Finding Ideal Levels for Masks & Social Distancing

Research Question:

What percentage of people wearing masks and people social distancing is needed to prevent the spread of disease depending on different population densities?

Why this matters:

- Disease Prevention
- Lockdown Duration
- How strict do Lockdown policies need to be

Variables of Interest:

Inputs

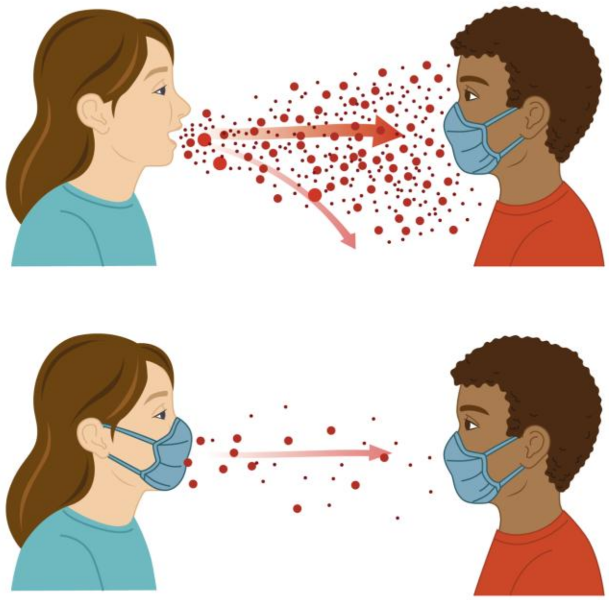
- Percentage of people wearing masks
    - Assuming government controls these values.
- Percentage of people who social distance
- Population Density

Outputs

- Rate of Infection Spread
- Highest Percentage of Infected
- Overall Mortality Level

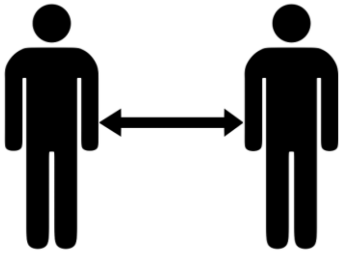
Subtopic 1: Masking

- 75% reduction in the rate of transmission when wearing a mask [1]
- Face masks are effective for reducing covid transmission [2]
- More dense populations used masks [3]
- Reduces disease spread



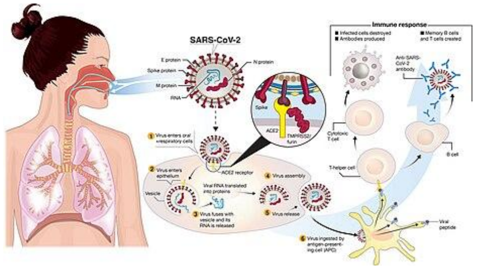
Subtopic 2: Social Distance

- “Implementation of one or more social distancing policies resulted in an additional 24.5% reduction in mobility. Decreases in mobility were associated with substantial reductions in case growth two to four weeks later” [4]
- Findings suggest that stricter social distancing measures are especially effective in higher density areas where the virus can spread more easily
- Emphasizes the effectiveness and value of social distancing, particularly when combined with mask use



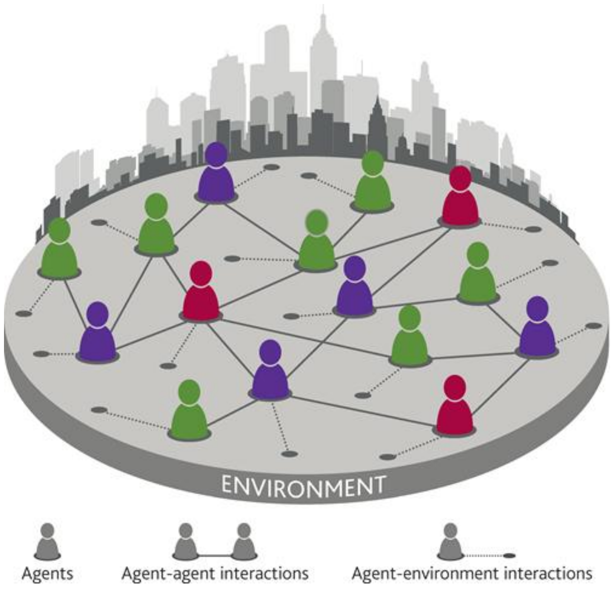
Subtopic 3: Infection & Population Density

- COVID-19 transmission rates are influenced by population density, with higher density areas experiencing faster spread
- Higher population density leads to more frequent interactions, therefore increasing infection risk [5]
- Study indicates that densely populated regions require stricter intervention measures, such as masking and social distancing, to effectively control outbreaks



Why ABM?

- Allows simulation of individual behavior
- Disease transmission is due to multiple factors [6], better simulation in ABM
- Showcases unique outcomes in different scenarios by varying parameters
- Allows us to measure impacts of disease spread in these different scenarios



Model Overview

Input Variables:

Percentage of people wearing masks: Proportion using masks, reduces infection probability.

Percentage of people who social distance: Agents move to avoid close contact with others.

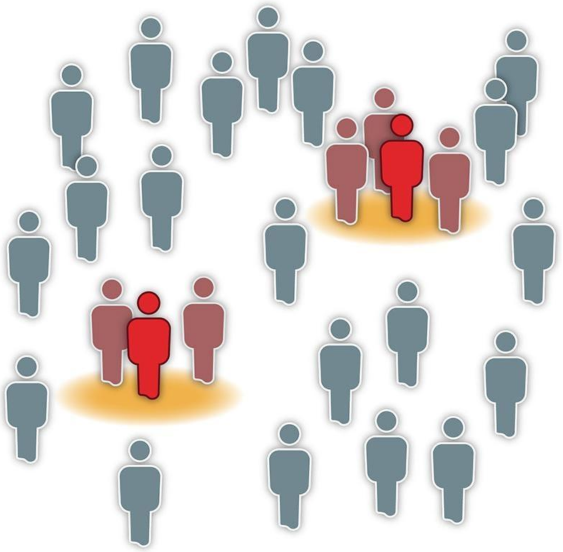
Population Density: # agents in space

Output Variables:

Rate of Infection Spread: Tracks how quickly the infection propagates within the agent population.

