Department of Industrial Engineering
IE206 – Scientific Computing for Industrial Engineering

Term Project 1 – Spring 2023

Group Number 1

"Academic integrity is expected of all students of METU at all times, whether in the presence or absence of members of the faculty. Understanding this, I declare that I shall not give, use, or receive unauthorized aid in this study."

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Introduction

We are appointed as (imaginary) consultants by the Ministry of Health to conduct research on the latest Coronavirus Outbreak. We began by creating a computational framework and simulate outbreak conditions and prevention methods. Simulations helped us to understand the impact of several parameters for 7 scenarios and came up with this report to show the results of our discoveries for those cases. Here are the findings of simulations conducted.

Case 1 - Impact of Initial Number of Infected People on the Spread of Pandemic Under Different Isolation Policies

We first wanted to study the impact of initial number of infected people using different isolation policies. We studied two different cases for both initial number of infected people and isolation policies, which resulted in four different set of graphs as seen from the *Table 1* below:

N (population)	**Δ_1 (percentage of infected people initially)**	**Initial number of infected people ($N * \Delta_1$)**	**Δ_2 (percentage of isolated infected people at the initialization)**	**No of Figure for the Data**
200	10	20	20	Figure 1
400	10	40	20	Figure 2
200	10	20	80	Figure 3
400	10	40	80	Figure 4

Table 1: Values of Parameters for Different Cases for Case 1

In this case, we used the performance criteria for newly infected, healed, and dead ones for each iteration displayed on the left and cumulative results displayed on the right. Since we wanted to observe the impact of number of initial infected people under different isolation policies, which is multiplication of N and Δ_1, we first kept Δ_2 and Δ_1 constant, as seen in *Figure 1* below.

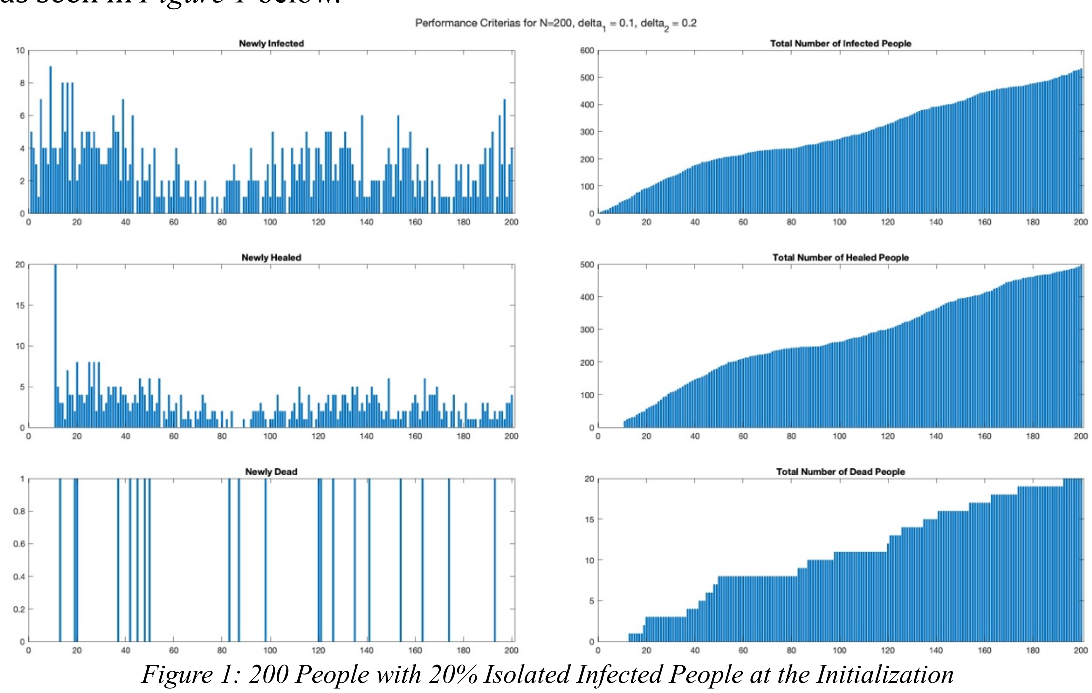

Figure 1: 200 People with 20% Isolated Infected People at the Initialization

In the next simulation, we doubled the population while keeping all other parameters constant. It can be seen from *Figure 2* that both iteration and cumulative graphs nearly become ~5 times larger. This means that when we increase the population density, the impact of this increase is much more in the performance criteria such as number of infected, healed, and dead people.

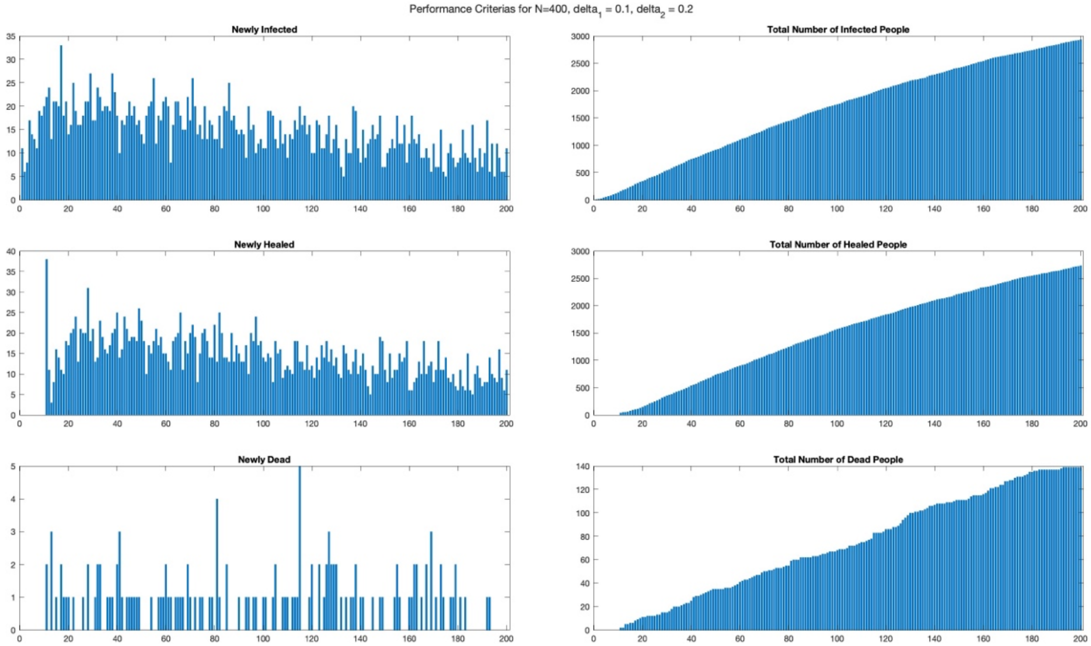

Figure 2: 400 People with 20% Isolated Infected People at the Initialization

Since the population density is larger in *Figure 2,* chance of people being interacted with each other is higher, which results in higher infecting, healing, and dying numbers are increased much more compared to doubling.
In both *Figure 1* and *Figure 2*, we studied the cases where Δ_2 is 0.2. Now we follow the same steps just by changing Δ_2 to 0.8.

