Analysis of Results

For the analysis, the development stages of the model was broken down into the following parts:

- Stage 0: Time calibration with ticks, and R0 calculation
- Stage 1: Daily schedule for persons
- Stage 2: Introduction of COVID-19
- Stage 3: Reduction of travel likelihood for symptomatic persons
- Stage 4: Policy intervention
- Stage 5: Fatalities

The formula for calculating R0 is as listed in the ODD, with the actual COVID-19 R0 = 2-6 (nformation for Clinicians: Frequently Asked Questions, 2020)

Stage 0

Every tick corresponds to a minute, this was done keeping in mind later developments in the model, such as adding a daily routine, and COVID-19. Furthermore, it was important to maintain the same configuration in terms of world size, number of people, number of initially infected, and so on to have an accurate comparison of R0 values as the model developed.

- num-people = 500
- num-infected = 10
- max-xcor = 215
- max-ycor = 150
- patch-size = 5
- turtle movement speed = random float value from 0 to 2 (inclusive)
- turtle movement direction = random value in range 30 right turn, random value in range 30 left turn

At the basic level, which we call Stage 0, we have R0 = 49 for all runs of the model. This is because the disease spreads in less than 1440 ticks (which is the equivalent of a day). Over 30 runs, it took an average of 734.7333 ticks (or minutes) for the infection to spread to everyone.

Stage 1

In adding the daily routine, a CBD area was created where all the workplaces and half the shops spawn. Each person is assigned one house, workplace and shop. Assigned shops change for each person everyday. In addition to these variables, persons also draw a chance of going to shops over work on a particular day (1/3rd), as well as different depart times for leaving home, shops or work. More details on the variables can be found in the ODD. The following parameters were used to get the resultant average R0 value:

- num-people = 500
- num-infected = 10
- max-xcor = 215
- max-ycor = 150
- patch-size = 5
- cbd-size = 74
- num-houses = 343
- num-workplaces = 39
- num-shops = 35
- turtle movement speed = random float value from 0 to 2 (inclusive)

When we add in a daily routine for the people, we notice a change in the number of ticks the model runs for before all people are infected. On average, over 30 runs, the model ran for 1737.6 ticks, which is around 1.2 days, which is approximately 1000 ticks (or minutes) more than the last stage. The average R0 value across 30 runs is 48.3, which is

not a significant change over the last stage, however it does make sense given the varied ways in which people are now interacting with each other, at work, shops or even some houses with more than 1 person.

Stage 2

When introducing COVID-19 into the model, the following defaults were chosen:

- Incubation period - Normally distributed with a mean of 7 days and standard deviation of 2.3 (total range of 14 days within 3 standard deviations) (Australian Health Protection Principal Committee (AHPPC) coronavirus (COVID-19) statements on 14 May 2020, 2020)
- Infectious period - 1-3 days before symptomatic period, chosen at random for each person (How long are you infectious when you have coronavirus?, 2020)
- Symptomatic period - 10 days (Lee, 2020)

The following parameters were used:

- num-people = 500
- num-infected = 10
- max-xcor = 215
- max-ycor = 150
- patch-size = 5
- cbd-size = 74
- num-houses = 343
- num-workplaces = 39
- num-shops = 35
- turtle movement speed = random float value from 0 to 2 (inclusive)