Highest Percentage of Infected: Peak proportion of infected agents in any time step

Overall Mortality Level: # agents marked ‘Dead’ by end of simulation



Methods

Model Description - Entities

Agent

- Infection Status (SIR model)
  - Simulate real world dynamics
- Infection Radius
  - Mechanism for the disease to spread
- Search Radius
  - Mechanism to find closest agents
- Social Distancing?
  - Showcases human behavior
- Wearing a mask?
  - Simulates protective measures
- Percent chance to die if infected
  - Simulates disease severity

Environment

- GridWidth x GridHeight
- Limited Space
- One Agent Per Cell

* Simulates the spatiality of the real world
* Realistic

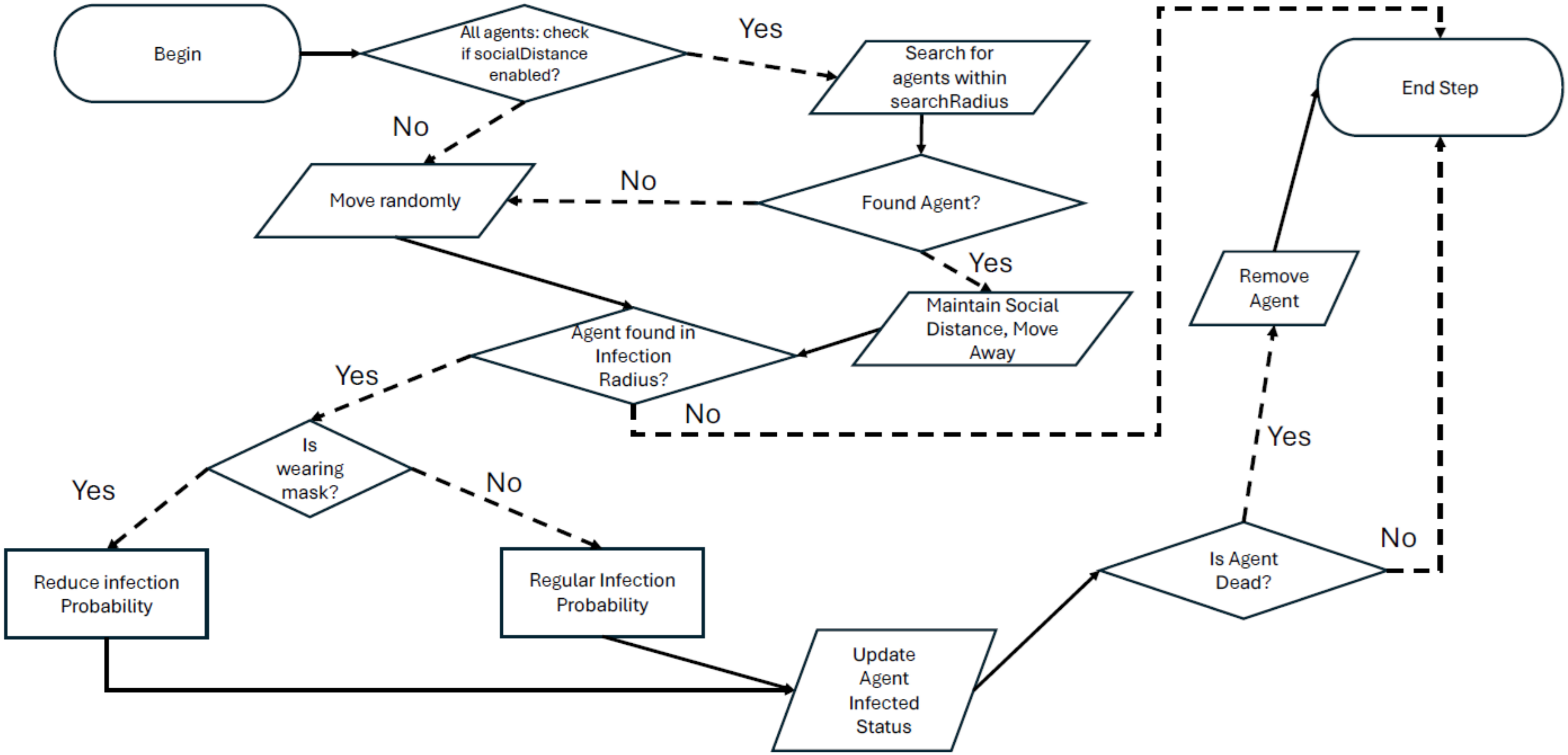
Model Description - Interactions

	Agent Type 1: Agent	**Structure 1:** Space

Agent Type 1:
 	
Agent
	- If infected, Infect others based on probabilistic distance function
	- If Agent social distances
	    - Move away from nearest neighbor
	- Else
	    - Move randomly
		n/a

Structure 1: Space	n/a	n/a

Model Description - Simulation



Virtual Experiments

- Population Density - proportion of people to total space
- Percentage of population who use masks
- Percentage of population who social distance
- Infection Radius
- Social Distance Radius
- Mask Effectiveness - Percentage of particles blocked
    - 0.5
- Death Rate - Chance of infected dying
    - 0.01

Hypotheses

- Percentage of people who use masks
- Percentage of people who social distance
- Infection radius with people who social distance
- Social Distance Radius with people who social distance

Parameter Sweeps

- Values create Low, Medium, High levels
- Test 1
  - Percentage of people who use masks
- Test 2
  - Percentage of people who social distance
- Test 3
  - Infection radius with people who social distance
- Test 4
  - Social Distance Radius with people who social distance

Parameter	Test 1	Test 2	Test 3	Test 4
Population Density	0.1, 0.5, 0.8	0.1, 0.5, 0.8	0.1, 0.5, 0.8	0.1, 0.5, 0.8
Percentage of people who use masks	0.1, 0.25, 0.5, 0.8	0	0	0
Percentage of people who social distance	0	0.1, 0.25, 0.5, 0.8	0.25	0.25
Infection Radius	5	5	3, **5**, 8, 10	5
Social Distance Radius	5	5	5	3, **5**, 10, 20

Results

Test 1

- Concrete Hypothesis: The effect of masks on the overall spread of diseases isn't directly proportional to the amount of people wearing masks.
- The values swept through were 0.1, 0.5, 0.8 Mask Percentage. (All tests sweep through 0.1, 0.25, 0.5 population density).
  - These values were chosen to represent low compliance, medium compliance, and heavy compliance with mask regulations.
- The relevant graphs
  - Figure 1 - 0.1 Population Density, 0.1 Mask Percentage
  - Figure 2 - 0.1 Population Density, 0.5 Mask Percentage
  - Figure 3 - 0.1 Population Density, 0.8 Mask Percentage
  - Figure 4 - 0.5 Population Density, 0.1 Mask Percentage
  - Figure 5 - 0.5 Population Density, 0.8 Mask Percentage
- By comparing the differences between figures 2 and 3 to the differences between figures 1 and 2, we can see that the difference between 0.5 and 0.8 Mask Percentage is less than the difference between 0.1 and 0.5 Mask Percentage. This supports our hypothesis by showing that the increase in Mask Percentage doesn't result in a direct decrease in disease spread.
- Interestingly, at higher population densities, increases in Mask Percentage results in lower infection peaks, but similar overall mortality rates.

