Executive Summary (2 pages max) - Nathan

- Synopsis of what we did, what we found and how the tools could be developed further
- Audience: project manager

- General assumptions and why we made these assumptions (specifically how they relate to the community of interest and to why its okay to make them bc they roughly resemble reality)
- How R0 and k impact infection spread
- Consistent vaccine production/distribution vs variable (Poisson) production (difference in infection rate)
- Need more info here
    - Vaccination strategies and each of their pros and cons (some numerical data to back things up)
- How tools could be developed further:
    - Consider the impact/importance of additional restrictions (lockdowns, isolation, etc.) to limit spread AND on the other hand, the effect of increased meeting frequency to

Modeling Approach, Assumptions, Parameters - Roy

- Describe the simulation in detail (what inputs drive the model and how we obtained them)
- Consider moving this to a Technical Appendix?
- Audience: intelligence non-specialist
- Talk about how we determined the two separate k values (for med and non-med) and why that matters
- Talk about the R0 we chose

Modeling Details-Swastik

- Describe the model in technical details, can include diagram for Markov chain
- How do we check that the model is working as expected

- Convince decision makers that your model can be trusted to answer the questions it was designed to answer

Modeling Analysis - Jane & Kelly

- Describe how we use the model to study different vaccination strategies
- Explain what each test is testing and present the output for each
- Sensitivity analysis for variables with uncertainty
- Analyze results and make recommendations
- Audience: not necessarily simulation specialists

-Hierarchy;
-Changing the number of vaccines given to each group
-Changing the availability of vaccines per day;
-Social distancing v.s. Vaccine availability: which more effective? Change the meeting rate, does that have dramatic impact on the number of people infected? --how many days it takes for the loop to stop;
-95% confidence interval --for the number of people in each subclass; -for time

Conclusions - everyone

- Recap findings and recommendations

Technical Appendix (Roy & Swastik)

- Data visualization:
  - Number of infected
  - Number of recovered
  - Number of susceptible
  - Number vaccinated

Divide it by classes

Modeling Analysis

We wanted to study how the implementation of different vaccination strategies would affect 1) infection rate and 2) the length of time it takes for the epidemic to be contained (which we defined as when there are no more susceptible individuals left in the population). By using the two aforementioned variables as metrics to evaluate effectiveness, we decided to use a simulation with no vaccination as a control group for baseline comparison and modify the following variables relevant to vaccination in order to assess which strategy was the most effective : 1) the number of vaccine doses available per day and 2) the number of doses distributed to each class (with the four classes being medical workers, non-medical essential workers, non-essential high-risk individuals and non-essential low-risk individuals). In addition, we also wanted to investigate whether social distancing or vaccination is more effective at containing the epidemic, with social distancing is reflected in the model by having smaller meeting rates between each class.

We want to test the effect that changing the availability and distribution of vaccines would have on the infection rate. In order to prevent other variables from interfering with the results, we set up 4 simulation models and within each model, we test for different combinations of the two variables, namely social distancing (determined by the meeting rate), and whether there are symptomatic people in the population. We defined symptomatic people as our second controlled variable since only asymptomatic people can meet with susceptible people from all classes; in other words, whether there are symptomatic people in the population is expected to greatly influence the infection rate.

We have outlined the models and the results for each simulation in details below:

The role of vaccines when there's no social distancing:

Model #1A: Control Group (no vaccination, no social distancing, symptomatic 0.8)

Model #1B: Introducing Vaccine (no social distancing, symptomatic 0.8), change number of dosages available (from 1% to 20%, 1%, 5%, 10%, 15%, 20%))

Model #1C: Introducing Vaccine (no social distancing, symptomatic 0.8), change the distribution of vaccine ([0.4, 0.2, 0.2, 0.2], [0.25,0.25,0.25,0.25], [0.2, 0.4, 0.2, 0.2])

The role of vaccines when there a fixed high level of social distancing

Model #3A: Control Group (no vaccination, with social distancing, symptomatic 0.8)

Model #3B: Introducing Vaccine (with social distancing, symptomatic 0.8), change number of dosages available (from

Model #3C: introducing vaccine (social distancing, symptomatic 0.8), change distribution of vaccine

If we have time:

Model #2A: Control Group (no vaccination, no social distancing, symptomatic 0.5)

Model #2B: Introducing Vaccine (no social distancing, with symptomatic 0.5), change number of dosages available

Model #2C: Introducing Vaccine (no social distancing, with symptomatic 0.5), change the distribution of vaccine

Model #4A: Control Group (no vaccination, social distancing, with symptomatic)

Model #4B: Introducing Vaccine (social distancing, symptomatic 0.5), change number of dosages available

Model #4C: introducing vaccine (social distancing, symptomatic 0.5), change distribution of vaccine

