Hw Kim: Simulation Delft

More documentation is available upon request.

What exactly is it? [1]

This model uses “corona in Simcity” approach to *study individual and social reactions to the containment policies*

This model is a tool for decision makers to *explore different scenarios and their effects*

It is not a model to *generate predictions*

It simulates the behavior of a *synthetic population given a set of* policies (for example when in a lock-down or voluntary isolation)

It enables to study the effects on both the spread of the contagion and on how people can be expected to react to the policies (e.g. potential violations or workarounds).

What answers does it provide? [1]

It models both the *possible effects on the spread of the coronavirus* and the *socio-economic effects* of the policies, providing possible answers to:

- How might policies based on achieving drastic behavioral change go *wrong?*
- How might one *work with existing social norms and habits* to effectively limit virus spread (what will work with populations and what will not?)
- How might we *reintroduce people* who have recovered from the disease back into society to help others and revive the economy without this leading to *social division* and a general breakdown of social distancing?
- What are the possible dangers of *social polarization* between vulnerable older people and the young who want to get together, how might we keep younger people “on board”, how might we stop them losing contact with other generations?
- For particular groups within societies, at particular times of year or day are there safe gathering *activities with very low risk of contagion?* Are there practices that are particularly dangerous.
- What *new social practices* might we develop that allow life in a world susceptible to waves of new infection (e.g. red and blue teams in hospital so there is no overlap)?
- *Timing and consequences* of lifting the restrictions

How does it work? [1]

The simulation is based on a set of *artificial individuals, each with given needs, demographic characters, and attitude towards regulations and risks* (ODD document)

All these agents decide each time what they should be doing

Because of this, many different possible effect of policies can be analyzed

NetLogo simulation:

- Number of *agents* exist in a grid: can *move*, *perceive* other agent, and *decide* on their actions based on their individual characteristics and their perception of the environment
- Environment: *constrains (limits) physical actions* of the agents, *impose* norms and regulations on the agent's behavior
  (for example: the agents must follow roads when moving between two places/ the environment can also describe rules of engagement such how many agents can occupy a certain location
- Through interaction, agents can take over characteristics from other agents
  For example: get infected with coronavirus/ receive information

Agents have:

- Needs (health, wealth, belonging)
- Capabilities (jobs, family situation)
- Personal characteristics (risk aversion, proposition to follow the law)
- A minimum wealth value to survive (receive by working/subsidies/living together with working agent)
- The ability to trade wealth for products and services in shops and workplaces
- To pay tax to a government that then uses this money for subsided, and the maintenance of public services (hospitals/schools)

Places:

- Homes (different households can be represented: families, students rooming together, retirement homes, three generation households, co-parenting divorces agents)
  → the distribution of these households can be set in different combinations to analyze the situations in different cities or countries
- Shops
- Hospitals
- Workplaces
- Schools
- Airports
- Stations

Policies:

- Interventions that can be taken by decision makers (social distancing, testing or closing schools and workplaces)
- Have complex *effects for health, wealth, and well-being* of all agents
- Can be extended in many different ways to provide an *experimentation environment* for decision makers

