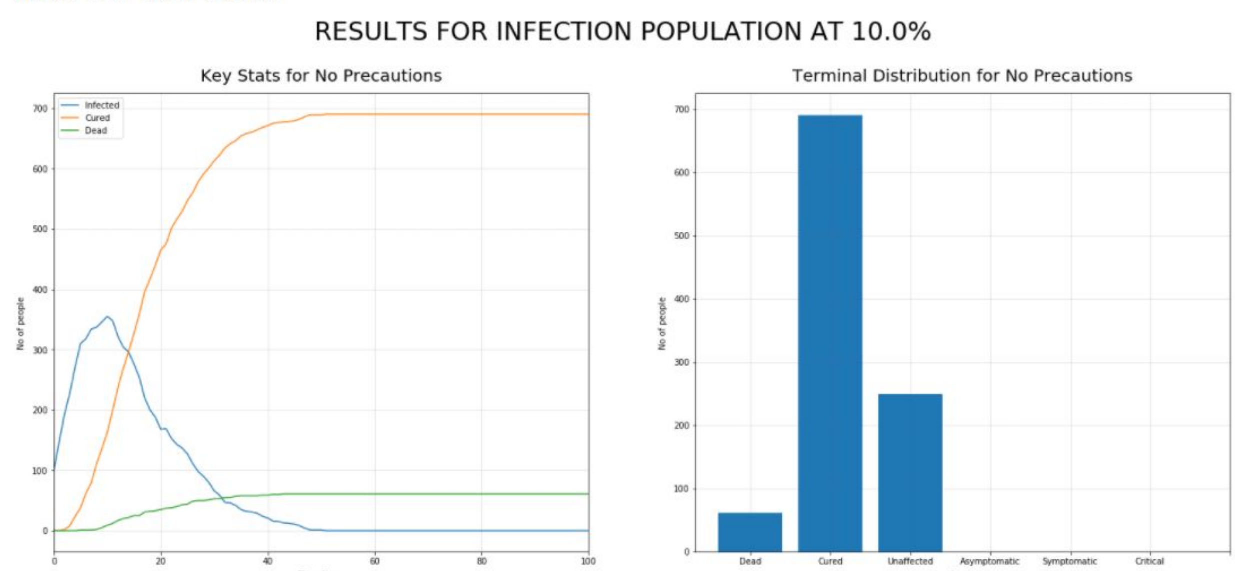
Social Assignment P2 - Karan R (krakesh)

Assumptions:

- All the initially infected people are put under the infected asymptomatic category.
- For all graphs, I have taken a constant level of infection transmission, i.e. , not affected by the number of infected people present in the place. This is because there is no reliable way to incorporate both rate of spread (0.5 regular, 0.1 with masks) as well as the percentage of infected people in the same formula. Hence, I have included those simulations under question 4 as an additional case to observe.
- For all graphs, I considered the probability of infecting the people at home as 1, if the infected person is home, since they will be in close proximity to their family members and in most real world cases, entire families get infected.
- All the runs are random, so comparing the 10% infection to the 25% infection to the 50% infection can only be seen as a single datapoint, but is not reproducible even within the same test run. The results from each case are run since they are run with different random numbers.

Part 1 (No Precautions)

```
>>>>> RESULTS FOR INFECTION POPULATION AT 10.0% <<<<<


----------------PART 1 (No Precautions)-----------------
Time Step at which maximum occur
Infected     10
Cured        51
Dead         43
dtype: int64

Max Values for each stat
Infected     355
Cured        690
Dead          61
dtype: int64
Uninfected :249

Text(0, 0.5, 'No of people')
```



Q1 : When does the simulation stabilize (reaches a termination criteria or experiences no further change)? How long will it take to reach that point (report your results in a number of days)?

The simulation will stabilize when the number of infected people reach 0, i.e. all the people are either unaffected, cured or dead. This is because nobody can get infected anymore.

This happens around ~50-65 steps usually. According to the snapshot above, it will be the maximum timestep of cured or dead since they are both non-decreasing functions, hence 51 will be the termination point. The histogram shows the split of states once the termination criteria is met. This range remains constant irrespective of the infected percentage (10%, 25% or 50%).

Q2 : When was the infection at its peak?

For infection rate at 10% , infections usually peak around ~5-15 time steps.
For infection rate at 25% , infections usually peak around ~4 time steps.
For infection rate at 50% , infections usually peak around ~3 time steps.
The following results can be attributed to the very low probability of death as well as the relatively high chance of being cured (over 10x more likely to be cured than die). And once a person is cured, they cannot be re-infected and hence it causes the overall pool of people who can be infected at the next time step to reduce thus causing a spike to form relatively early.
In the example above, the spike for 10% infection rate is 355 people and occurs at time step 10.

