# ISyE 6644 – Simulation – Mini Project #2 – Spring 2021

# "Pandemic Flu Spread Simulation"

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**Content:**

## 1. Abstract

We tried simulating a virus spread in city with a population of half a million. The virus spread starts in the city with the entry of 10 infectious people. The infectious person spread the disease to others whom they come in contact with for the next 7 days. Once the infected person gets cured, he/she is no more susceptible to the virus anymore. We added some pre-conditions like certain population already having a natural immunity towards the virus, contagious people keep on meeting their friends despite their infection and city authorities trying various strategies to contain the virus spread. We compared various such scenarios in which usage of masks are made mandatory, lockdown is imposed, and population starts getting a vaccine after certain days.

We attempted to find the best strategy to contain the virus spread and free the city from the pandemic. We found that when masks are made mandatory and lockdown is imposed along with the entire population getting the two shots of vaccine comes out as the best strategy, which is quite intuitive. The pandemic stops in 71 days with peak achieved on $40^{th}$ day with 152114 infections at most.

## 2. Background and Description of the problem

We have tried to simulate the situation of pandemic in the school started by one infected kid in our mini project 1. It looks like authorities couldn't keep the virus spread contained in a school and it has spread out in the entire city. The city of RaShar has a population of half a million. 10 people gets infected by the virus and they start spreading the infection in the city. Each resident has some friends whom they continue meeting despite being infected by virus. The infectious period lasts for 7 days and the infected person is capable of infecting other citizens during his/her 7 days of illness. The number of friends each resident meet is determined randomly using normal distribution with mean 5 and standard deviation 1.5. It is assumed that 15% of the population already has a natural immunity to fight the virus and hence, even if they come in contact with the infected person, they do not get sick. Rest of the citizens fall sick if they come in contact with the infectious person. The infected person gets recovered in 7 days and after that, he/she also develops an immunity to fight the virus. Hence, once recovered, a citizen in not susceptible to the virus again. Antibodies are fighting their way out!

Now the city authorities get alarmed by rising cased of citizens infected by people. So, they try various ways to curb the contamination and stop the spread of the virus. The city authorities make the usage of mask compulsory which reduces the chances of spread by the infectious person to non-infectious person by half. The city authorities also try imposing lockdown which reduced infected person's chance of meeting another person by 70%. City doctors are very talented, and they develop the vaccine within 40 days. City authorities start vaccinating the population from the 40$^{th}$ day itself and the first dose of vaccine reduced the susceptibility to the infection by 20%. The vaccine is developed in such a way that second dose to be administered within next 10 days so second vaccination drives start at the 50$^{th}$ day which further reduces the susceptibility to infection to 5%.

We carried out the simulation for various strategies such as no mask & no lockdown, only mask enforcement, mask along with lockdown, mask + lockdown and just one dose of vaccine and finally mask + lockdown and 2 doses of vaccine.

## 3. Main Findings

**Application Area:**

- The pandemic flu spread simulation analysis can be used in wide variety of applications where a certain member of population affects other members of the population with a given probability.
- This analysis is most relevant in the case of infectious diseases caused by microorganisms. The disease originates in a small subset of population and gets transmitted to others through various medias like air, water, blood, physical contact etc.
- World has seen such examples like Ebola, HIV, H1N1, COVID-19.
- Simulation to forecast extent of the spread of the disease is a crucial activity in medical science which aids in taking decisions like devising an action plan to contain the spread, isolate and cure the affected people, planning and distribution for production and supply of medicine, vaccine, medical equipment, PPE gears etc.

**Input Data:**

- In a city of 500000 residents, 20 infected people enter on Day 0.
- Any infected person has a potential to spread it to whoever they meet. Each person has a set number of friends/colleagues (gaussian randomization for accuracy) and they may meet any one or more of these friends on a day to day basis.
- The number of friends of each person are assumed to be normally distributed with mean = 5 and standard deviation = 1.5
- 15% of the city residents are assumed to have natural immunity to the disease.
- After getting infected, each person stays 7 days infected (contagious) while spreading the disease to his friends whom he meets. After 7 days, the infected person gets recovered and is no more susceptible to the disease.
- We assumed that the mortality rate of the disease is negligible ( $\cong$ 0%)
- To reduce the spread of the virus, various measures are proposed like using masks, lockdown and vaccination in 2 phases.
- Using masks reduces contagiousness of the disease from an infected person by 50%.
- Enforcing lockdown reduces number of friends an infected person is likely to meet by 70%.
- Vaccines become available after certain days have passed. As the availability of vaccine is low, only 1$^{st}$ dose of vaccine can be provided to the residents, reducing disease contagiousness to 20%.

