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COE 322
17 December 2019

Disease Propagation Simulation Write-Up

In our final project, we explored how the vaccinated percentage impacted the length of the disease and how it would impact “herd-immunity” in an Austin-sized population. We fixed the population at 964,254, the most recent population estimate of Austin, fixed the number of daily interactions at 10, as we found it realistic, and ran the simulation for fixed probabilities of transmission ranging from 0.1 to 1.0 at intervals of 0.1. As it was such a large population vector, the runtime lasted over 8 hours!

We had our code output the contagion assumptions (given in the book) to the screen, followed by the current infection probability and the number of days taken, percent of population vaccinated and percent of unvaccinated who never get sick for each iteration. *Example below.*

```
Population/Contagion Assumptions:
- when recovered, but not vaccinated, one can be infected
- when sick, one can infect susceptible 'neighbors' (those directly in front and behind in the vector) and those who the individual randomly interacts (currently fixed at 20) with on that given day
- day after recovery, one becomes vaccinated


Infection Probability: 0.1
Number of Days Taken: 41
Percent of Population Vaccinated: 0
Percent of Unvaccinated Never Sick: 0.238112

Number of Days Taken: 38
Percent of Population Vaccinated: 5
Percent of Unvaccinated Never Sick: 0.33612

Number of Days Taken: 39
Percent of Population Vaccinated: 10
Percent of Unvaccinated Never Sick: 0.4585
```

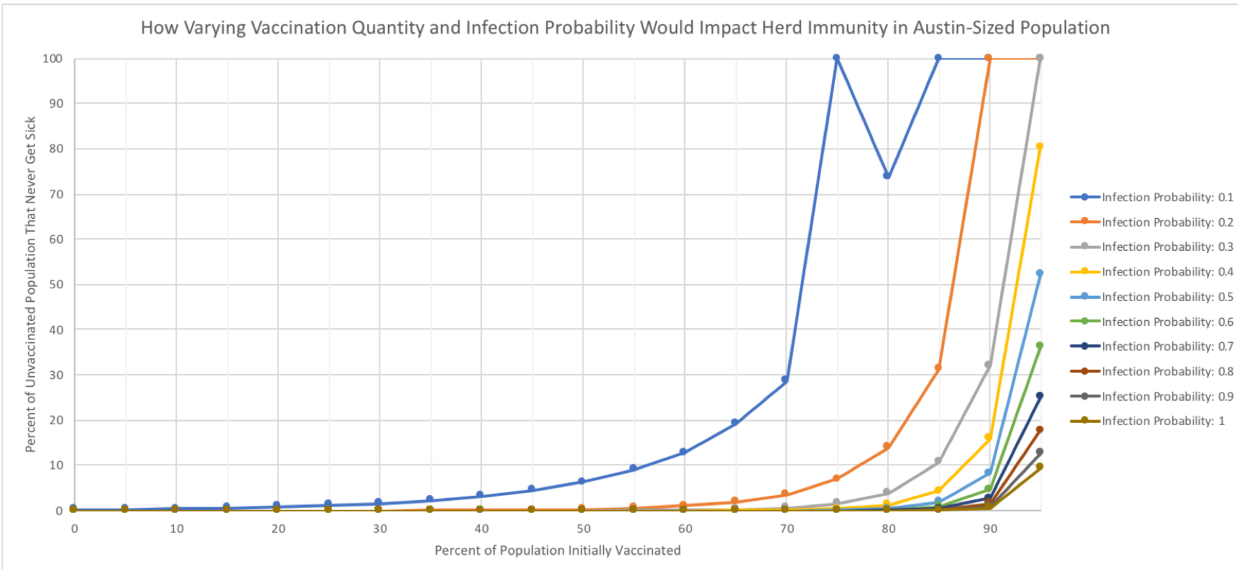
Simultaneously, we had this same information written into a .txt file (separated by commas) that we later imported into Excel in order to visualize and graph the data. *Example to the right.*