Q3 : How many people die by the time the simulation stabilizes?

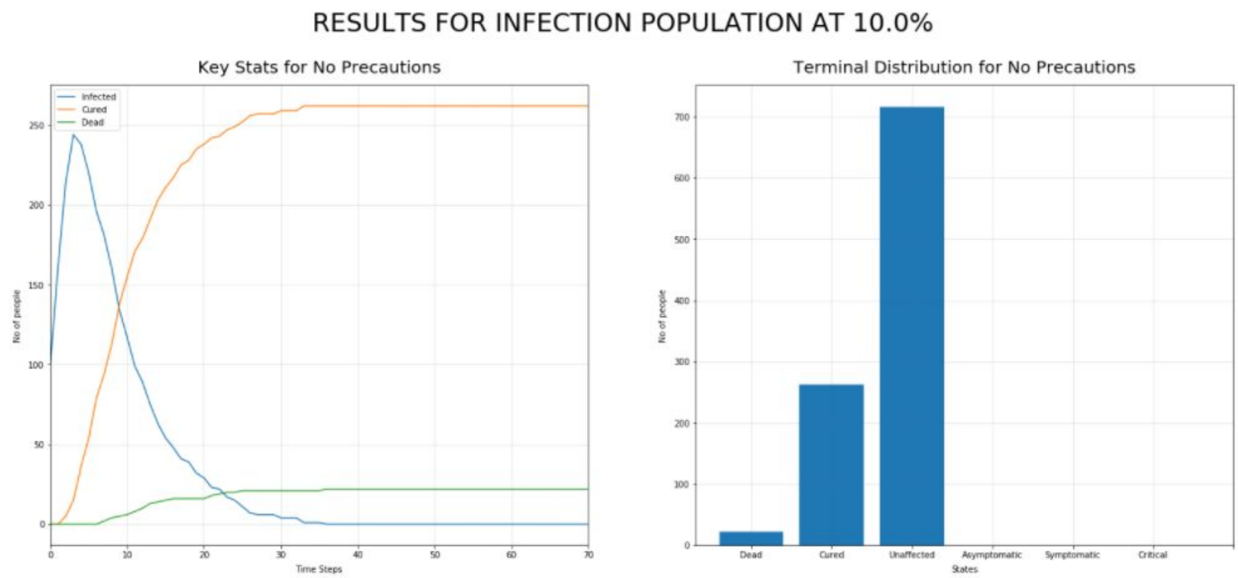
For infection rate at 10% , deaths are usually around ~45-65 out of ~750 infected.
For infection rate at 25% , deaths are usually around ~55-75 out of ~850 infected.
For infection rate at 50% , deaths are usually around ~65-85 out of ~925 infected.
The ratio of probability of death to cure is around 8 : 92, calculated from the probabilities in the state diagram (ignoring the probability of staying in the same state since eventually they will transition to either death or cure as a termination for the agent). So we can say 8% of the people will die. And for these infection rates, as the infection rate increases, it moves closer to this value : 10% infected -> 7.4% dead, 25% infected -> 7.7% dead, 50% infected -> 8.1% dead.

Q4 : Plot graphs for the spread of the disease based on results from your simulation (with the number of active COVID-19 cases on the y-axis and time steps (days) on the x-axis)

Graphs named “Key Stats” presents the active number of cases as a function of the time step under the *Infected* line. It also presents the number of deaths and cured people.

Also included the values while percentage of infections were used to modify transmission below:

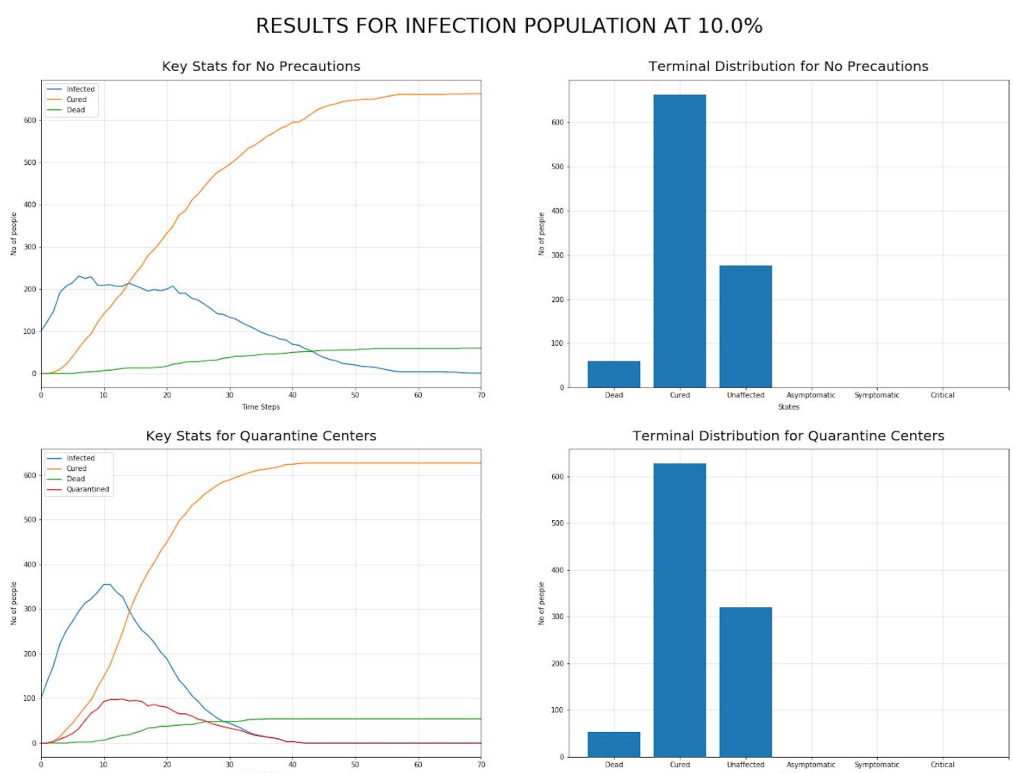
```
>>>>> RESULTS FOR INFECTION POPULATION AT 10.0% <<<<<


----------------PART 1 (No Precautions)-----------------
Time Step at which maximum occur
Infected     3
Cured       33
Dead        36
dtype: int64

Max Values for each stat
Infected    244
Cured       262
Dead         22
dtype: int64
Uninfected :716

Text(0, 0.5, 'No of people')
```



Here since the spread of transmission is based on the percentage of infected people, it causes the simulation to have most of the people not be affected by the virus at all since the probability of getting infected at a shop of 10 people with 1 infected person is only 10% rather than 50% in the fixed rate case. And the termination condition is also arrived at much earlier since the infection is obtained at an early time step and then infection is then very low from there onwards.

Part 2 (Quarantine Centers)

```
>>>>> RESULTS FOR INFECTION POPULATION AT 10.0% <<<<<


----------------PART 1 (No Precautions)-----------------
Time Step at which maximum occur
Infected     6
Cured       68
Dead        67
dtype: int64

Max Values for each stat
Infected    231
Cured       663
Dead         60
dtype: int64
Uninfected :277
----------------PART 2 (w/ Quarantine Centres)-----------------
Time Step at which maximum occur
Infected       10
Cured          42
Dead           36
Quarantined    13
dtype: int64

Max Values for each stat
Infected       355
Cured          627
Dead            54
Quarantined     98
dtype: int64
Uninfected :319
```



Key Points:

- With quarantine centres, the number of infections and the peak of infection are not adversely affected.
- The number of unaffected people drop significantly though
- Also the peak in the number of infected people in quarantine scenario comes earlier than the peak in the no precautions scenario since we start moving people to quarantine and hence cut the rate of spread earlier in the quarantine case.

Q2. The quarantine centres usually approach full capacity but do not get full in 10% case whereas in 25% and 50%, they reach full capacity in the first 10 time steps itself. In the plot shown in the previous page, we can see that the maximum capacity of quarantine is 98 and it is reached in the 13th time step.

Q1 a : When does the simulation stabilize ? How long will it take to reach that point (report your results in a number of days)?

The simulation will stabilize when the number of infected people reach 0, i.e. all the people are either unaffected, cured or dead. This is because nobody can get infected anymore.

This happens around ~45-60 steps for 10%, ~40-50 for 25% and ~35-45 for 50%. According to the snapshot above, it will be the maximum timestep of cured or dead since they are both non-decreasing functions, hence 42 will be the termination point. The histogram shows the split of states once the termination criteria is met.

Q1 b : When was the infection at its peak?

For infection rate at 10% , infections usually peak around ~4-10 time steps.
For infection rate at 25% , infections usually peak around ~4 time steps.
For infection rate at 50% , infections usually peak around ~3 time steps.

Q1 c : How many people die by the time the simulation stabilizes?

