

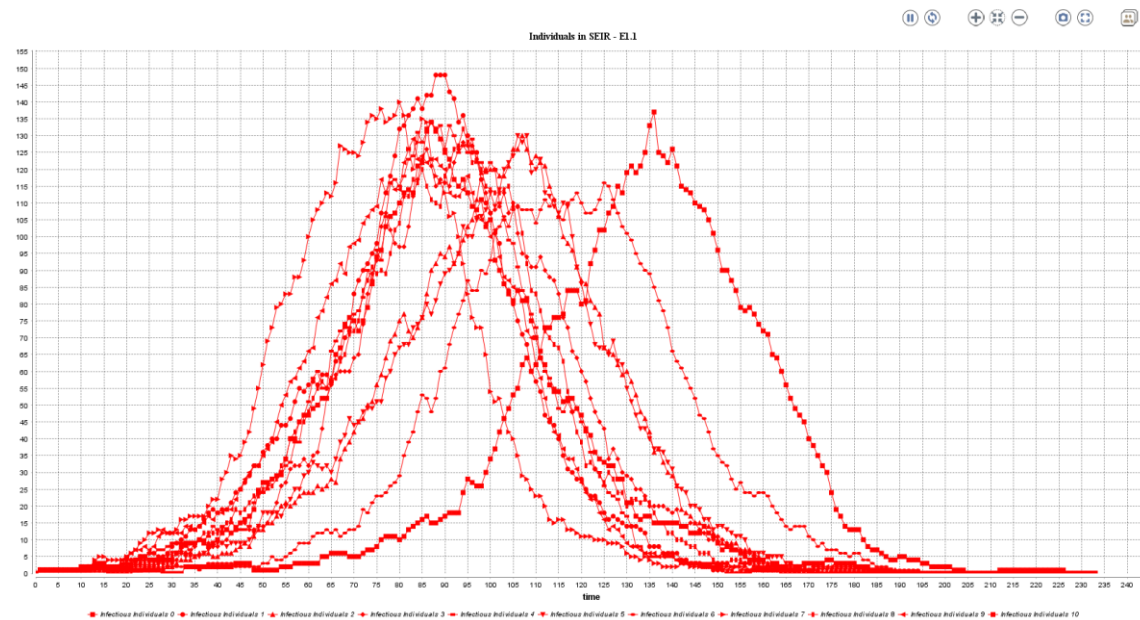
MODELLING AND SIMULATION OF COMPLEX SYSTEMS

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1. Spread of the disease

Exploration E1.1. Effect of randomness

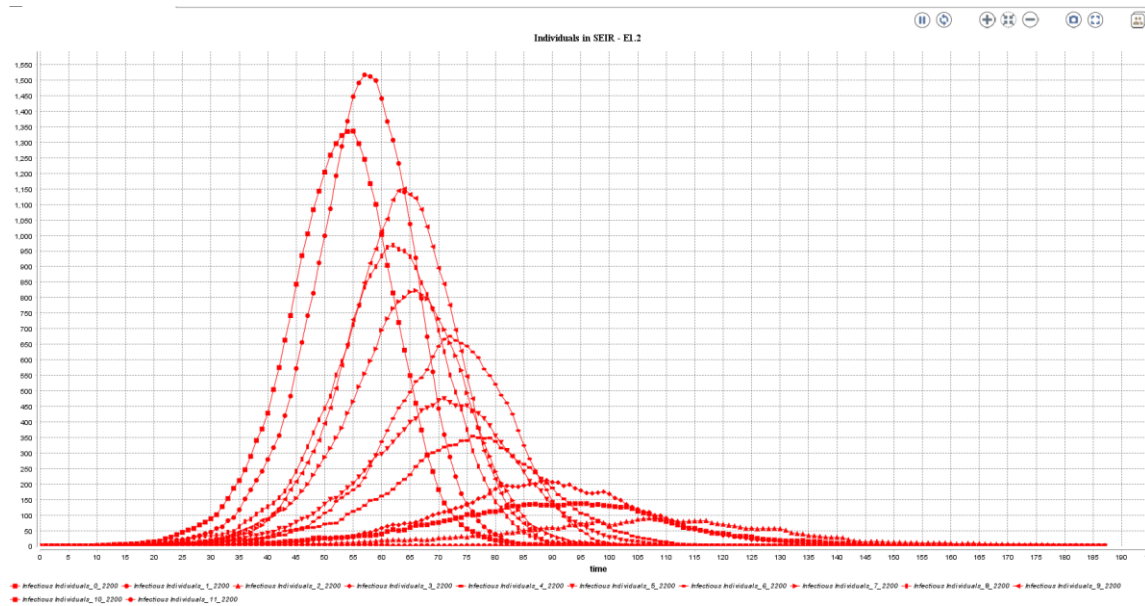
In the chart, each simulation corresponding with a line reaches to a different peak at a different time (cycle). The heights of the peaks vary in the range from 116 to 148 (Individuals) and with time step between 80 and 136. It can be observed that there are about 70% of lines stay close to each other and so they come to the slightly difference height of peak ($\Delta = 5$) and time ($\Delta = 15$ cycles). The randomness which mainly outcomes to the difference of simulations mainly is on the random in movement of Individuals. Understanding how different seed affect the randomness is interesting. The order of execution of reflexes of Individuals agent can also lead to difference, but overall, I think those order can cancel the random effect by themselves.

