NEW YORK CITY VS. CHEMICAL BOB

An exploration of New York's preparedness against a Smallpox Attack.

Abstract: This paper explores the preparedness of New York City against a smallpox-based Bio Terrorist Attack by a fictional threat actor, Chemical Bob, using a computer simulation. The simulation uses real word data regarding the disease such as the contact rate, death probability, populations etc. The results show that NYC, as it is now, is unprepared against such an attack with an estimated death toll of 69.67%. However, including medical interventions lead to a stabilization and minimization of the death toll and brought it down to 3.60%. Serious contingencies and measures need to be taken to defend against such an event.

Muneeb Khawaja,

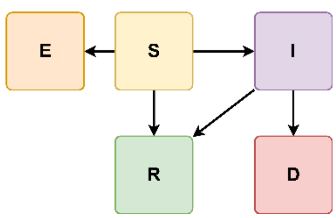
Wangjie Lian

Professor Christopher Hanusa

MATH 245- Project 3

New York City is a target and has been victimized by numerous threat actors across the last couple of decades. One such potential threat faced by the city consists of a Smallpox based bio-terrorist attack. Smallpox is an acute, contagious, and potentially fatal disease caused by the variola virus. Moreover, it is classified as a Category A agent due to its dangerous characteristics. According to the Centers for Disease Control and Prevention, the smallpox was "declared eradicated" in 1980, but the "U.S. government is taking precautions to be ready to deal with a bioterrorist attack using smallpox as a weapon." (CDC, p. 1). In a hypothetical scenario, we explore such an event with New York at its epicenter. Bill De Blasio, the mayor of New York City, has tasked our fictional consulting agency to gauge the preparedness of NYC against a Smallpox based Bio-Terrorist Attack, while considering how long the outbreak will last, the day and quantity of the maximum infected population, the projected death-toll and also suggesting contingencies along with interventions if the city is not.

In order to answer these questions, our agency decided to develop a computer simulation. The simulation models an augmented variant of the epidemiological SIR model and is predictive and deterministic in nature. In addition, the primary threat actor is a fictional character named Chemical Bob who is planning to bomb Central Park and its neighboring areas. Furthermore, the base SIR model consists of three populations: Susceptible, Infected and Recovered. Our model, which will be referred to as the SIRED model going forward, considers two additional populations: Dead and Escapees. These additional populations are taken into consideration as a consequence of the fatalistic nature of Smallpox and the fact that terrorist attacks tend to encourage emigration.



As such, the Escapee group represents the factor of the total population that escapes the City, while the Dead group describes the factor of the population that has died as a consequence of the disease. Both populations cannot transition into any other sub-group. Finally, the simulation halts when the uninfected population is approximately zero.

Moreover, each step of the simulation represents one day, and each step involves recording the SIRED populations in a TimeFrame slice. The values used to setup these populations are taken from various sources. The Initial Population of New York is approximated as ~ 1.6 million (WPR). Recalling that Central Park is the detonation site, we considered how many people visited the area. As 42 Mil. Visit Central Park every Year. **(**Smithsonian**)** we approximated the initial infected population as $\cong \frac{42000000}{365} \cong$ **115000.** Thus, the total initial population is 1715000, with 1600000 being the initial susceptible population.

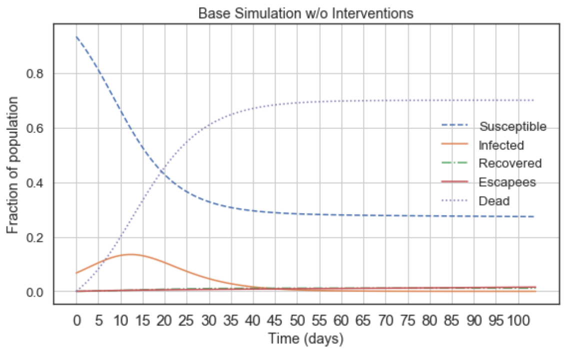
In addition, our model considers an evolved version of the smallpox disease which is more dangerous and resilient against conventional medicine. Consequently, the simulated disease spreads faster and kills faster. While the actual disease does have a vaccine to defend against it and infected individuals can receive it, our simulation only allows for the vaccine to work on the uninfected population. Moreover, vaccination results in spontaneous immunity w/o side effects.