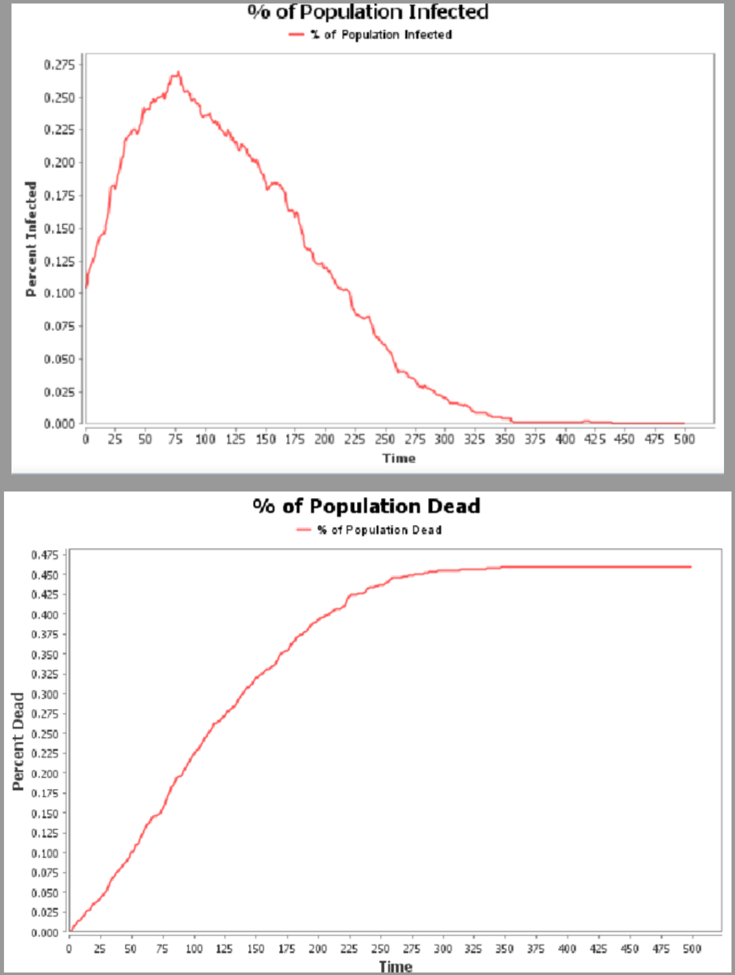


Figure 1

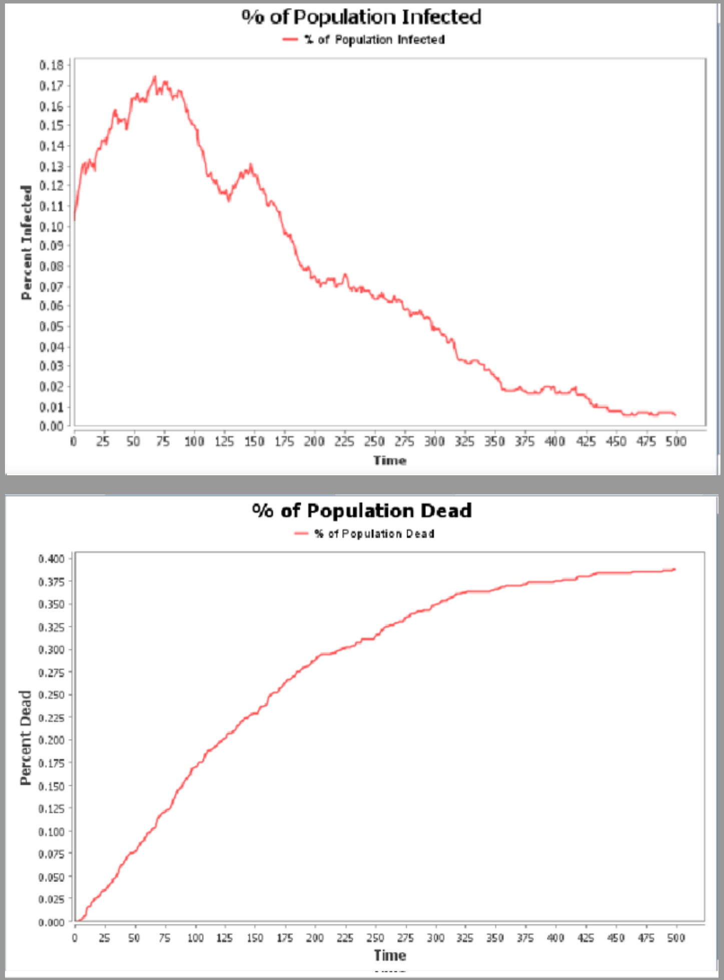


Figure 2

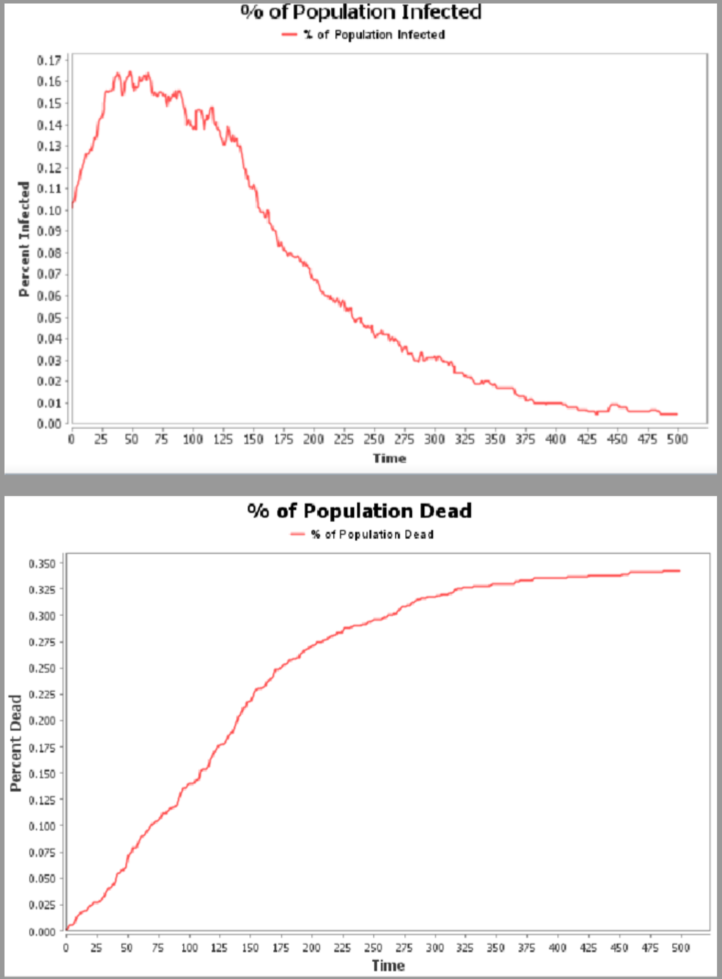

% of Population Infected
% of Population Infected
Percent Infected
Time
% of Population Dead
% of Population Dead
Percent Dead
Time