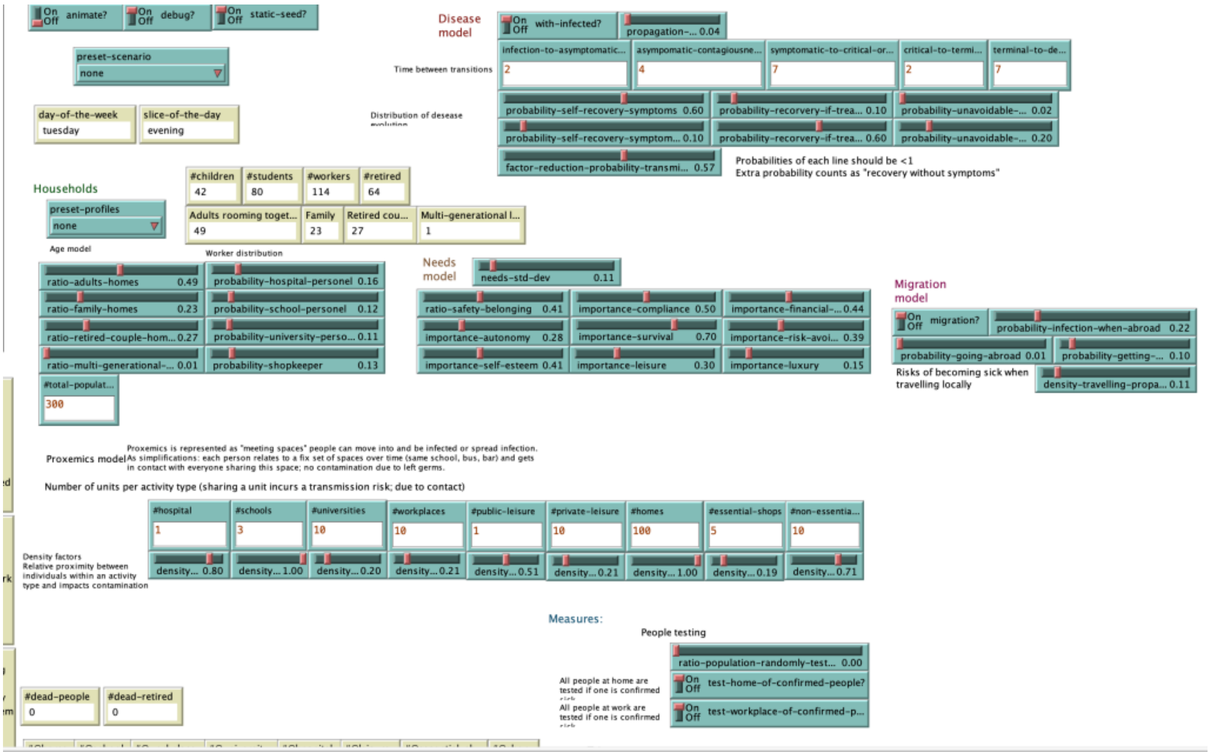

Figure 1. a screenshot of the parameter setting in the NetLogo model. (ASSOCC, 2020)

Based on theories from sociology that describes individual behavior as a result of a combination of *basic values, motives, and affordances* over many *contexts*

This is implemented as a combination of 3 types of needs:

1. psychological needs
2. social needs
3. physical needs

together they determine the reaction of agents to policies and their physical and social context

<u>design</u>

The framework is based on the fact that individuals have to *balance their needs over many contexts*

The following image shows how people manage this balancing act in their daily life:

Figure 2. balancing of needs. (ASSOCC, 2020)

- assume that people have a *value* system that is reasonably consistent over times, contexts and demands (Critique: values might chance because of the impactful pandemic)
- second type of drivers of behaviors: *motives*: indicates that people want to achieve some goals
  - *achievement*: wanting progress from the current situation to something better
  - *affiliation*: basic need to be together with other people and socialize
  - *power*: wanting to be self-efficacy: being able to do task without help
  - *avoidance*: avoiding situations in which we don't know how to behave or what to expect from others

  example: I might go to a colleagues office to ask a question rather than e-mail her, just because I want to have a chat '

- third type of elements that determine behavior: *affordance*: determine what kind of behavior is available and what type of behavior is salient
  example: in a bar one often drinks alcohol. Even though it is not obligatory it is salient and also afforded easily
- individuals have to *balance their values, motives and affordances* to determine what behavior would be more appropriate in each situation: *norms*, *conventions, social practices, organizations, institutions*

