

O.D.D. description of the COMOKIT Macro model

Projet: COMOKIT - <http://comokit.org/>

Version: 2.0

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We describe in this document the COMOKIT macro model using the standard O.D.D. protocol¹ in its first review version.

Overview

Purpose

This model aims at simulating and comparing the application of COVID-19 spread mitigation policies at the scale of a big city or a country, the transmission of the disease being modeled at the scale of individual groups. Its purpose is to support decision makers and researchers in

¹ Grimm V, Berger U, DeAngelis DL, Polhill JG, Giske J, Railsback SF. The ODD protocol: A review and first update. *Ecological Modelling*. 2010 Nov 24;221(23):2760–8.

answering questions such as: Is the containment of a neighborhood more effective than that of an entire city? Does closing schools decrease the transmission peaks ? How does wearing masks impact the dynamics of the epidemic ? How long should a lockdown ideally last ? What proportion of the population should be allowed to undertake activities during a lockdown ?

One case study is provided with the model: the province (Région) of Alpes-Maritimes in France.

Beyond this case study, the model has been designed as a framework generic enough to be applied to any case study as long as the correct input data is provided. A great deal of the design effort has been put on this aspect.

Entities, state variables, and scales

Scales

The model has been designed to be adapted to any scale and in particular to city and country scales. The spatial units considered can represent an individual building, a neighborhood, a city, a region or even a country.

The simulations are not launched from a specific starting date, but rather from the introduction of the first infected cases in the population and will run until the end of the epidemic. The simulation step is by default set to 1 hour (but it is possible to take into account a less fine time step). As a consequence, movements from one activity place to another one are not simulated: groups of individuals are always located in an activity place. The underlying assumption is that no infection cannot occur during the travel time.

Entities

The model is designed to simulate the COVID-19 spread at the individual group scale. As a consequence, the core entity of the model is `Group` type of agents (or species): it represents a homogenous group of individual inhabitants that share similar characteristics with respect to the disease and governance response (incubation time, likelihood of hospitalization, likelihood of wearing a mask, likelihood of following restrictions...). A `Group` allows to know for each epidemiological status (*susceptible*, *latent*, *pre-symptomatic*, *symptomatic*, *asymptomatic*...), the number of individuals in the group with that status. To take into account the temporal evolution of the disease, the number of individuals in each status is not kept as a simple integer, but as a table, each cell of the table corresponds to one day, e.g. the integer in the second cell of the table corresponding to the *latent* status corresponds to the number of individuals in the *latent* status for 2 days.

Another important type of agent is `Compartment`, which is an encapsulation of a `Group`, which represents a group of inhabitants living in the same `Spatial_unit` and which shares the same agenda. The agenda describes, depending on the day of the week and the time of day, the

number of people in the `Compartment` who will go to each `Spatial_unit`, to perform this or that type of activity in the different types of buildings.

`Spatial_unit` agents are spatial entities where the individuals can perform an activity. They are characterized by a set of `Compartment` agents representing the inhabitants of the area, by a set of building types and for each one by the area that it represents, and finally by a set of `Group` agents representing at the current time step the individuals that are located in the area for each type of building.

As our main goal is to simulate and compare the application of various mitigation and control policies, a specific focus is made on policies that modify the population behavior to reduce contacts and thus infection between people. As a consequence, the possibility for individuals of `Compartment` agents to carry out an activity in a given `Spatial_unit` and building type is constrained by the allowance of the `Authority` agent. This agent manages the various `Policy` that are adopted. When a `Compartment` agent asks it for authorization to perform an activity, the `Authority` asks all the policies it has adopted the allowance rate for the `Compartment` to do the given `Activity`. Examples of `Policy` include total containment, close the schools, close the work spaces... These policies can be limited to a given area (using `SpatialPolicy`) or be more or less tolerant (e.g. containment can be for every body or for every body but some people, or some rate of the population, using `PartialPolicy`).

All the agent species are summarized and organized on the UML diagram presented in **Figure 1**. A specific diagram describing exhaustively all the policies is presented in the Sub-model section.