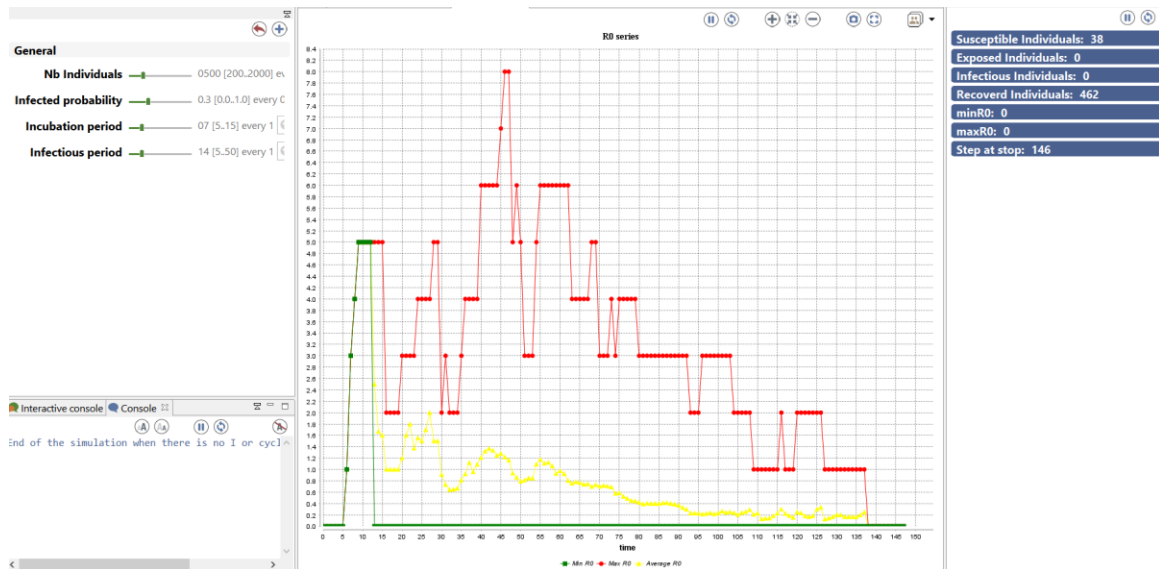


Exploration E1.2. Impact of the number of individuals.

With exploration E1.2, the chart shows clearly and definite the effect of crowd over epidemic. When the population size is large, it leads to the higher density and so people stay closer to each

other and then the epidemic can spread more quickly to many more people. In reality, lives and communities organizing into city is the model which supports epidemic.





2. Spread in a city with a heterogeneous population

In this section the building shape files of traffic model is reused to generate the buildings, roads, etc.

To generate households, the buildings with types are generated at first. After that looping through the building with types home and create the people for that household following the family structure.

Hours of a day and days in a week is also defined base on the step cycle. With day and time available, then agenda for individual with respect to their ages are set up. Agenda only means where to go at what time. Here is the agenda:

* *Week days:*

- *adult: 9-17 100% at work, 18-21: 50% at home, 50% shop, coffee, park, restaurant, 22-8 100% at home*

- *elder: 9-11 100% at hospital, 12-16 100% at home, 17-19 100% at park, coffee, shop, restaurant, 20-8 100% at home*