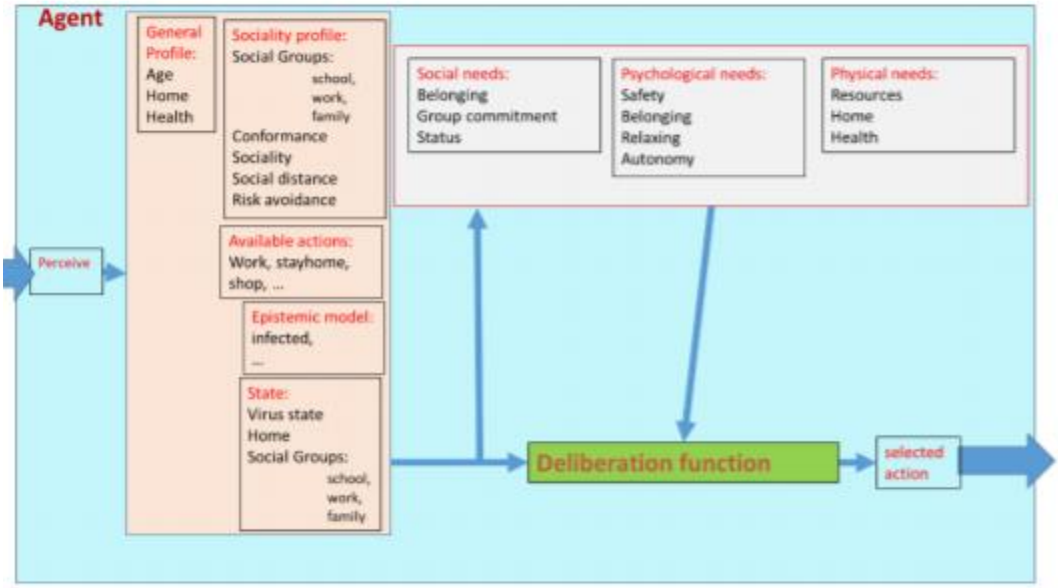

Figure 3. agent architecture. (ASSOCC, 2020)

The most relevant values are picked for the base situation

Other values can be added when specific when particular aspects are focused on (critique solved)

The needs drive the *deliberation function* that determines the *behavior* at each moment

Input comes from *needs* and *agent profile and state*

Epistemic state: indicates whether an agent knows whether he is infected, immune or not

selecting an *action:*

1. an agent creates a *list of all possible places* (gathering-points) it can go with different motivations = an action
   this list is based on their current age, time of day, day in week, parameters set in the model
2. for all these actions, the global *expected effect* on the needs is calculated (summing over the expected effects x the desire for each main need)
3. the action that satisfied the *highest number of needs* is selected to be acted upon

after all agents have moved to the location where they want to execute their action, the actions get executed, and the needs get updated

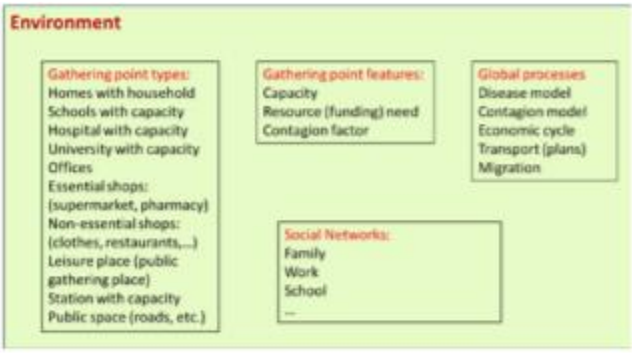

Figure 4. the environment contains the following social and physical elements. (ASSOCC, 2020)

3 cycles that influence the daily activities and interactions between the agents:

1. *daily pattern* of life that forms the basis of all actions of an agent
2. *COVID-19 status*: agents do not know whether they are infected or not until they are tested or have symptoms
3. *Closed economy cycle*: implemented in order to handle the fact that schools, hospitals, shops, and offices/production needs labour in order to produce their services or products.
   Example: when agents cannot work in the shops the shops have to close

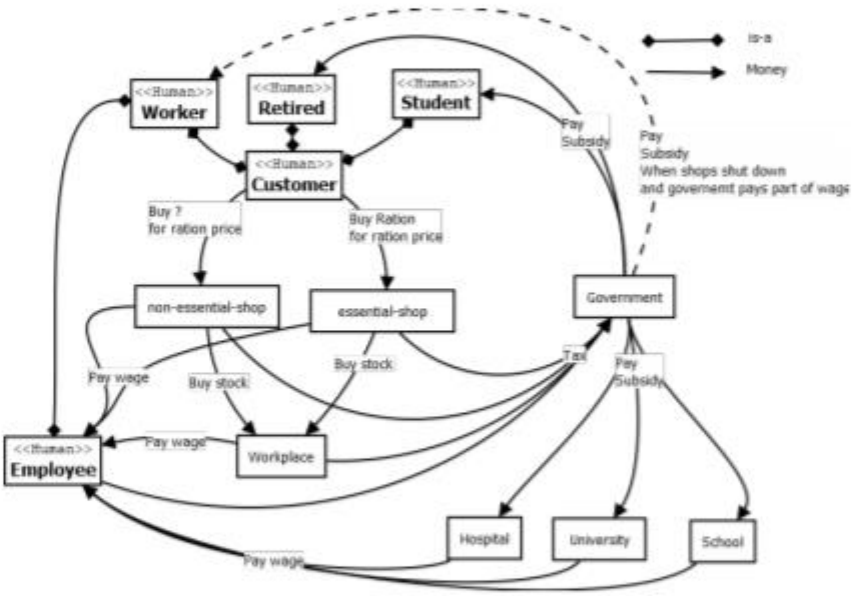

Figure 5. main cycle economic cycle. (ASSOCC, 2020)

