CT561 – Assignment 2

Extending the SIR Model and Exploring Downstream Effects following the Introduction of a Novel Pathogen to a Susceptible Population

The aim of this assignment is to build on the previous workshop model, and extend this so that it models downstream effects, namely, demand on hospital services. The infectious disease model has the following features:

STEP 1: Create the SEIR Model

1. Add an exposed stock that models people who have become infected but are not yet infectious. Assume the duration of exposure is 3 days.

2. There are now two kinds of infectious people (assume an infectious delay of 3 days):
    a. Sub-clinical, where they do not show symptoms. Sub-clinical people are half as infectious as clinically infectious people.

    b. Clinical, where people show symptoms

3. The breakdown between the two types of infectious people is determined by a constant called *clinical fraction*.

4. Add an estimate of R_0 to the model, given that R_0 is defined as "the average number of secondary infectious persons resulting from a typical infectious person following their introduction to a totally susceptible population."

5. Add an estimate of R_N to the model, given that R_N is defined as "The average number of secondary infectious persons resulting from one infectious person in a given population in which *some individuals may already be immune because of infection or vaccination."*

6. Run for a population of 1M people, where 10 people are initially infectious (sub-clincal stream). Assume people have, on average, 10 contacts per day, and the infectivity for clinical people is 10%. Assume that 40% of the population do not show any symptoms.

The following are the main stocks for this part of the model (with the initial values, the flows are excluded)

Susceptible = INTEG(XXXX , N - Initial Infectious Sub Clinical)

Exposed = INTEG(XXXX, 0)

Infectious Clinical = INTEG(XXXX , 0)

Infectious Sub Clinical = INTEG(XXXX , Initial Infectious Sub Clinical)

Removed = INTEG(XXXX , 0)

STEP 2: Add the hospitalisation stream

A fraction of Infectious Clinical (Hospitalisation Fraction) are routed into the hospital system, and so flow into the following stocks (in succession):

- Pre-Hospitalised Non-Infectious (Pre-Hospitalisation Delay)
- In Hospital Stage 1 (Stage one, Second order delay), Delay of Hospital Average Length of Stay (ALOS)
- In Hospital Stage 2 (Stage two, Second order delay)
- Removed

Important information relevant to the hospital stream includes:

- The Number of Hospital Beds Per 100,000 (see parameters)
- The total number of Hospital Beds (To be calculated)
- The Standard Occupancy Rate (see parameters)
- The total number of non-infectious disease cases in hospital (to be calculated)
- The total number of infectious disease cases in hospital (to be calculated)
- The Total Hospital Demand
- The hospital capacity indicator (ratio of Total Hospital Demand to Hospital Beds).

The following are the main stocks for this part of the model (with the initial values, the flows are excluded)

"Pre-Hospitalised Non-Infectious" = INTEG(XXXX, 0)

In Hospital Stage 1 = INTEG(XXXX , 0)

In Hospital Stage 2 = INTEG(XXXX , 0)

STEP 3: Adding Mobility Reduction to the Model

The mode must include an effect structure to model mobility change. The contacts will be formulated as an equation involving:

- The Normal Contact Rate (see parameters)
- The Effect of Mobility on Contacts. The effect function is based on the ratio of the Normal Mobility Index and the Mobility Index
- The Mobility Index is a stock that decays over time. It has a minimum value, and the fractional change rate is constant. This reduction is activated at the time when the restrictions start (day number)

Model Parameters

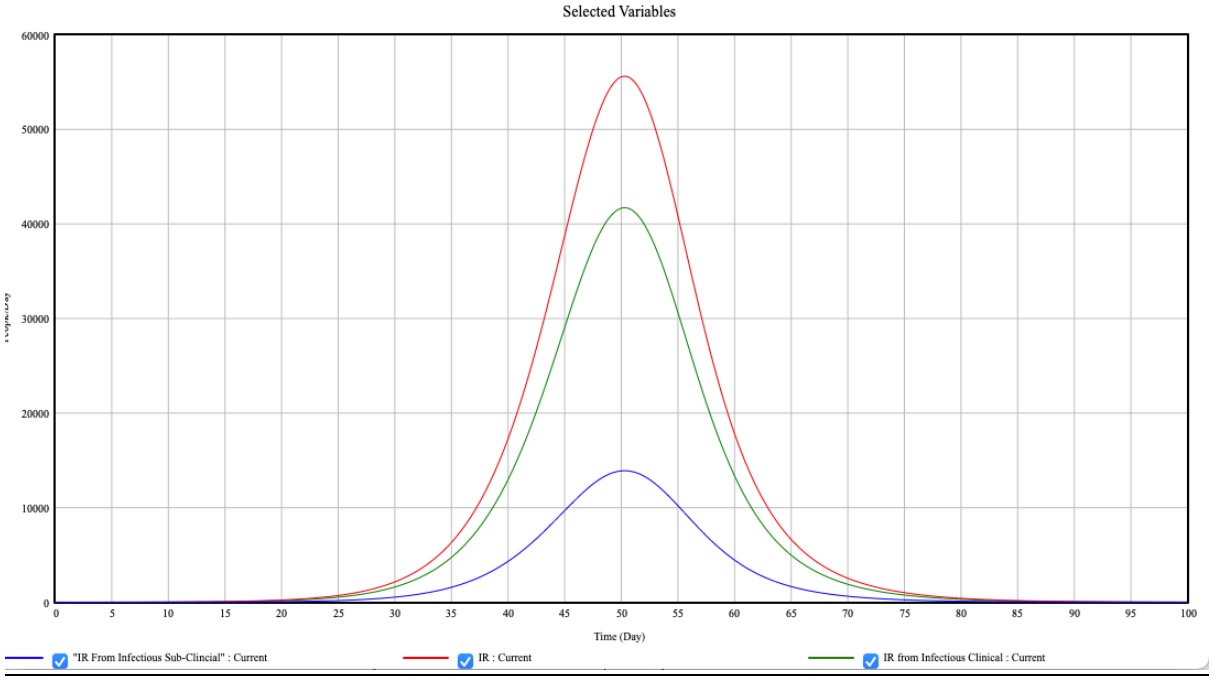
The following model parameters should be used.