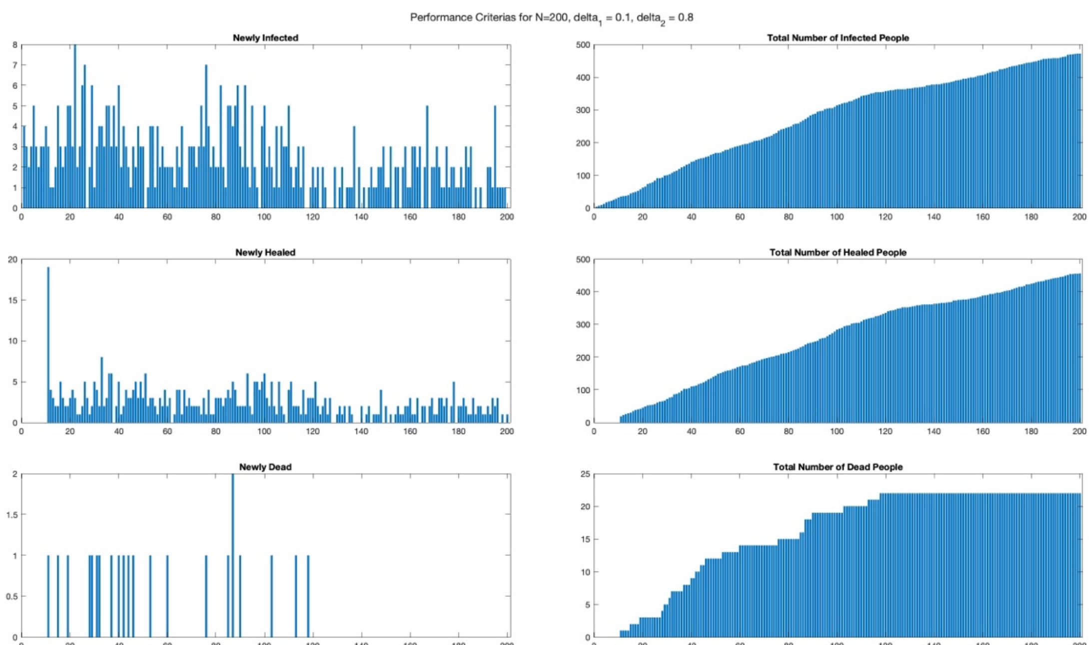

Figure 3: 200 People with 80% Isolated Infected People at the Initialization

Comparing *Figure 3* with *Figure 1* where we study the case by the same parameters except Δ_2, we can see that when the isolation percentage at the initialization is higher, there is a slight decrease of number of total infection and as the iterations increases, we see a significant decrease in the number of death people per iteration. Like the comparison of *Figure 1* and *Figure 2*, we can come up with almost the same result such as the impact of initial number of infected people. It can be seen than doubling the population led much increase in all the performance criteria studied here. When we compare *Figure 3* above and *Figure 4* below, we can see that for each iteration, there is significant increase in all criteria.

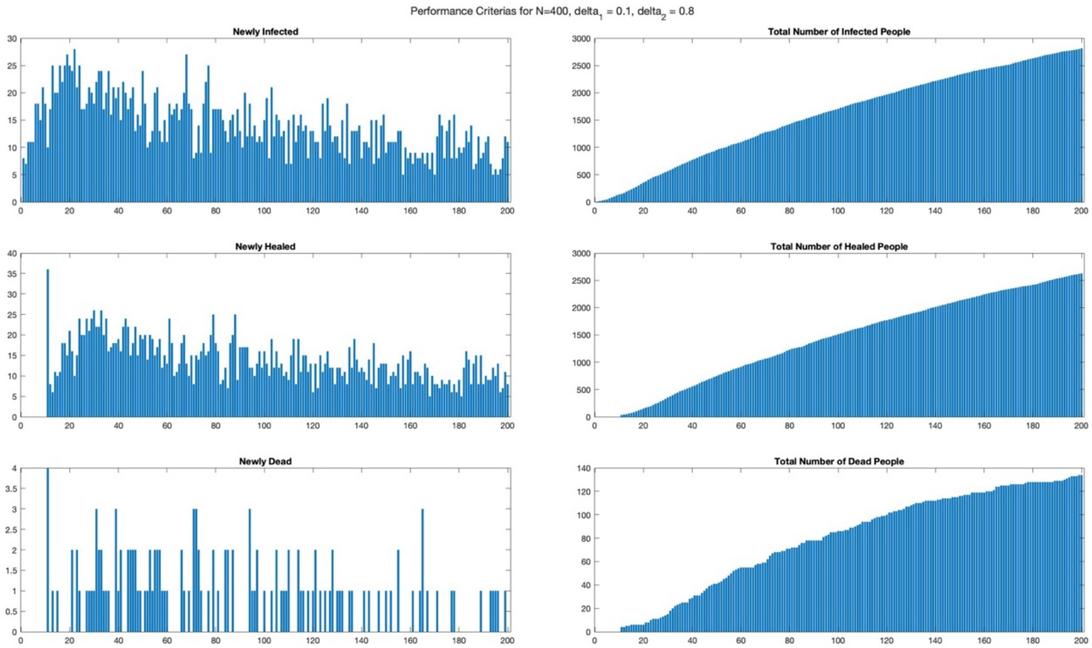

Figure 4: 400 People with 80% Isolated Infected People at the Initialization

Those 2 sets of figures above can be thought to follow similar trends but they don't. Since the scales are different, at some point, case in *Figure 3* seems to be stopping but the other case is continuing throughout the whole iterations.