1. Change social distancing (keep same dosage, distribution): change the meeting rate and see how it affects the infection rate

   ```
   run_SIR_clusters_2(10,4,100000,1.5,[0,0,0,0],[0.25,0.25,0.25,0.25],0.01)
   ```

```
run_SIR_clusters_2(10,1.5,100000,1.5,[0,0,0,0],[0.25,0.25,0.25,0.25]
,0.01)
```

2. Change vaccination dosage availability (keep same meeting rate, distribution)

```
run_SIR_clusters_2(10,1.5,100000,1.5,[0,0,0,0],[0.25,0.25,0.25,0.25]
,0.01)
run_SIR_clusters_2(10,1.5,100000,1.5,[0,0,0,0],[0.25,0.25,0.25,0.25]
,0.05)
run_SIR_clusters_2(10,1.5,100000,1.5,[0,0,0,0],[0.25,0.25,0.25,0.25]
,0.10)
run_SIR_clusters_2(10,1.5,100000,1.5,[0,0,0,0],[0.25,0.25,0.25,0.25]
,0.15)
run_SIR_clusters_2(10,1.5,100000,1.5,[0,0,0,0],[0.25,0.25,0.25,0.25]
,0.2)
```

3. Change distribution of vaccines amongst classes (keep same meeting rate, total dosage)

```
run_SIR_clusters_2(10,1.5,100000,1.5,[0,0,0,0],[0.25,0.25,0.25,0.25]
,0.01)
run_SIR_clusters_2(10,1.5,100000,1.5,[0,0,0,0],[0.4,0.2,0.2,0.2],0.0
1)
run_SIR_clusters_2(10,1.5,100000,1.5,[0,0,0,0],[0.2,0.4,0.2,0.2],0.0
1)
```

<u>Problem</u>

1. Need to keep track of time that it takes to “contain” the disease (ideally the number of days since it makes the most sense)
2. We want everything in terms of days but only vaccine dosage is in days right now, all the meeting rates are not
3. Vaccine dosage given too much that the vaccination rate much higher than the rate of infection and rate of recovery; need to make the way we compute time for vaccination and time for infection consistent/comparable

Expect medical personnel to meet

1.5 people (social distancing)-k=3 (normal expected people to run into in a day), gamma=15;

Modeling Approach, Assumptions, Parameters

The goal of our simulation is to create an accurate representation of a pandemic, and then determine a strategy that contains the pandemic as quickly as possible with as few infections as possible. To accomplish this goal, our model revolves around the following set of parameters:

- k_high - the average number of people a high-risk individual meets in a day
- k_low - the average number of people a low-risk individual meets in a day
- R0 - the reproduction rate of the virus. This is used in conjunction with k_high and k_low to determine the recovery rate of infected individuals
- n - population size
- Probability of being symptomatic - this is useful when calculating the spread of the infection. When an individual is symptomatic, they are only permitted to interact with medical personnel
- Probability of being vaccinated - this is used to determine the number of vaccines each class gets. We prioritize vaccinating essential medical staff over the 3 other classes
- gamma - the number of vaccines made available each day.

Additionally, our model is designed around the following assumptions:

- Vaccine stock is replenished every day, and the same amount is made available each day. We figured that in a situation where a vaccine has been legalized and is being mass produced, they will be created at a constant rate
- Asymptomatic people can spread the infection
- When vaccines are made available, susceptible agents will immediately claim these vaccines before interacting with any other agents
- Symptomatic individuals will only interact with medical personnel, as instructed
- In models with social distancing, people will obey social distancing guidelines
- Once an individual recovers or is vaccinated, they cannot be infected or spread the infection

We decided on two distinct models to understand the spread of infection. Each model has a control group and two additional permutations that showcase the effect certain vaccination strategies have. In our first model we examined how an infection spread in a population not practicing social distancing, without a vaccine. This serves as the control by which we measure the effectiveness of every other strategy. We then introduced a vaccine into this model, and varied the vaccine production/availability as a function of population size. Finally we changed the probability of being vaccinated between classes to see if prioritizing vaccinating a specific class would be more effective. In our second model we introduce social distancing, and repeat the same process of introducing vaccines, varying production rate, and varying probability of being vaccinated.

Modeling Details-Swastik

There are two major components to our model: the vaccinations and the general population consisting of four clusters. These four clusters are: medical workers, essential non-medical workers, non-essential high-risk, and non-essential low-risk. In our model each class contains the same number of people. The total population is thus split evenly amongst these four classes. Agents in a class can be in one of four states: Susceptible, Infected but Asymptomatic, Infected and Symptomatic, and Recovered.

Conclusions

Technical Appendix

R0, the reproduction rate of the virus was chosen to be 1.5 in accordance to previous modeling assignments co