Midterm Paper

Zachary Stept

CDS 205: Introduction to Agent-Based Modeling and Simulation

March 27, 2022

The beginnings of every pandemic leave people wondering how the disease will affect a population and what interventions can be taken/enforced to reduce the effects. The Covid-19 pandemic is perhaps the most well-known pandemic which is caused by the Coronavirus disease. At the beginning of the pandemic, people were wondering how many would become infected with the disease and how many would die from the disease as numbers seemed to be increasing heavily as days passed. As the pandemic continued, interventions were put in place such as social distancing, masking, quarantining, and vaccinating. The use of these interventions became very useful in slowing down the number of people infected with the disease as well as the number of people who have died from the disease.

Graphical user interface, application

Description automatically generated with medium confidence

The figure above (Figure 1) shows the percentage of a population who were never infected became infected, were immune or became immune, or died from this disease over the course of one year without any interventions put in place. In creating Figure 1, ten repetitions were ran on a single experiment with the following parameters being used:

* There are 10,000 people in the area.
* On average, each day people move around at a rate given as 75 out of 100 using a fancy measure of sociability.
* 10 people are already infected with the disease.
* In the absence of vaccination or masking, the odds of an infected person transmitting the disease to a susceptible person when they meet, is, on average, 1 out of 4.
* A person can transmit the disease as soon as they are infected.
* Symptoms start to appear, on average, around 5 days after a person contracts the disease. At this point, if they are inclined to quarantine when sick, they will do so.
* The area can treat up to 500 people at a time.
* Once a person contracts the disease, the base case fatality rate for the disease is 1%. Any day when the number of people infected exceeds the treatment capacity, the actual fatality rate increases at an increasing rate as the number of people infected grows.
* The average length a person remains infected and infectious, is, on average 14 days.
* It is believed that persons have permanent immunity if they recover from the disease.
* Currently, no one is social distancing, masking, quarantining, and vaccinating.

Using, these parameters and the averages from ten different repetitions it has been discovered that the peak of this epidemic arises around one month (about 30 days) since the start of the epidemic. At this peak moment in the epidemic, around 17% of the population have been infected and around 1% of the population have died due to the coronavirus diseases. After this peak moment, it takes roughly three weeks for the effects of the disease to become steady for the rest of the year (maintain the same number of never infected, infected, immune, and dead). By the end of the year, the population has experienced 9,702 people being infected and 156 people dying from the coronavirus disease.

Graphical user interface, text, application

Description automatically generated

However, there is a common assumption that if everyone were to distance, mask, quarantine if infected and get a vaccination, the epidemic will burn out very quickly, with very few infections and deaths. To test this assumption, a similar experiment was conducted with one major difference. Instead of no one social distancing, masking, quarantining, and vaccinating, everyone is doing so (100% efficacy). As it turns out, this is assumption is fairly accurate as results show that only the original ten people infected with the disease are the only people out of the entire 10,000 people in the population to be infected throughout the entire year. The results also show that no one will die from the disease as the four interventions help to isolate those infected and protect those not infected. The figure (Figure 2) above shows what happens when these four interventions are enforced. Unlike Figure 1, there is no peak in the epidemic. As shown in Figure 2, the trends for those never infected, infected, immune, and dead due to the coronavirus do not change throughout the entire year as the entire population is extremely cautious to not spread or receive the disease. However, not all four interventions are put in place at the same time and not everyone in the population is following those put in place.

****

As much as it is wanted to live in a world where all four interventions were followed by everyone, that is not the case. The table above (Table 1) shows what happens when focusing on one intervention at a time (with 100% efficacy) using 25% intervals (0% not shown due to Figure 1 representing those results for all interventions). As shown in Table 1, increasing the intervention percentage decreases the number of deaths and infections from the coronavirus disease. There are also a few things to notice from Table 1. First, increasing the percentage who distance to at least 75%, provides an outcome with no deaths. Second, distancing at 100% is the only intervention that shows no deaths and only ten infections (starting number of infections). So, it is possible to conclude that if the population were to only distance, the disease would not be able to spread and create more cases which eventually leads to deaths. Thirdly, increasing the percentage who distance, shows a drastic decrease in the number of deaths and infections.