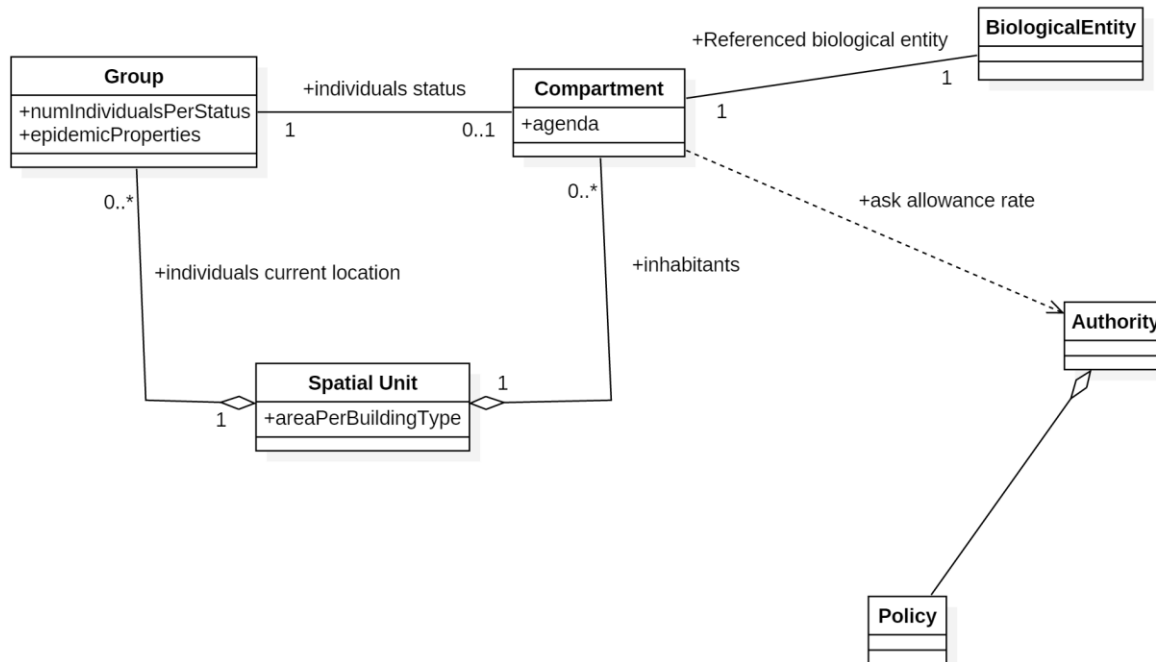


Figure 1. UML class of an overview of the COMOKIT Macro model

Process overview and scheduling

The model simulates the spread of the COVID-19 in a population at the group level under the control of mitigation policies or individual behaviors (such as wearing masks). The dynamics of the model can thus be summarized by four main dynamics: the epidemic status updating of `Compartment` agents, the activities of the `Compartment` agents, the disease spreading, and the dynamics of policy adoption and application.

At the beginning of each new day, the epidemiological status of the group of each `Compartment` agent is updated. More precisely, for each epidemiological status, the number of individuals in each cell will be transferred to the next cell, corresponding to the next day. For the number of individuals in the last cell, transition rates to new statuses are used to know to which status these individuals will be transferred.

The most important dynamic, which is triggered at each simulation step, is the movement of individuals to conduct their activity. More precisely, each `Compartment` agent will calculate according to its agenda and current policies the number of individuals who will go to each `Spatial_unit` agent to conduct their activity in a given type of building. This number will then be managed as a `group` agent located in the target `Spatial_unit` agent and linked to a building type. The set of these groups will then allow to calculate the number of susceptible individuals that will be infected for each `Compartment` agent.

Finally, the Authority agent checks its current Policy and tries to apply it (e.g. executing a test campaign for example).

Design Concepts

Basic principles

As far as the epidemiological dynamics is concerned, we rely on much scientific evidence that the disease could be represented by a SEIR model (44) with an infectious state that can be presymptomatic, symptomatic or asymptomatic, with a certain degree of survivability of the virus in the environment and the possibility of people being infected by it.

The individual group agents' behavior is described using an activity-based approach²: people have a set of activities associated with some day hours. This agenda makes the individuals in the group jump between spatial units and types of buildings.

Emergence

The main emergent (or at least complex to predict) results are the evolution of the number of infected cases given the different parameters that intervene in the definition of a policy, notably its geographical, social and temporal extents.

Adaptation

Up to now, only the Authority agent can be considered as having an adaptive behavior when it uses some specific policies. As an example, some policy can be applied when a condition is fulfilled. This condition can be described in terms of a number of infected people, a time period, or a spatial area to quarantine.