To continue, the disease and populations interact according to rate parameters which include the: contact rate, recovery rate, escapee rate and death rate. The contact rate determines the fraction of the susceptible population that gets infected and depends on disease incubation in that the disease is not contagious during this period but only becomes contagious after. According to the CDC, incubation takes between 7-14 days (CDC) , however we have bumped this number up to $\cong 3\ days$. The recovery rate determines how much of the infected population will transition into the recovered group i.e. become cured. We assume that the recovery will take approximately the number of days equivalent to the sum of the contagious phases provided in the CDC document, which is about 20 days. Recovery takes longer in our simulation and is set to take $30\ days$. The death rate on the other hand controls the fraction of the infected population that will die because of the disease. Historically, 30% of smallpox cases were lethal (Health NY). As the disease has evolved, we have bumped up the likelihood of fatality up to $\mathbf{50}$ %. The escape rate determines the fraction of the susceptible population leaving the city. We choose an arbitrarily factor for the sole purpose of highlighting the movement of the population.

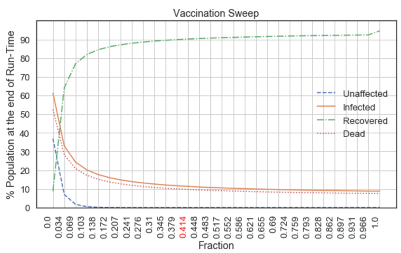
Our primary metric is the percentage of the population that dies i.e. the death toll, while our secondary metrics consist of the maximum number of infected people at any one day and the total number of people who get infected. Being pragmatists, we consider the idea of acceptable loss, which is a term used primarily by the military to indicate the threshold of acceptable casualties. In our simulation, the acceptable loss is 10% of the total population dying.

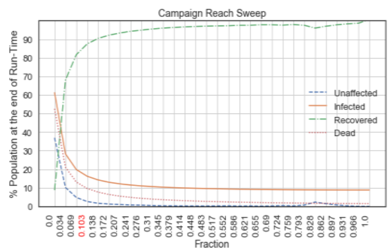
Our interventions include vaccinations, medical screenings and a disease education campaign with the intended goal of minimizing the death rate. Instead of interventions that work before detonation, in our model, interventions are implemented to work on a day-by-day basis after detonation during the crisis. To continue, the purpose of the vaccinations is to foster heard immunity, which safeguards the uninfected population and works towards the eradication of the disease. Secondly, medical screenings are in place to detect the disease early on and provide adequate care where necessary. And finally, as smallpox has been considered eradicated for nearly half a century, we assume that a lot of people will not recognize symptoms. This is where the education campaign contributes by encouraging people to seek medical care early on. Moreover, Interventions work under a blank cheque in that we assume that garnering funding from the US Government should not be problem considering this is a threat to national security.

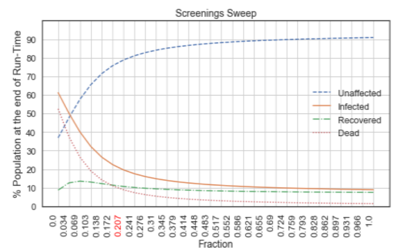
After running the simulation with no interventions, we end up with the following results. The Simulation lasts for approximately 104 days. 27.337 % of the population is unaffected in that they represent the left-over susceptible population that did not receive any vaccinations, were not infected and did not flee



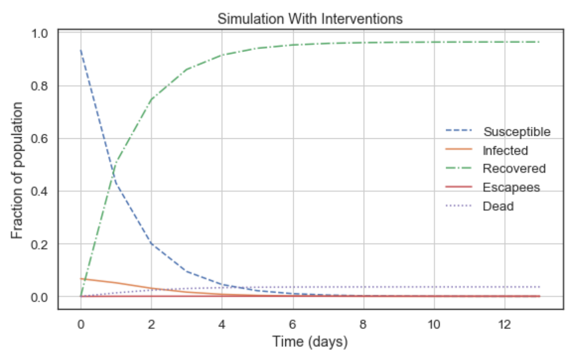
the city. This population turns out to be around 468834 individuals. 71.132 % of the total population gets infected at some point during the simulation, with a magnitude of 1219910. Only 1.166 % of the population recovers with a magnitude of 19998. The total death toll turns out to be 69.962 % with a magnitude of 1199846. And finally, 1.534 % of the population flees the city with a magnitude of 26308. The maximum number of infected individuals is 231238 on day 12.