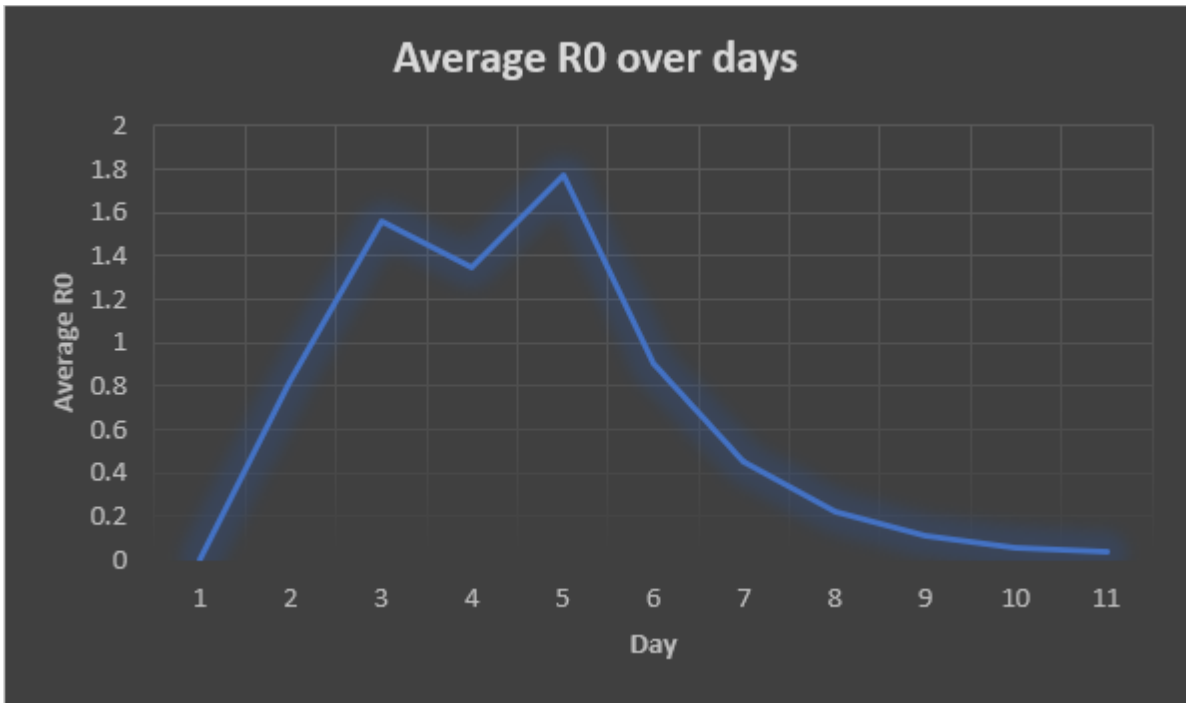
After running the model for 30 iterations with these parameters, we get the following table of results:

Stage 2 Table of Results

	Day 0	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10
Run 1	0	0	2.5	1.685714	1.712766	0.627451	0.171084	0.026749			
Run 2	0	0	2.3	1.909091	1.729167	0.553435	0.184275	0.029046			
Run 3	0	0.8	0.222222	1.227273	2.22449	0.949367	0.425325	0.129841	0.004032		
Run 4	0	0	0.7	1.411765	1.95122	1.066116	0.56	0.225641	0.041841		
Run 5	0	0	0	0.9	7	1	0.490132	0.094923			
Run 6	0	0	0	0	8.4	1.053191	0.803109	0.318966	0.071895	0.014228	
Run 7	0	0	1.5	2.92	1.020408	0.525253	0.450331	0.13242			
Run 8	0	0	0.7	0.647059	0.678571	1.489362	1.376068	0.57554	0.109589		
Run 9	0	5.1	1.918033	0.808989	0.372671	0.11991					
Run 10	0	0	6.3	0.821918	1.112782	0.565836	0.106818	0.022587			
Run 11	0	2.6	0.944444	1.357143	0.884848	0.376206	0.147196				
Run 12	0	0	2.3	1.757576	1.516484	0.742358	0.203008				
Run 13	0	0	0	4.6	2.357143	0.696809	0.442006	0.073913	0.010121		
Run 14	0	2.6	2.583333	0.953488	0.373016	0.317919	0.078947	0.014228	0		
Run 15	0	0	3.9	1.77551	0.860294	0.517787	0.234375	0.050633			
Run 16	0	0	2.4	1.029412	1.304348	1.138365	0.364706	0.056034			
Run 17	0	0	0	0	4.9	1.050847	1.380165	0.368056	0.215736	0.039666	
Run 18	0	0.7	0.411765	3.125	1.767677	0.521898	0.165468	0.026749			
Run 19	0	1.2	2.090909	1.397059	0.822086	0.410774	0.164678	0.022541			