ODD protocol: Overview, Design concepts, Details

Variables agents:

Variable Name	Values	Description
Age	youth, student, worker, retired	Age group of the agent. Youth refers to children, and students to university students.
Infected Status	Not infected, immune, unknown, infected-mild, infected-serious, infected-critical	Infection status of the agent. Unknown means that the agent doesn't know if she is infected or not. Infected-mild means only showing mild symptoms. Infected-serious means care at home. Infected-critical means hospitalized.
Epistemic status	Healthy, infected, immune	Belief about own infection
Mobility (globally)	Isolated, quarantined, free	Mobility of the agent. Isolated means here working from home but going to grocery store and for a walk.
Social Aspects		
Social		Importance of social contact to the person
Keep Social Distance		How important is keeping social distance to the person
Follow Rules		How likely is the agent to follow rules
Risk-avoidance		How risk avoidant is the agent, e. g. is she easy to fear and stay at home, similar to Granovetter's model
Social Network		Friends of the agent

Needs: got and gone away

Event	Needs satisfied	Needs depleted
Being with your friends/family at a private leisure place/home	Belonging	Safety
Being alone at a gathering point		Belonging
Being at gathering point with food	Survival	
Going to work	Financial need	
Going shopping	Belonging, Self-Esteem	Financial need
Going to school/university	Compliance	
Being locked up		Autonomy
Following the rules	Compliance, safety	Autonomy
Being at leisure place	Self-Esteem	Risk-avoidance, safety
Avoiding other agents	Risk Avoidance, Safety	Belonging
Testing	Safety	
Not being constrained in your actions	Autonomy	Compliance
Do what your social network is doing	Conformity	

Gathering points: contexts where people get near to each other = a central factor for virus propagation in the disease model

Gathering point		
Type	hospital school shop office public leisure private leisure home ...	Type of business conducted within this activity (serves as a motivational factor for agent decisions)
Proximity-factor	[0,1]	Proximity induced by this activity.
Can be practiced at a distance	yes/no	
Available food rations	Integer	Amount of days one agent can survive based on the available food at the store
Amount of capital	Integer	Amount of capital a gathering point has

Current profit	Integer	Amount of profit made this tick
Max. amount of capital to retain	Integer	Amount of capital the gathering point wants to keep
Stock of goods	Integer	Amount of goods available for sale

Each agent is related to a set of gathering points and each gathering point is related to a set of agents

Various agents can have different relations to the same gathering point, thus entailing different reactions to e.g. lockdown or fear

Household = set of agents, which is related to a gathering point home

Gathering relations		
Commitment	[0,1]	Importance given by the person to the activity (vs. fear)
features	list of motives	Why this person would get in this gathering (e.g. work, rest, supply), whether work can be completed from this gathering point

Gathering points are set up as follows:

Gathering Point	**Amount**
Homes	100
Schools	3
Universities (More like faculties)	10
Essential shops	5
Non-essential shops	8
Hospital	1
Workplaces	10
Station / Airport	1
Public Leisure places	1
Private Leisure Places	10

Different households:

Type	Implications
Adults rooming together	One or more agents who are workers or students
Retired couple	Agent is retired and has a partner based on probability
Family	At least one agent is a worker. Either or both of these agents can be divorced (only relevant for initialization) with a certain probability. They can also get assigned zero or more agents of age “youth” or “student”. If either of the parents is divorced, then these children can get assigned to two households
Multi-generational living	Families live with 1 to 2 retired agents

Disease model: describes how the COVID-19 disease is implemented in the model

The following states are implemented:

State	Days between transition
Infection	2
Asymptomatic contagiousness	4
Symptomatic contagiousness	7
Critical or Heal	2
Terminal	7
Death	-

Agents transition into the next state:

