelm the medical potential of countries. Because of this property, governments around the world began enforcing different sets of practices. To predict whether these sets of practices would work or not, we can simulate the virus on a virtual environment. In that environment, we can change the bounding parameters and see the outcomes of potential applications. We can implement a mathematical model with given sets of differential equations and constants.

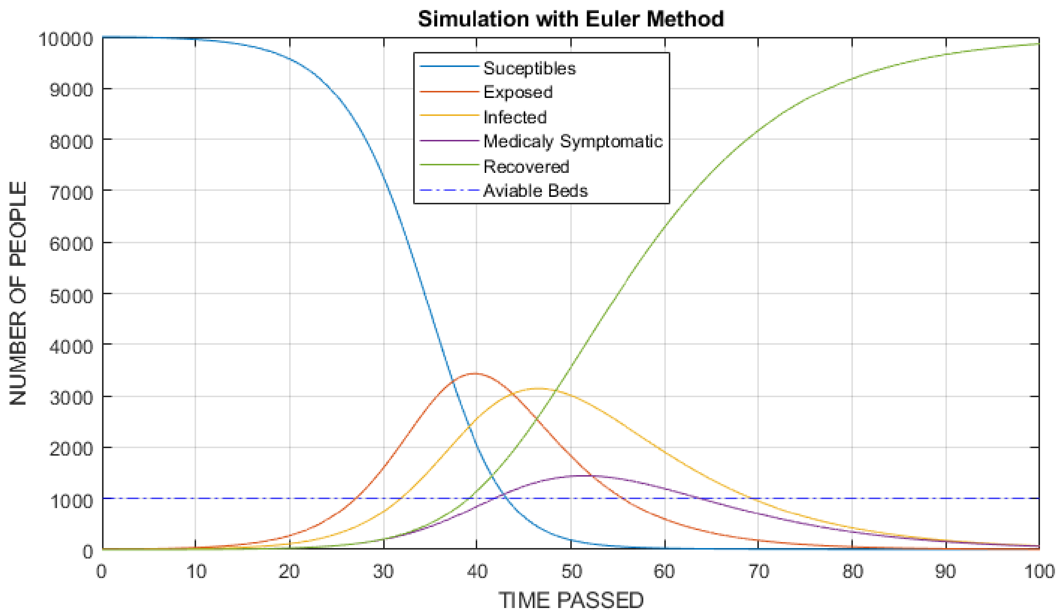
Let us divide a test group of people to five different sections. The population of these groups will be dependent of time, so we can treat them as a function of time. Also, we will define some parameters that are constant throughout the simulation. We can tinker with them to try different possibilities.

The five groups are:	With the constants:
S(t) → People who are susceptible to the virus.	α → The rate at which infected become infectious.
E(t) → People that are exposed to the virus.	β → Transmission probability per encounter.
I(t) → People that are infected by the virus.	c → Encounters per day
M(t) → People that need to be hospitalized.	Y → Rate at which infected person Becomes symptomatic.
R(t) → People that recover from the disease.	W → Rate at which the person recovers.

While solving the question given to us, we will take α=0.125, β=0.2, c=4, Y=0.1 and W=0.2. We also start with initial values S(0)=10000, E(0)=10, I(0)=0, M(0)=0 and R(0)=0. We will also assume a constant number of available beds. We will later tinker with different parameters and assume non-constant parameters.