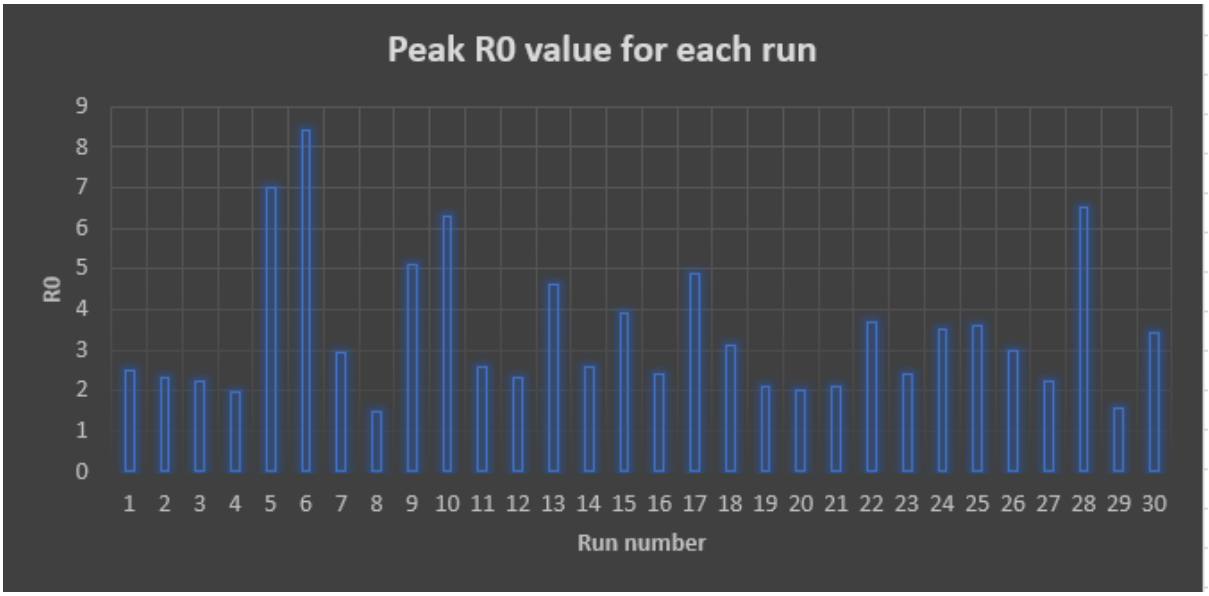
Run 20	0	0.8	0.222222	0.363636	2	1.266667	0.593137	0.36	0.095023		
Run 21	0	0	0.3	2.076923	1.025	1.604938	0.687204	0.280899	0.078947		
Run 22	0	0	0	0	0	3.7	1.404255	1.530973	0.444056	0.154964	0.035639
Run 23	0	0	2.4	0.470588	2.4	0.882353	0.390625	0.096629			
Run 24	0	3.5	0.533333	0.695652	1.213675	0.583012	0.187805	0.022587			
Run 25	0	3.6	2.043478	1.042857	0.513986	0.124711	0.024641				
Run 26	0	3	0.525	1.360656	0.916667	0.568841	0.13164				
Run 27	0	0	0	1.8	1.214286	2.241935	0.547264	0.340836	0.170264	0.020492	
Run 28	0	0	6.5	2.066667	0.7	0.204604	0.055202				
Run 29	0	0	0	1.2	1.409091	1.584906	1.087591	0.5	0.13986		
Run 30	0	0.7	3.411765	1.026667	0.638158	0.550201	0.243523	0.03125			

Taking the average R0 over each run for each day, we get a plot that looks like this:



Plot of Average R0 over days

The results from the table reflect the average R0 value across all 30 runs for each day, with the virus spreading to all people by an average of 8 days. While it may seem that the model is not reflecting the COVID-19 R0 value, since the graph peaks at 1.8, this is because for each run of the model the peak R0 value happens on different days. If we take the peak R0 value for each run of the model, we get a graph that looks like this:



Bar graph of Peak R0 value for each run

The minimum here is 1.5, while the maximum is 8.4, with an average peak R0 value of 3.4, which is within the observed COVID-19 R0 range of 2-6.

Nevertheless, it is evident that having specific infectious days post contact plays a key role in reducing the R0 value, and thus reducing and prolonging the spread of infection.

Stage 3

The following parameters were used:

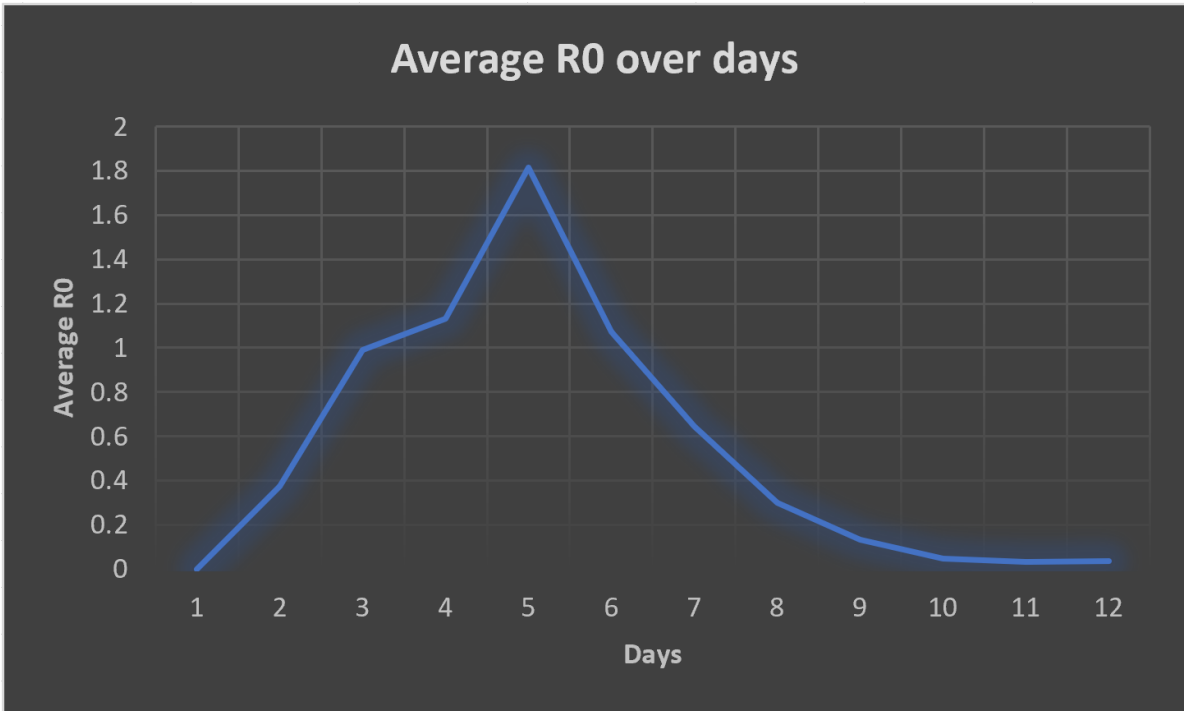
- num-people = 500
- num-infected = 10
- max-xcor = 215
- max-ycor = 150
- patch-size = 5
- cbd-size = 74
- num-houses = 343
- num-workplaces = 39
- num-shops = 35
- staying-home-when-sick? = true
- percentage-staying-home = 100
- turtle movement speed = random float value from 0 to 2 (inclusive)

And the following results were observed:

Stage 3 Table of Results

	Day 0	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11
Run 1	0	0	0	0	8.4	1.670213	0.553785	0.228205	0.041754			
Run 2	0	0	1.7	0.333333	2.361111	1.520661	0.314754	0.182045	0.044304	0.008081		
Run 3	0	0	0	1.5	3.24	0.990566	0.64455	0.239193	0.130233	0.026749		
Run 4	0	0	0	1.5	3.24	0.990566	0.64455	0.239193	0.130233	0.026749		
Run 5	0	0	0	0	4.2	0.865385	1.103093	0.70098	0.299712	0.086475		
Run 6	0	0	0	2.8	2.289474	0.736	0.700461	0.254743	0.064795	0.010142		
Run 7	0	0.8	0.055556	1.421053	2.521739	0.864198	0.410596	0.126761	0.03125	0.008081	0	
Run 8	0	1.7	0.888889	1.411765	1.113821	0.492308	0.21134	0.059574				
Run 9	0	0	1.9	2.344828	0.597938	0.651613	0.578125	0.185644	0.041754			

