ORTA DOĞU TEKNİK ÜNİVERSİTESİ
MIDDLE EAST TECHNICAL UNIVERSITY

MÜHENDİSLİK FAKÜLTESİ
FACULTY OF ENGINEERING
ENDÜSTRİ MÜHENDİSLİĞİ BÖLÜMÜ
DEPARTMENT OF INDUSTRIAL ENGINEERING

IE206 Project Report

2023-2024 Spring

Policy Making on Corona Virus Spread

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, we declare that we shall not give, use, or receive unauthorized aid in this project.

Group ID#	*Student ID Number*	*Full Name*	*Signature*
31	*2577419*	*Ekin Akçay*	
31	*2517704*	*Emir Can Dağlı*	

Table of Contents

Introduction

As industrial engineers, we are hired (hypothetically) as consultants providing government assistance for understanding future outbreaks. We are expected to study the recent coronavirus outbreak, create a model for the spread of the coronavirus, and perform computational analysis to develop different policies and their effectiveness under several settings to control the spread of the disease. Hence, the government can effectively respond to a future outbreak. We are expected to study 4 cases with different approaches and policies. Finally, we are expected to find a combination of policies and variables to keep the healthcare system afloat under various types of viruses by changing the variable "p".

Model Parameters

Through all the cases, we used the model parameters as displayed in Table 1 below:

Table 1. Model Parameters

Parameter	Explanation	Value
T	Grid size	25 x 25
N	Population size	200
Δ_1	Percentage of infected people initially	10%
p	Infection probability in scenario of encounter	0.5
Δ_2	Percentage of isolated infected people at the initialization	50%
q_s	Isolation probability of a newly infected person	[0.0 - 1.0]
M	Duration of infectious period (in number of iterations)	25
t_s	Iteration number where vaccination starts	20
r_s	Infection probability of vaccinated healthy people	0.1
t_{sec}	Number of iterations between two vaccinations	10
ω	Second vaccination probability of healthy people	[0.4 - 0.8]
Δ_3	Rate of vaccination of healthy people	$\frac{1}{k*(t_v-19)}$
t_v	Derived Variable of t_s	$t_s+(n-1)$
k	Constant	{1.5 ,2 ,3 ,4}

0. No Implementation of Policies

In the case 0, we must create a simulation representing the outbreak and observe the case when no isolation or vaccination policy is enforced, as this was considered a policy in some countries. We created a matrix representing the people and manipulated that matrix to store the data corresponding to the position, whether the person is infected or not, iteration number of infected individuals, etc.

In this case, we used the performance criteria for newly infected, healed, and dead ones for each iteration displayed on the top and the cumulative results displayed on the bottom, as seen in Figure 1 below.