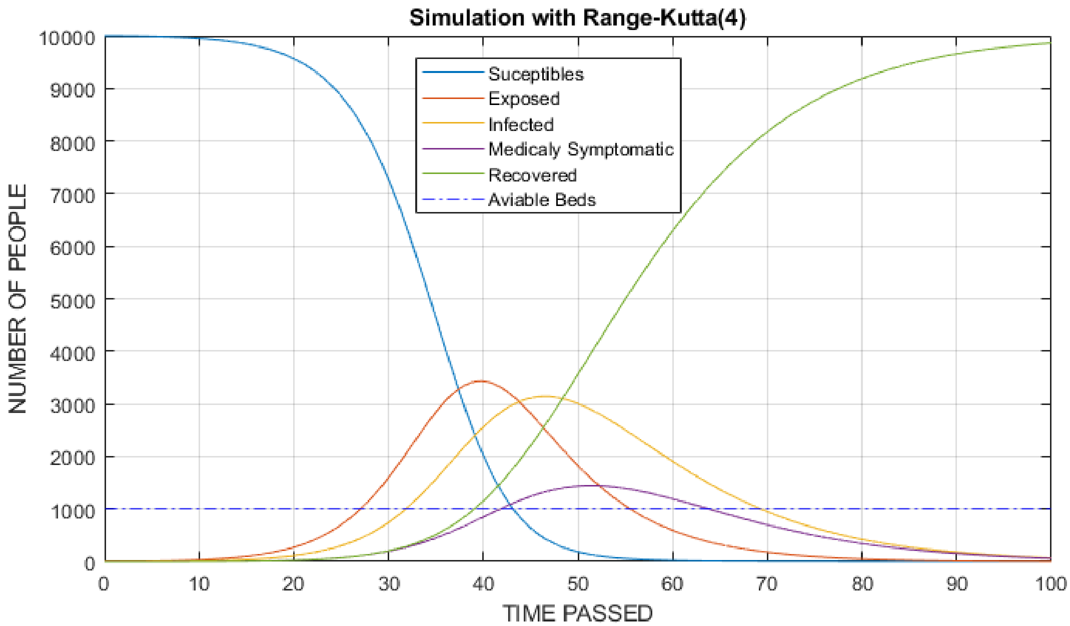
A) Euler Method

We will implement Euler's method with h=1/500. It took 0.011461 seconds to run Euler's method.



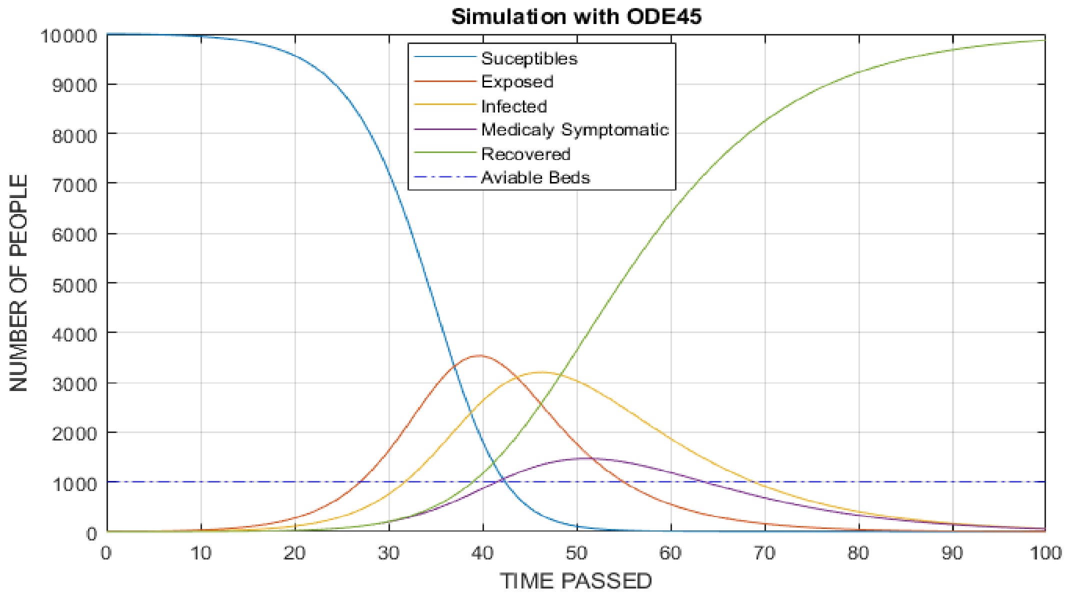
B) RK-4 Method

We will implement Range-Kutta(4) Method with h=1/500. It took 0.202403 seconds to run rk4



C) SOLUTION USING ODE45

Now we will use the ode45 function that is built in MATLAB. ode 45 is an efficient way of solving differential equations. It took 0.168243 seconds to run ode45.