Run 10	0	0	1.7	2.037037	0.914634	0.923567	0.423841	0.127907	0.026804			
Run 11	0	0	0	1.9	2.068966	1.696629	0.683333	0.175743	0.035789			
Run 12	0	0.8	1	1.472222	1.191011	0.887179	0.279891	0.059448				
Run 13	0	1.4	0.583333	0.789474	1.308824	1.025478	0.349057	0.135198	0.024641	0		
Run 14	0	0	0	0.6	1.3125	0.72973	1.546875	0.907975	0.453376	0.095133		
Run 15	0	0	7.6	0.906977	0.786585	0.464164	0.121212	0.037422				
Run 16	0	0	0	0	2.9	2.410256	1.045113	0.463235	0.165829	0.064655	0.010121	
Run 17	0	0	1.6	0.307692	2.852941	0.725191	0.530973	0.34104	0.06681	0.006061		
Run 18	0	0	0	0.5	0.933333	0.275862	1.432432	1.177778	0.647959	0.294118	0.136364	0.035789
Run 19	0	0	1	2.45	0.84058	1.015748	0.546875	0.189394				
Run 20	0	1.2	1.318182	0.921569	0.877551	0.771739	0.411043	0.069565				
Run 21	0	0	0.3	2.461538	1.577778	1.189655	0.566929	0.213568	0.020704	0.006085		
Run 22	0	0	0	0.6	0.9375	2.741935	1.086207	0.603306	0.237113	0.035417	0.004024	
Run 23	0	0	0	2.1	1.612903	0.888889	0.745098	0.486891	0.183879	0.053191	0.006061	
Run 24	0	0	2.7	0.621622	1.383333	0.811189	0.621622	0.135714	0.033543			
Run 25	0	0	2.1	1.064516	0.421875	1.021978	0.86413	0.338192	0.071895	0.014228		
Run 26	0	0.4	0.142857	1.4375	0.74359	0.838235	1.096	0.561069	0.168704	0.031381		
Run 27	0	0	1.5	0.84	0.456522	1.656716	0.724719	0.364821	0.157518	0.02268		
Run 28	0	0	1.4	0.291667	1.612903	1.962963	0.575	0.214286	0.082789			
Run 29	0	3.4	1.022727	0.786517	0.924528	0.359477	0.137019	0.048626				
Run 30	0	1.5	1.16	0.518519	0.792683	0.938776	0.461538	0.138756	0.044118			

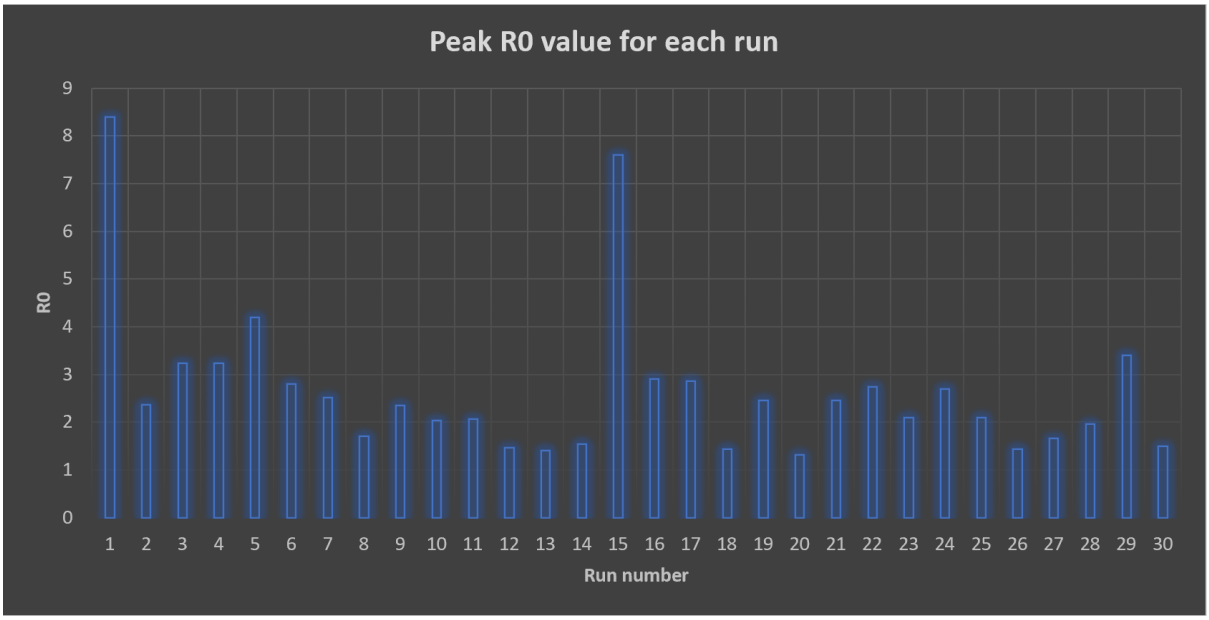


Plot of Average R0 over days

The results from the table reflect the average R0 value across all 30 runs for each day, with the virus spreading to all people by an average of 9.6 days. When comparing to Stage 2, this is an increase of around a day and a half, and represents a 20% delay in days for the virus to spread to all people. Thus it can be said from these results that it