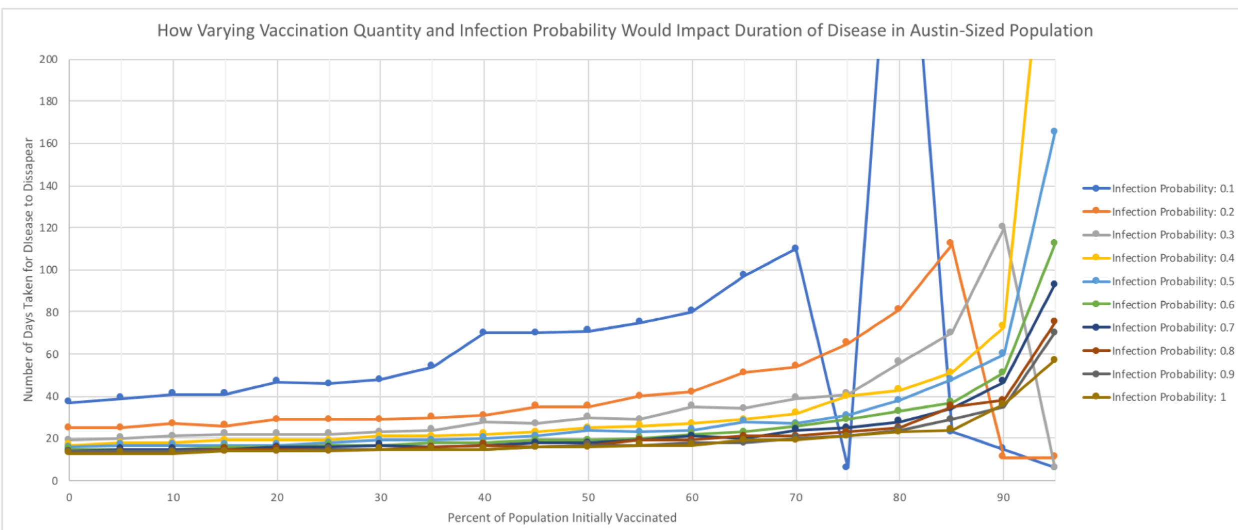
In order to import it into Excel, we used the sftp method and then had Excel separate data wherever there was a comma. *Example below.*

```
Infection Probability : 0.1
Percent Vaccinated , Percent Never Sick , Days Taken
0 , 0.233652 , 37
5 , 0.329024 , 39
10 , 0.437413 , 41
15 , 0.613824 , 41
20 , 0.875287 , 47
25 , 1.19816 , 46
30 , 1.63309 , 48
35 , 2.2916 , 54
40 , 3.20887 , 70
45 , 4.46883 , 70
50 , 6.31307 , 71
55 , 9.00799 , 75
60 , 12.8747 , 80
65 , 19.1245 , 97
70 , 28.6964 , 110
75 , 99.9996 , 6
80 , 73.6283 , 340
85 , 99.991 , 23
90 , 99.9938 , 15
95 , 99.9979 , 6
Infection Probability : 0.2
Percent Vaccinated , Percent Never Sick , Days Taken
0 , 0.000311121 , 25
5 , 0.000873322 , 25
10 , 0.00195891 , 27
15 , 0.00317222 , 26
20 , 0.00687059 , 29
25 , 0.0143807 , 29
30 , 0.0247415 , 29
35 , 0.042121 , 30
40 , 0.0907436 , 31
45 , 0.153864 , 35
50 , 0.304899 , 35
55 , 0.540198 , 40
60 , 1.02592 , 42
65 , 1.90377 , 51
70 , 3.62213 , 54
75 , 7.04087 , 65
80 , 14.015 , 81
85 , 31.2986 , 112
90 , 99.9979 , 11
95 , 99.9958 , 11
```