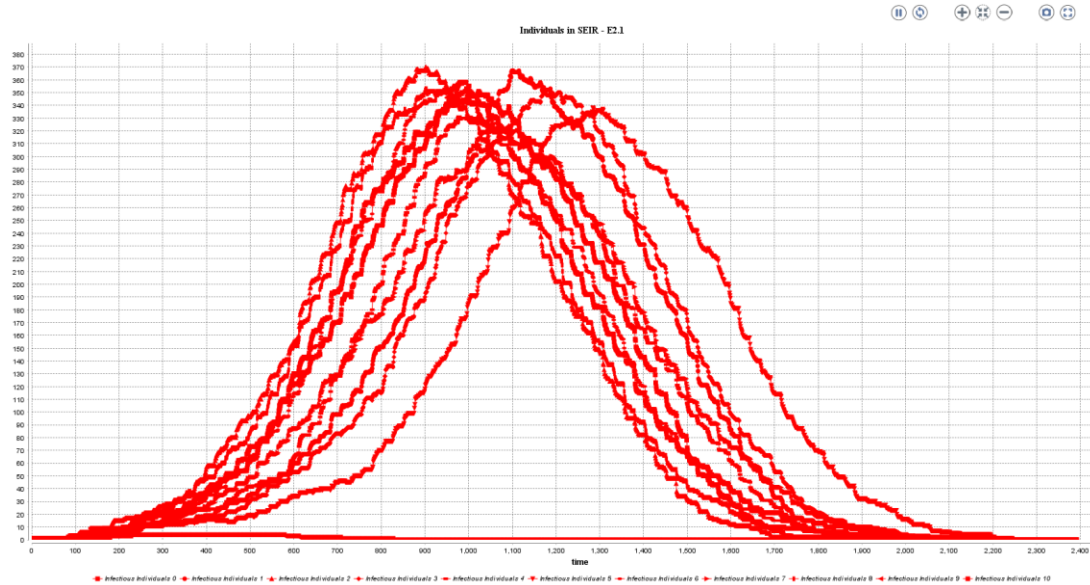
- *student: 9-16 100% at school, 17-18 100% at park, 19-8 100% at home*

* *Weekend:*

- *same agenda: 9-12 shop/supermarket, 13-16 home, 17-21 park/shop/coffee/restaurant*

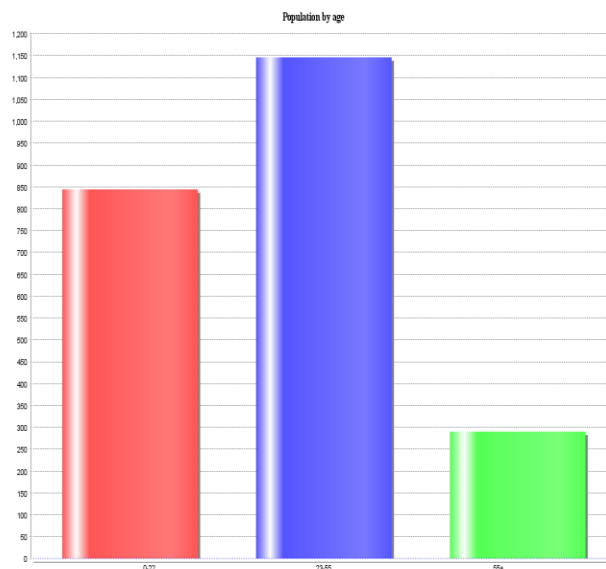
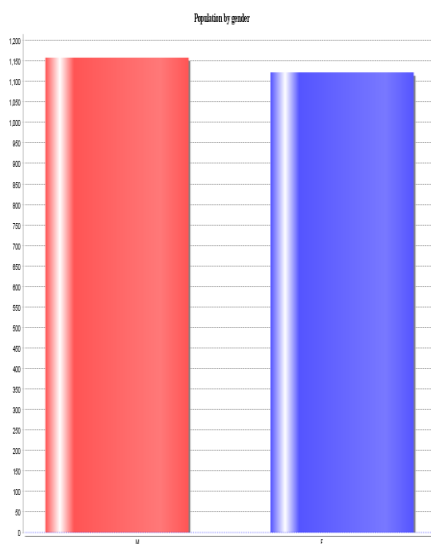
Exploration E2.1. Effect of randomness

The chart shows the difference by randomness, but the lines corresponding with simulations is very close and similar in shape to other. This can be explained by in this model people only move from buildings to buildings (763 buildings), smaller number of places to meet for the virus spreading lead to less random.