Clinical Fraction = 0.6 Exposure Delay = 3 FINAL TIME = 100 The final time for the simulation. Hospital ALOS = 15 Hospital Beds Per 100000 = 538 Hospitalisation Fraction = 0.1 Infectious Delay = 4 Infectivity = 0.1 Initial Infectious Sub Clinical = 10 INITIAL TIME = 0 The initial time for the simulation. Minimum Mobility Index = 0.2 Mobility Index Fractional Change Rate = 0.4	N = 1e+06 Normal Contact Rate = 10 Normal Mobility Index = 1 "Pre-Hospitalisation Delay" = 3 Standard Occupancy Rate = 0.85 Start Time of Restrictions = To be varied Subclinical Effect on Infectivity = 0.5 TIME STEP = 0.125 The time step for the simulation.

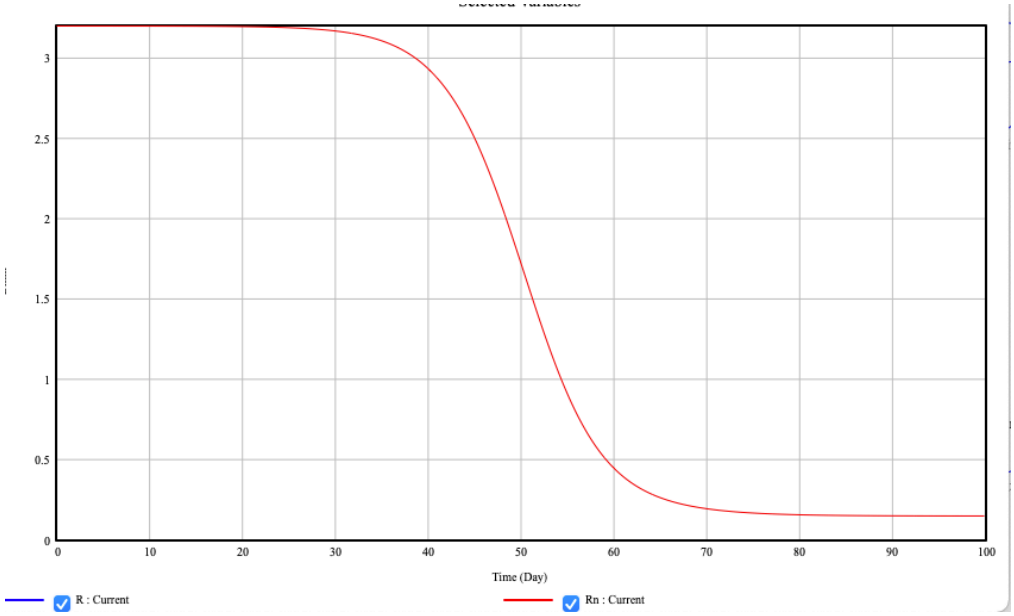
Test Case 1: No Mobility Reduction

The following results should be obtained when running the model without any reduction in mobility.

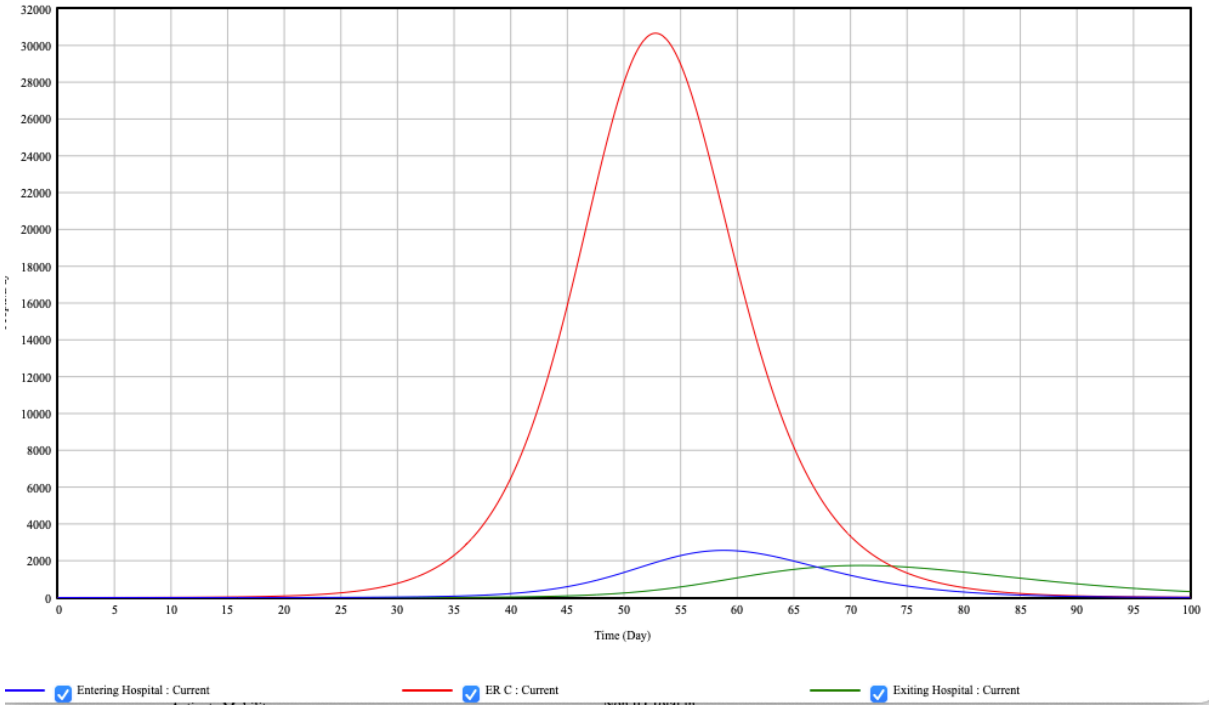
1. *Infection Rates (Total, Clinical and Sub-Clinical)*