D) DISSCUSSION OF METHODS USED

D.1) Euler's method vs. Range-Kutta(4)

Euler's method is a first order method. It estimates the next point based on the rate of change. That is why it may fail in certain ODE's that are rather stiff. Range-Kutta(4) however, is a fourth order method and can provide accurate solutions where Euler's method fails. It has a good balance between accuracy and computation cost within the RK family. Even though this function is not rather stiff, still it would be better to use Range-Kutta(4) as we have no shortage of computation power, given that we are a government organization. Since we would rather use Range-Kutta(4) than Euler's method, we will not be comparing Euler's method with ode45.

D.2) Range-Kutta(4) vs ODE45

ode45 uses Range-Kutta(4), Infact, the number 4 in the name ode45 is the 4 of RK4. It also has some practical conveniences. It automatically adjusts the step size in rather stiff ODE's in other to keep the error relatively small. It is also offering fast, and optimized results, again because it automatically adjusts the step size. It is also easier and shorter to implement ode45 than Range-Kutta(4), also giving less room for errors caused by coding mistakes.

D.3) General Overview and final decision

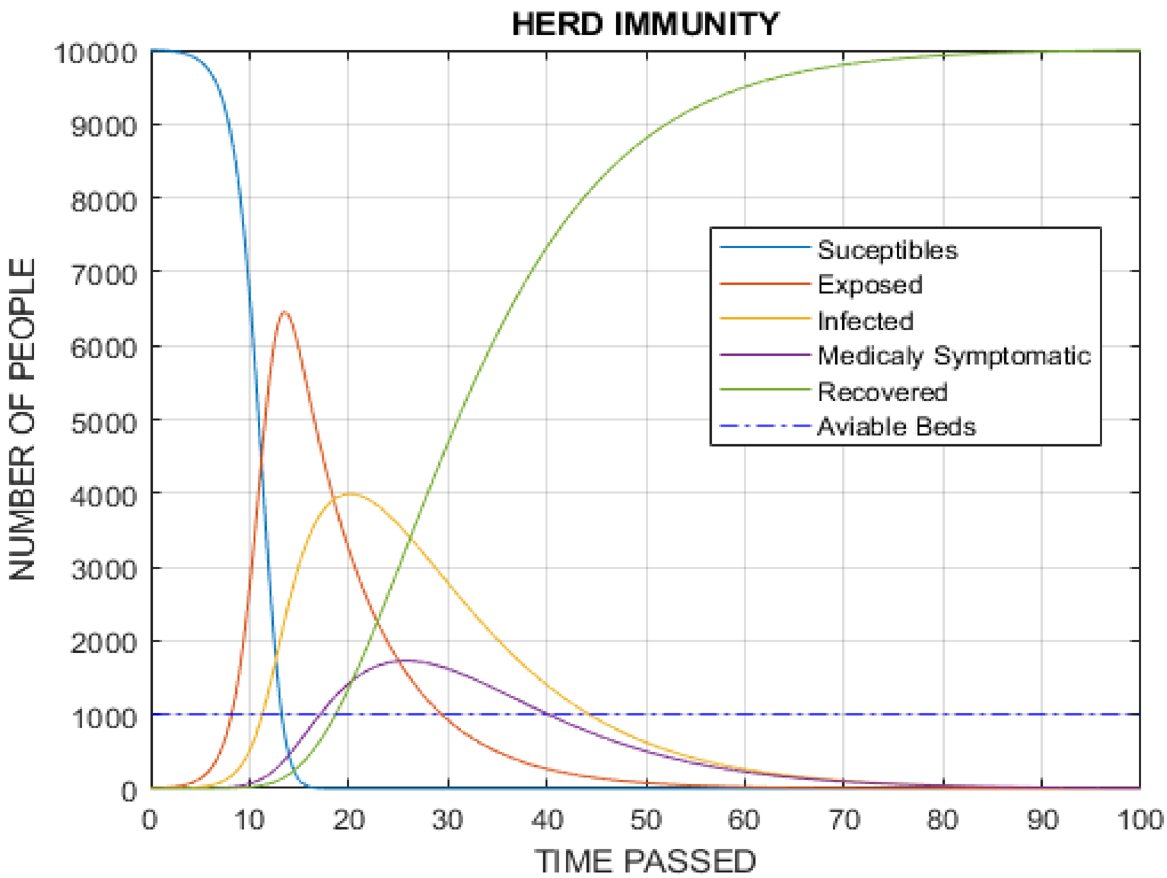
Computation speed is not as important as accuracy. Based on these ideas we can conclude ode45 is the way to go for this problem. If, however, we had to choose between Range-Kutta(4) and Euler's Method, implementing Range-Kutta(4) would be a better choice.