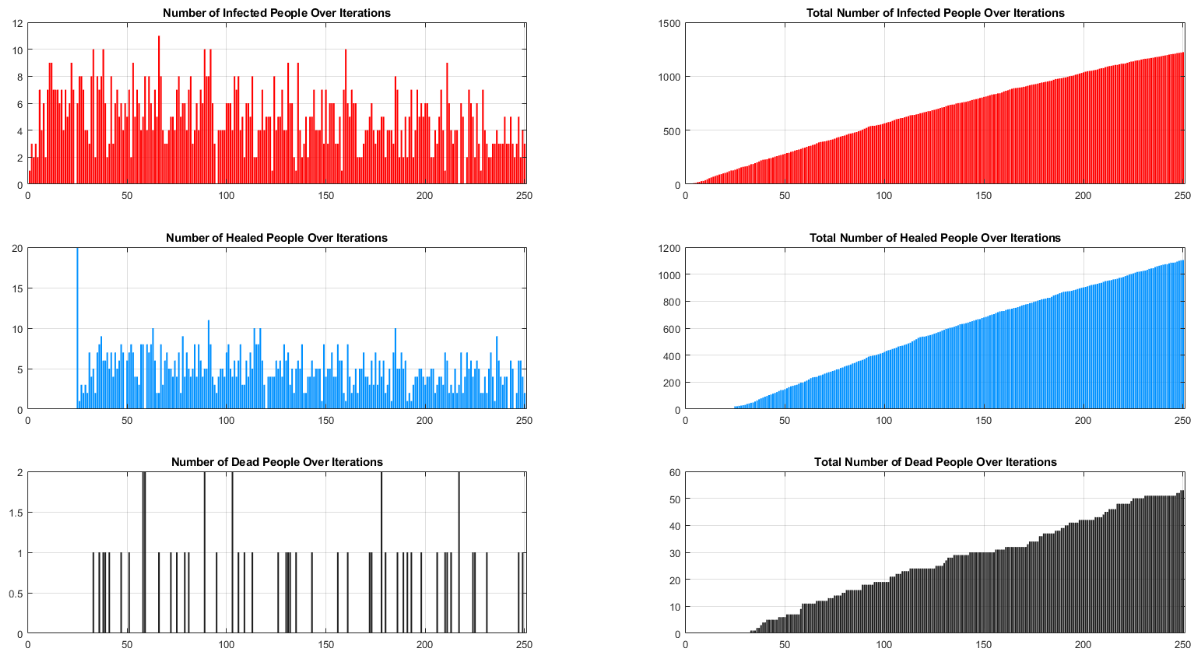

Figure 1. Performance critereas for the base case (case 0)

1. Implementation of Isolation Policy

In the first case, we are required to observe the spread of the disease in the scenario in which government only enforces an isolation policy. The isolation policy requires the individual to have a chance q_s of accepting the isolation, and the individual can only move to neighbors of the cells where it gets infected.

We have to add the isolation mechanic to our simulation in order to observe and comment on the results of the isolation policy on the spread of the disease. We built a function representing the isolation policy, which manipulates the matrix representing the people.