Case 2 - Impact of the Implementation of Isolation on the Spread of the Pandemic

In this case, we study the impact of the implementation of isolation of the spread of the pandemic. Thus, we keep all variables constant except Δ_2 constant, which helps us to understand how the change in Δ_2 affects the performance criteria. In the first set of graphs, *Figure 5*, set $\Delta_2 = 0\%$ and in *Figure 6*, we set $\Delta_2 = 100\%$ to compare the cases where there is no implementation of isolations full implementation of isolation.

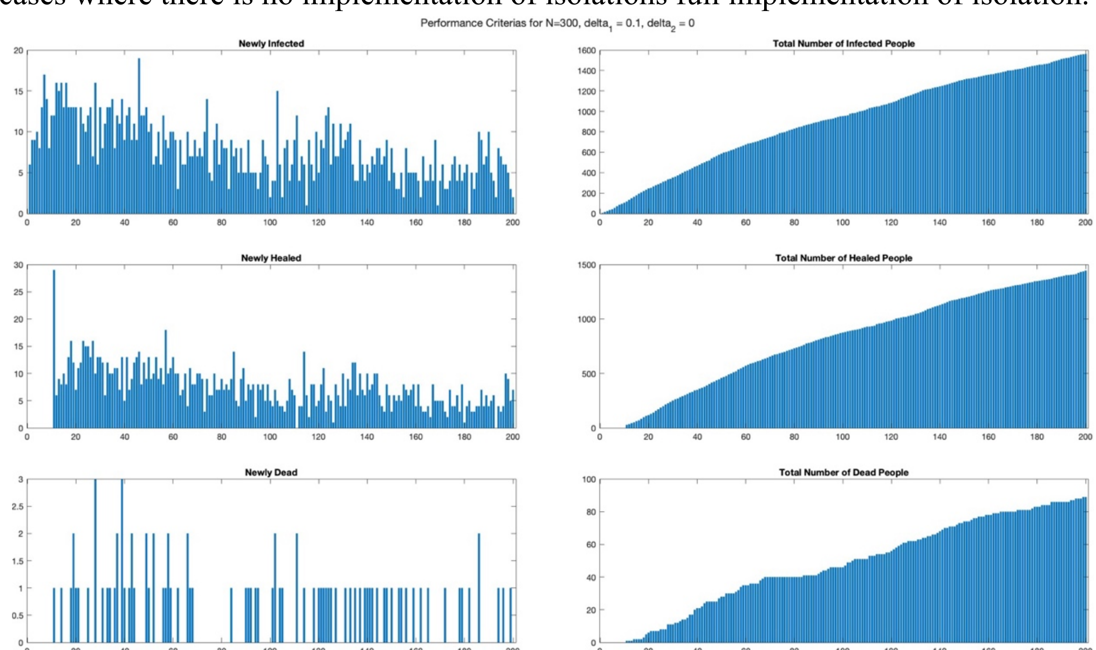

Figure 5: 300 People with 0% of Isolated at the Initialization

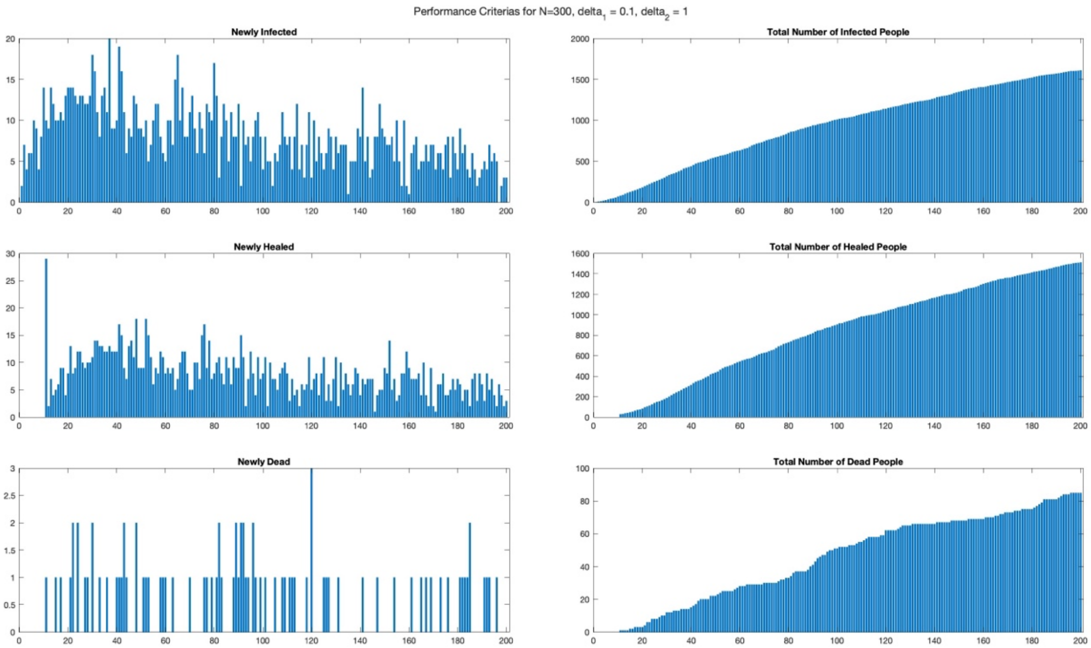

Figure 6: 300 People with 100% of Isolated at the Initialization

When we compare *Figure 5* and *Figure 6*, there is nearly no change in the performance criteria studied. Thus, we can conclude that Δ_2 has no effect alone when other parameters are kept constant.

Case 3 - Impact of the Vaccination Rate on the Spread of the Pandemic

When we consider the impact of the vaccination rate on the spread of the pandemic in the case where there is single vaccination available and the government does not implement an isolation policy, we kept all variables constant ($N = 300, \Delta_1 = 8\%, \Delta_2 = 0.5, p = 0.4, M = 10$) and changed the value of k, which directly affected the rate of vaccination, Δ_3.