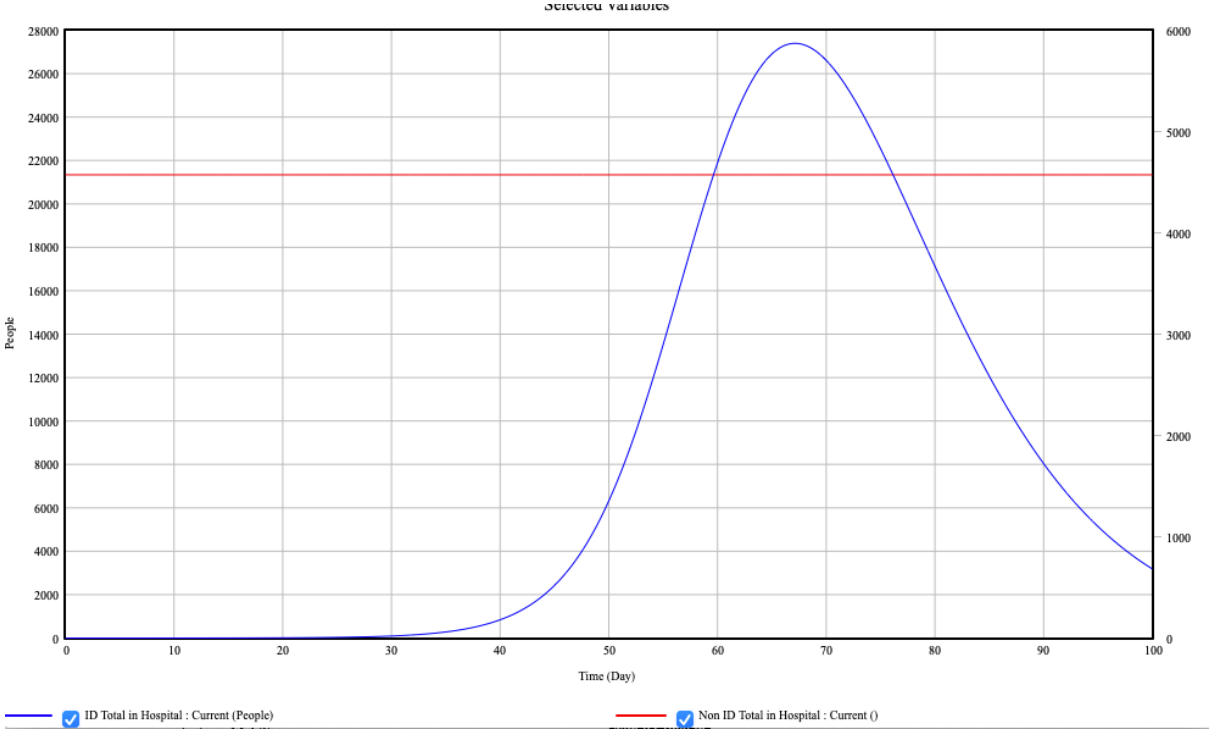
2. *R_0 and R_N (Note R_0 = 3.2)*



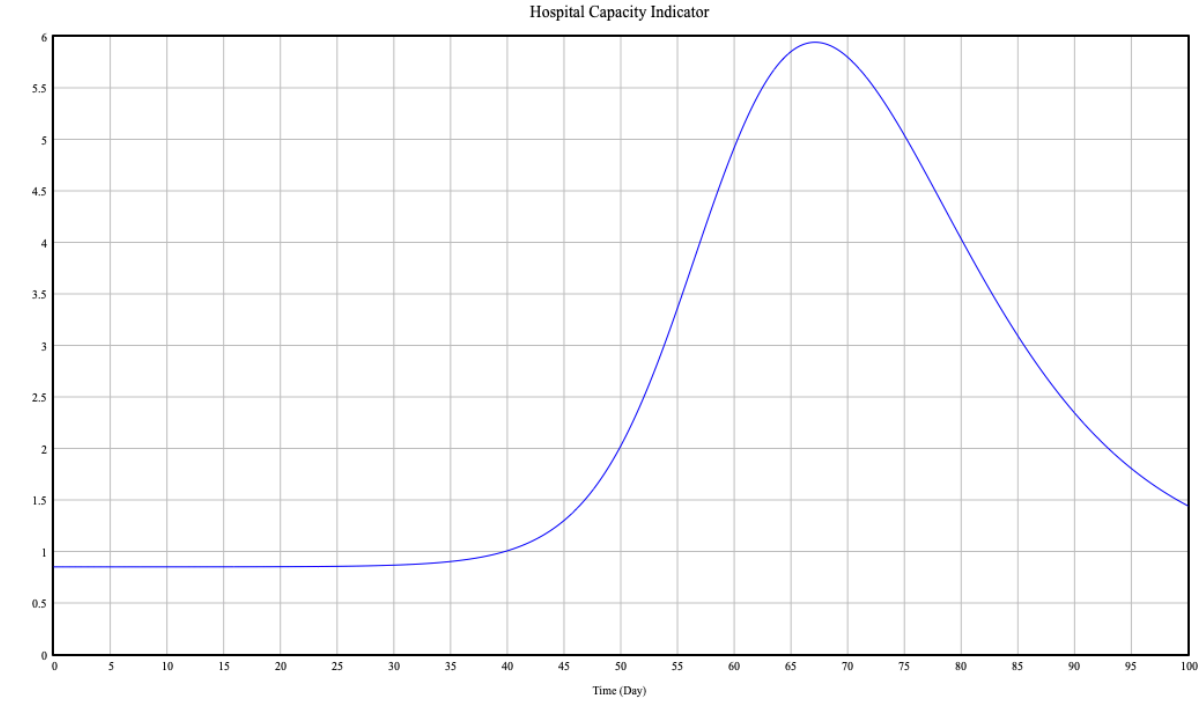
3. *Symptomatic Rate (following Exposure) and Hospitalisation Rate, and Departure Rate*