In this case again, we used the performance criteria for newly infected, healed and dead ones for each iteration displayed on the left and the cumulative results displayed on the right as seen in Figure 2 below.

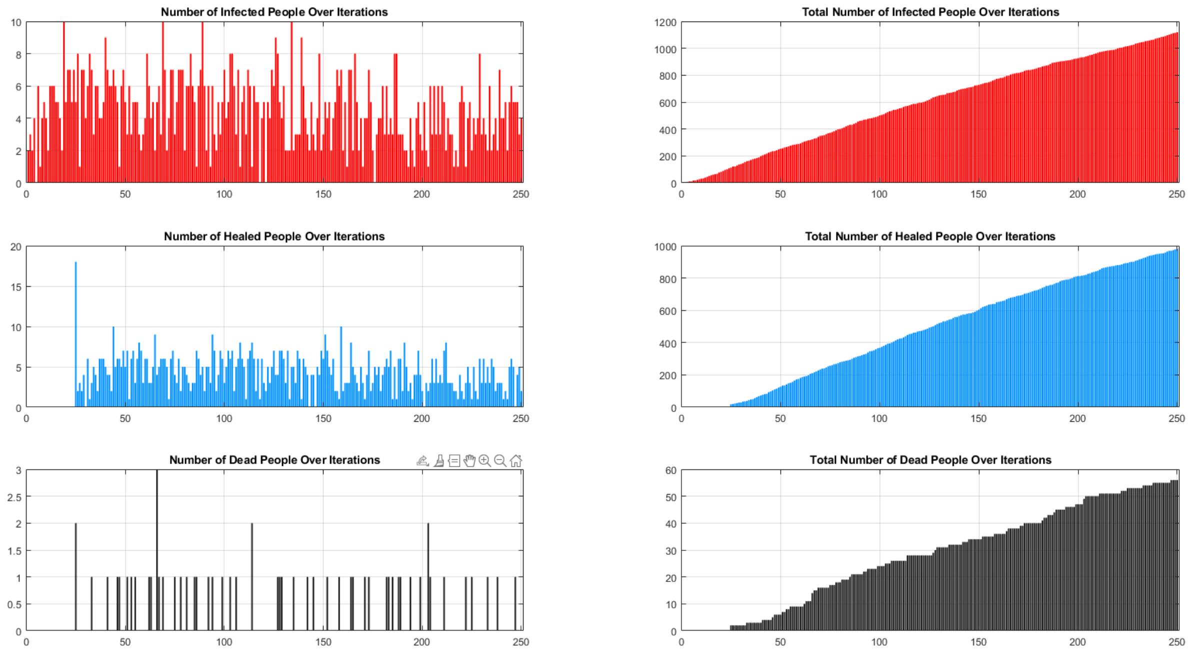

Figure 2. Performance critereas for the case 1

When we compare Figure 2 and Figure 1 we observe a slight to none decrease in both, the total number of dead people and total number of infected people. Although the isolation policy has made a small difference in the spread of the disease, the difference may not be enough for governments to stabilize the spread and sustain a stable healthcare system.