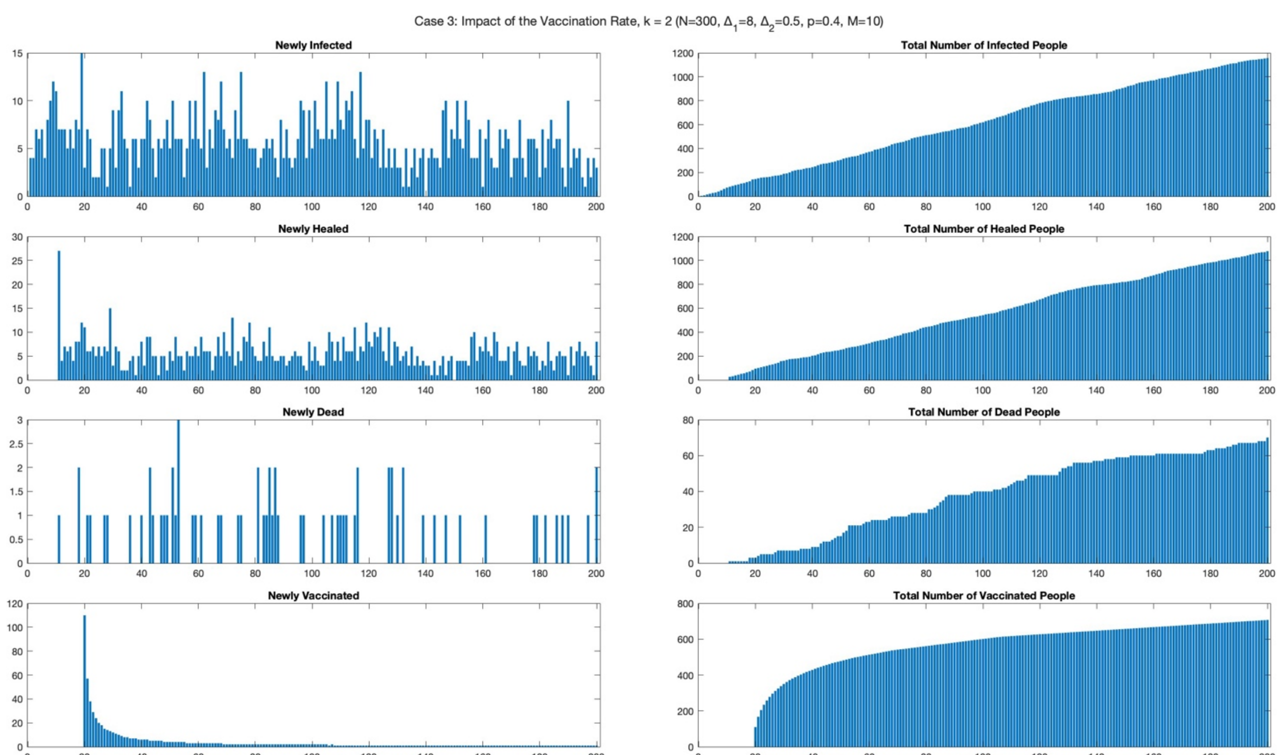

Figure 7: Impact of the Vaccination Rate, k = 2

Doubling the value of k results the rate of vaccination Δ_3 to decrease to half. By comparing *Figure 7* above and *Figure 8* below, it is observed that there is a slight decrease in the total number of infected people while other performance criteria showed no significant change.

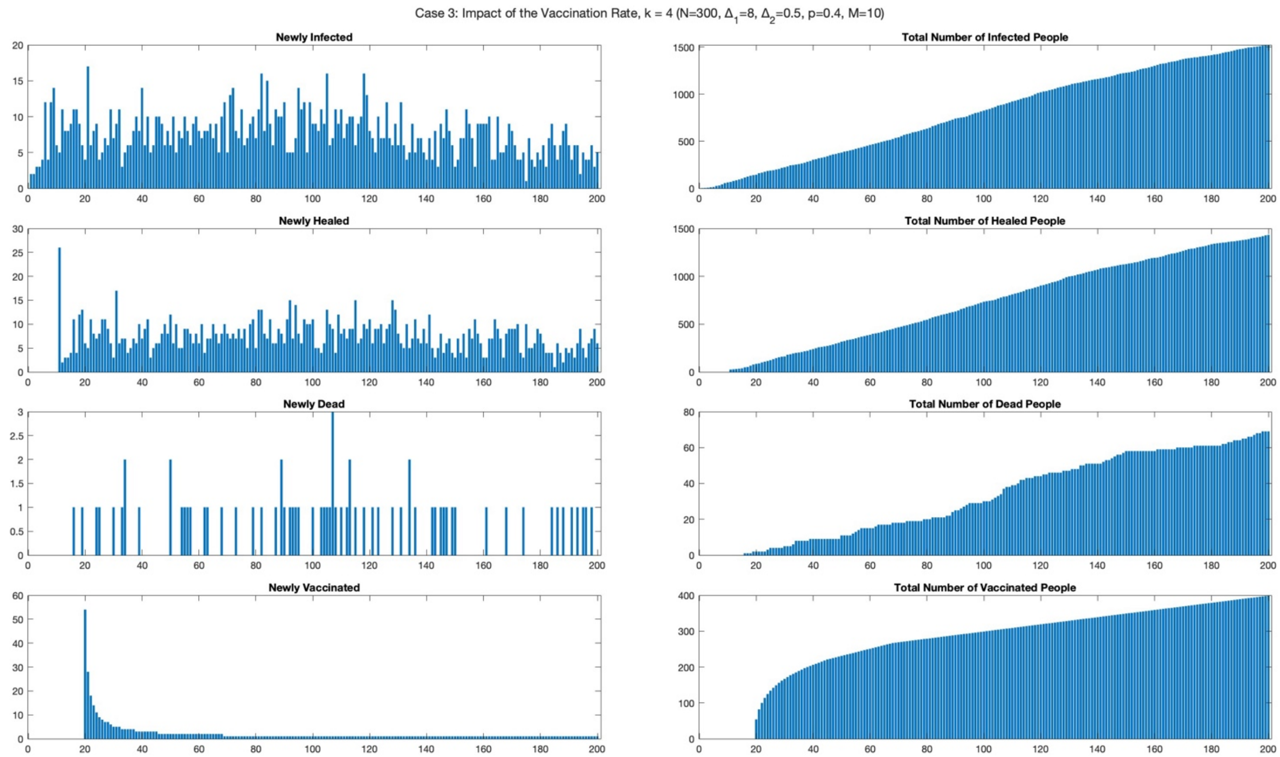

Figure 8: Impact of the Vaccination Rate, k = 4

Case 4: The Impact of Contagiousness on the Spread of the Pandemic

To study the impact of contagiousness, p,under a certain isolation policy, $\Delta_2 = 50\%$ and constant population, $N = 300$ we compared cases where $p = 0.2$ and $p = 0.6$.