Conversely (and this is a limitation that could be overcome in a future version of the model) Compartment agents do not have any adaptation behavior: as an example, when children are forbidden to go to school, they only stay home, whereas in reality they would go to the park, play with other children in the same street ...

Sensing

Mainly due to the huge number of asymptomatic infectious people, we consider that the Authority agent cannot have a knowledge of the individuals' epidemiologic state. To access this information (that is mandatory to apply or release a given policy taken into account the number of infectious cases), the Authority can only test people. These tests are not perfect: they have probabilities to return false negative and false positive results. As a consequence, the perception of the Authority agent is neither perfect, nor complete on the epidemiological state of its population: it cannot test everybody at each simulation step (for resource limitations).

Interaction

The first type of interaction is the dynamics of contamination. Group agents in the same spatial unit and in the same types of buildings will contaminate each other.

Interactions between Compartment agents and the Authority agents occur in both directions: Compartment agents ask the Authority's agent authorization to execute a given Activity and reversely the Authority agents can apply a Policy to check the epidemic state of the individuals inside the Compartment agents.

² Chapin FS. Human activity patterns in the city: Things people do in time and in space. Wiley-Interscience; 1974.
Illägrstrand T. What about people in regional science?. In Papers of the Regional Science Association 1970 (Vol. 24).

Stochasticity

As we integrate in our model an heterogeneous population, and that a great deal of data is impossible to know with certainty (e.g., when infected, what is the time spent by an Individual time in each epidemiological state?), many values are randomly generated in a range of values coming from the literature.

1. At the initialization, here are the Groups attributes randomly generated: the distribution of compartment attributes related to the disease: latent period for symptomatic and asymptomatic, presymptomatic period, infectious period for symptomatic and asymptomatic, symptomatic rate, hospitalization rate, ICU rate, death rate, reduction factor on contact rate for asymptomatic and the contact rate
2. Most of the dynamics are based on rates, for example to calculate the number of infected individuals or the number of individuals moving in such type of building in such area, which can lead to real numbers of individuals involved and not an integer: to go from real number to integer, a random draw is made with the probability “real number - integer part (real number)” to know if it adds 1 to the result.
3. The application and the allowance choice of some Policy agents can be stochastic: DetectionPolicy: Individuals that will be tested are chosen randomly in the population.

Observation

The observation interface of the COMOKIT simulations can be defined depending on the experiments' needs. As the model has been mainly designed to assess and compare policies, most of the experiments run several simulations in parallel with different parameter values. The observation interface will thus contain a display of the spatial evolution of the disease for each parameter value and a chart plotting the evolution of the number of infected individuals over time. Figure 2 shows an example of the classic interface for a single policy (here, no containment). Each spatial unit is represented on the map with the rate of infected individuals (the more red the color, the higher the proportion of infected individuals). Figure 3 shows an example of a comparison of 3 policies.