2. Implementation of a Single Vaccination Policy Without an Isolation

In the second case, we are required to observe the spread of the disease in the environment when government only enforces a single vaccination policy without an isolation policy. In this case, vaccination starts after t_s, Δ_3% of healthy individuals at that time who have not been vaccinated yet are vaccinated. Once an individual gets vaccinated, its infection probability reduces to $r_s$and remains in r_s for the following 20 iterations, then rises back to p.

We have to add the single vaccination mechanic to our model in order to observe and comment on the impact of the policy on the spread of the disease. We built a function representing the single vaccination policy, which also manipulates the matrix representing the people.

In this case, we used the performance criteria for newly infected, healed and dead ones for each iteration displayed on the top and the cumulative results displayed on the bottom, as seen in Figure 3.1 below.

Additionally, a bar graph of number of infected and vaccinated people and number of vaccinated people in each iteration is displayed in the Figure 3.2 below.

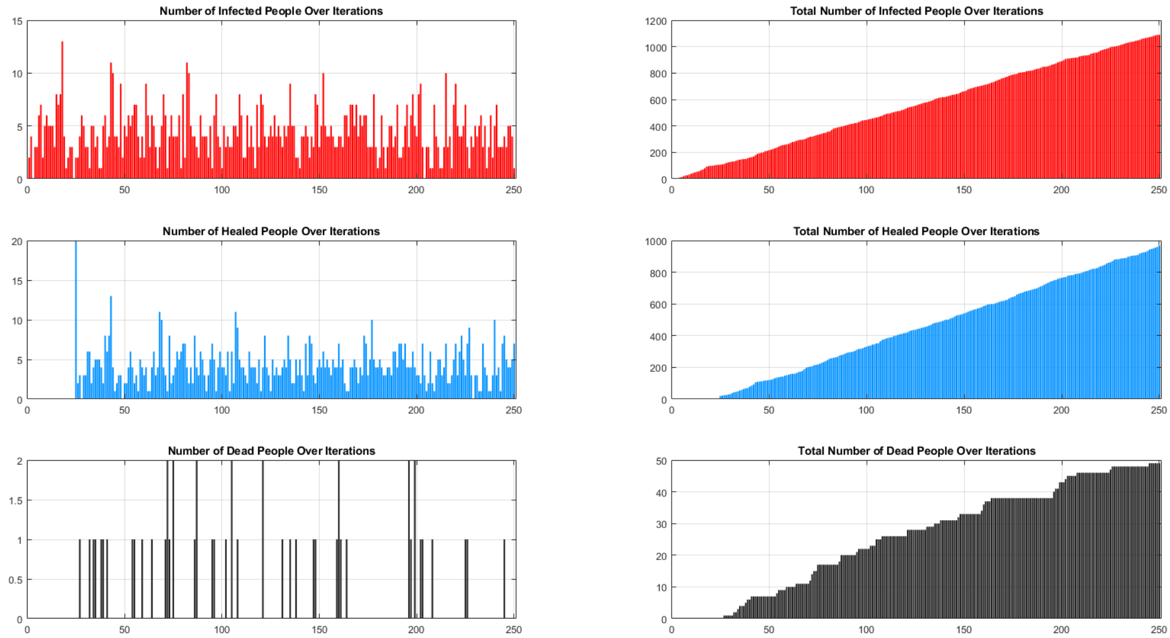

Figure 3.1 Performance critereas for the case 2

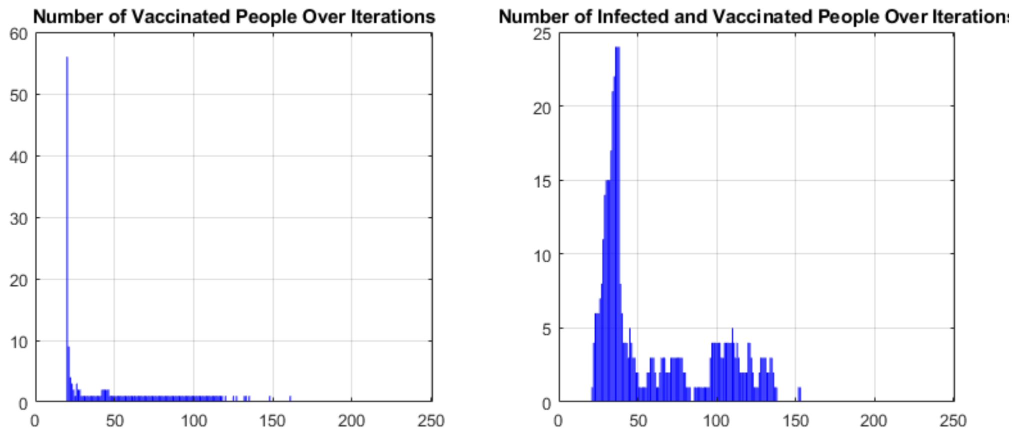

Figure 3.2 Additional Performance critereas for the case 2

Comparing Figure 3.1 with Figure 1 we observe a slight decrease in both, the total number of dead people and total number of infected and healed people. Although the single vaccination policy has made a difference in the spread of the disease, the difference may not be enough for governments to stabilize the spread and sustain a stable healthcare system.

3. Implementation Of Double Vaccination Policy Without an Isolation

In the third case, we are tasked to observe the spread of the data in the given condition where the government only implements a double vaccination policy without an isolation policy. Here we are required to observe the impact of double vaccination policy and the impact of the willingness rate “ω”.

In the first observation we used $\omega = 0.5$ and plotted the results as seen in Figure 4.1 & 4.2 below.

In the second observation we used $\omega = 0.8$ and displayed the results as seen in Figure 4.3 & 4.4 below