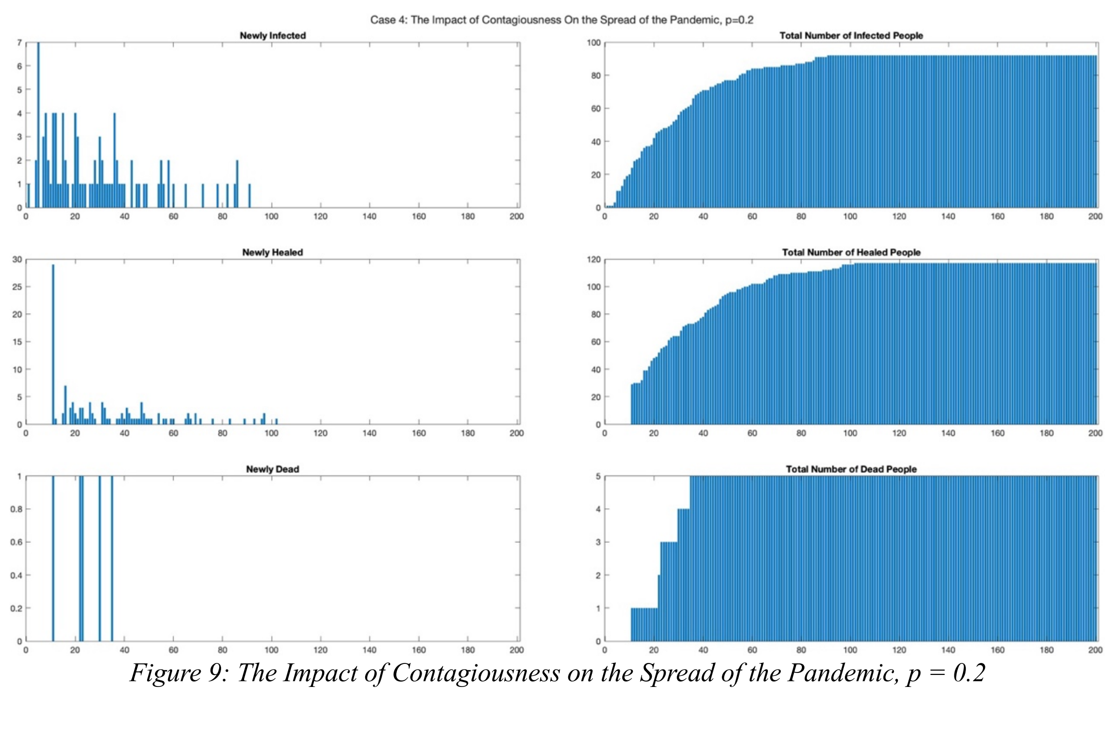

Figure 9: The Impact of Contagiousness on the Spread of the Pandemic, p = 0.2

Figure 9 above shows the set where $p = 0.2$ and *Figure 10* below shows the set where $p = 0.6$. It can be observed that when contagiousness is lower, after some iterations the spread nearly stops but when contagiousness is higher, the spread continues throughout the whole iterations. Additionally, we can observe that performance criteria are ~25 times larger in the case where contagiousness is higher. Observing *Figure 7,* we can see that all the cumulative performance criteria are constant after some point, which tells us that the spread of the pandemic is over.

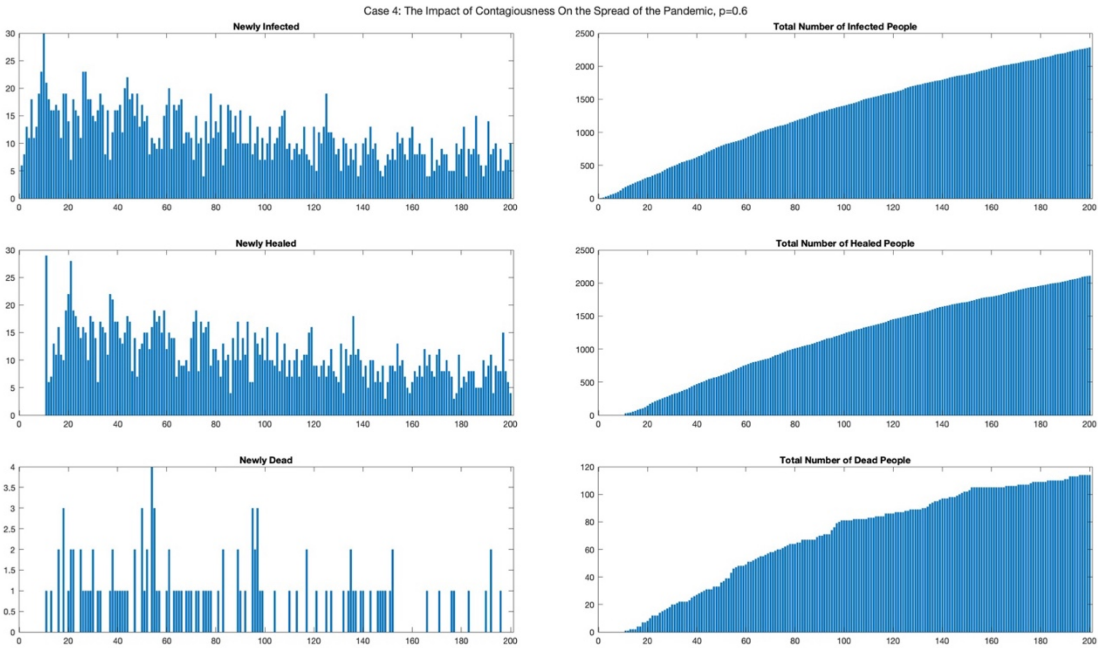

Figure 10: The Impact of Contagiousness on the Spread of the Pandemic, p = 0.6

Case 5: Impact of the Prevention of Vaccination Under a Double-Vaccination Policy for Different Numbers of Iterations Between Two Vaccinations