E) TRIAL OF DIFFERENT CASES

We will test six different models with different assumptions.

E.1) HERD IMMUNITY

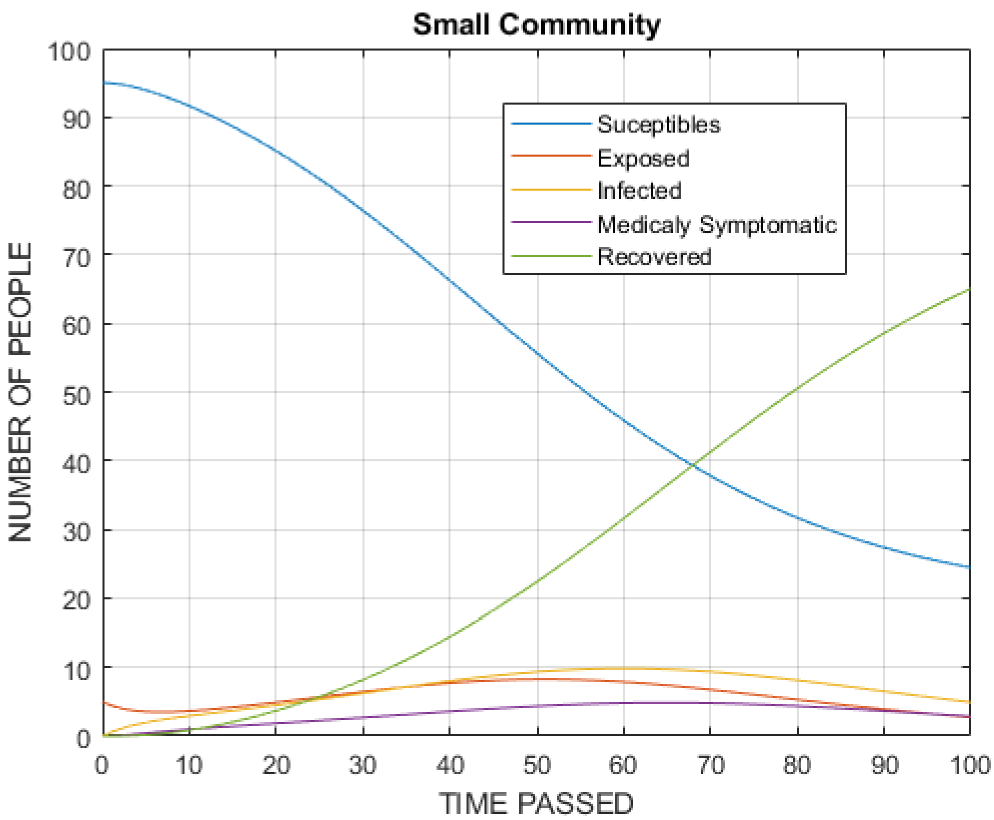
When the virus first emerged, a strategy called" herd immunity" was hypothesized. According to this hypothesis, if we were not intervene to the virus, the majority of the public would be immune to the virus after some time, and casualties would not be major. Since we take no precautionary measures, we will take c(encounters per day) = 8 and β (Transmission probability per encounter) = 0.6 since people will not be wearing masks or be cautious of social distancing.