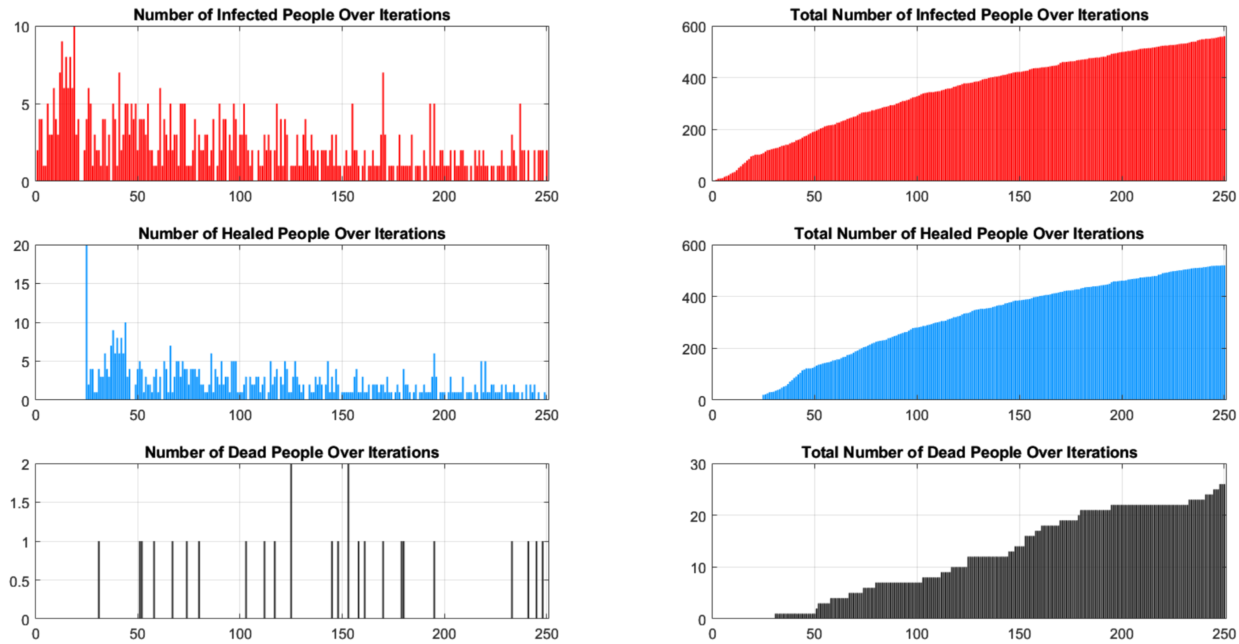

Figure 4.1 Performance critereas for the case for $\omega = 0.5$

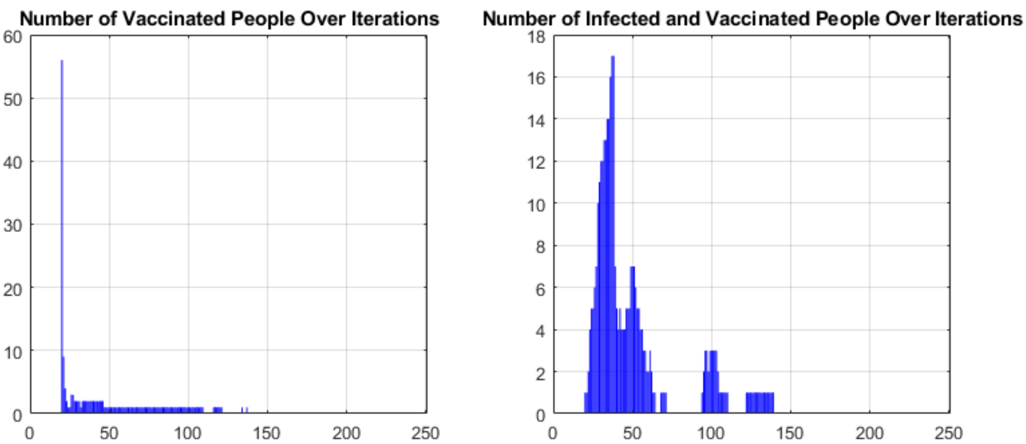

Figure 4.2 Additional Performance critereas

When compared, Figure 4.1 and Figure 4.3 we observe a fall in the both total number of people dead and total number of infected people. The willingness rate of people "ω" s observed to have a positive effect at controlling the spread when increased to 0.8 from 0.5.

Additionally, when compared Figure 4.1 with Figure 1 we can observe that double vaccination policy has a considerable impact on the spread. Comparison of total number of deaths and total number of infected people visualizes the effectiveness of double vaccination policies.

Furthermore, comparing Figure 4.1 with both Figure 3.1 and Figure 2 we also see the impact of the double vaccination policy has a greater impact on the spread rather than single vaccination and isolation policies.