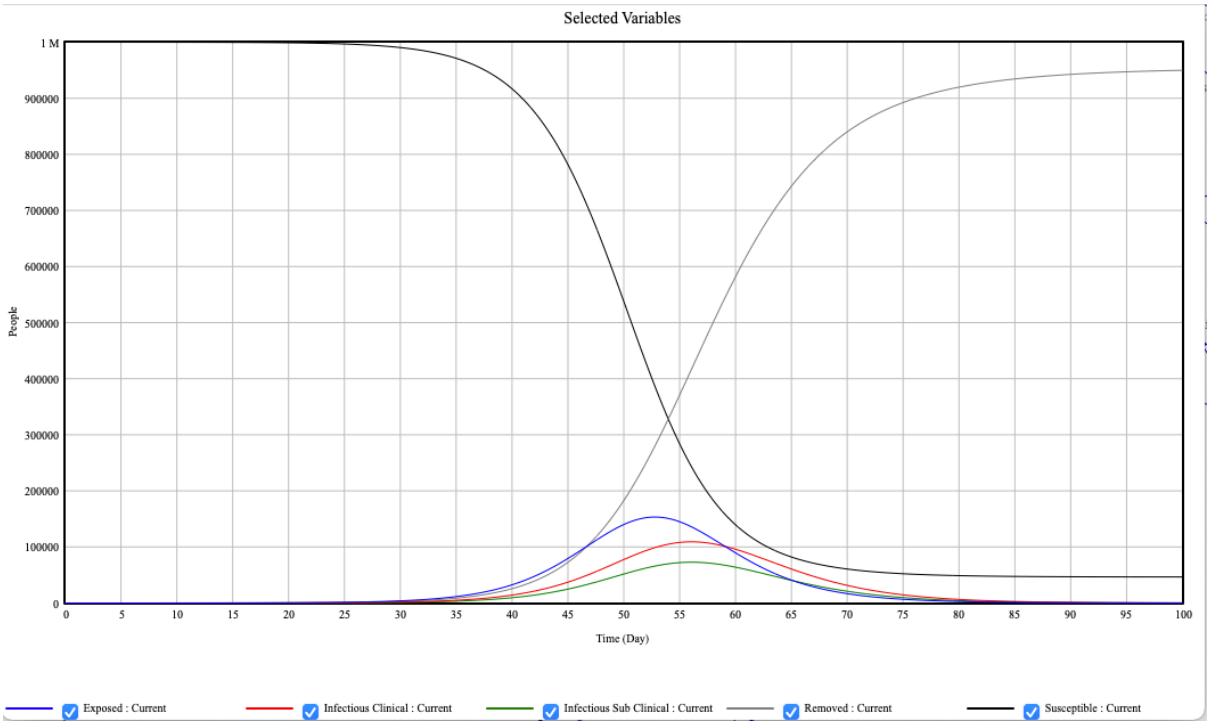
4. *Hospitalisation Numbers (Note Total Hospital Demand is the sum of these)*