Exploration E2.2. Population characteristics

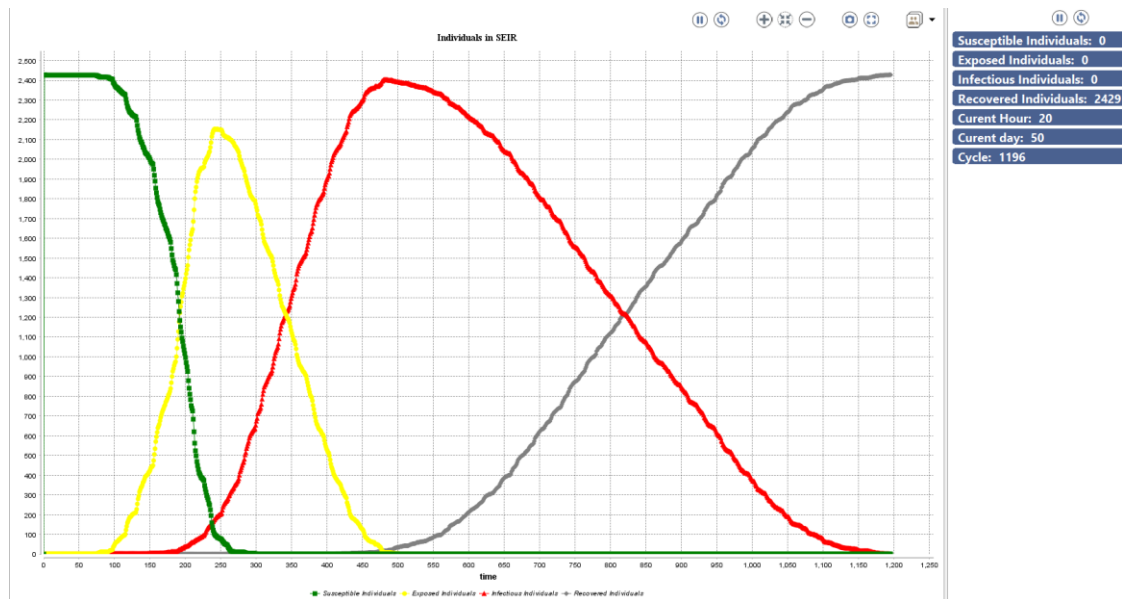
The population is characterized by gender and age. By gender, the ratio of Male to Female is approximately 1:1 and generated randomly. Characterizing by age, the population is young with amount of 37% of people less than 22. The workforce is predominant with half of the population. The rest are elder man with 13%. Golden population of developing country.



Exploration E2.3. Epidemic plotting

Without any policy or restriction, everyone moves freely and the number of parks, schools, offices... are small. Therefore, people will be in same place in some buildings and have high

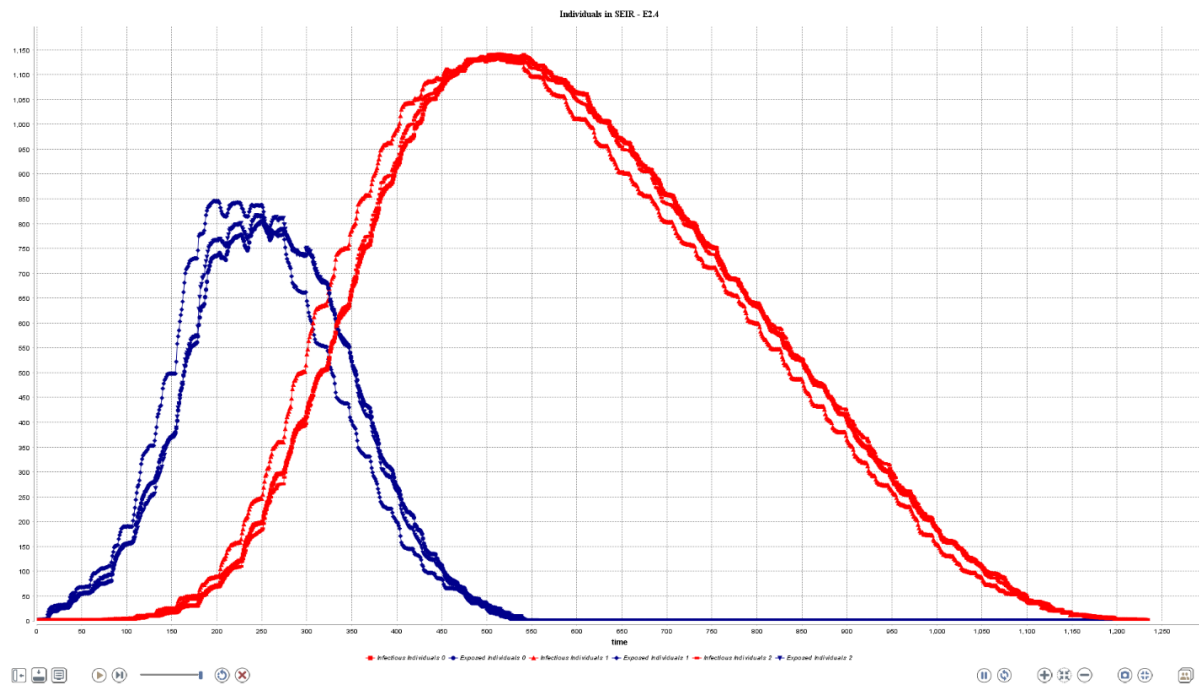
chance to be infected. That explain why the number of susceptible individuals reduces rapidly and vice versa with exposed ones.