Infection Probability: 0.1		
Percent Vaccinated	Percent Never Sick	Days Taken
0	0.233652	37
5	0.329024	39
10	0.437413	41
15	0.613824	41
20	0.875287	47
25	1.19816	46
30	1.63309	48
35	2.2916	54
40	3.20887	70
45	4.46883	70
50	6.31307	71
55	9.00799	75
60	12.8747	80
65	19.1245	97
70	28.6964	110
75	99.9996	6
80	73.6283	340
85	99.991	23
90	99.9938	15
95	99.9979	6

Final Results:





Discussion:

We observed a few trends from the final results. The duration of the disease seems to be exponentially related to the number of people initially vaccinated. As the vaccination percentage increases, the duration of the disease increases slowly at first, with rapid growth beginning around seventy-five percent. Although this seems counterintuitive, deeper analysis reveals a possible explanation.

Think about a single sick individual living in the population. This individual will randomly interact with ten people every day. When a low percentage of the population is vaccinated, the individual is likely to interact with unvaccinated people, which leads to a much higher chance of infection. In the event that this individual infects someone else, the probability of further infection increases. Thus, when a low percentage of the population is vaccinated, the disease spreads more rapidly. On the other hand, when a high percentage of the population is vaccinated, fewer people are susceptible to infection, and thus the disease cannot spread as quickly.

Furthermore, our research suggests that "herd immunity" is only attainable when a very high percentage of the population is vaccinated. Additionally, the exact target of 95% herd immunity was only attainable when the infection probability was 0.3 or less. In each case (infection probabilities of 0.1, 0.2 and 0.3), the required vaccination percentages were 80-85, 85-90, and 90-95 percent, respectively. From these results, we concluded that the target of 95% "herd immunity" was only realistic when the disease isn't very contagious and when an extremely large percentage of the population is vaccinated. This is fairly realistic, as when a large percentage of the population is vaccinated, sick people are much more likely to interact with people they cannot infect, thus leading to most of the few unvaccinated people remaining healthy throughout the duration of the disease.

Drawbacks/Flaws in the Model:

As with any simulation, we recognize that ours has its flaws, especially due to its simplicity. These oversimplifications include disregarding the variance in the strength of one's immune system, a constant number of daily interactions among all individuals, a random spread of vaccinations across the population, and a lack of geographic consideration. Furthermore, since we only ran each case once and since there is a random element to one getting infected, it resulted in a few outliers. In the first graph, there is clearly an outlier at infection probability of 0.1 and percent vaccinated of 70, as it does not follow the exponential trend. In the second graph, there are outliers not shown on the graph. It took 340 days at an 80 percent population vaccination and 0.1 infection probability, 314 days at a 95 percent population vaccination and 0.4 infection probability. However, we found our overall results quite consistent, as we believe we created a fairly realistic simulation to represent the Austin population.

Below we have all the data we collected in tables organized by their infection probability.

Infection Probability: 0.1		
Percent Vaccinated (%):	Percent Never Sick (%):	Days Taken:
0	0.233652	37
5	0.329024	39
10	0.437413	41
15	0.613824	41
20	0.875287	47
25	1.19816	46
30	1.63309	48
35	2.2916	54
40	3.20887	70
45	4.46883	70
50	6.31307	71
55	9.00799	75
60	12.8747	80
65	19.1245	97
70	28.6964	110
75	99.9996	6
80	73.6283	340
85	99.991	23
90	99.9938	15
95	99.9979	6

Infection Probability: 0.2		
Percent Vaccinated (%):	Percent Never Sick (%):	Days Taken:
0	0.000311121	25
5	0.000873322	25
10	0.00195891	27
15	0.00317222	26
20	0.00687059	29
25	0.0143807	29
30	0.0247415	29
35	0.042121	30
40	0.0907436	31
45	0.153864	35
50	0.304899	35
55	0.540198	40
60	1.02592	42
65	1.90377	51
70	3.62213	54
75	7.04087	65
80	14.015	81
85	31.2986	112
90	99.9979	11
95	99.9958	11