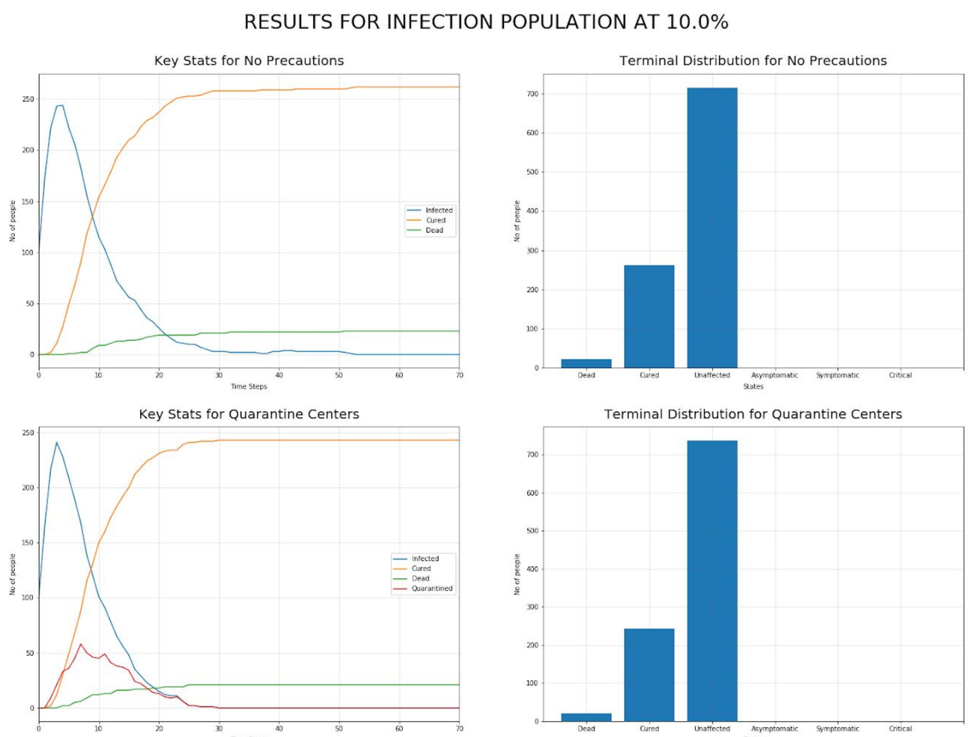
For infection rate at 10% , deaths are usually around ~45-55 out of ~700 infected.
For infection rate at 25% , deaths are usually around ~60-75 out of ~850 infected.
For infection rate at 50% , deaths are usually around ~65-85 out of ~925 infected.

Q1 d : Plot graphs for the spread of the disease based on results from your simulation (with the number of active COVID-19 cases on the y-axis and time steps (days) on the x-axis)

Graphs named “Key Stats” presents the active number of cases as a function of the time step under the *Infected* line. It also presents the number of deaths and cured people.

Also included the values while percentage of infections were used to modify transmission below:

```
>>>>> RESULTS FOR INFECTION POPULATION AT 10.0% <<<<<


----------------PART 1 (No Precautions)-----------------
Time Step at which maximum occur
Infected     4
Cured       53
Dead        51
dtype: int64

Max Values for each stat
Infected    244
Cured       262
Dead         23
dtype: int64
Uninfected :715
----------------PART 2 (w/ Quarantine Centres)-----------------
Time Step at which maximum occur
Infected        3
Cured          30
Dead           25
Quarantined     7
dtype: int64

Max Values for each stat
Infected       241
Cured          243
Dead            21
Quarantined     58
dtype: int64
Uninfected :736
```