takes 20% longer for the virus to spread to all people when we reduce the travel likelihood for symptomatic persons to 0.
When it comes to the graph, both Stage 2 and Stage 3 peak at approximately 1.8, and on the same day – Day 5. And then slowly reduce in value for the remaining days. However, on Day 3 Stage 2 has a noticeable Average R0 value of 1.6, whereas Stage 3 has an Average R0 value of 1, representing a slower transmission in the initial days than Stage 2. However, apart from this the change is not too drastic, and this can be attested to the fact that the infectious days are within a range of 1-3 days before the symptomatic period, so people can easily spread the virus within these days before realizing they're symptomatic and decide to stay home and prevent any further spread.

As with Stage 2, we consider the peak R0 value for each run



Bar graph of Peak R0 value for each run

The minimum here is 1.3, while the maximum is 8.4, with an average peak R0 value of 2.7, which is within the observed COVID-19 R0 range of 2-6. Compared to Stage 2, the minimum is less by 13%, while interestingly the maximum is the same. The average peak R0 value of 2.7 represents a 20.5% reduction from the value of 3.4 in Stage 2.

Stage 4

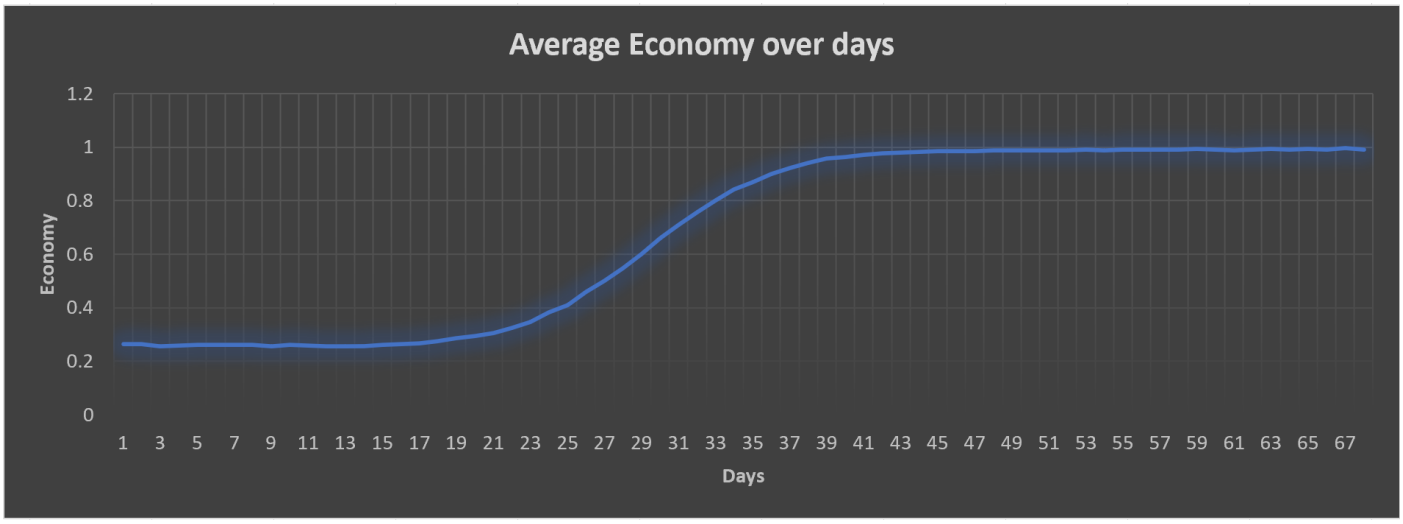
The policy intervention chosen for this stage was to limit the percentage of the population that is allowed to travel per day. In the real world, it would function as handing out a number group to each individual, and only allowing people within a certain number group to travel out to work or the shops on a particular day. Different number groups would correspond to different days. The intervention is largely successful in keeping the R0 value under 1, while also keeping the economy afloat.