It is apparent that the number of Medically Symptomatic people increases, almost doubles while available beds remain constant. The original model was not considering deaths. If deaths were to be considered, this would be catastrophic. It is worth noting that the virus dies rather quicker, with the expense of the public good.

E.2) A SMALL COMMUNİTY

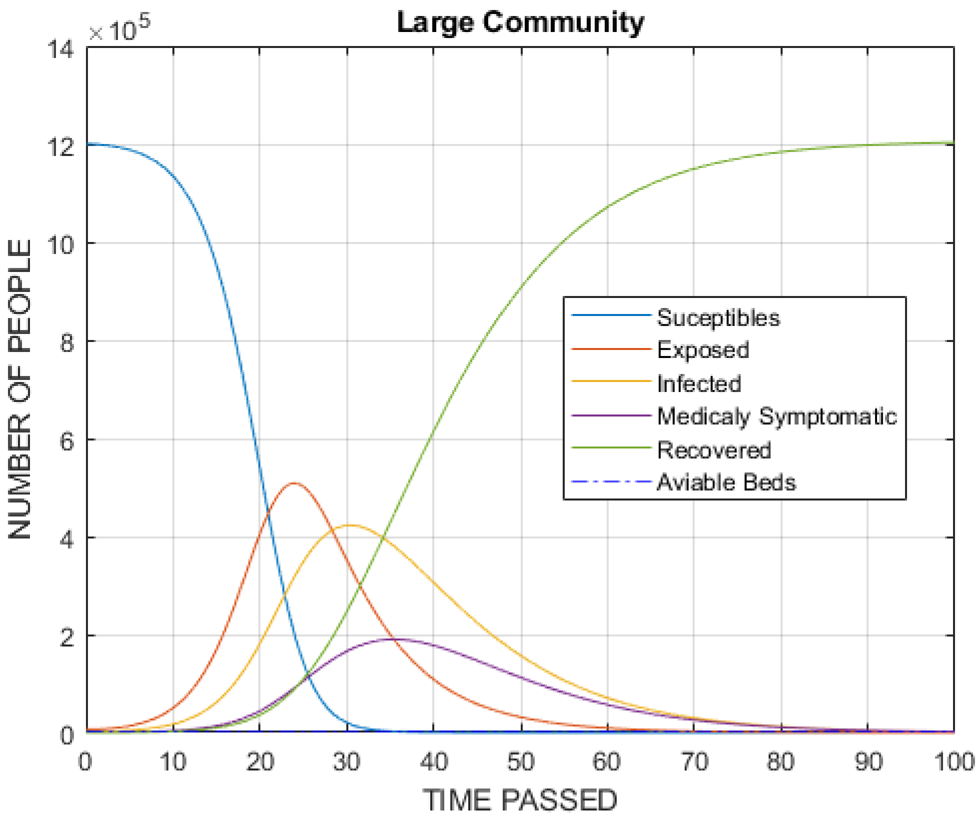
We had a population of 10000 at the original problem. However some communities are almost closed and very small. A rural village might be an example for that. So, take village with a population of 100 (S(0)=95 & E(0)=5) and run the model. Since the area is rural, we can take c=1 (Less encounters per day).