Figure 3

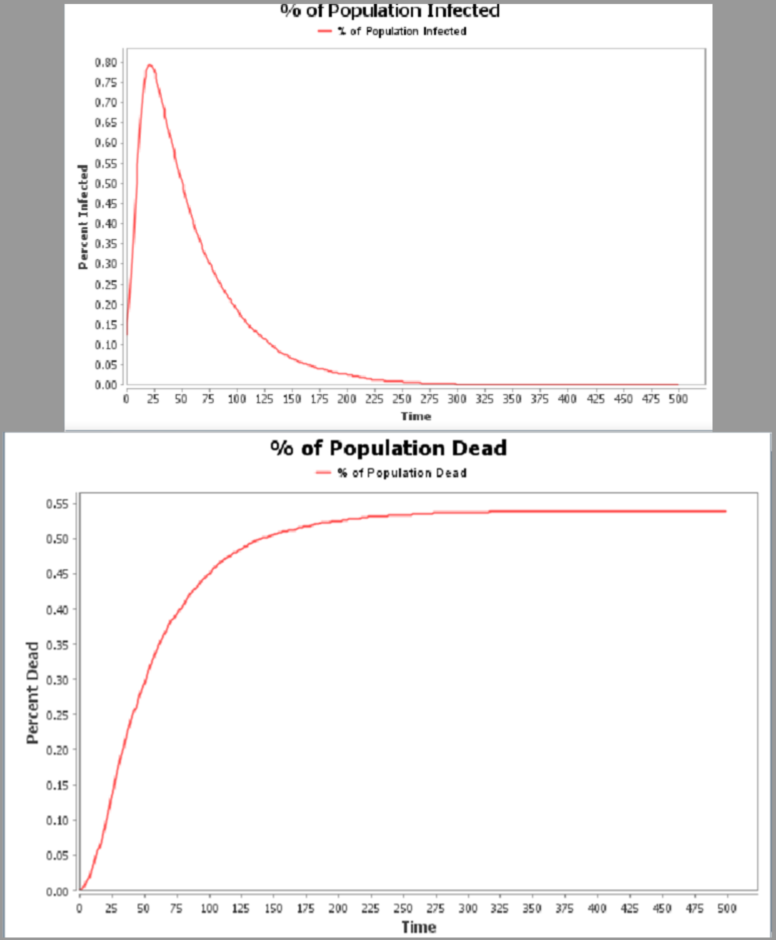


Figure 4

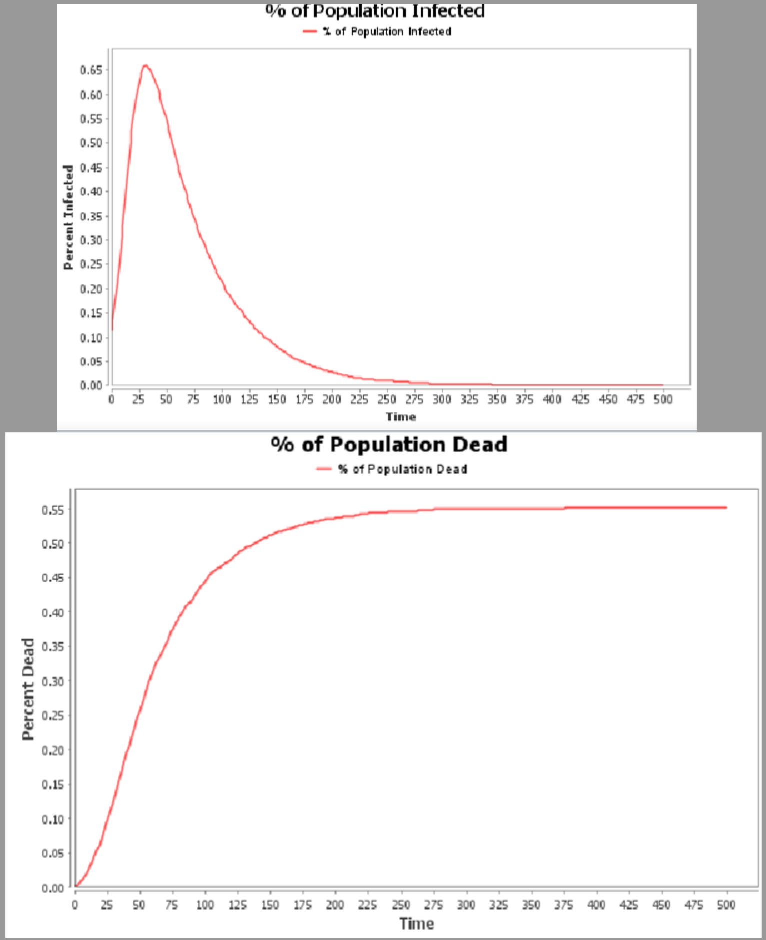


Figure 5

Test 2

- Concrete Hypothesis:"We hypothesize that there will be a point where social distancing starts to become ineffective due to the limited amount of space. At this point, the outcomes of interest will not change as we increase the percentage of people who social distance."
- The values swept through were 0.1, 0.5, 0.8 Social Distance Percentage. (All tests sweep through 0.1, 0.25, 0.5 population density).
    - These values were chosen to represent low compliance, medium compliance, and heavy compliance with social distancing regulations.
- The relevant graphs
    - Figure 6 - 0.1 Population Density, 0.1 Social Distance Percentage
    - Figure 7 - 0.1 Population Density, 0.8 Social Distance Percentage
    - Figure 8 - 0.25 Population Density, 0.1 Social Distance Percentage
    - Figure 9 - 0.25 Population Density, 0.8 Social Distance Percentage
- The data supports our hypothesis (explained in the voiceover).