However, having no deaths does not go for masking, quarantining, and vaccinating. These three types of interventions are only good for reducing the number of infections and deaths which is not a bad thing when it comes to a pandemic of this magnitude. In comparing these three interventions, masking does not do a great job as it consistently shows a high number of deaths in each 25% interval. Masking also proves to be ineffective at reducing the number of infections as the percentage of those masking increases in which it can be inferred that masks do fully prevent the disease from spreading. It would be recommended that if you want to reduce the number of infections and deaths, everyone should be distancing so that the disease cannot spread so easily. If not possible, it would be recommended for everyone to get vaccinated and/or quarantine when infected. Masking would be last on the list of recommended interventions for reducing the number of infections and deaths caused by the coronavirus.



For those that are more on the risk-averse side, the most important variable in the model used is the fatality rate as it controls how fatal the disease is for someone that becomes infected. The table above (Table 2) shows that if all four interventions are fully present (with 100% efficacy), then no matter what the fatality rate is there will be no deaths and only ten infections (starting number of infections). However, when there are no interventions present, then the disease has much more of a risk associated with it. When there is no fatality rate, the disease does not cause any deaths, but it does cause around 9,600 infections. As the fatality rate increase, the number of deaths increases at an alarming rate. There is something unusual that happens with the number of infections when the fatality rate increases. Instead of more infections when the rate is higher than 1%, the opposite occurs, and the number of infections starts to slowly decrease. When the fatality rate is below 1%, the number of infections slowly increases which is expected with a disease unlike when the fatality rate is above 1%. As it is known, being exposed to the coronavirus is already considered a big risk, but in terms of a changing fatality rate, there are two ways of looking at the risks involved. A fatality rate below 1% causes more infections. A fatality rate above 1% means fewer infections and more deaths, so anyone infected by the disease has a greater possibility of dying from the disease.