We can see that the virus dies out before being able to infect every human. This however, is not a perfect representation of a small community as there would be interference with the outer world in the real life.

E.3) A LARGE COMMUNİTY

We had a population of 10000 at the original problem. However some communities are much larger and in contact with other populations. A big city might be an example for that. So, take the city of Balıkesir with a population of 1,227 million (S(0)=1220000 & E(0)=7000) and run the model. Since the area is rural, we can take c=6 (More encounters per day)

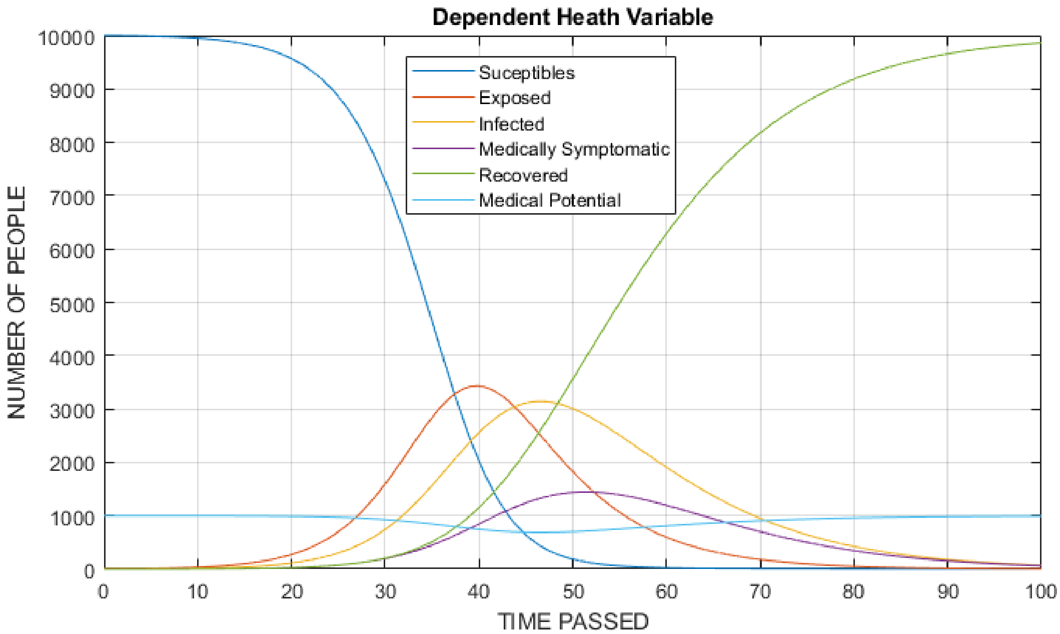


We can see that the situation in this case is very bad. The number of medically symptomatic people rise up to almost 2 million, and we are not even considering death, risk factors etc. So the policy makers absolutely must do something about this.

E.4) REPLACING MAX BEDS WITH A DEPENDENT VARIABLE

In our original model, we assumed that those who medically symptomatic only need an available bed. The truth is, this is a big simplification. In reality, those people also need available doctors, nurses and public funding. Let us replace the number of available beds with a new variable called "Medical Potential". This will include, although in a very simplified way, the doctors and nurses that get sick and the public funding that might be decreased because of shortage.