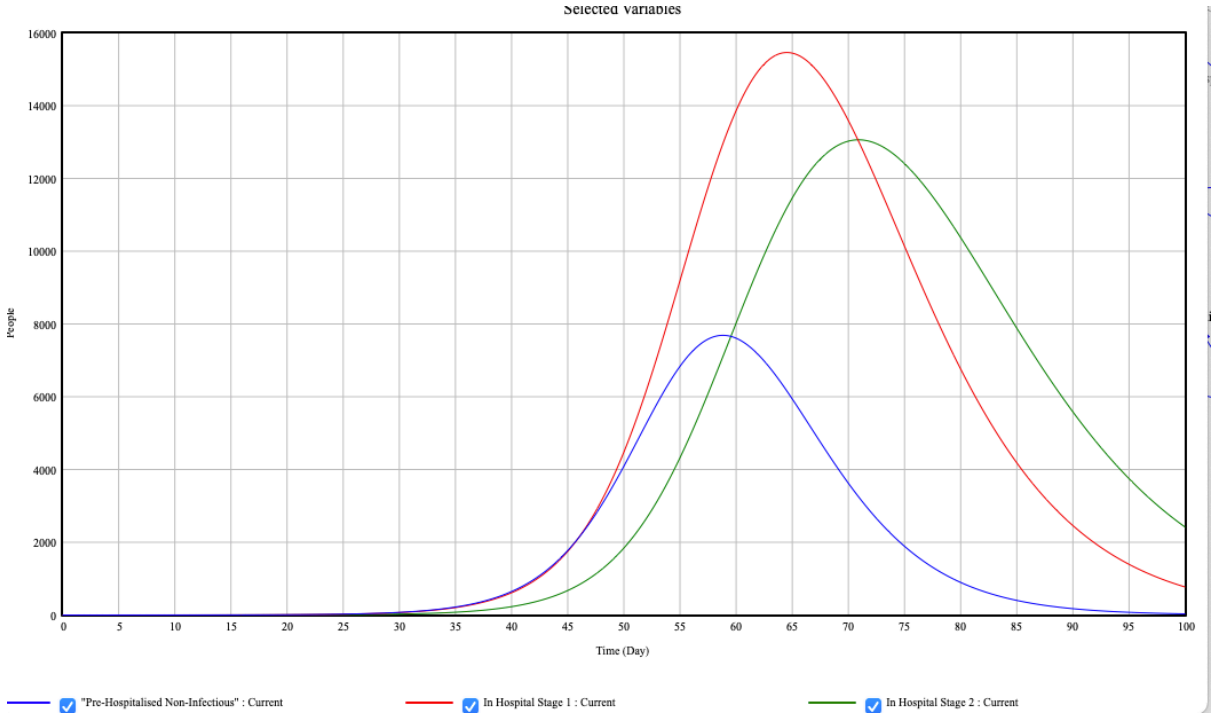
5. *Hospital Capacity Indicator*



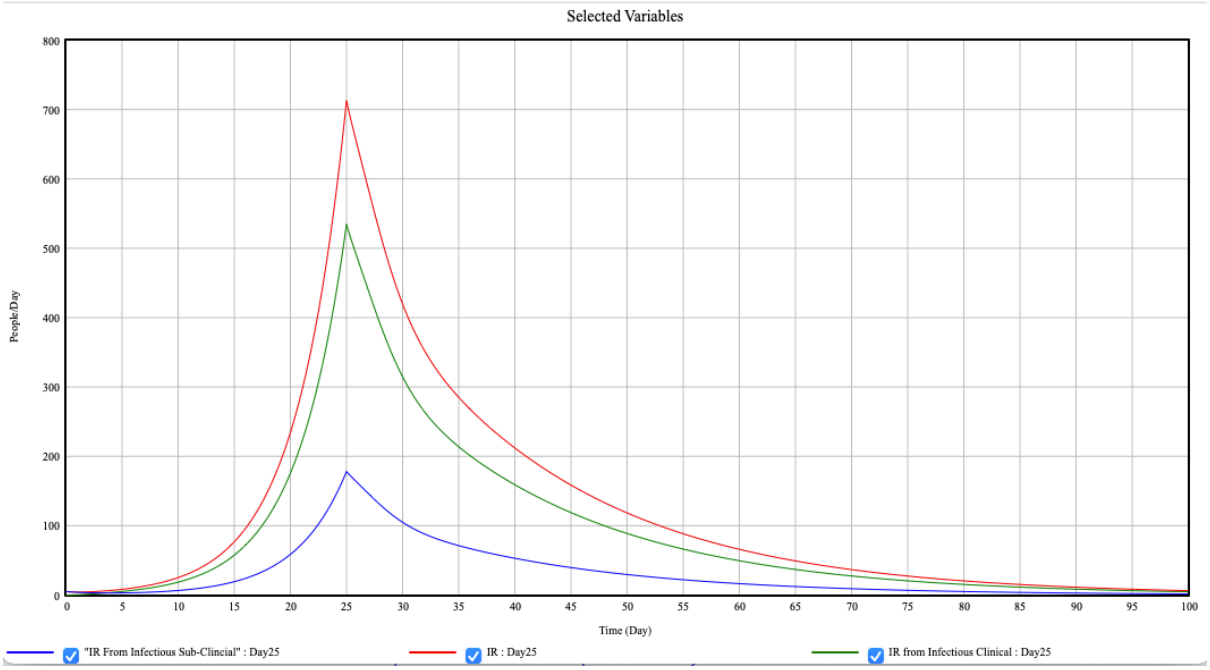