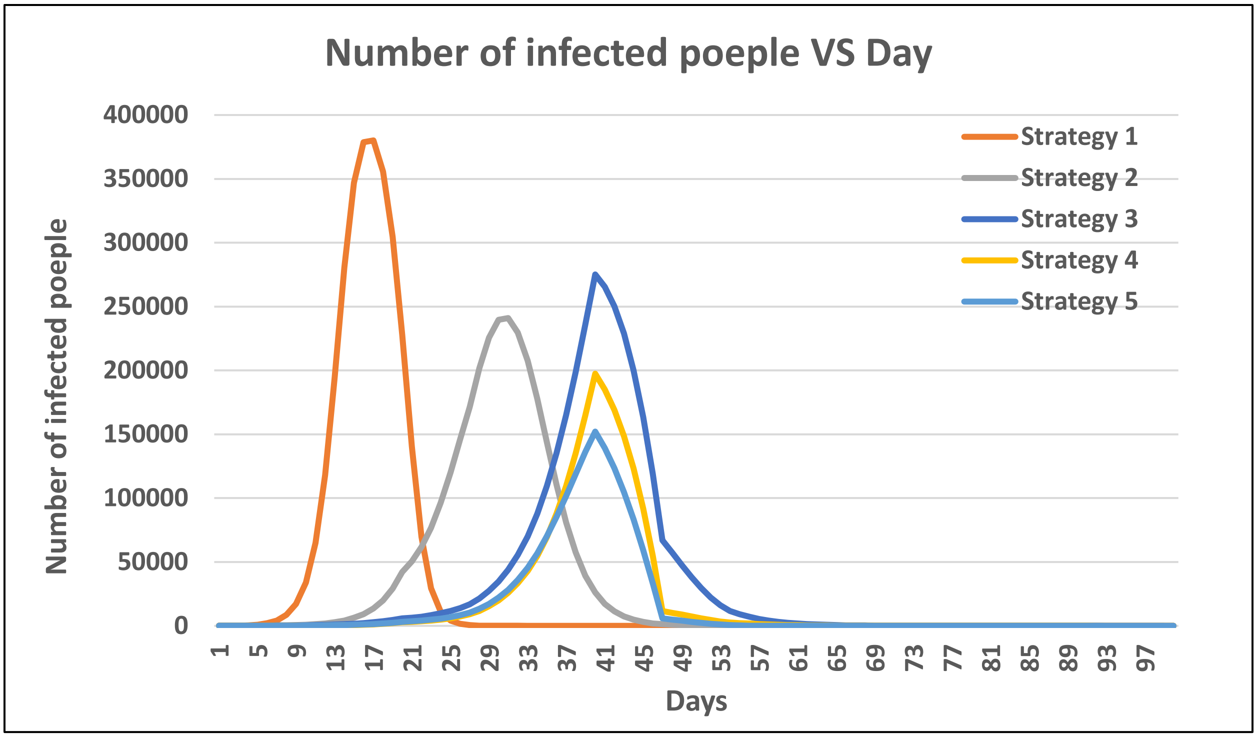
- If the vaccines are available after providing 1st dose to all the residents, the 2nd dose of vaccine can be provided, reducing the disease contagiousness to 5%.