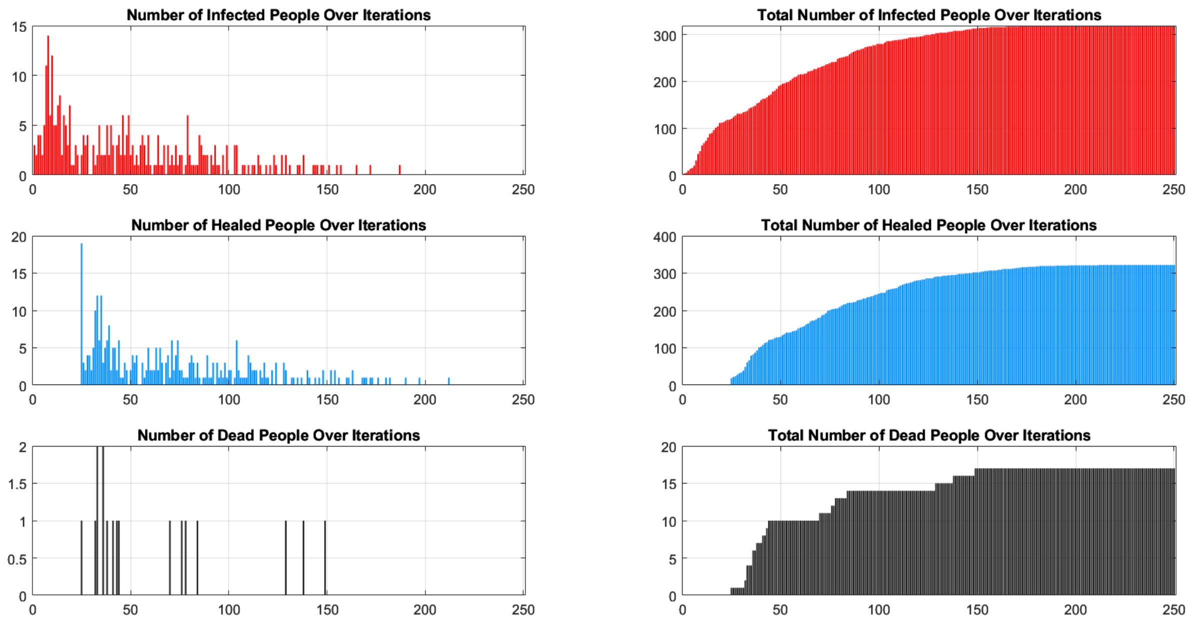

Figure 4.3 Performance critereas for the case $\omega = 0.8$

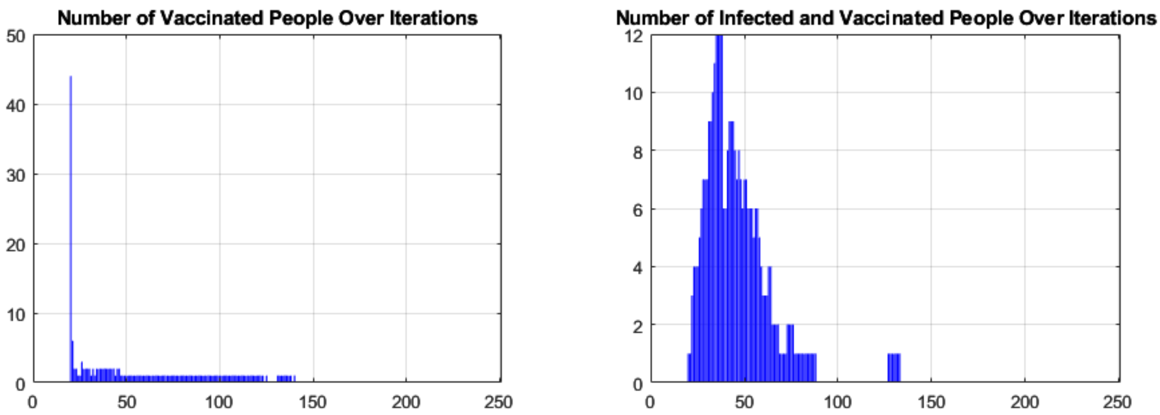

Figure 4.4 Additional Performance critereas

4. Implementation Of Both Isolation and Vaccination Policies

In the fourth case, we are required to observe the spread of the infection when government decides to implement both isolation and double-vaccination policies together.

Here we combine our model from case 2 and case 3. We used the performance criteria for newly infected, healed and dead ones for each iteration as seen in Figure 5.1. Additionally, a bar graph of number of infected and vaccinated people and number of vaccinated people in each iteration is displayed in the Figure 5.2 below.