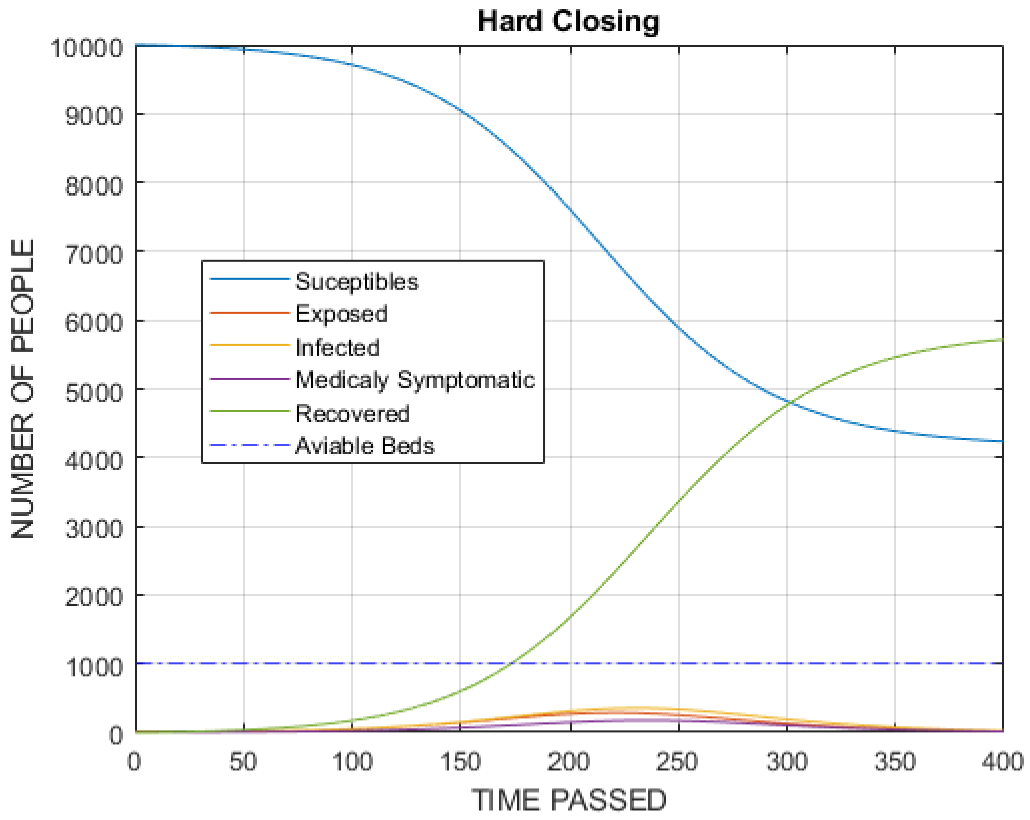
We define P(t)=k_1-k_2*I(t) and take k_1=1000, k_2=0.1



From the graph above, we see a negative, bell-shaped curve in between days forty and sixty. This would mean that the situation might be worse than the original model predicted.