6. *All Epi Stocks together*

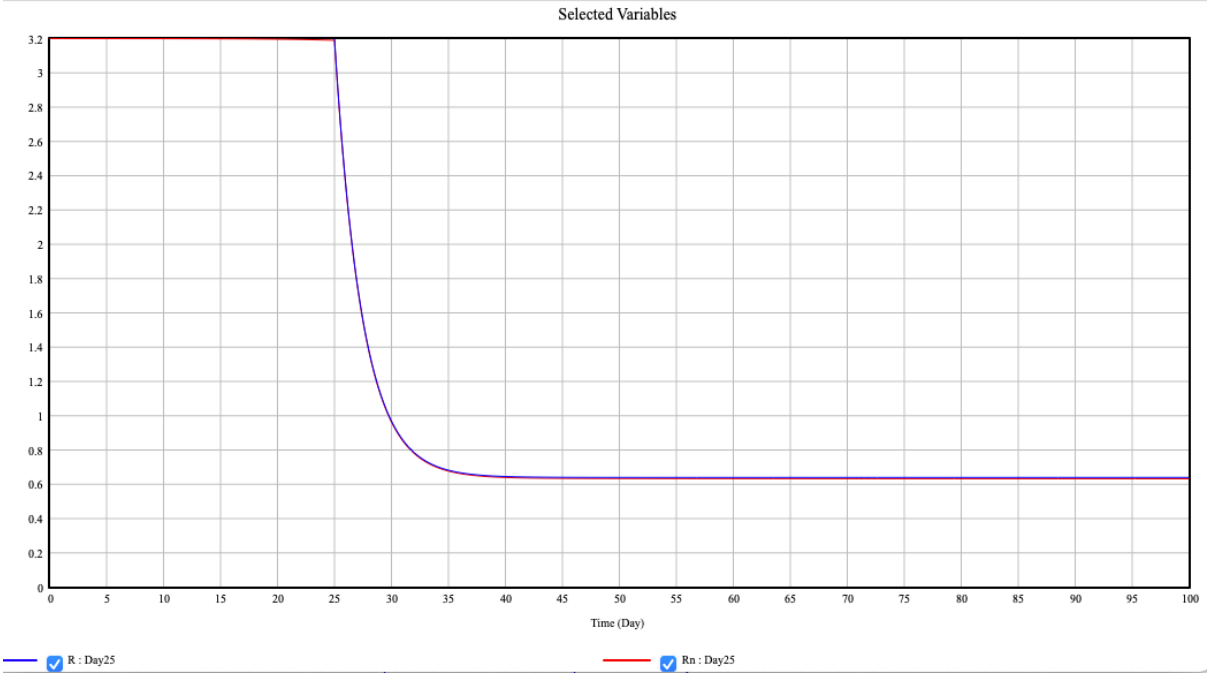


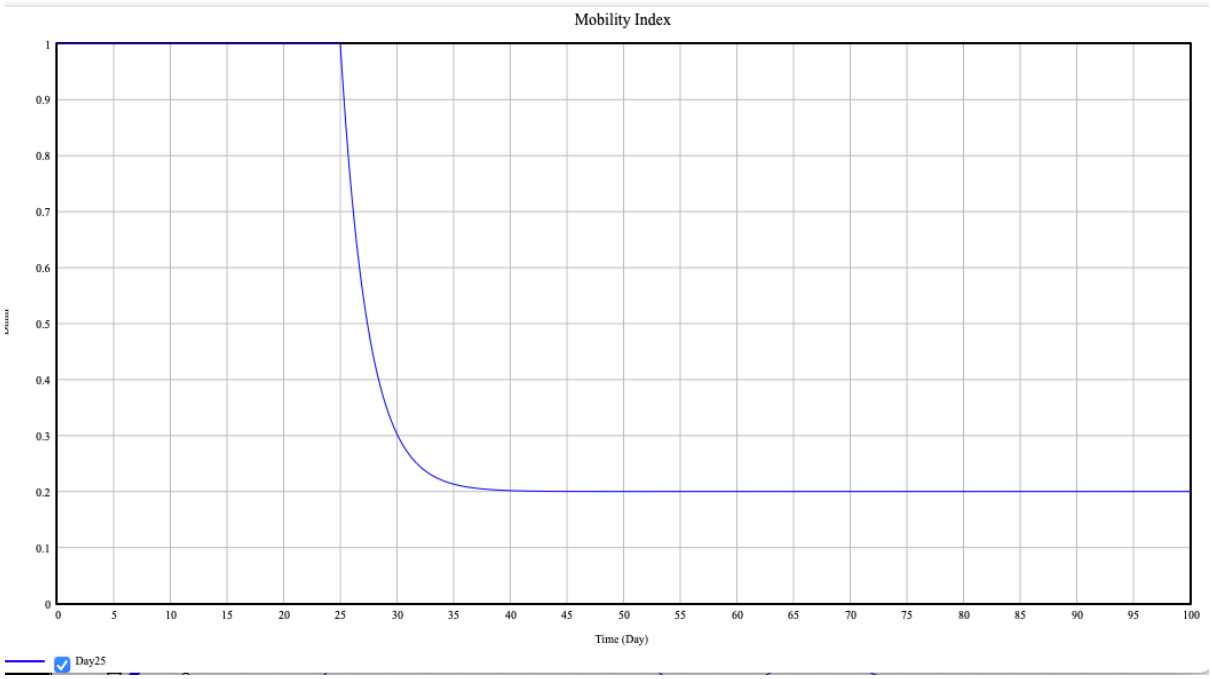
7. *All Hospital Related Stocks*