The following parameters were used:

- num-people = 500
- num-infected = 10
- max-xcor = 215
- max-ycor = 150
- patch-size = 5
- cbd-size = 74
- num-houses = 343
- num-workplaces = 39
- num-shops = 35
- staying-home-when-sick? = true
- percentage-staying-home = 100

- policy-intervention? = true
- percentage-daily-travel = 20
- turtle movement speed = random float value from 0 to 2 (inclusive)

The table of results is too big to fit into this report. However the following plots summarize the findings:

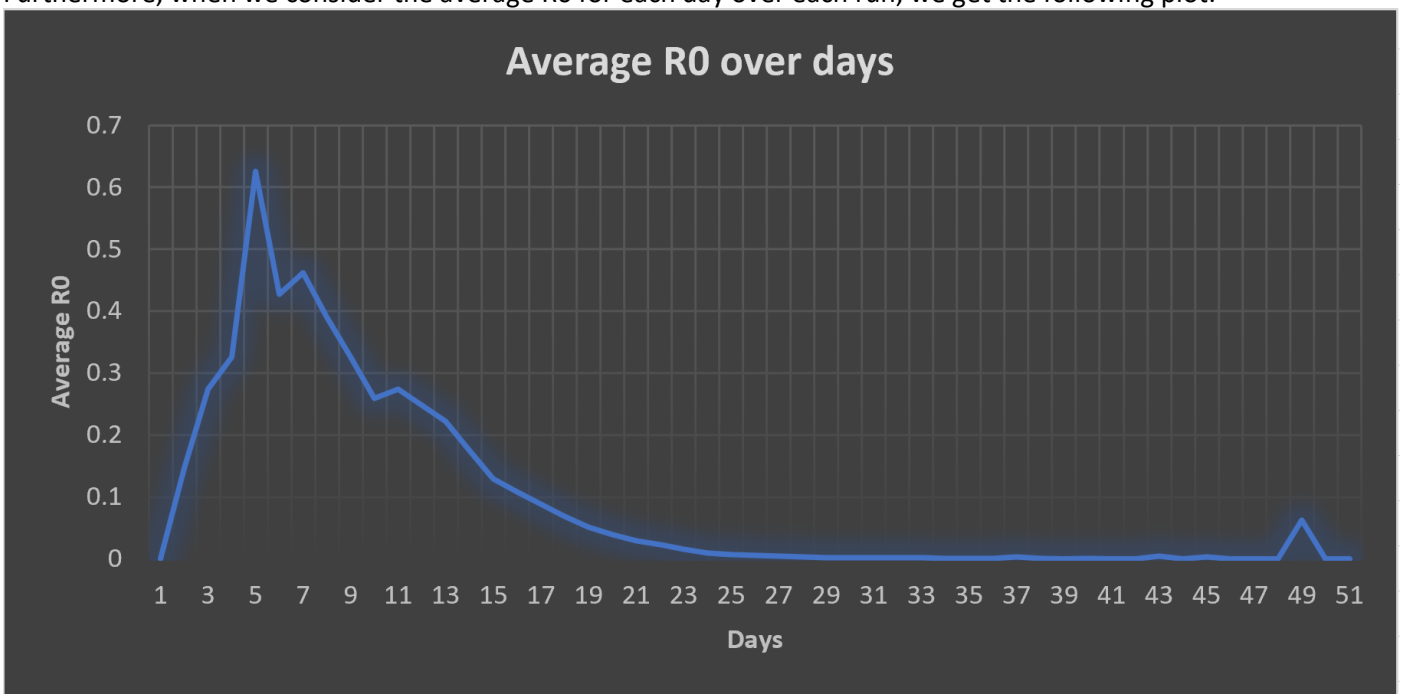


Plot of Average Economy over days

Here we can see how for each day, the average economy value for a particular run increases over time. On Day 1, the policy intervention is in place, and this keeps the economy relatively stable until Day 23, when more people start becoming immune to the virus and are allowed to go back to work and the shops, until Day 45 when the economy resumes to normal with everyone either immune or the virus completely eradicated.

Without the policy intervention, if maintaining that 100% of people stayed at home when sick, the economy value, on average, reached a low of 0.083. With the policy intervention, on average, the economy reached a low of 0.206, which is approximately 2.5x times larger.