Disease profile	Description
self-recovery with no symptoms	The agent will recover after a few days without displaying symptoms
self-recovery with symptoms	The agent will recover after a few days, and will also display symptoms
recovery if treated	The agent will only recover if it gets treatment
unavoidable death	The agent will transition through the different disease states until it dies

Distribution of the diseases:

Parameter	Description
Propagation risk	Risk of propagating the disease
Self recovery	Probability of self recovery when having symptoms
Self recovery old people	Probability of self recovery when having symptoms for old people, i. e. retired agents
Reduction probability transmission young	Young people, i. e. youth agents, have a lower probability of transmitting the disease
Recovery if treated	Probability of recover if getting treated
Recovery if treated old	Probability of recover if getting treated for old people, i. e. retired agents
unavoidable death	Probability of unavoidable death due to the disease
unavoidable death old	Probability of unavoidable death due to the disease or old people, i. e. retired agents

In order to determine if an agent gets the disease, the propagation risk is multiplied by a factor that represents the density of the gathering point they are currently at

They can only get contaminated if they are at a gathering point where there is another agent with the disease

Epistemic status:

Belief	Reasoning
Healthy	No symptoms
Infected	Sick and visible symptoms
Immune	Belief infected and not showing symptoms for three days

Agents can decide to get tested: update their epistemic status

Probability of mode choice:

	Child	Student	Worker	Retired
Solo transport	25%	30%	45%	75%
Public transport	75%	60%	40%	20%
Car sharing	0%	10%	15%	5%

Migration model: in order to model the effects of traveling

Parameter	Description
Probability going abroad	Probability of the agent going abroad
Infection when abroad	Probability of the agent getting infected when e´being abroad
Probability getting back from abroad	Probability of the agent coming back when being abroad
Density travelling propagation	Risk of getting infected when travelling locally (within the city')

Government guidelines and interventions: sliders can be used to make the time they are in place adjustable (intervention corona app is not present)

Policy	Description
Social Distancing (contact)	Public gatherings of max. X people are allowed
Social Distancing (space)	Keep at least X meters between you and other people
Self-Isolation	Stay at home if possible (including home-office), but still allowed to go shopping
Self-Quarantine (person)	Stay at home and not allowed to outside anymore
Shielding	Extremely vulnerable people stay at home and have only contact to people who provide essential support
Quarantine (city, area)	Put the city or area under quarantine and let no one leave or enter
Home-office	People should do home-office if possible
Closing schools, and universities	Close schools and universities
Closing non-essential shops	Close non-essential shops, such as clothing stores
Closing leisure places	Closing public leisure places, such as parks, restaurants, bars, ...
Lockdown	

Different functional groups can have different schedules:

Functional group	Schedule
School	Home – School – Home
	Home – School – Leisure – Home
University	Home – School – Home
	Home – School – Leisure – Home
	Home – School – Shopping – Home
Work	Home – Work – Home
	Home – Work – Leisure – Home
	Home – Work – Shopping – Home
Retired	Home
	Home – free choice (except work) – Home

Actions implemented in the model and performed by agents:

Action	Description
Essential Shopping	Going to essential shops, supermarket, once ration are needed
Non Essential shopping	Going to non essential shops
Relax at leisure places	Agents can relax at leisure places
Testing	Agents can decide to get tested at the hospital.
Getting treatment	If there are beds available at the hospital and the agent beliefs it is sick, then it can get treatment at the hospital
Stay at home	Agents can decide to stay at home either during lockdown or whenever they want, like retired agents for example.
Go to work	Work agents will go work in the morning and leave in the evening on work days
Go to university	Student agents will go to university in the morning and leave university in the evening on work days
Go to school	Youth agents go to school in the morning and leave school in the evening on work days
Working from home	Agents can work from home, if their work is doable from home and lockdown is active.