Infection Probability: 0.3		
Percent Vaccinated (%):	Percent Never Sick (%):	Days Taken:
0	0	19
5	0	20
10	0	21
15	0	22
20	0	22
25	0.000138276	22
30	0.000296306	23
35	0.00127639	24
40	0.00380259	28
45	0.00848512	27
50	0.0209488	30
55	0.0419437	29
60	0.105522	35
65	0.27912	34
70	0.642637	39
75	1.59294	41
80	3.91701	56
85	10.7385	70
90	32.038	120
95	99.9979	6

Infection Probability: 0.4		
Percent Vaccinated (%):	Percent Never Sick (%):	Days Taken:
0	0	17
5	0	18
10	0	18
15	0	19
20	0	19
25	0	19
30	0	21
35	0	21
40	0.000172845	22
45	0.000942791	23
50	0.000829657	25
55	0.00299598	26
60	0.0121856	27
65	0.0429644	29
70	0.134473	32
75	0.381641	40
80	1.31552	43
85	4.28446	51
90	15.976	73
95	80.4016	314

Infection Probability: 0.5		
Percent Vaccinated (%):	Percent Never Sick (%):	Days Taken (%):
0	0	16
5	0	17
10	0	17
15	0	17
20	0	17
25	0	18
30	0	19
35	0	19
40	0	20
45	0.000188558	21
50	0	24
55	0.00069138	23
60	0.00337048	24
65	0.0100744	28
70	0.0283465	27
75	0.115737	31
80	0.478089	38
85	1.83837	48
90	8.282	60
95	52.1353	165

Infection Probability: 0.6		
Percent Vaccinated (%):	Percent Never Sick (%):	Days Taken:
0	0	15
5	0	15
10	0	15
15	0	16
20	0	16
25	0	17
30	0	17
35	0	18
40	0	18
45	0	19
50	0	19
55	0.00023046	20
60	0.000518535	22
65	0.00148153	23
70	0.00518534	26
75	0.0315269	29
80	0.163857	33
85	0.887727	37
90	4.70724	51
95	36.2184	112

Infection Probability: 0.7		
Percent Vaccinated (%):	Percent Never Sick (%):	Days Taken:
0	0	14
5	0	15
10	0	15
15	0	15
20	0	16
25	0	16
30	0	17
35	0	16
40	0	17
45	0	18
50	0	18
55	0	19
60	0	21
65	0.000296306	20
70	0.000345689	24
75	0.00995586	25
80	0.0487423	28
85	0.390628	34
90	2.7503	47
95	25.1198	93

Infection Probability: 0.8		
Percent Vaccinated (%):	Percent Never Sick (%):	Days Taken:
0	0	14
5	0	14
10	0	14
15	0	15
20	0	15
25	0	15
30	0	15
35	0	16
40	0	17
45	0	16
50	0	17
55	0	19
60	0	19
65	0	21
70	0.000345689	21
75	0.00207414	23
80	0.0233341	25
85	0.188054	35
90	1.66138	38
95	17.682	75

Infection Probability: 0.9		
Percent Vaccinated (%):	Percent Never Sick (%):	Days Taken:
0	0	14
5	0	14
10	0	14
15	0	14
20	0	14
25	0	15
30	0	15
35	0	15
40	0	15
45	0	16
50	0	17
55	0	17
60	0	18
65	0	18
70	0	20
75	0.000414828	21
80	0.00725949	24
85	0.0836565	29
90	0.928173	35
95	12.6667	70

Infection Probability: 1		
Percent Vaccinated (%):	Percent Never Sick (%):	Days Taken:
0	0	13
5	0	13
10	0	13
15	0	14
20	0	14
25	0	14
30	0	15
35	0	15
40	0	15
45	0	16
50	0	16
55	0	17
60	0	17
65	0	19
70	0	19
75	0.000414828	21
80	0.00259268	23
85	0.0442481	24
90	0.560015	36
95	9.4684	57