The death toll far exceeds our loss threshold. To minimize the death toll, we introduce our interventions. We swept the three variables independently considering thirty values between 0 and 1, which represent a fraction of the population. We determined that in order to bring down the death toll to below 10%, 0.414 of the susceptible population must be vaccinated every day, with the education campaign reaching 0.103 of the susceptible and infected populations daily and 0.207 of the infected population being screened per day. After running the simulation with our interventions in play, we reduced the length of the epidemic down to 13 days instead of 104. 9.8% of the total population gets infected, with a magnitude of 168068. 96.16% of the population recovers or receives vaccinations, with a magnitude of 1651826. The final death toll falls to 3.607 % with a magnitude of 61858. And finally, 0.07 % of the population flees the city with a magnitude of 1196. The maximum number of infected individuals are on day zero with a magnitude of 115000. It is observed that medical interventions and other supports have a significant impact, as the death rate is reduced by less than 50% compared to the original simulation execution without any interventions. Moreover, the disease is eradicated in less than two weeks. The results indicate that New York is not prepared for a chemical attack without interventions in place.



The results of our model make sense. In the original execution, the city has no interventions in place. This leads to the disease spreading very fast, with a good portion of the population getting infected. The greater the infected population, the greater the final expected death toll. There are no vaccines which can help to recover from the disease at such a high scale or even reach the entire population in this run. The main take away from the base simulation is that if the disease is not stopped initially, then the number of casualties will be unboundedly high, and it will take a long time to actually ensure that the disease is fully eradicated. The execution of the simulation with the interventions in play actually deals with this issue in multiple ways. That is, the vaccinations make sure that there are less people who are able to get infected in the first place, while the screenings and education campaign are what ultimately help nip the infection in the bud. Because they implement the requirements necessary to treat the infected early on and ultimately eradicate the disease within two weeks.

Our model moderately simulates the real-world well because we are able to generate a progression of how the populations change with time. We make a lot of assumptions which are useful for developing the simulation but detrimental as they do not fully capture the chaotic nature of reality. For example, we assume an unlimited supply of money to implement the interventions. This may not necessarily be true depending on the governing powers at play. To add on, we also implicitly assume that the city will be able to successfully deliver the vaccines required for the disease and that the other interventions will meet their quotas as well. This may hold true for the vaccines due to the nature of the intervention, however, the sweep results for screenings and campaign reach are very optimistic figures. This is not necessarily that bad of an assumption as much as it is an incomplete one. In order to truly qualify any of these assumptions, a fact-finding study would need to take place that provides concrete information about what the current capabilities of the city. More concrete assumptions and implication can follow from there, which will lead to a much more robust and accurate mode.

Moreover, we consider constant rates for disease spread, death, and recovery. In reality, these rates are unpredictable and can vary drastically. However, as a counter point, we went with very high probabilities and rates which may serve as an upper bound of how the actual disease might spread. That is, we’re considering the absolute worst-case scenario. This is beneficial as it ensures that any measures or interventions do not run into a bottleneck in terms of supply during the actual crisis. Secondly, our simulation assumes that the older vaccine will still work but only on the susceptible population. In reality, the old vaccine might as well be useless if the disease has evolved. In reality however, unless the US is facing state sponsored terrorism, in which case the threat actors have unbounded resources and technology to back them up, any attack will probably make use of the original disease.

Additionally, the population in New York is always in flux with a huge plethora of tourists immigrating to and emigrating from the city. These movements may lead to the event of a plague bearer carrying the disease with them and spreading it to other areas outside of New York. This is in fact a very serious issue and could lead to an HIV/AIDS-esque disease spread that may claim an uncountable number of lives before it is eradicated.

In addition to these limitations, another flaw of the simulation is that it does not consider the human factor. In other words, people's behavior. Once breakout hits its stride, panic will become a problem in the city. Essentially, mass panic will kick in as people realize what happening, which would then lead to unpredictable events taking place. For example, a teenage was shot and dead in a riot by an Ebola quarantine (2014, Sliver). The same thing could also happen in New York if and when there is a quarantine due to smallpox. Military or peacekeeping interventions may be necessary, and our simulation does not account for these cases.

By understanding these limitations, we were able to come up with some suggestions to improve it the model. For example, we could implement an intervention that involves a strict quarantine. This intervention would help restrict the disease and also reduce the contact rate. Another possible improvement is to introduce some variability to our rates and use rates from a collection rather than just one specific rate, which consequently improves the model in terms of realism at the cost of the loss of generality.

To conclude, the model is fruitful because it gives a reasonable approximation of how events may progress during and in the aftermath of a pathological attack. Moreover, the interventions considered by the model can be taken to mitigate the death toll and eradicate the disease if such an event does arise. However, due to our assumptions, the simulation is arguably general. Yet it is precise enough to be extended to handle other pathogens if enough information is available. New York City as it is now, is not prepared to defend itself against malicious actors like Chemical Bob. Serious contingencies and measures need to be planned out in order to defend against such an event.