Exploration E2.4

The code is implemented with a new variable added `global_env_set` to run the simulation and comparing the disease spread with and without environmental transmission corresponding with value of the variable is set to true or false. In the chart below the line, which is marked with 1, is the simulation with environmental transmission.

It can be seen that with environmental transmission, the number of exposed people on the claiming side is always higher than without environmental transmission in two other lines. The peak is also slightly higher. The difference is only slightly because in the implementation, the virus can only live in the building for 16 hour (less than a day) and the environmental infected probability reduce linearly to the number of hour it lasts. Therefore, it can be seen that effect of environmental transmission is not tremendous.



3. Public health policy

The first counter measure is wearing mask when few first individuals with virus infected symptoms. In the heart of policy to deal with CoVid19 is quarantine and quarantine is defined in two social state are partial lockdown and strictly total lockdown. When partial lockdown is activated, people which are infectious, people meet he or she and the building those people entered will be quarantined. As there is not yet defined the building type specified for healthcare or quarantine center, people will quarantine at home. In the case that hospitals are overloaded or social immune development program allowing self-quarantine at home is eligible. People in state *is_quarantine* have small infected probability to other (demonstration of cross transmission in hospitals). Other which is not in quarantine can still move freely. In total lockdown, only 10% of adults are allowed to go out for work, in the essential situation.

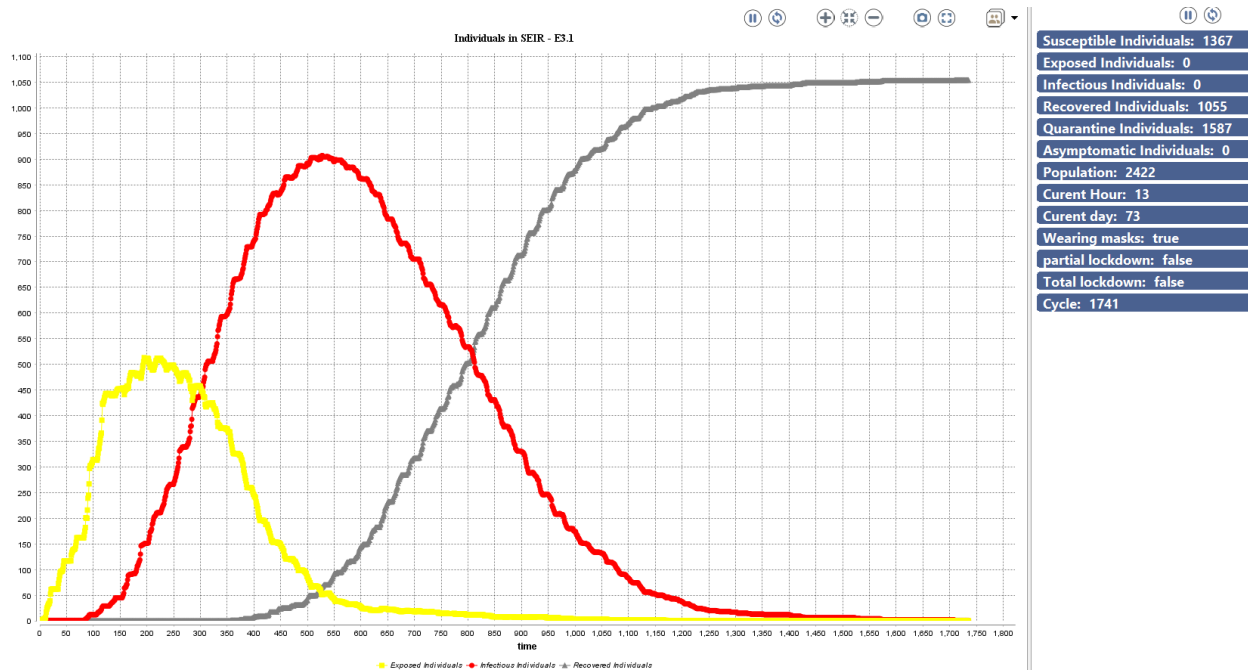
The policy and action by test is defined in Model M3.2 and it is support the decision who to be quarantined (one time positive) and when the quarantine is released (three tests in series negative).