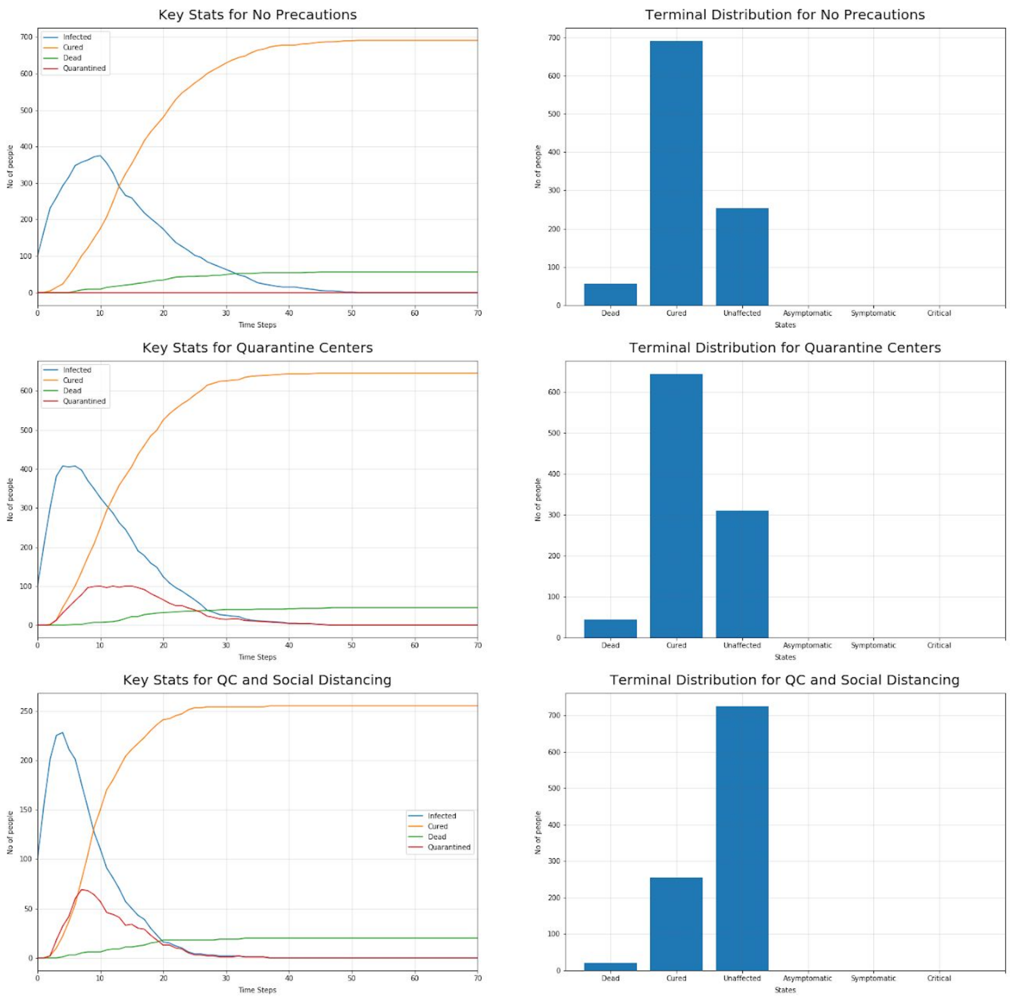


We can notice slight differences here, but the key points mentioned earlier are more or less mitigated by the fact that overall infection rate will be low due to the drawbacks of using percentage as an infection rate (mentioned in part 4 of previous section)

Part 3 (Social Distancing)

```
>>>>> RESULTS FOR INFECTION POPULATION AT 10.0% <<<<<


----------------PART 1 (No Precautions)-----------------
Time Step at which maximum occur
Infected       10
Cured          51
Dead           45
Quarantined     0
dtype: int64

Max Values for each stat
Infected       375
Cured          691
Dead            56
Quarantined      0
dtype: int64
Uninfected :253
----------------PART 2 (w/ Quarantine Centres)-----------------
Time Step at which maximum occur
Infected        4
Cured          45
Dead           47
Quarantined    10
dtype: int64

Max Values for each stat
Infected       407
Cured          645
Dead            45
Quarantined    100
dtype: int64
Uninfected :310
----------------PART 3 (w/ Quarantine Centres and Social Distancing)-----------------
Time Step at which maximum occur
Infected        4
Cured          37
Dead           33
Quarantined     7
dtype: int64

Max Values for each stat
Infected       228
Cured          255
Dead            20
Quarantined     69
dtype: int64
Uninfected :725
```

RESULTS FOR INFECTION POPULATION AT 10.0%



Key Points:

- With social distancing, every stat is vastly improved. The number of unaffected people drastically increases, the number of infected people drop, hence the number of cured and dead people also drop significantly.
- The social distancing model also almost always stabilizes faster than the other two models since there are so few infections and hence the simulation can reach a state of 0 infected people rapidly.

Q1 : When does the simulation stabilize (reaches a termination criteria or experiences no further change)? How long will it take to reach that point (report your results in a number of days)?

The simulation will stabilize when the number of infected people reach 0, i.e. all the people are either unaffected, cured or dead. This is because nobody can get infected anymore.

This happens around ~30-45 steps for 10%, ~40-50 for 25% and ~45-55 for 50%. According to the snapshot above, it will be the maximum timestep of cured or dead since they are both non-decreasing functions, hence 37 will be the termination point for the Social Distancing Case (Part 3). The histogram shows the split of states once the termination criteria is met.

Q2 : When was the infection at its peak?

For infection rate at 10% , infections usually peak around ~3-4 time steps.
For infection rate at 25% , infections usually peak around ~3 time steps.
For infection rate at 50% , infections usually peak around ~3 time steps.

Q3 : How many people die by the time the simulation stabilizes?

For infection rate at 10% , deaths are usually around ~20-30 out of ~300 infected.
For infection rate at 25% , deaths are usually around ~35-45 out of ~600 infected.
For infection rate at 50% , deaths are usually around ~60-75 out of ~850 infected.

Q4 : Plot graphs for the spread of the disease based on results from your simulation (with the number of active COVID-19 cases on the y-axis and time steps (days) on the x-axis)

Graphs named "Key Stats" presents the active number of cases as a function of the time step under the *Infected* line. It also presents the number of deaths and cured people.