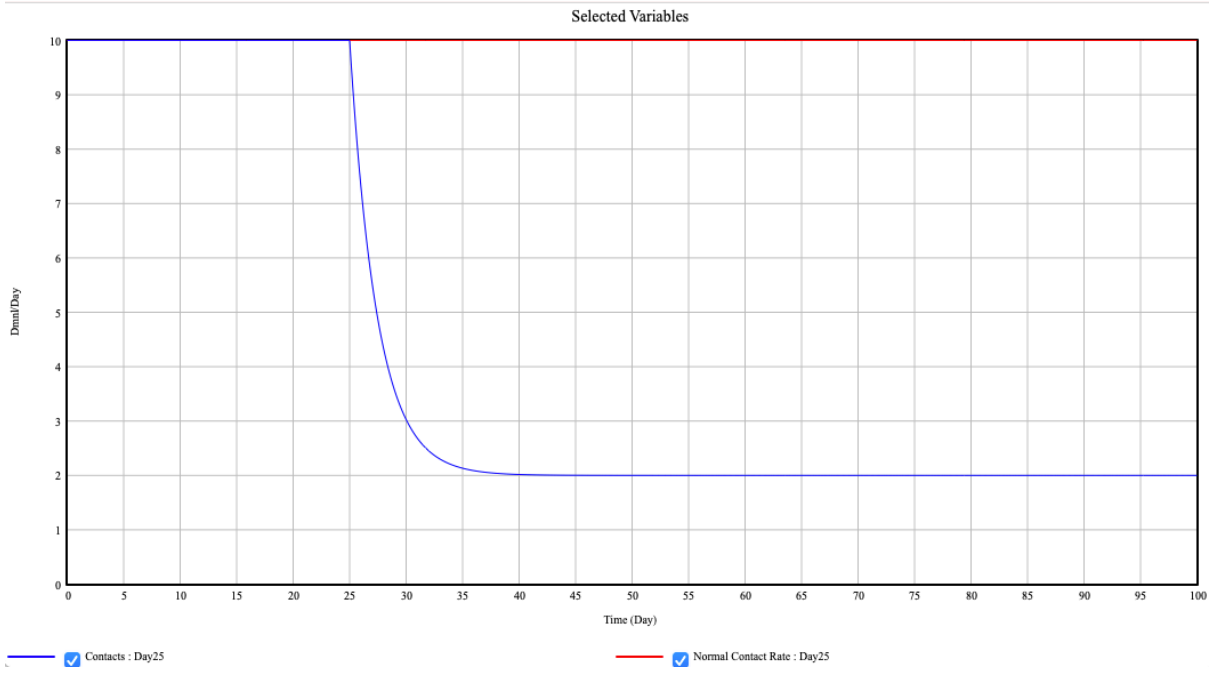


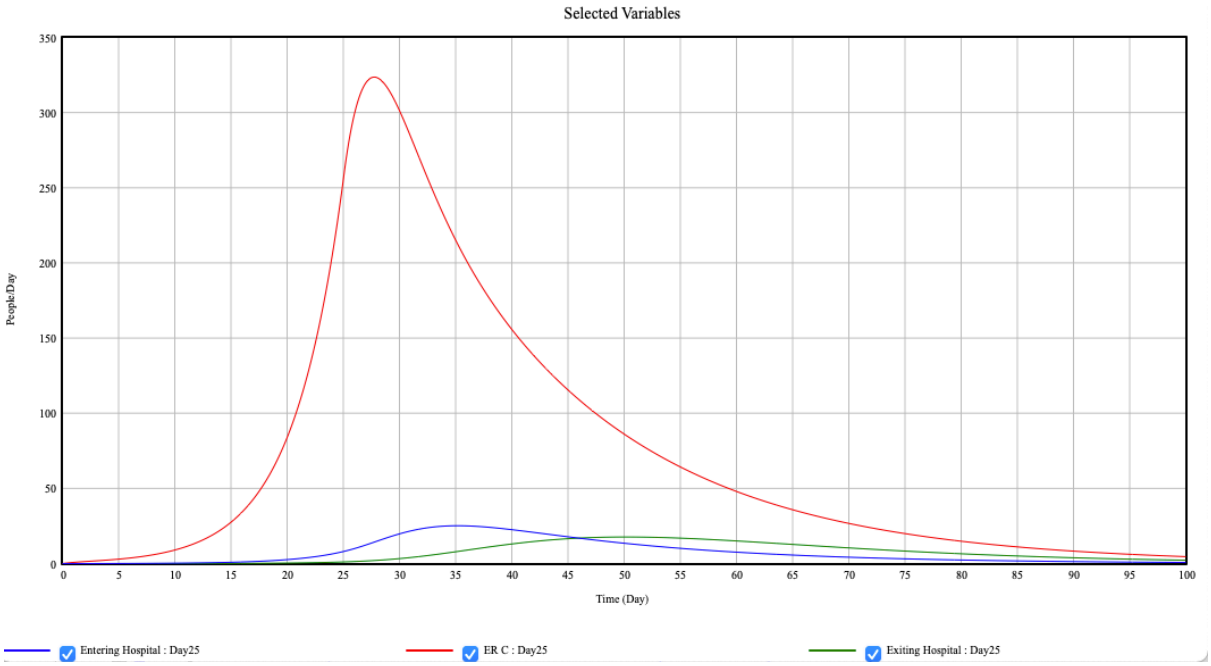
Test Case 2: Mobility Activated at Time 25