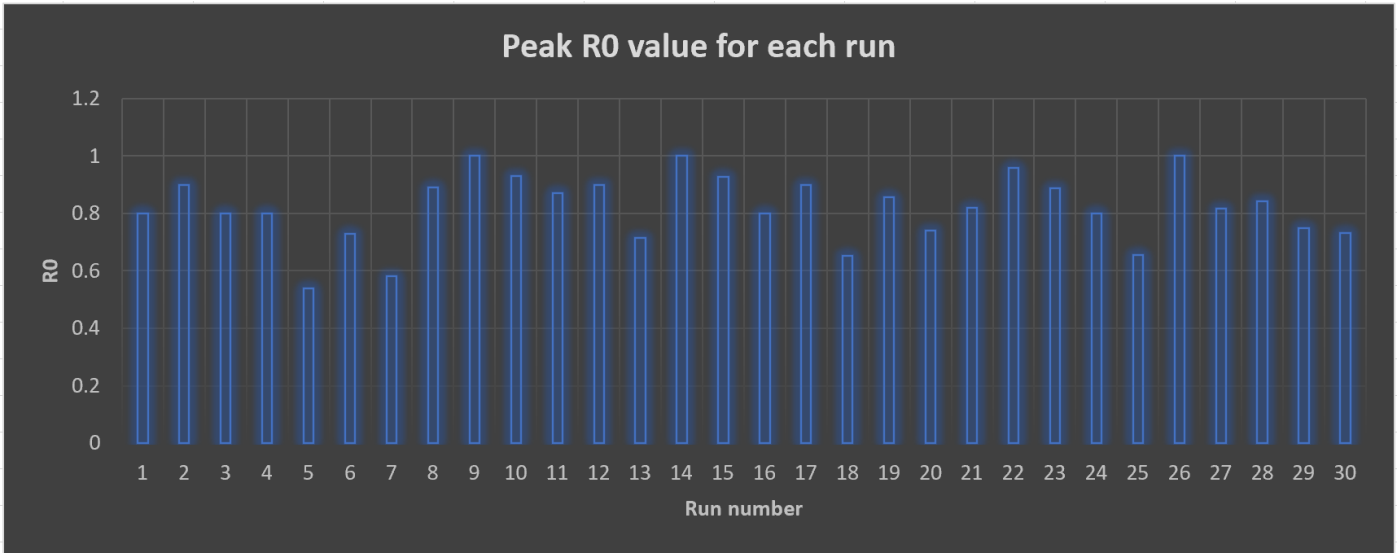
Furthermore, when we consider the average R0 for each day over each run, we get the following plot:



Plot of Average R0 over days

Here we can see that the maximum is approximately 0.625, which is well below 1. The spike occurs on the same day as the other stages, but is significantly lower. However, from previous stages we know that different runs peak on

different days, therefore it is important to consider the peak R0 values here as well. The following plot summarizes the findings:



Bar graph of Peak R0 value for each run

The minimum here is 0.54, while the maximum is 1, with an average peak R0 value of 0.82. This is significantly lower than the R0 values in previous stages.

Stage 5

For the introduction of fatalities, the following parameters were used:

- num-people = 500
- num-infected = 10
- max-xcor = 215
- max-ycor = 150
- patch-size = 5
- cbd-size = 74
- num-houses = 343
- num-workplaces = 39
- num-shops = 35
- staying-home-when-sick? = true
- percentage-staying-home = 100
- policy-intervention? = true
- percentage-daily-travel = 20
- fatalities? = true
- mortality-rate = 3.5
- turtle movement speed = random float value from 0 to 2 (inclusive)

Across the 30 runs that were conducted, the results were almost indistinguishable from Stage 4. There was a slight variance in the peak R0 value, however it could easily change if the runs were to be conducted again. The following results were observed:

- Maximum value of economy: 1
- Average low of economy: 0.2
- Maximum R0 over average for each day: 0.65
- Minimum of peak R0 value: 0.49
- Maximum of peak R0 value: 1

It is clear that 3.5% of the people suffering fatalities is not proportional in any way to any perceptible changes in the values of R0 and the economy, and this may be attested to the fact that the fatalities happen at random during the

symptomatic period, thus 1 or 2 fewer persons each day hardly makes a difference, since it also updates the total number of persons, which leaves the R0 and economy in the same ratio.

Limitations

A lot more runs can be done in order to get a better average, 30 may be a small number of runs for this prupose. However, running these models is very resource and time consuming, especially as the stages progress with more variables to measure thrown into he mix. Moreover, BehaviourSpace doesn't allow for gathering data at a certain tick amount, which for us would be 1440 ticks at the end of the day, therefore a lot of manual work has to be done to extract the data from the output file in excel for preprocessing.

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