Conclusion

1. There were different modes of simulation that I experimented with, which had different impacts on the model.
    a. I tried to implement the simulation without the infected person infecting his entire household, this caused a larger gap between the cases since the infected person had the same chance to infect members of his family as he did people from outside.
    b. I tried implementing the percentage infection rate, this turned out to not give very desirable results as it caused all the simulations to have low infection rates overall and only created a significant impact in the higher initially infected cases since then it caused the spread to be more than in the case where we consider the infection rate to be static (0.5 for part 1 and 2, or 0.1 for part 3).
    c. I tried to implement the infection of the household from the members' perspective as well as the infected person's perspective. For instance, if A was infected, in his household, I considered when his step function is called, we see who is at home and infect them, while the other alternative was to go to each person in the house and see if they are with an infected person and then infect them. This

caused the model to give slightly different results. The former method was more effective in spreading infection than the latter, which is probably due to the random activation that occurs.

d. The introduction of infecting everyone at home caused all the peaks to occur much earlier since the infection multiplied as soon as any infected person went home since they spread it to everybody in their household.

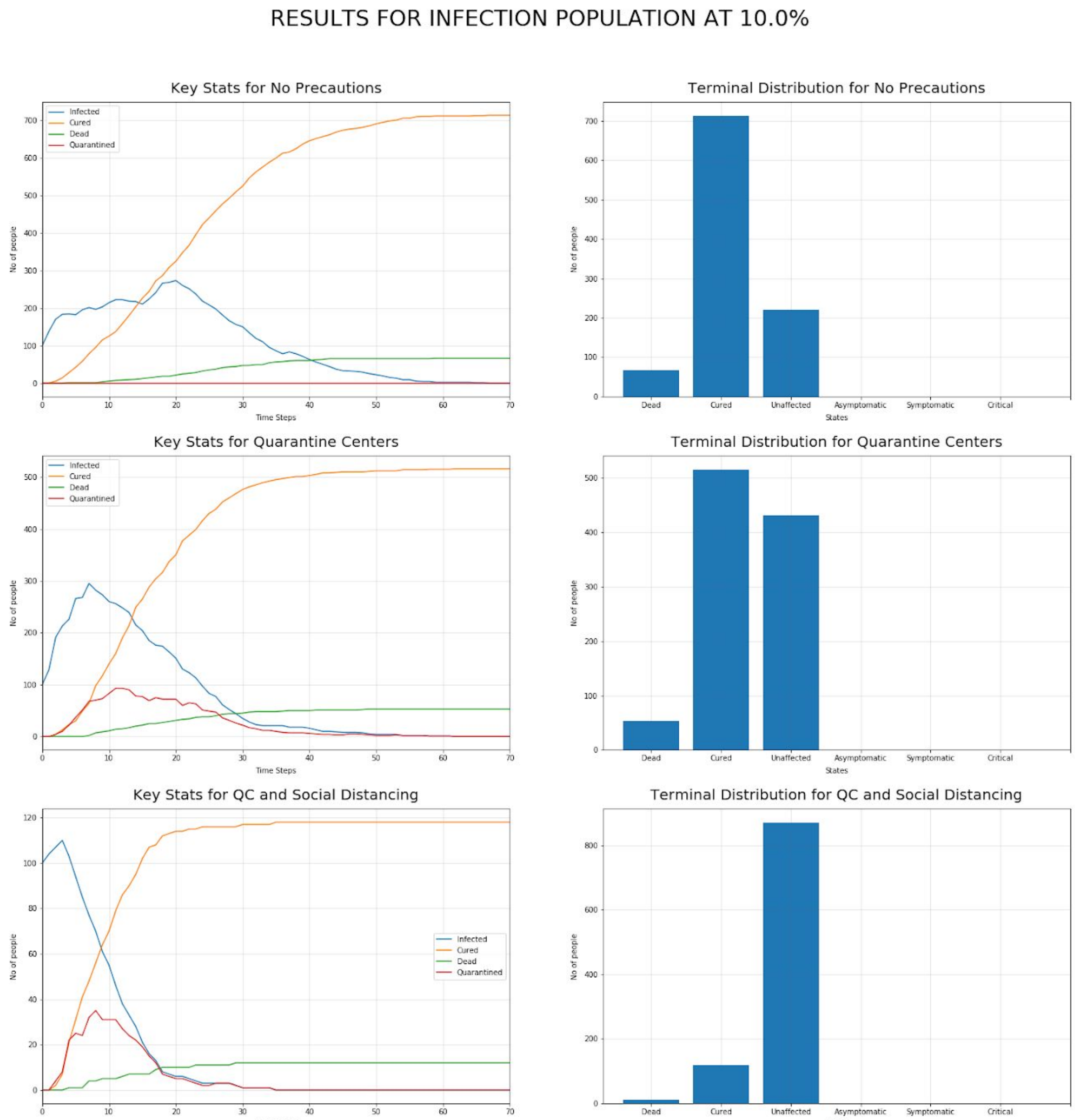
2. It is clear that measures like quarantine and social distancing worked as they reduced the number of people affected by the virus. While quarantine was a more passive approach that involved limiting the exponential spread of the virus once the person had reached more advanced stages, the social distancing helped actively reduce the infections by limiting the potential of people transmitting the virus through best practices.