In the model, these actions are represented as a location, a motivation, and whether or not the agent will apply social distancing

actions are chosen based on the depletion of the needs

day is divided into four slices in the simulation: morning, afternoon, evening, night

If we know what variables will change due to the implementation of our Corona app, and how exactly these variables will change, we can adjust these variables in this model and see the effect of it

Disease and contagion models

The following parameters for disease and contagion are used

State	Days between transition
Infection	2
Asymptomatic contagiousness	4
Symptomatic contagiousness	7
Critical or Heal	2
Terminal	7
Death	-

Not yet modeled:

- Asymmetric contacts for gathering points (e.g. cashiers at shops meeting many customers; whereas customers meet only few people).
- Detailed duration
- Size of the space, distance in meters between people
- Points of contacts, confined highly-used, one-person-at-a-time areas (e.g. elevators)
- Advanced model of air flows (indoors vs. outdoors, vs. ventilation)

Track and trace apps [2]

In this scenario:

- assume a perfect app aligned with all functional, legal and ethical requirements

- study the effectiveness of such an app performing by 3 experiments:

1. effect of the app depending on *different percentages of the population using the app*,
2. comparing the effect of using the app with that of *randomly testing* a percentage of the population
3. effect of the app depending on the *characteristics* of the users (percentage of risk-avoidance agents that use that app).

The following conditions are used:

- percentage of app users = (0%, 60%, 80% or 100%)
- percentage of app users = 0.0 and percentage of population tested randomly daily = (0% or 20%)
- percentage of app users = 60% and percentage of risk avoidance app users = (0%, 30% or 60%)

results: [2]

Experiment 1: Differing amounts of population using the app

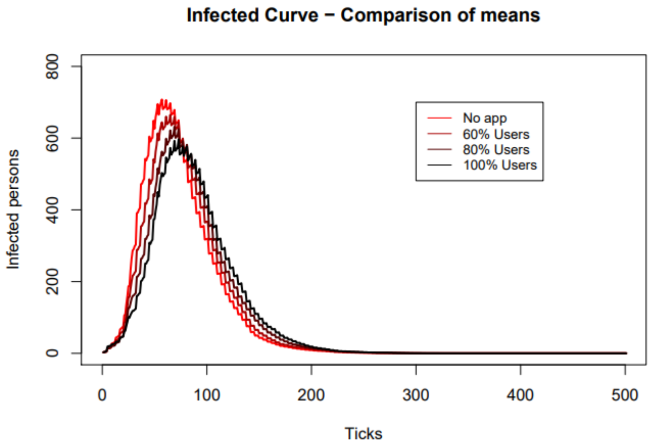

Figure 6. infected curve. (ASSOCC, 2020)

Using the app results in a lower infection peak. However the differences are not significant in a test using 15 randomised runs for each setting, as depicted in figure 6 comparing the settings for no app users, 60% app users, 80% app users and 100% app users, with a population of 1000 agents.

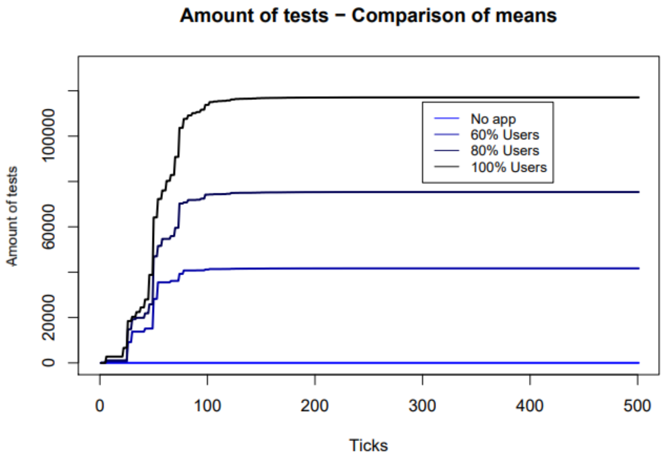

Figure 7. amount of tests. (ASSOCC, 2020)

However, as depicted in Figure 7, increasing the number of users results in a sharp increase of testing given that all those that are alerted of being in contact with an infected agent will need to be tested (or required to quarantine themselves)

These results left us with the question how does the usage of the app compare with a similar amount of random testing. This gave the basis for experiment 2.