The condition when the policies or lockdown can be removed is also defined.

About the implementation in this sections two species, *LocalAuthority* and *Policy*, are added.

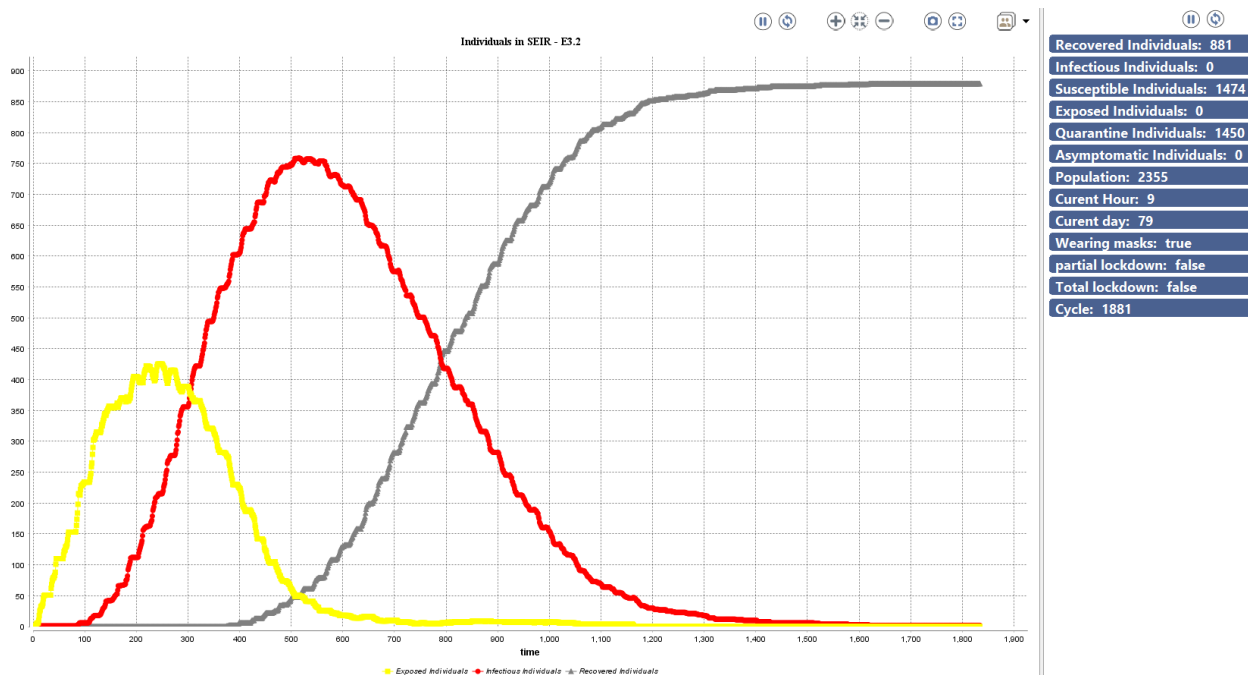
Exploration E3.1. Impacts of these policies

The policies and actions by authority shows its impact clearly in the development of the epidemic. The number of exposed and infectious people in total and at peak reduce greatly. This is great help for hospital system. However, the downside is economic impact and lot of other people lives is not comfortable in quarantine.



Model M3.2. Improve epidemic model

To deal with asymptomatic cases, test policy is introduced at this model. Impact is about 15% reducing of number of exposed and infectious case at peak.



4. Space of freedom

Many real things can be added to the model, more complicated family structure and agenda for ages or adults staying at home to take care of baby, etc. More category of buildings can also be added and can change the place to quarantine. However, I will leave it for future time if I have a chance.