3. The most influential factor is the probability of the virus transmitting from an infected to a healthy person. And hence, the best way to deal with the virus would be to ensure that mitigation strategies are implemented to prevent that. Since we know that this virus is transmitted to contact and proximity, ensuring social distancing and masks is a good way to ensure the virus is kept under control.
   The second most influential factor is the amount that people leave their houses. For instance, if people were to stay at home if they have been incontact with someone who contracted the virus, they would limit the spread of the virus by not going into public places where they can spread it to another person. That is why lockdowns are implemented and have worked successfully at flattening the curve.

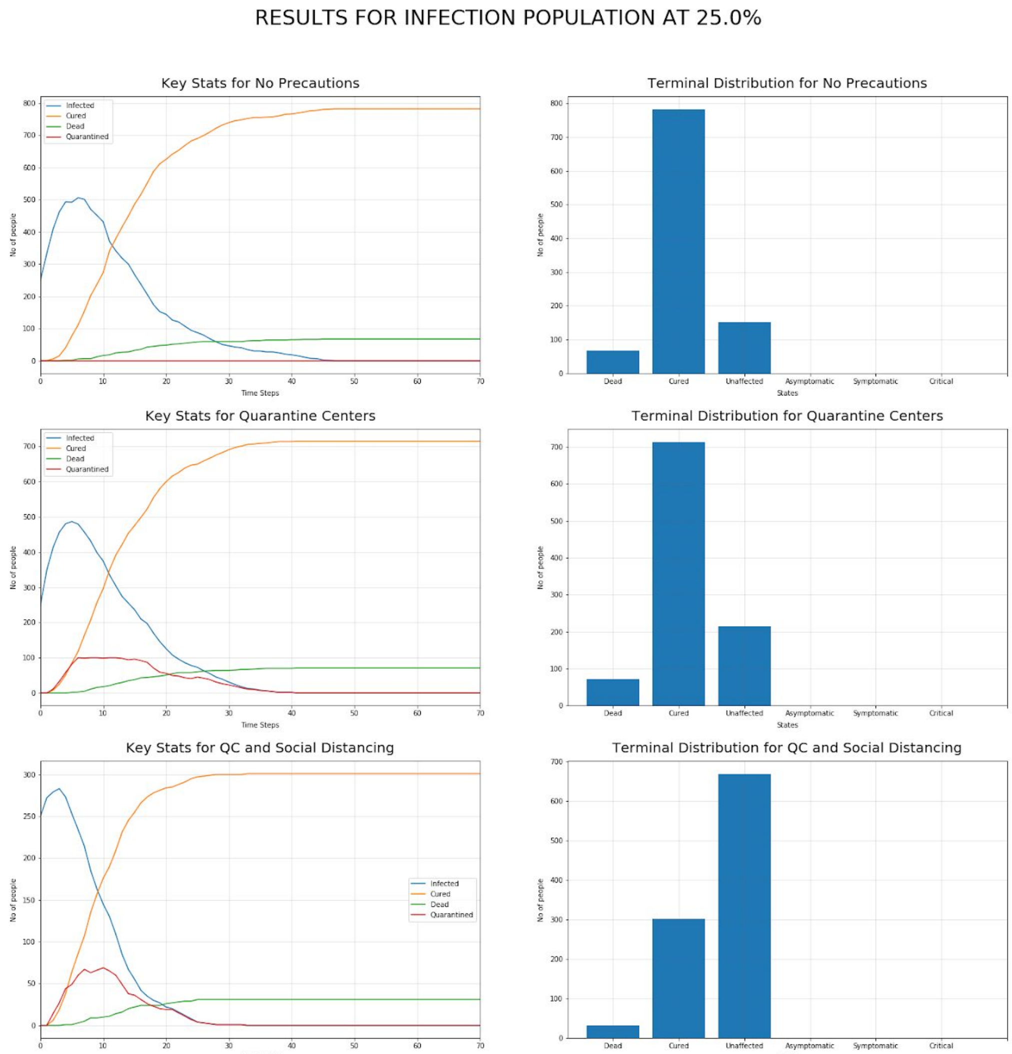
Appendix

Graphs for case where 1) static chance of transmission. 2) Probability of Infected person transmitting disease at home is not 1, instead it is the same as the rate of transmission.