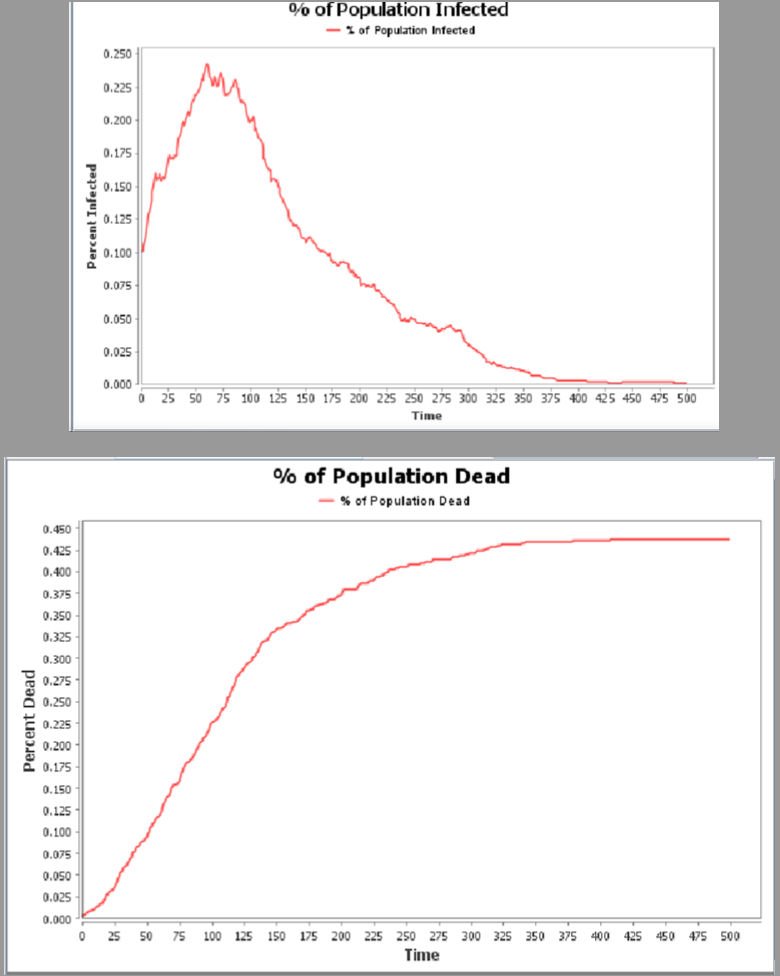


Figure 6

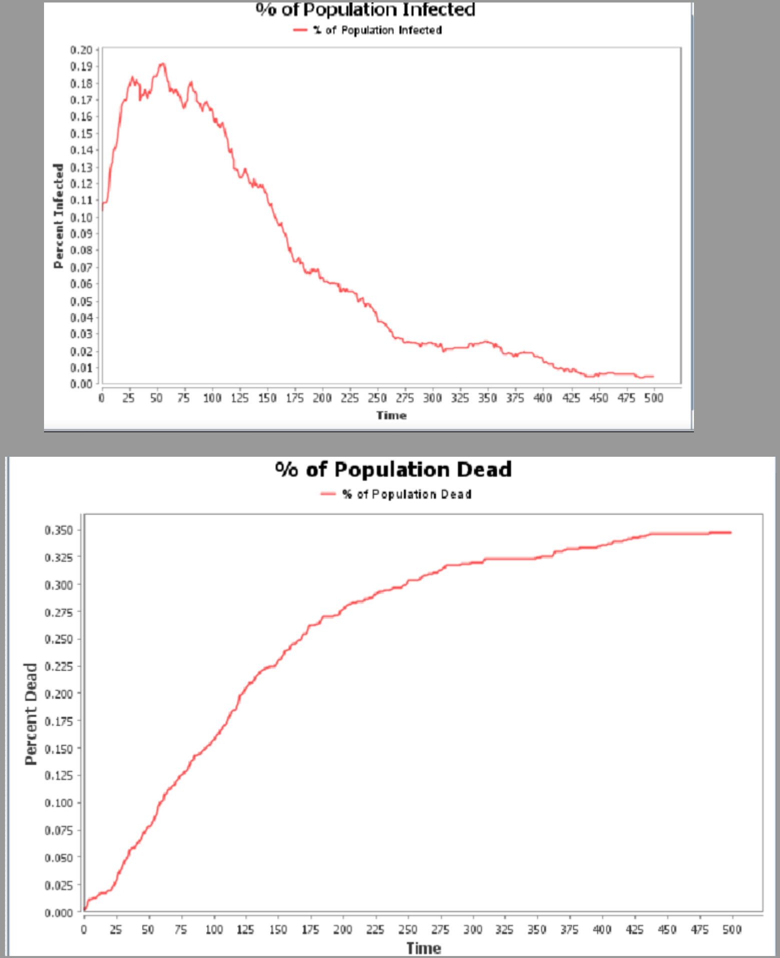


Figure 7

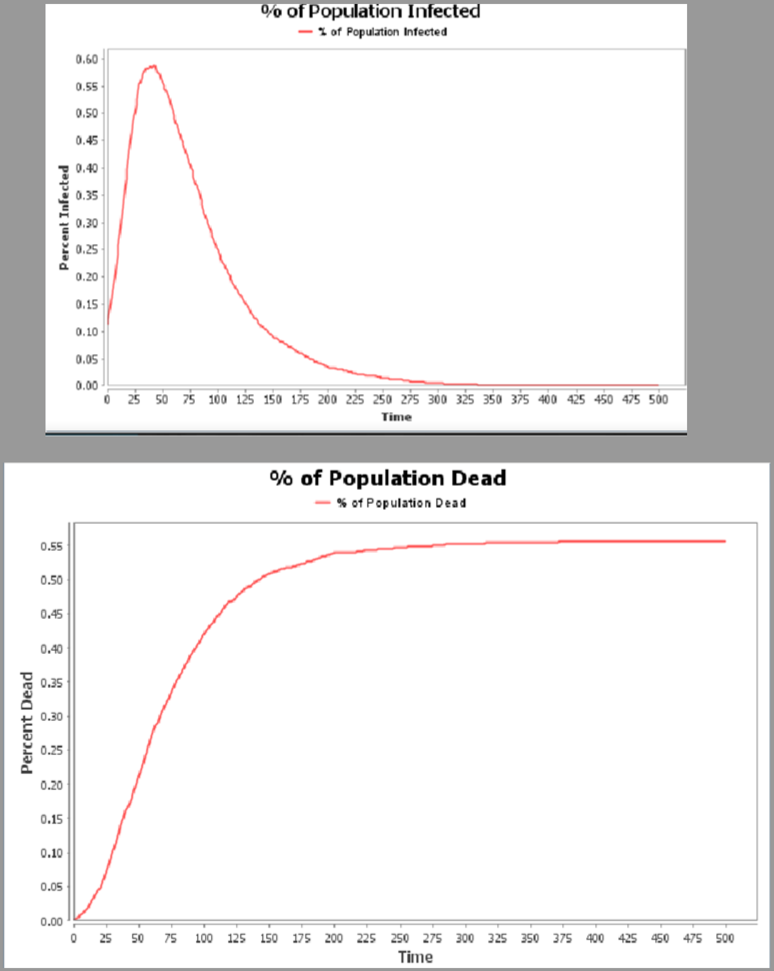


Figure 8

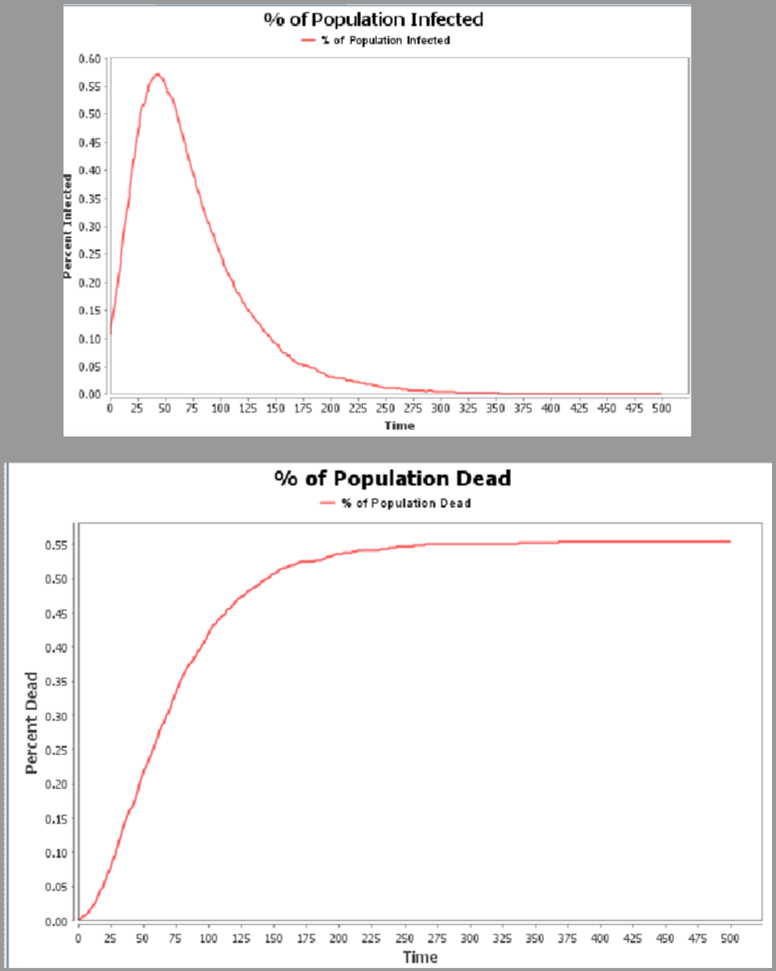


Figure 9

Test 3

- Concrete Hypothesis: “As the infection radius increases, we will see social distancing becoming less effective. We will notice that as infection radius increases, the outcome variables will proportionally increase”
- The values swept through were 3, 5, 8, 10 infection radius. (All tests sweep through 0.1, 0.25, 0.5 population density).
    - 5 was treated as the default value. 3 and 8 were chosen arbitrarily as lower and higher values from 5. 10 was added to express an extreme case.
- The relevant graphs
    - Figure 10 - 0.1 Population Density, 3 Infection Radius
    - Figure 11 - 0.1 Population Density, 10 Infection Radius
    - Figure 12 - 0.5 Population Density, 3 Infection Radius
    - Figure 13 - 0.5 Population Density, 10 Infection Radius
- From the data, there are no notable differences between Infection radii. Figure 10 and 11 share near identical graphs. Figure 12 and 13 also share near identical graphs. Changing the Infection Radius seemed to have no effect on any of the outcome variables.
- This would refute our hypothesis, which states that infection radius would have a proportional effect to the outcome variables.