E.5) STRICT MEASURES AND HARD CLOSING

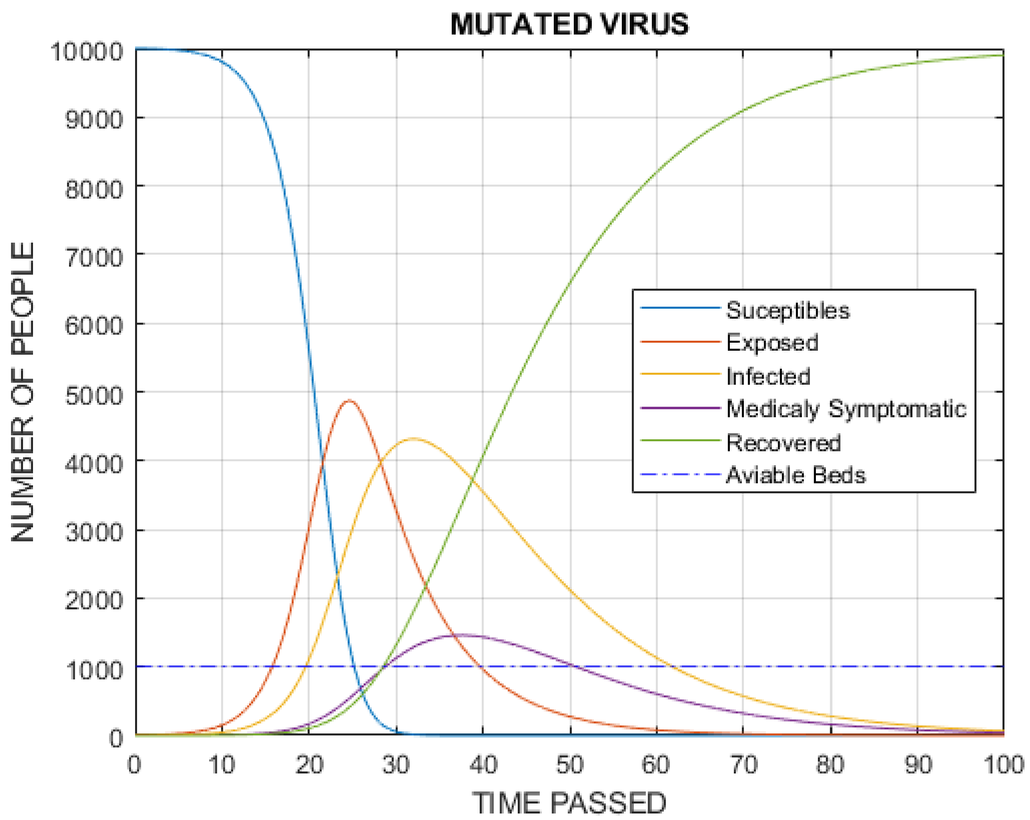
Some people, from the beginning of the virus, hypothesized that if the government applied strict rules and everyone stayed at home, the virus would die out before spreading to masses. This would mean that people would not be working, and economy would take serious damage. Let us assume that the government can keep the economy healthy for only a limited amount of time during a hard closing. Let us test, if the hypothesis is true and if it is economically possible. Let us take c (encounters per day) = 0.75.



We see that the disease dies out in 400 days with only being able to infect half of the population. While this is a theoretically possible management style, it is hard to implement in real life, as there would be economic and psychological damage to the public.

E.6) A NEW MUTATION

Recently, there has been news about a new mutation on COVID-19. It is said that this new virus is more infectious but less damaging to ones health. So let us try to simulate what this new mutation would look like. we will take Y(rate of becoming symptomatic) = 0.075 and β (Transmission probability per encounter) = 0.4.



It goes through the population faster, but the public damage stays rather similar to the first model due to its less dangerous nature. But since the parameters are arbitrary, the real result might me different.

F) ASSUMTIONS OF THE MODEL GIVEN IN THE QUESTION

Some assumptions made by the model is given below, they will be criticized in section G.

F.1) MEDICAL QUALITY

As discussed in E.4, the non-dependent variable maximum beds represent the potential of getting access to healthcare for a medically symptomatic person.

F.2) AGES AND RISK GROUPS

The model assumes that no one is at a risk group and also assumes that every resident of the population to be independent of age.

F.3) HOMOGENEUS SOCIETY

The model assumes that every encounter is equally probable between different groups.

F.4) DEATH

The model does not take death into account.

G) CRITISISIMS OF GİVEN ASSUMPTIONS

F.1) MEDICAL QUALITY

As discussed in section E.4, The medical experience one might live, will change throughout time. Funding will decrease and increase with time, doctors and nurses will get sick and recover with time, even new hospitals can be built like china did.

F.2) AGES AND RISK GROUPS

People who have diseases like asthma and pneumonia are more susceptible to the virus and can be considered as a risk group. Old people, in the same way are more likely to suffer from the COVID-19.

F.3) HOMOGENEUS SOCIETY

People that are medically symptomatic will go into a process of isolation, often called quarantine, and therefore will not have as many encounters as the other groups.

F.4) DEATH

Death can change the equation both ways. If the virus is extremely lethal, it might run out of infected people before reaching to all of the population. Or, it might affect the healthcare workers, drop the efficiency of the medical system, therefore increasing number of deaths. This would cause a loop of death that would be terrible for the public.