**Simulation:**

- We start with collecting inputs from the user.
- The inputs collected are Day on which lockdown is enforced, Day on which mask usage is enforced, Day on which Vaccine dose 1 is provided, Day on which vaccine dose 2 is provided.
- Based on the simulation inputs and assumptions made, we run the simulation for 100 days, collecting number of infected people on each day.
- In the simulation we compared 4 possible strategies that can be adapted to contain the disease spread:
  1) Strategy 1 - No lockdown, no mask enforcement, no vaccination
  2) Strategy 2 - Mask enforcement from 20th day, no lockdown, no vaccination
  3) Strategy 3 - Mask enforcement from 20th day, lockdown from 40th day, no vaccination
  4) Strategy 3 - Mask enforcement from 20th day, lockdown from 40th day, only 1st vaccine dose on 40th day
  5) Strategy 3 - Mask enforcement from 20th day, lockdown from 40th day, 1st vaccine dose on 40th day and second vaccine dose on 50th day

- Output data of the number of people infected on each day is saved in a text file.
- The output data is copied to a spreadsheet to plot the distribution of number of infected people vs Day.
- The plots provide visual comparison between various strategies that can be used to contain the pandemic spread.
- Summary statistics like peak infections day, number of infected person on peak day, duration of the pandemic are also retrieved from the output data.

## 4. Results and Analysis




- The results obtained for the various strategies are contrasted to suggest the best strategy to contain the pandemic.
- As no lockdown, mask or vaccination measures are used, the Strategy 1 resulted in peak daily cases of 380125 cases on day 17 with pandemic lasting for 32 days. Although the pandemic lasted for a short period, the peak daily cases went very high, which could result in huge workload and failure of the medical infrastructure. If the mortality rate of the disease were high, Strategy 1 would have resulted in highest fatality.
- Enforcing masks in the Strategy 2 slightly reduced peak daily cases, delayed the peak day, allowing the medical infrastructure and facilities some time to get ready. Still the overall disease spread was very high.
- Enforcing masks with lockdown in Strategy 3 resulted in a drop in daily cases and delayed the peak day. But total duration of the pandemic was increased.
- Strategy 4 with masks, lockdown and 1$^{st}$ vaccine dosage resulted in reducing the daily cases, peak cases as well as the pandemic duration.
- Strategy 5 with all the measures like masks, lockdown, both vaccine dosages resulted in best overall results with minimum disease spread, and a shorter pandemic duration.

The chart below summarizes results obtained for the 5 strategies implemented.

| | Strategy 1<br>No Mask<br>No Lockdown<br>No Vaccination | Strategy 2<br>Mask = 20th Day<br>No Lockdown<br>No Vaccination | Strategy 3<br>Mask = 20th Day<br>Lockdown = 40th day<br>No Vaccination | Strategy 4<br>Mask = 20th Day<br>Lockdown = 40th day<br>Vaccine1 = 40th day<br>No Vaccine 2 | Strategy 5<br>Mask = 20th Day<br>Lockdown = 40th day<br>Vaccine1 = 40th day<br>Vaccine2 = 50th day |
|---|---|---|---|---|---|
| **Pandemic Duration** | 32 | 62 | 92 | 91 | 71 |
| **Peak Cases** | 380125 | 241003 | 275164 | 197456 | 152114 |
| **Peak Day** | 17 | 31 | 40 | 40 | 40 |

As we can clearly see, Strategy 5 is the best alternative considering peak number of cases, peak day and total pandemic duration. Although Strategy 1 results in a shorted pandemic duration, the peak cases obtained are very high and are observed very early, making the medical system in the city prone to a catastrophic failure.

## 5. Conclusion

It was an interesting activity to see how an even a small number of infectious people i.e., 10 can start a pandemic which will affect the entire city with a population of half a million.

We have had some hands-on experience of simulation using python. Each time we ran simulation of various cases for pandemic spread and its control measures, we got the different results due to the certain randomness we have introduced in our code. We could compare various scenarios under which virus spread would affect the city and we could see by ourselves how different measures taken to contain the virus spread achieved the different results. We got the quite an intuitive result that with each extra step taken to contain the virus spread, pandemic takes a different and a less harmful shape.

We can try out different values of probability and even different probability distributions for the spread of the virus. We kept the population of the city intact. We can add another element of other infectious people coming into city from outside and how they would affect the virus spread. We kept the mortality rate zero. We can add the mortality parameter as well to the simulation to make it more real-life.

The whole world is living through this real-life mega simulation right now - a highly contagious virus COVID-19 is still raging like anything. The simulation activity carried out here can be implemented on a larger scale. With the warlike efforts going around the world for the vaccination and virus mutating against it causing the situation still out of control poses may more aspects that can be added to the simulation activity.