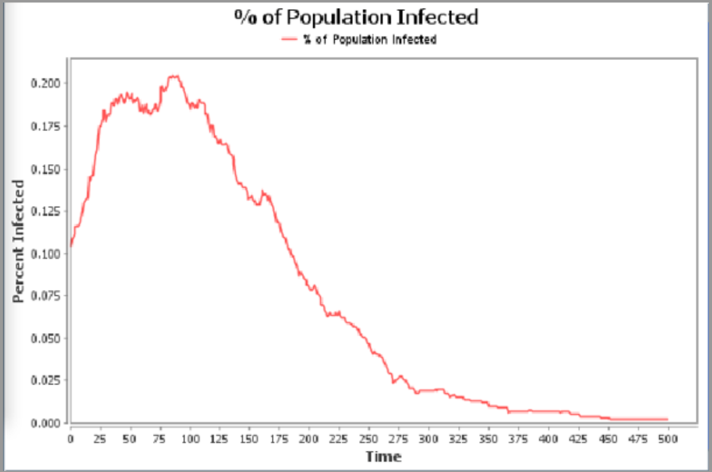


Figure 10

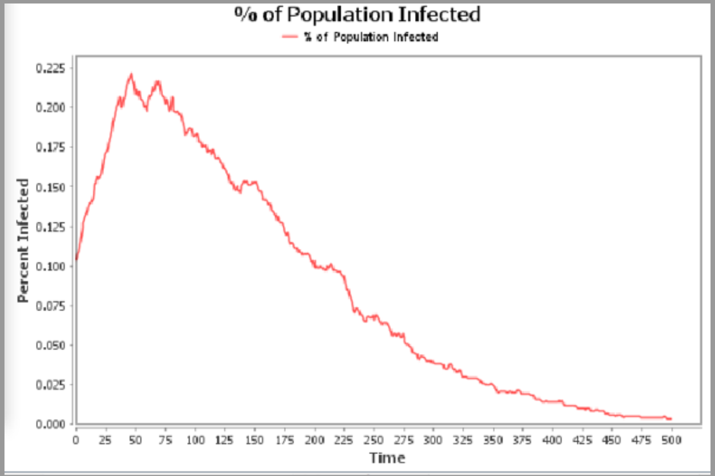


Figure 11

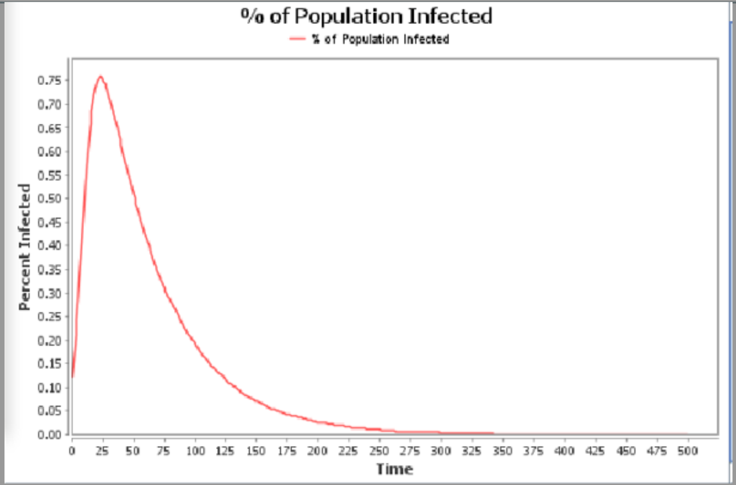


Figure 12

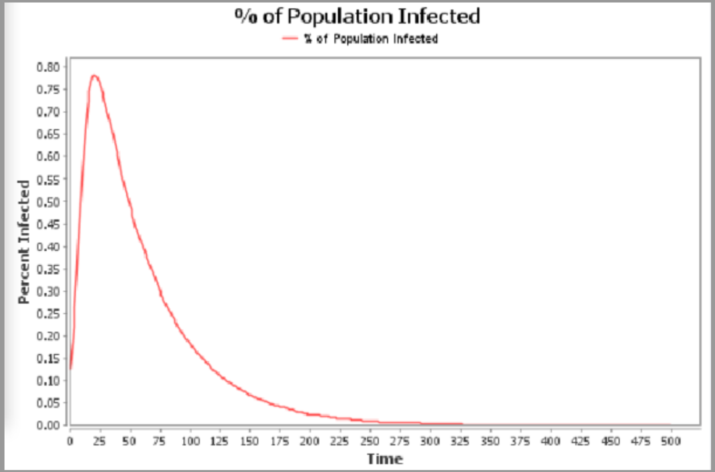


Figure 13

Test 4

- Concrete Hypothesis: “We are conducting this test to see if there is any difference between changing infection radius and changing social distance radius. Our hypothesis is that there is virtually no difference between the two. We will notice that as the social distance radius decreases, the outcome variables will increase.”
- The values swept through were 3, 5, 10, 20 social distance radius. (All tests sweep through 0.1, 0.25, 0.5 population density).
  - 5 was treated as the default value. 3 and 10 were chosen arbitrarily as lower and higher values from 5. 20 was added to express an extreme case.
- The relevant graphs
  - Figure 14 - 0.1 Population Density, 3 Social Distance Radius
  - Figure 15 - 0.1 Population Density, 10 Social Distance Radius
  - Figure 16 - 0.25 Population Density, 3 Social Distance Radius
  - Figure 17 - 0.25 Population Density, 10 Social Distance Radius
- Same as Test 3, there was virtually no difference between social distance radius values. Figure 14 and 15 as well as figures 16 and 17 had no notable differences between the graphs. Both sets of figures followed similar general curves and had similar peaks.
- This both supports and refutes our hypothesis. We hypothesized that Social Distance Radius and Infection Radius had virtually no difference. Therefore, by both of them demonstrating no change to the output variables, they display the same properties. However, we also predicted that social distance radius was inversely related to the outcome variables, which was false. Therefore the data refutes that social distance radius is inversely related to the outcome variables.