Details of Simulations Runs and Experiments

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **No Interventions** | **All Interventions** | | **Some Interventions: Distancing** | **Some Interventions:**  **Masking** |
| |  | | --- | | ["transmissibility-scalar" 0.7] | | ["treatment-capacity" 500] | | ["init-infected" 10] | | ["vaccine-efficacy" 0] | | ["base-length-of-immunity" 0] | | ["Super-Spreader-Threshold" 10] | | ["mask-efficacy" 0] | | ["percent-who-distance" 0] | | ["base-recovery-time" 14] | | ["base-sociability" 75] | | ["base-quarantine-start" 5] | | ["base-prob-of-transmissibility" 25] | | ["shape-r" 1.5] | | ["Transmission-shape-parameter" 2] | | ["percent-who-quarantine" 0] | | ["percent-to-vaccinate" 0] | | ["percent-who-mask" 0] | | ["base-case-fatality-rate" 1] | | ["num-people" 10000] | | |  | | --- | | ["transmissibility-scalar" 0.7] | | ["treatment-capacity" 500] | | ["init-infected" 10] | | ["vaccine-efficacy" 100] | | ["base-length-of-immunity" 0] | | ["Super-Spreader-Threshold" 10] | | ["mask-efficacy" 100] | | ["percent-who-distance" 100] | | ["base-recovery-time" 14] | | ["base-sociability" 75] | | ["base-quarantine-start" 5] | | ["base-prob-of-transmissibility" 25] | | ["shape-r" 1.5] | | ["Transmission-shape-parameter" 2] | | ["percent-who-quarantine" 100] | | ["percent-to-vaccinate" 100] | | ["percent-who-mask" 100] | | ["base-case-fatality-rate" 1] | | ["num-people" 10000] | | | |  | | --- | | ["transmissibility-scalar" 0.7] | | ["treatment-capacity" 500] | | ["init-infected" 10] | | ["vaccine-efficacy" 0] | | ["base-length-of-immunity" 0] | | ["Super-Spreader-Threshold" 10] | | ["mask-efficacy" 0] | | ["percent-who-distance" 25 50 75 100] | | ["base-recovery-time" 14] | | ["base-sociability" 75] | | ["base-quarantine-start" 5] | | ["base-prob-of-transmissibility" 25] | | ["shape-r" 1.5] | | ["Transmission-shape-parameter" 2] | | ["percent-who-quarantine" 0] | | ["percent-to-vaccinate" 0] | | ["percent-who-mask" 0] | | ["base-case-fatality-rate" 1] | | ["num-people" 10000] | | |  | | --- | | ["transmissibility-scalar" 0.7] | | ["treatment-capacity" 500] | | ["init-infected" 10] | | ["vaccine-efficacy" 0] | | ["base-length-of-immunity" 0] | | ["Super-Spreader-Threshold" 10] | | ["mask-efficacy" 100] | | ["percent-who-distance" 0] | | ["base-recovery-time" 14] | | ["base-sociability" 75] | | ["base-quarantine-start" 5] | | ["base-prob-of-transmissibility" 25] | | ["shape-r" 1.5] | | ["Transmission-shape-parameter" 2] | | ["percent-who-quarantine" 0] | | ["percent-to-vaccinate" 0] | | ["percent-who-mask" 25 50 75 100] | | ["base-case-fatality-rate" 1] | | ["num-people" 10000] | |
| **Some Interventions: Quarantining** | **Some Interventions: Vaccinating** | | **Fatality Rate:**  **No Interventions** | **Fatality Rate:**  **All Interventions** |
| |  | | --- | | ["transmissibility-scalar" 0.7] | | ["treatment-capacity" 500] | | ["init-infected" 10] | | ["vaccine-efficacy" 0] | | ["base-length-of-immunity" 0] | | ["Super-Spreader-Threshold" 10] | | ["mask-efficacy" 0] | | ["percent-who-distance" 0] | | ["base-recovery-time" 14] | | ["base-sociability" 75] | | ["base-quarantine-start" 5] | | ["base-prob-of-transmissibility" 25] | | ["shape-r" 1.5] | | ["Transmission-shape-parameter" 2] | | ["percent-who-quarantine" 25 50 75 100] | | ["percent-to-vaccinate" 0] | | ["percent-who-mask" 0] | | ["base-case-fatality-rate" 1] | | ["num-people" 10000] | | |  | | --- | | ["transmissibility-scalar" 0.7] | | ["treatment-capacity" 500] | | ["init-infected" 10] | | ["vaccine-efficacy" 100] | | ["base-length-of-immunity" 0] | | ["Super-Spreader-Threshold" 10] | | ["mask-efficacy" 0] | | ["percent-who-distance" 0] | | ["base-recovery-time" 14] | | ["base-sociability" 75] | | ["base-quarantine-start" 5] | | ["base-prob-of-transmissibility" 25] | | ["shape-r" 1.5] | | ["Transmission-shape-parameter" 2] | | ["percent-who-quarantine" 0] | | ["percent-to-vaccinate" 25 50 75 100] | | ["percent-who-mask" 0] | | ["base-case-fatality-rate" 1] | | ["num-people" 10000] | | | |  | | --- | | ["transmissibility-scalar" 0.7] | | ["treatment-capacity" 500] | | ["init-infected" 10] | | ["vaccine-efficacy" 0] | | ["base-length-of-immunity" 0] | | ["Super-Spreader-Threshold" 10] | | ["mask-efficacy" 0] | | ["percent-who-distance" 0] | | ["base-recovery-time" 14] | | ["base-sociability" 75] | | ["base-quarantine-start" 5] | | ["base-prob-of-transmissibility" 25] | | ["shape-r" 1.5] | | ["Transmission-shape-parameter" 2] | | ["percent-who-quarantine" 0] | | ["percent-to-vaccinate" 0] | | ["percent-who-mask" 0] | | ["base-case-fatality-rate" 0 0.5 1 1.5 2] | | ["num-people" 10000] | | |  | | --- | | ["transmissibility-scalar" 0.7] | | ["treatment-capacity" 500] | | ["init-infected" 10] | | ["vaccine-efficacy" 100] | | ["base-length-of-immunity" 0] | | ["Super-Spreader-Threshold" 10] | | ["mask-efficacy" 100] | | ["percent-who-distance" 100] | | ["base-recovery-time" 14] | | ["base-sociability" 75] | | ["base-quarantine-start" 5] | | ["base-prob-of-transmissibility" 25] | | ["shape-r" 1.5] | | ["Transmission-shape-parameter" 2] | | ["percent-who-quarantine" 100] | | ["percent-to-vaccinate" 100] | | ["percent-who-mask" 100] | | ["base-case-fatality-rate" 0 0.5 1 1.5 2] | | ["num-people" 10000] | |
| **Number of repetitions for all experiments** | | **Measures for all experiments** | | |
| 10 | | |  | | --- | | count turtles with [never-infected?] / num-people \* 100 | | count turtles with [infected?] / num-people \* 100 | | count turtles with [immune?] / num-people \* 100 | | count turtles with [dead?] / num-people \* 100 | | count turtles with [dead?] | | cumulative-infections | | | |