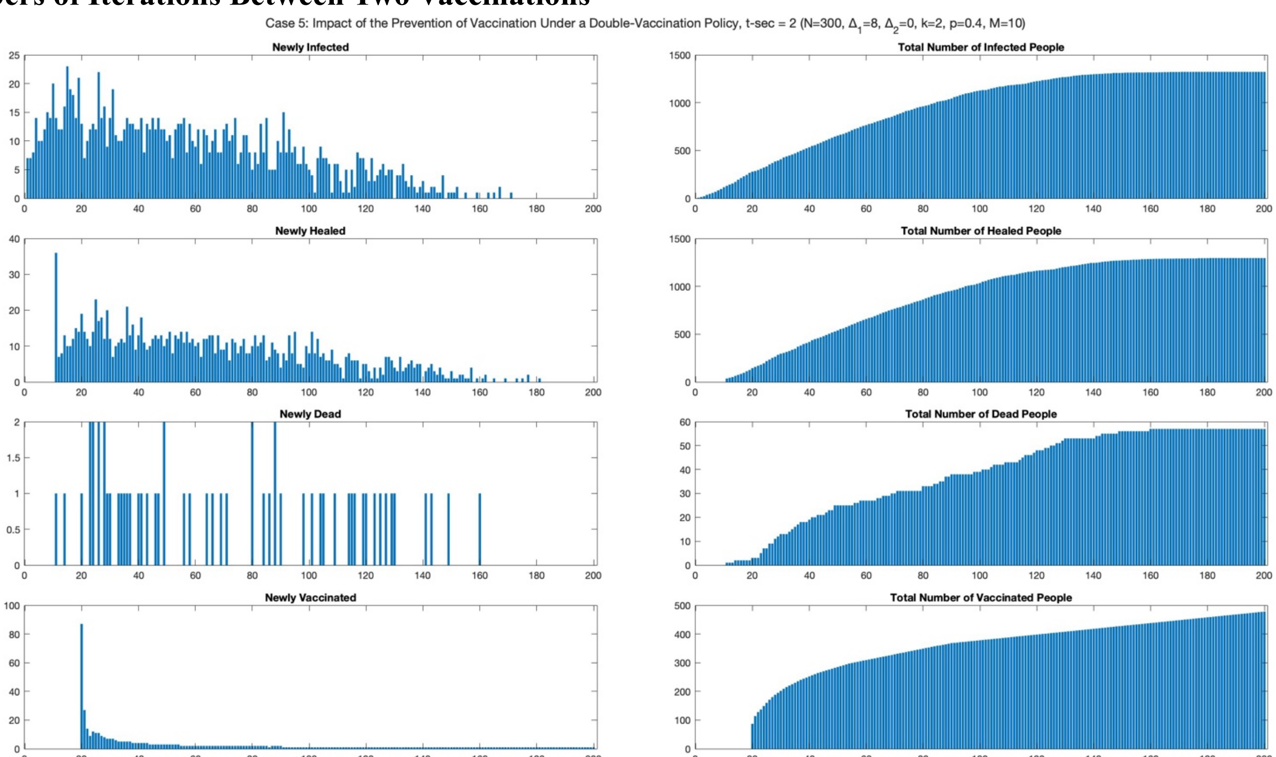

Figure 11: Impact of the Prevention of Vaccination Under a Double-Vaccination Policy, t_{sec} = 2

For this case, we want to study the impact of the prevention of vaccination on the spread of the pandemic under a double vaccination policy for different no. of iterations between two vaccinations, t_{sec}. By holding all parameters constant ($N = 300, \Delta_1 = 8\%, \Delta_2 = 0,\ k = 2,\ p = 0.4,\ M = 10$) and changing the value of t_{sec} from 2 to 10, we obtained *Figure 11* above and *Figure 12* below respectively.

Comparing the total number of dead people, there is a slight decrease in this parameter when t_{sec} is increased. Additionally, we can see from the cumulative graphs of dead people that when t_{sec} is higher, number of dead people comes to a stable point before the case where t_{sec} is lower. Moreover, we can see a significant decrease in number of infected people when t_{sec} become higher since the immunity increases when we vaccinate people. One last difference for those cases is that when t_{sec} is higher, it requires more time to do the half of the vaccinations compared to the case where t_{sec} is lower.

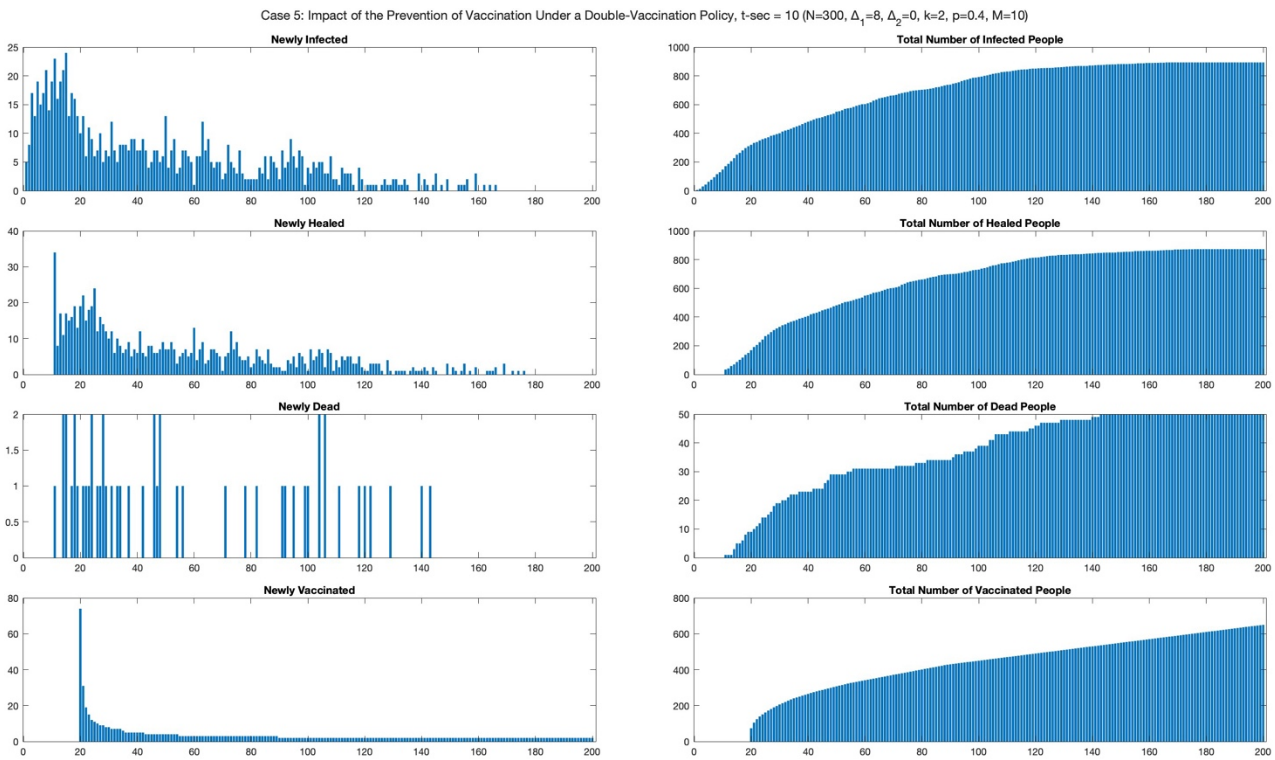

Figure 12: Impact of the Prevention of Vaccination Under a Double-Vaccination Policy, t_{sec} = 10