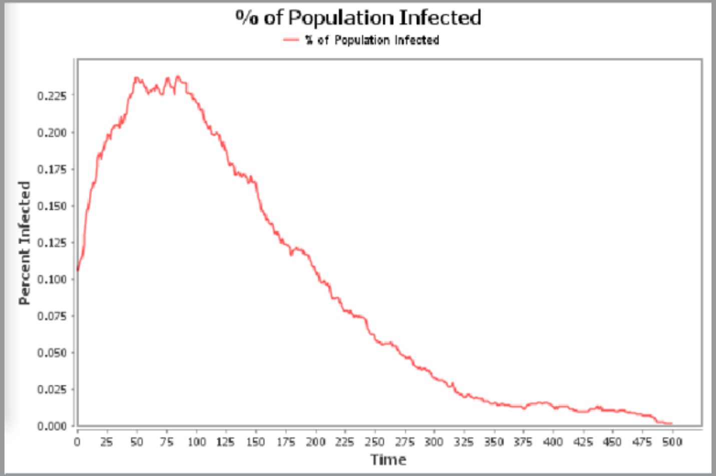


Figure 14

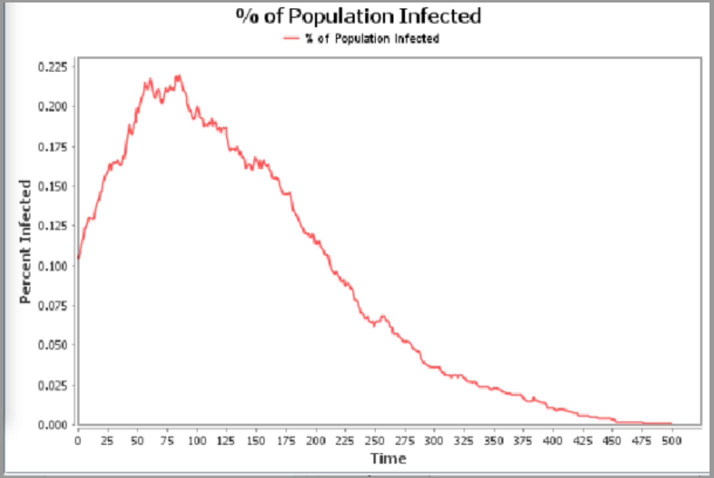


Figure 15

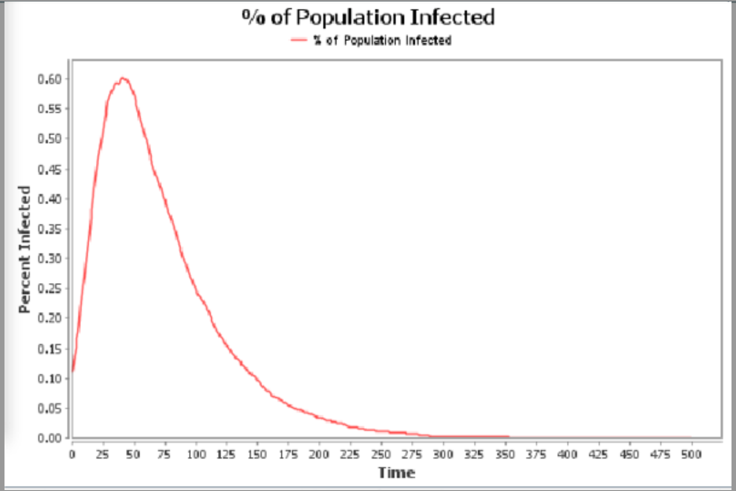


Figure 16

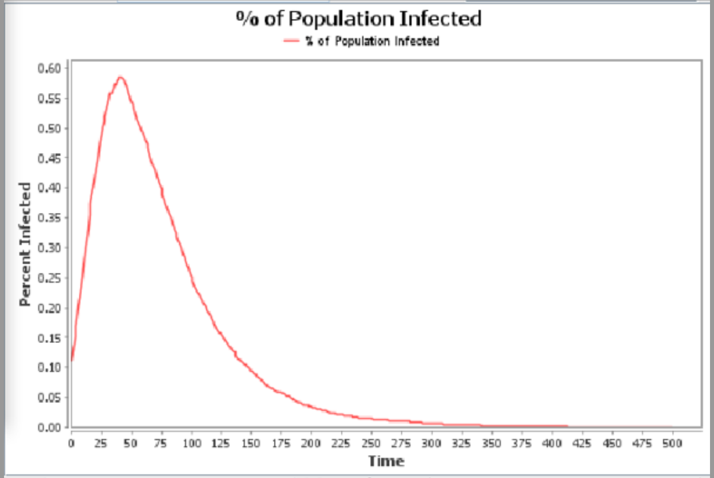


Figure 17

Conclusion

Research Question: What percentage of people wearing masks and people social distancing is needed to prevent the spread of disease depending on different population densities?

- Strengths
  - Effectively simulates crowded environments
  - Is adjustable
  - Agent qualities can be randomized for realism
- Limitations
  - Infection formula is oversimplified
  - Agents are oversimplified and equal in their qualities (mask quality, infection period, death rate), which is not realistic
  - Agent movement is simple
  - Infection cycle is simple
- Key Takeaway
  - In testing, found that social distancing and masks work best below population density of 25%
  - Mask effectiveness becomes negligible beyond 50% compliance

Transparency Statement

Generative AI was used as a citation tool to cite articles.

References

- [1] Endo, Yori. “Masks are musts: Airborne transmission makes face covering indispensable.” The British journal of surgery vol. 107,11 (2020): e534-e535. doi:10.1002/bjs.12010
- [2] Greenhalgh, Trisha et al. “Masks and respirators for prevention of respiratory infections: a state of the science review.” Clinical microbiology reviews vol. 37,2 (2024): e0012423. doi:10.1128/cmr.00124-23
- [3] Damette, Olivier, and Toan Luu Duc Huynh. “Face mask is an efficient tool to fight the Covid-19 pandemic and some factors increase the probability of its adoption.” Scientific reports vol. 13,1 9218. 6 Jun. 2023, doi:10.1038/s41598-023-34776-7
- [4] Wellenius, Gregory A et al. “Impacts of social distancing policies on mobility and COVID-19 case growth in the US.” Nature communications vol. 12,1 3118. 25 May. 2021, doi:10.1038/s41467-021-23404-5
- [5] Wong, David W S, and Yun Li. “Spreading of COVID-19: Density matters.” PloS one vol. 15,12 e0242398. 23 Dec. 2020, doi:10.1371/journal.pone.0242398
- [6] Hunter, Elizabeth, et al. “A hybrid agent-based and equation based model for the spread of infectious diseases.” Journal of Artificial Societies and Social Simulation, vol. 23, no. 4, 2020, https://doi.org/10.18564/jasss.4421.
- [7] Alaliyat, Saleh, and Harald Yndestad. “An agent-based model to simulate contagious disease dynamics in fish populations.” International Journal of Simulation Systems Science & Technology, 29 June 2020, https://doi.org/10.5013/ijssst.a.16.03.08.
- [8] OpenAI. ChatGPT – Generative AI Tool for Citation Assistance, 2024