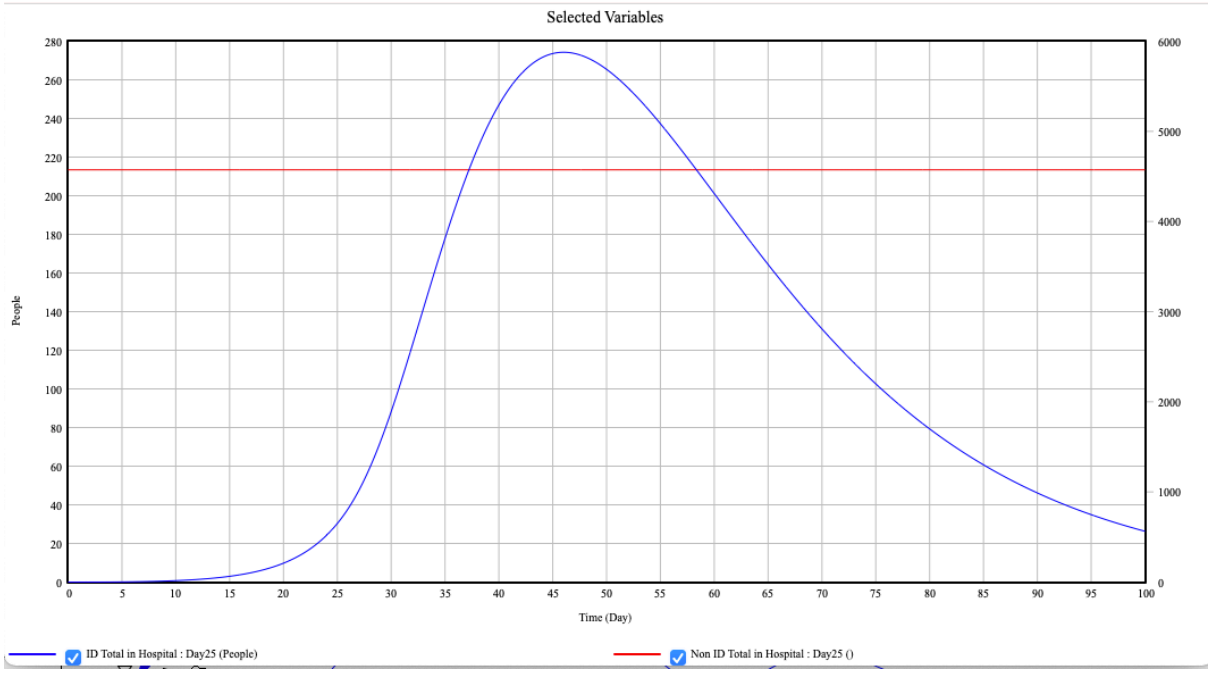


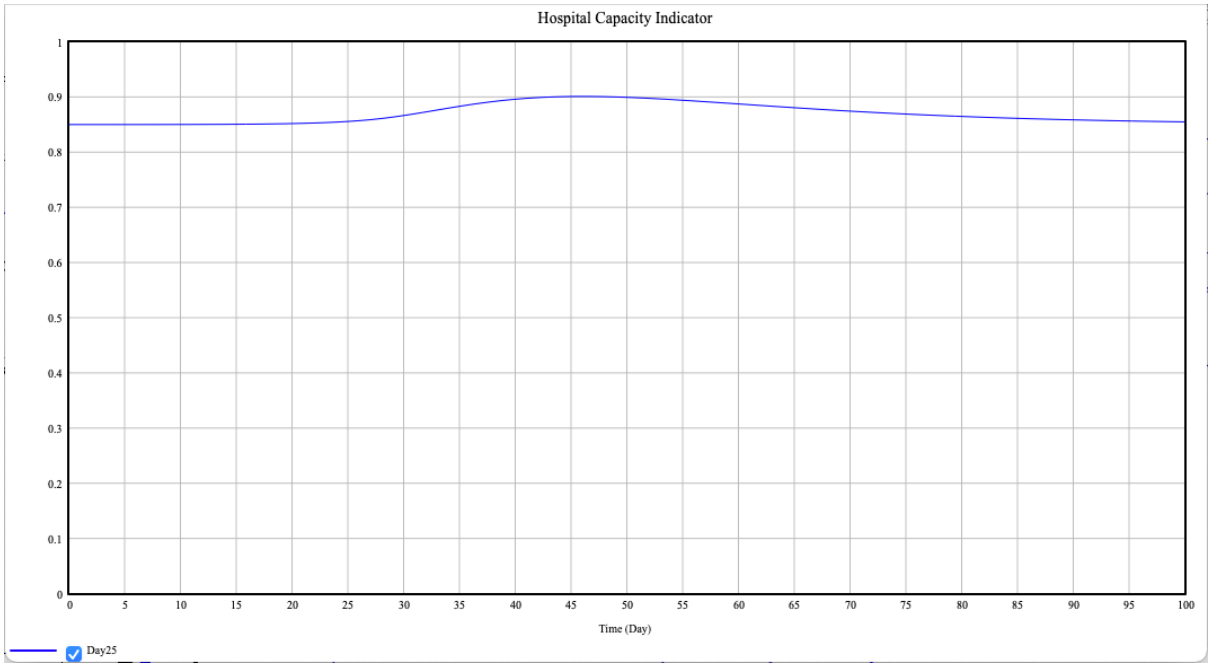


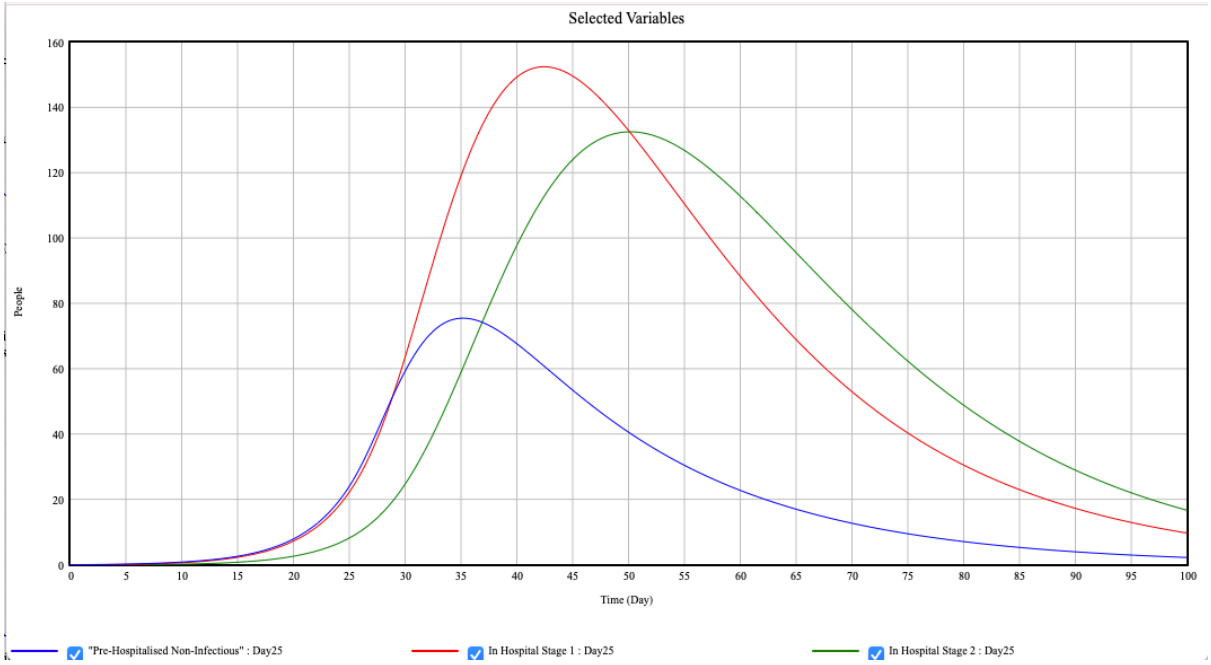

Mobility Index
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Time (Day)
Day25


Selected Variables
Dmnl/Day
10
9
8
7
6
5
4
3
2
1
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Time (Day)
Contacts : Day25
Normal Contact Rate : Day25


Selected Variables
People/Day
Time (Day)
Entering Hospital : Day25
ER C : Day25
Exiting Hospital : Day25


Selected Variables
People
Time (Day)
ID Total in Hospital : Day25 (People)
Non ID Total in Hospital : Day25 ()


Hospital Capacity Indicator
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Time (Day)
Day25


Selected Variables
160
140
120
100
80
60
40
20
0
People
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Time (Day)
"Pre-Hospitalised Non-Infectious" : Day25
In Hospital Stage 1 : Day25
In Hospital Stage 2 : Day25

TASKS

1. Build and test the model. Ensure that it is dimensionally consistent. Check against the model output data set.

2. For the following intervention days scenarios, plot the day of intervention (x axis) against the Maximum Hospital Capacity Indicator. Use Excel to display this relationship.

Intervention Day	Maximum Hospital Capacity Indicator
10	
15	
20	
25	
30	
35	
40	
45	
50	
55	
60	
65	
70	
75	
80	

3. Discuss (1 page) the insights you have gained from these results.

4. Submit:
    - The MDL file
    - The spreadsheets
    - A pdf doc with the chart, and the 1 -page summary of insights.