Case 6: Impact of the Willingness of People, w, for the Second Vaccination

In this case, we are studying the impact of the willingness of people for the second vaccination where the government implements a double vaccination policy. To study the impact of w, we kept all other parameters constant ($N = 300, \Delta_1 = 8\%, \Delta_2 = 50,\ k = 2,\ p = 0.4,\ M = 20, t_{sec} = 4$) and changed the value of w from 0.4 to 0.8. *Figure 13* and *Figure 14* below show the performance criteria for $w = 0.4$ and $w = 0.8$ respectively. As it can be seen from the figures mentioned here, there is no significant change in the performance criteria mentioned here. Thus, by keeping all the other values constant, we can say that willingness of the people ,i.e. second vaccination probability of healthy people, has no impact on the spread of the pandemic.

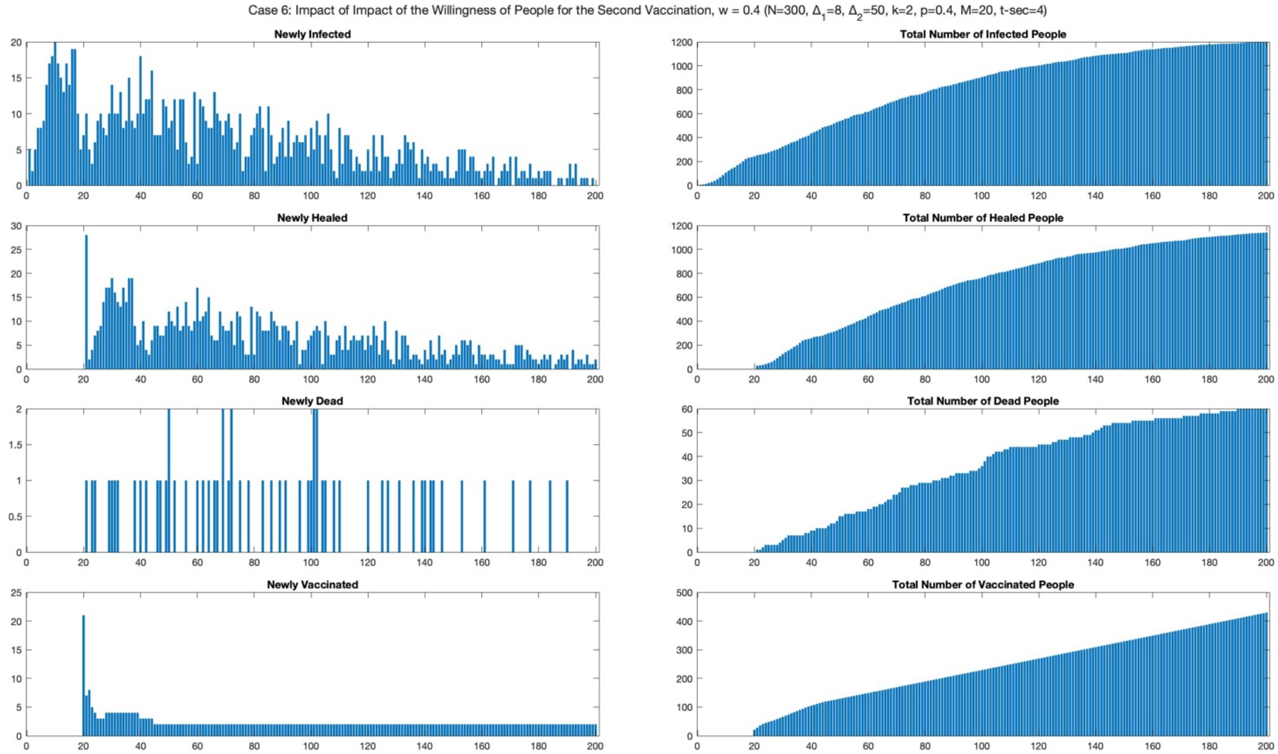

Figure 13: Impact of the Willingness of People for the Second Vaccination, w = 0.4