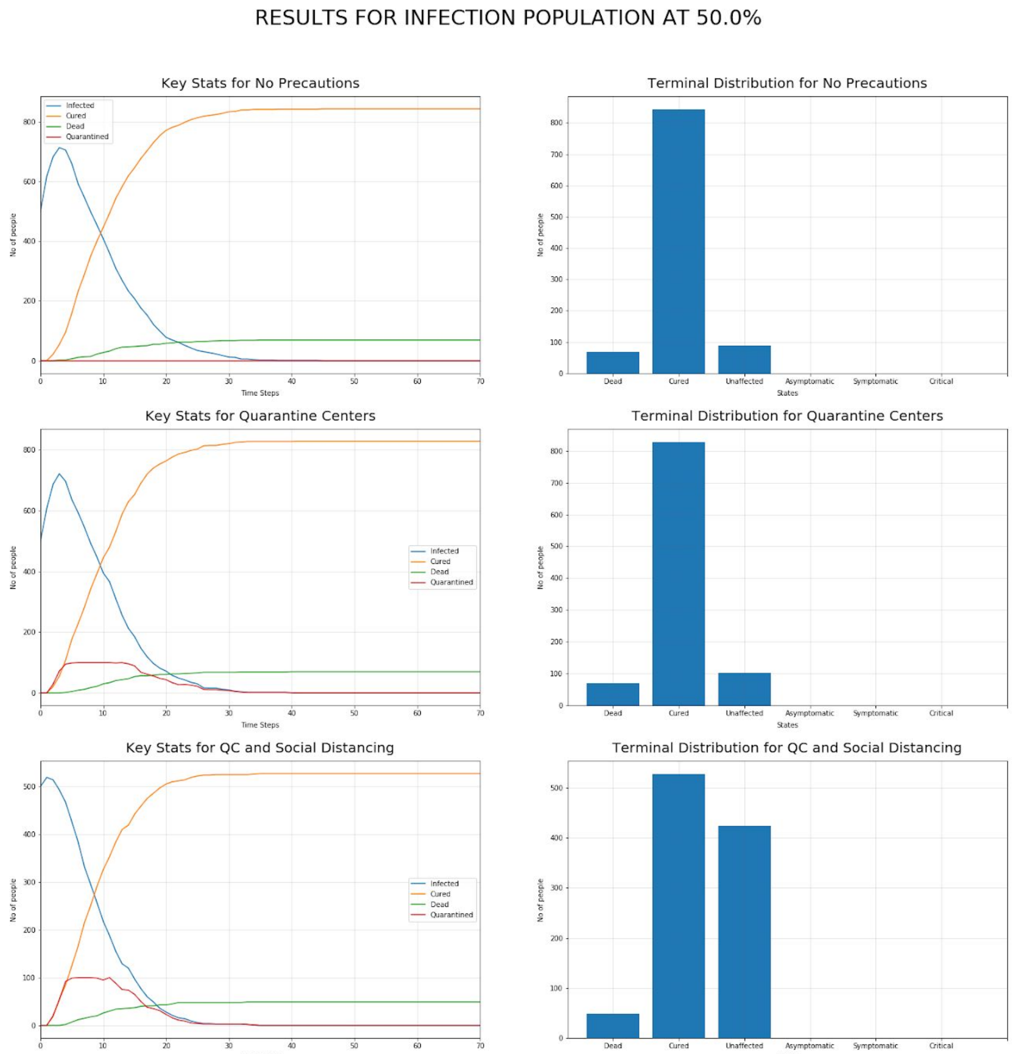
10% Infected :



25% Infected


RESULTS FOR INFECTION POPULATION AT 25.0%
Key Stats for No Precautions
Terminal Distribution for No Precautions
Key Stats for Quarantine Centers
Terminal Distribution for Quarantine Centers
Key Stats for QC and Social Distancing
Terminal Distribution for QC and Social Distancing
Infected
Cured
Dead
Quarantined
No of people
Time Steps
Dead
Cured
Unaffected
Asymptomatic
Symptomatic
Critical
States

50% Infected


RESULTS FOR INFECTION POPULATION AT 50.0%
Key Stats for No Precautions
Terminal Distribution for No Precautions
Key Stats for Quarantine Centers
Terminal Distribution for Quarantine Centers
Key Stats for QC and Social Distancing
Terminal Distribution for QC and Social Distancing
Infected
Cured
Dead
Quarantined
No of people
Time Steps
States
Dead
Cured
Unaffected
Asymptomatic
Symptomatic
Critical