Experiment 2: comparing tests performed through app with random testing

Random testing raises infection awareness even when the tested agent had no reason to suspect infection. The differences on number of infected agents under different conditions is shown if Figure 8

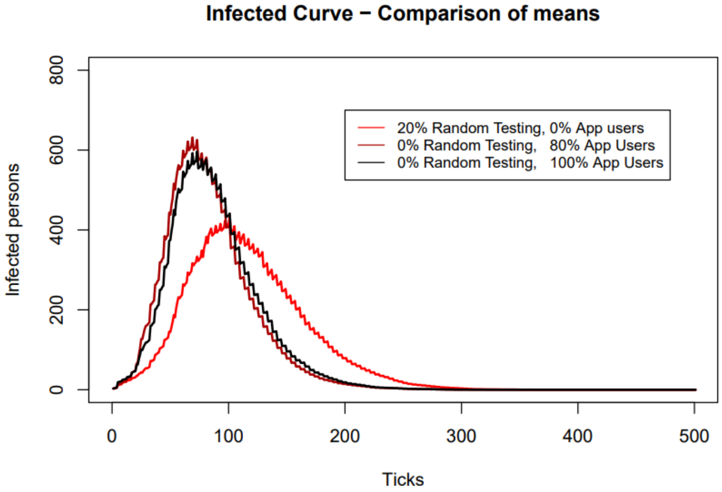

Figure 8. infected curve. (ASSOCC, 2020)

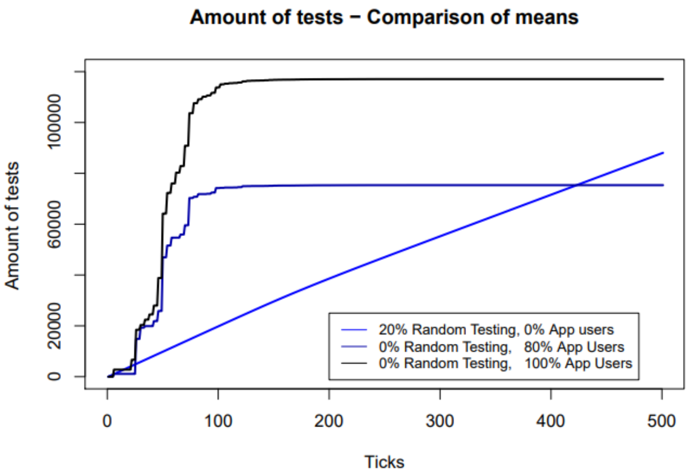

Figure 9. difference in number of tests

Experiment 3: effect of the type of app users.

We hypothesized that the people who are most likely to use the app are probably those that are more risk averse.

However, in initial tests, we were not able to see a significant difference under this condition

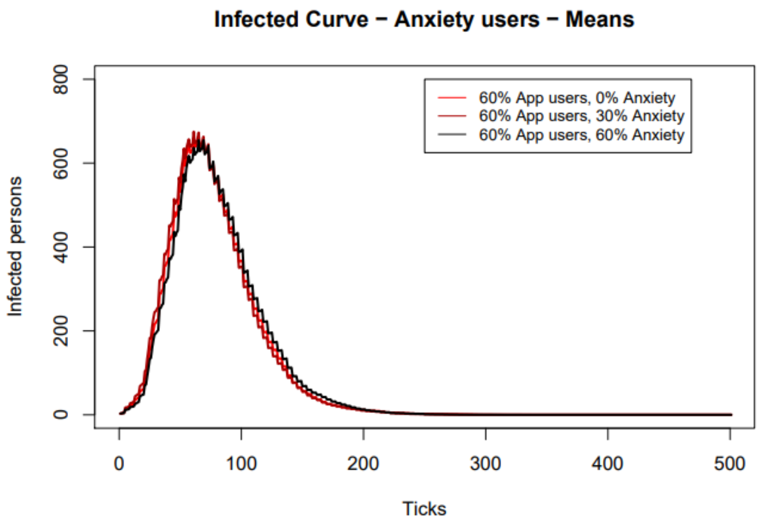

Figure 10. infected curve. (ASSOCC, 2020)

Conclusion: [2]

the effectiveness of tracking and tracing apps on lowering the number of infected agents is limited and lower than that of random testing

the use of the app results in a sharp increase on the number of agents that need to be tested, which may be above the capacity available in the system.

We therefore conclude from this data that the app (with around 60% use) makes no significant contribution to a virus-free Netherlands.

[1] ASSOCC. (2020, April 20). The simulation. Retrieved from https://simassocc.org/assocc-agent-based-social-simulation-of-the-coronavirus-crisis/the-simulation/

[2] ASSOCC. (2020b, April 21). Scenario: effect of track&trace apps. Retrieved from https://simassocc.org/scenario-effect-of-tracktrace-apps/