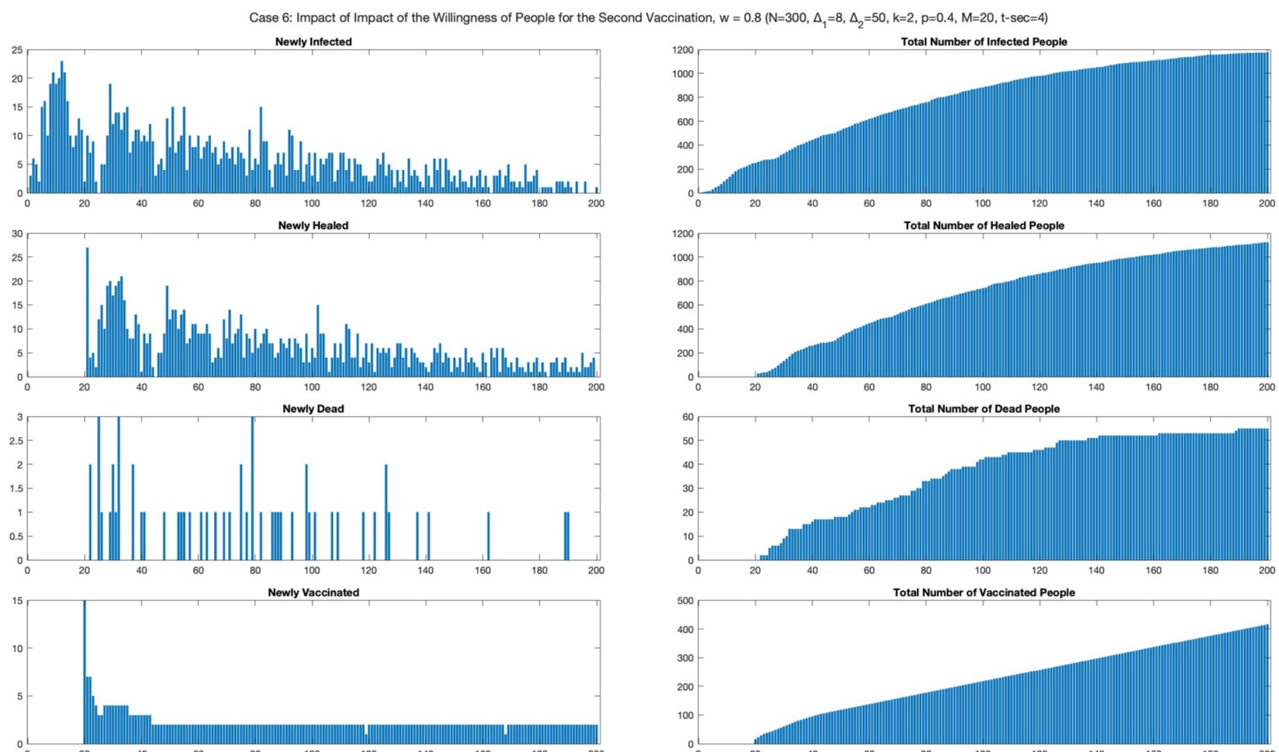

Figure 14: Impact of the Willingness of People for the Second Vaccination, w = 0.8

Case 7: Policy Recommendations to the Government to Control the Spread at Most 30% Infected People

In this case, aim of the the government is to control the spread such that at most 30% of the population is infected. We have the restrictions such as $N = 150$, $p = 0.5$, $\Delta_2 = 0.05$, $M = 30$. For this case, we simulated iterations several times and stored the values the total number of infected people on the current iteration. When we checked the maximum value for these iterations, we realized that there are parameters that helps us to control the spread at the aimed level. Those two parameters are k and w, which we observed the changes for. Additionally, as it can be seen from *Table 2* below, we set $\Delta_1 = 0.01, t_s = 20, t_{sec} = 4, p = 0.5$ as constant values which does not change during any scenario.

	k	w	Δ_1	t_s	t_{sec}	p	$max\ \#\ of\ infected$
Scenario 1	1.5	0.8	1%	20	4	0.5	28
Scenario 2	3	0.8	1%	20	4	0.5	49
Scenario 3	1.5	0.4	1%	20	4	0.5	38
Scenario 4	3	0.4	1%	20	4	0.5	62

Table 2: Values of Parameters for Different Scenarios for Case 7

In *Figure 15*, we can observe the ratio comparisons of maximum number of infected people and maximum number of non-infected people for the different scenarios. As it can be seen, aimed level by the government is achieved in Scenario 1 and Scenario 3, where we set the value $k = 1.5$. On the other two cases, where we decrease the rate of vaccination of healthy people to the half, we failed to hit the target. *Figure 15* below represents the ratios for each scenario.

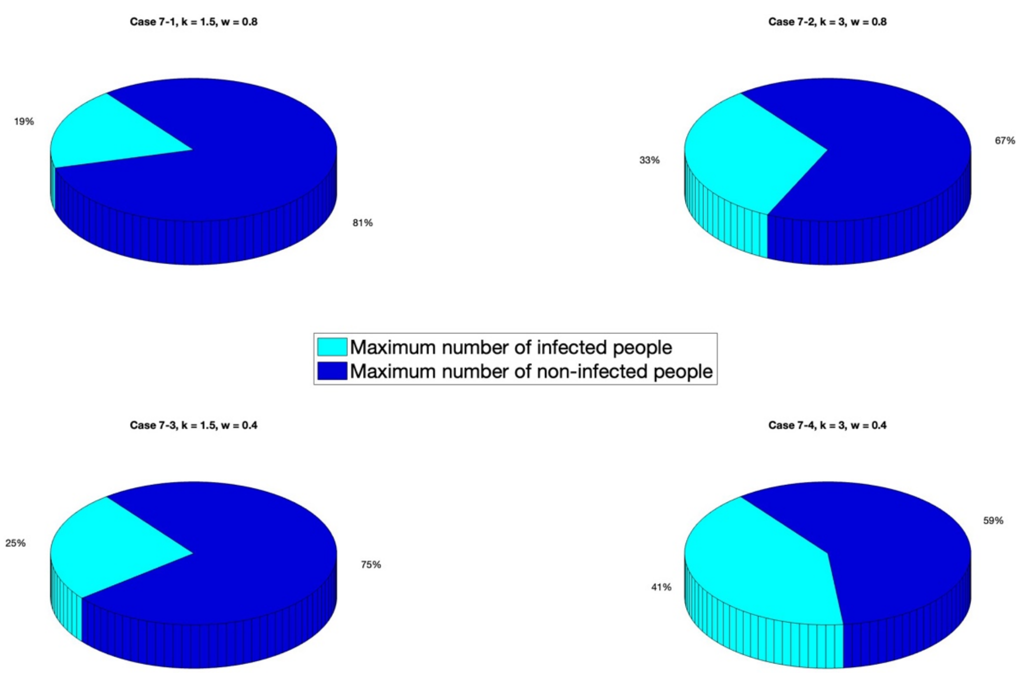

Figure 15: Different Scenarios for Case 7

It should be noted that since those are the average ratios after repetitions of same simulations, real values may slightly differ from those, but the recommendations will not be affected from this slight change.

Here is the list of recommendations to the government:

- Rate of vaccination of healthy people should be set at its highest possible value, so the immunity increases while the infection rate decreases. In order to do that, the vaccines should be supplied from the manufacturers immediately.
- There should be numerous places where people can get vaccinated. Reaching the vaccination should be easier and any obstacles which makes it harder to reach the vaccine should be removed.
- People should be encouraged to take the second dose of the vaccine, there should be given government incentives. There can be public education campaigns which provides the accurate information by the people who has a huge influence on the society. Public awareness for the effectiveness of the vaccines should be increased, by several advertisement campaigns.
- Whenever the virus is discovered, restrictions should be implemented in order to sharply reduce the interaction between people. Because it is known that number of initially infected people has a significant effect on the spread of the pandemic, government can oblige companies to shift to remote work, there should be implementations on the usage of masks, and inspection should be applied strictly. Moreover, flexible work schedules should be encouraged.