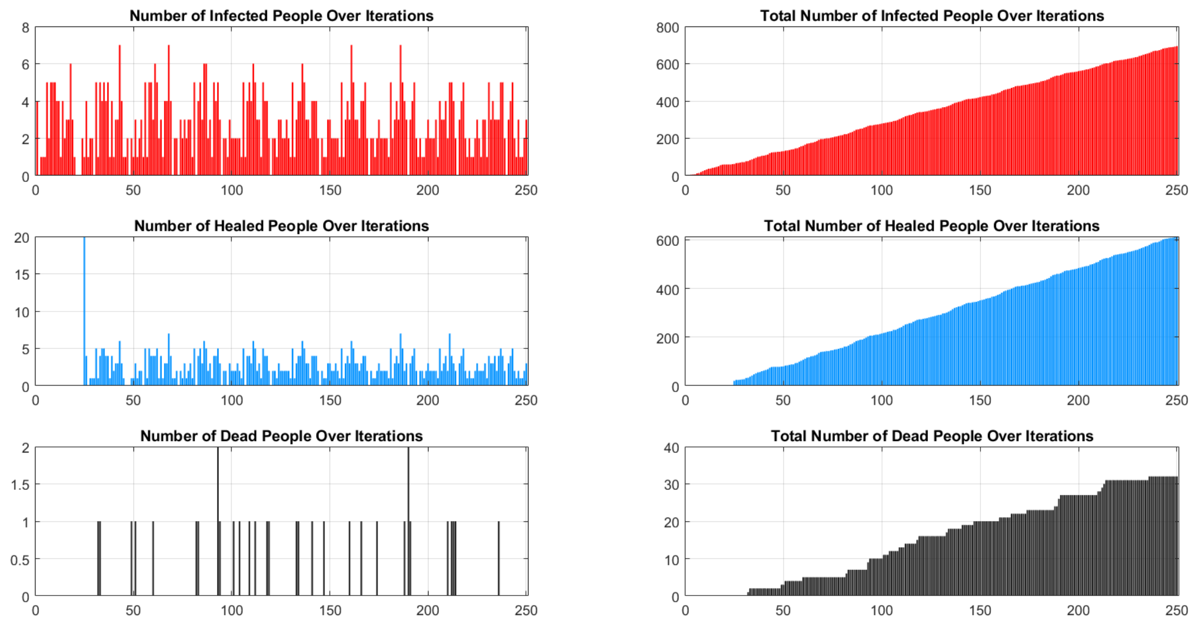

Figure 5.1 Performance critereas for the case

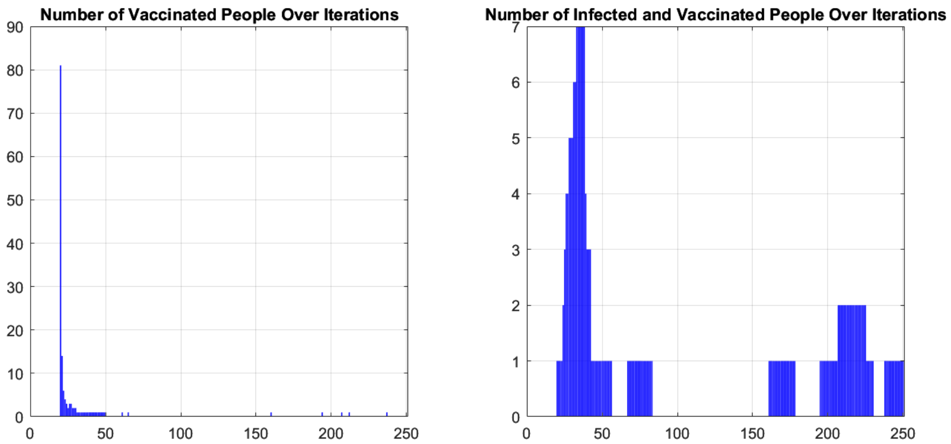

Figure 5.2 Additional Performance critereas

When we compare the Figure 5.1 and 5.2 with figure 4.1 we observe similar results since we already observed that isolation policy in Case1 has a little to none effect on spread of the infection. Therefore, we can conclude from the comparison of Figure 5.1 and Figure 1 implementation of both isolation and double vaccination policies could create a considerable impact on the spread of the disease. Similar with the Case 3.

5. Designing an Experimental Setting to Keep the Infection at a Sustainable Rate For Different Infection Probabilities

In the fifth and final case, we are required to keep the spread at a maximum rate of 25% for different infection probabilities. We are required to change the variables and enforce different combination of policies.

Our variables for different values of p is visualized as seen in table 2 below.

Table 2. Variables values used to keep the Maximum Number of Infectefd People below 25%

$\boldsymbol{p}$	Δ_2	$\boldsymbol{q_s}$	$\boldsymbol{t_s}$	$\boldsymbol{\omega}$	$\boldsymbol{k}$	$\boldsymbol{t_{sec}}$	**Maximum % of people infected**
0.25	0.5	0.5	10	0.6	3	10	%24.00
0.5	0.5	1	10	0.8	2	10	%24.50
0.75	0.7	1	10	0.8	1.5	10	%23.50

In the final case, we used the performance criteria for newly infected, healed and dead ones for each iteration displayed on the top and the cumulative results displayed on the bottom. Additionally, we plotted the number of people vaccinated in each iteration at the top right and total number of vaccinated and infected people on the bottom right for each p value as seen is Figure 6.1, Figure 6.2 and Figure 6.3.

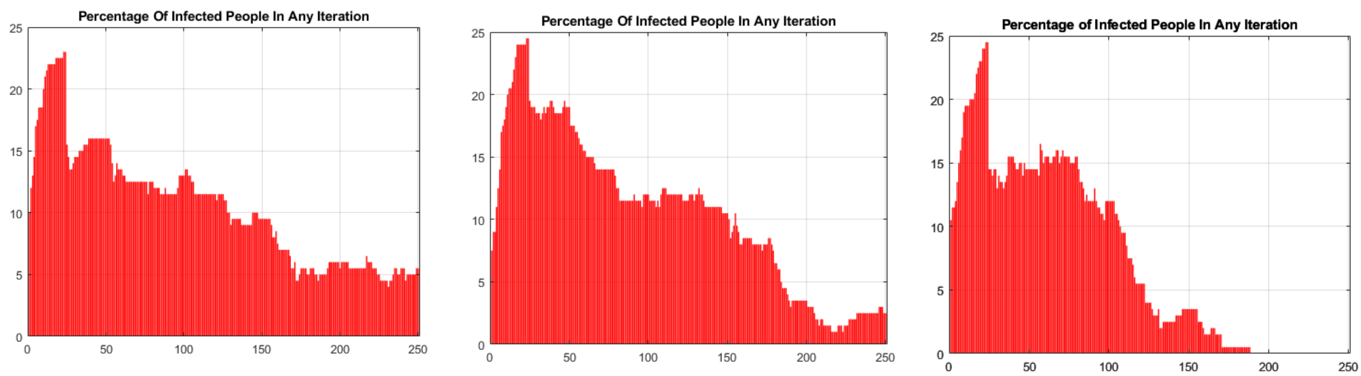

Figure 6.1. Performance Critereas for p = 0.25, p = 0.5 and p = 0.75

When the transmission rate of a virus is at 0.25, the government doesn't have to take too many precautions. However, if the government starts the vaccination after the first 20 iterations, it can be difficult to control the spread of the virus. Hence, the government should take proactive measures early on. They should begin vaccinating people as soon as possible, even if the number of vaccines available is limited. They can also be flexible with the second dose and isolation rules.

To effectively control the spread of the virus when the transmission rate is equal to 0.5, the government must implement strict policies. Firstly, mandatory compliance with isolation rules should be enforced, followed by an early start to the vaccination program. The initial vaccination volume should be increased, and the frequency of administering the second dose should be maximized.

In the case of a highly contagious and deadly virus (at p =0.75) , the government should implement strict rules to control the spread. Infected individuals must follow isolation guidelines without fail, and the vaccination rates, both initial and second dose, must be increased. However, even these measures may not be sufficient. In the event of the first 20 infected individuals, the compliance rate for isolation guidelines is only 50%. If the number of identified cases is increased and the isolation compliance rate is raised to 75%, the disease can be easily managed in its early stages.

In addition, since it is not possible to predict what kind of health problems will occur if the second dose is administered early, no change has been made in the duration of the second dose.

6. Case and Government Recommendations

- The simulation is performed in an area of 625 squares in total. This is a very small area for a total of 200 people because the probability of encountering any individual after a person's movement is quite high. In order for the simulation to give more accurate results, it would be appropriate to perform it in a larger area or with fewer people.

- Even if the single-dose vaccine policy is implemented due to economic conditions, it cannot be said to be very effective in spreading the virus and reducing death rates in the long term. The reason for this is that although it reduces the spread of the disease, it does not change the death rate. In other words, whether the individual receives a single dose of vaccine or not, the individual's reaction to the disease will be the same. In addition, people's acceptance of the second dose is quite low in some scenarios. However, if there is a goal to end the disease in the short term, the government should encourage more people to receive the second dose of vaccine. For this purpose, awareness campaigns and propaganda should be carried out.

- Reducing the number of iterations between the second dose of vaccine and the first dose of vaccine may create risky results due to the side effects that the vaccine may cause. However, although the spread of the disease decreases significantly after the first dose, there is a high probability that the person will come across many infected individuals. If the person has accepted a single dose of vaccine, the person can be asked to accept isolation conditions until the second dose. Thus, the risk of encountering an infected individual until the second dose is significantly reduced.

- Isolation is only used for infected people. However, this does not prevent a non-patient from treating the infected person. We know from real-life examples that people who were not sick were also encouraged to isolate. In order for the simulation to provide more accurate results, a certain percentage of uninfected people may need to be isolated.

- Infected people are isolated but not quarantined. Not being quarantined means that people can interact with individuals who are not infected. This situation causes the disease to continue. An algorithm can be developed to ensure that uninfected people do not go to places where infected people are. If the algorithm is improved, the spread of the disease can be significantly reduced.

- There does not appear to be any action to cure infected people in any of the policies. If the person is infected, they are left to their own fate. In real-life examples, when people are infected, the disease can be cured with certain medications. In the algorithm, situations can be created with drugs that will reduce the number of iterations in which infected people are infected or reduce the death rate. Thus, results closer to reality can be produced.