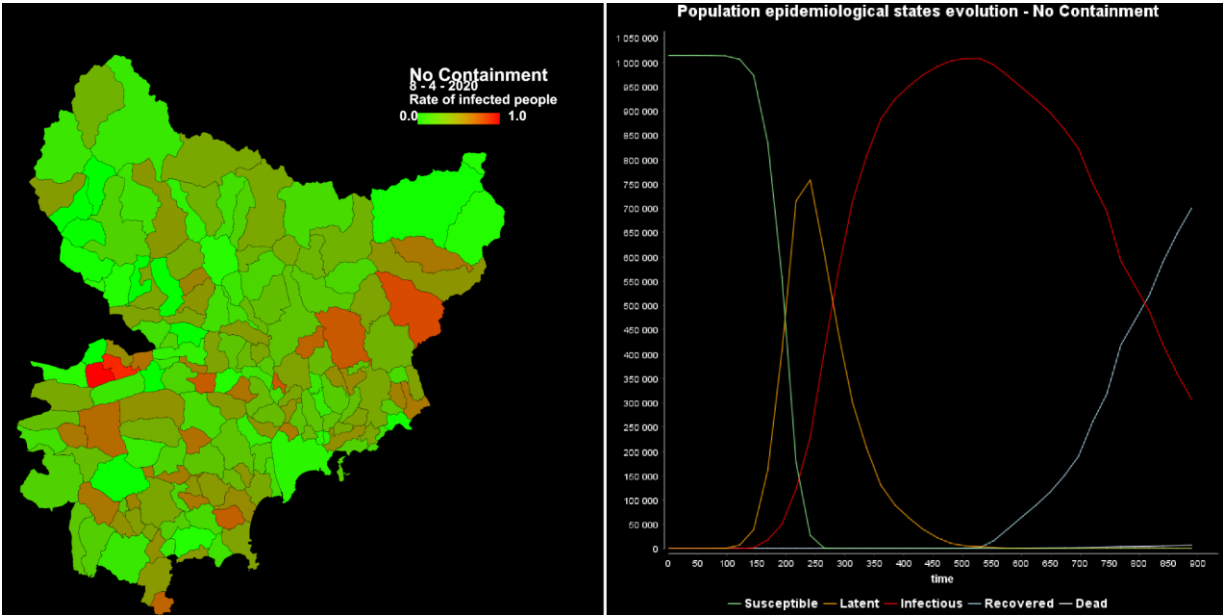


Figure 2. Example of Graphical User Interface of a COMOKIT macro experiment on the Alpes-Maritimes provinces with no containment.

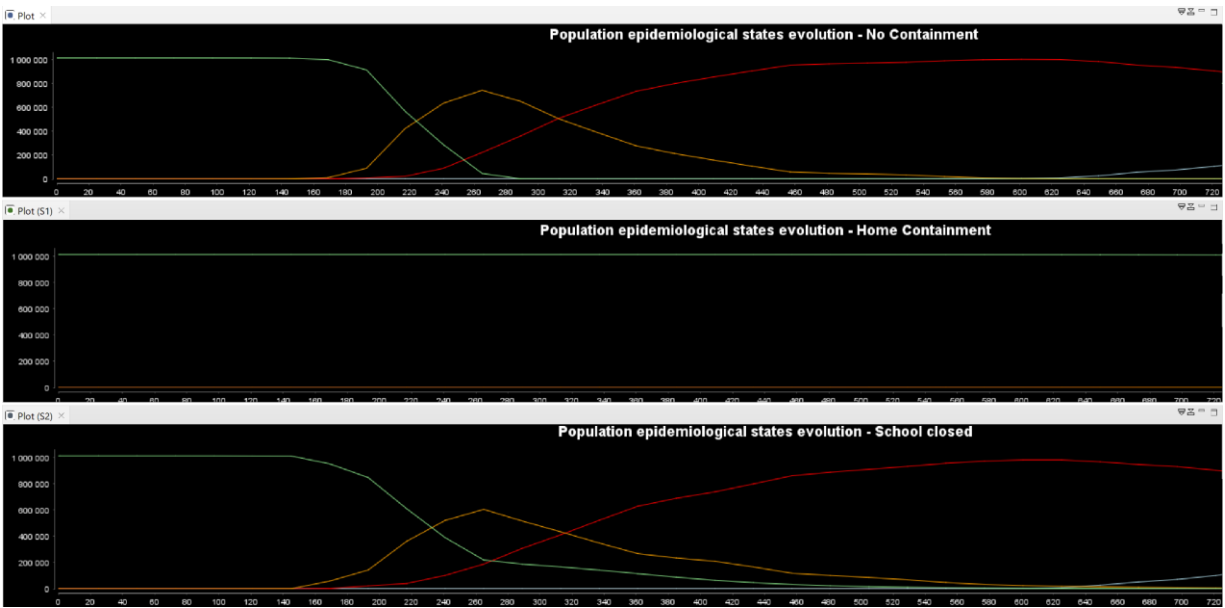


Figure 3. Example of Graphical User Interface of a COMOKIT macro experiment on the Alpes-Maritimes provinces with the comparison of 3 policies: no containment, home containment, and school containment

Details

Initialization

In order to keep the model as generic as possible, many parameters and initial values are stored in case-dependent external files. A parameter file for the epidemiological model is stored in a general purpose parameter folder. In order to use it in a custom version of COMOKIT, users should either redefine them or give the path to this folder relative to the new project (for example, see Template Projects in COMOKIT). The initialization of a simulation combines reading files and assigning values to the main parameters, with synthetic population characteristics (location, social network, agenda) generators as follows:

1. Initialization of the epidemiological parameters from the associated csv file.
2. Creation of the Boundary and Spatial Unit agents from corresponding shapefiles, the Spatial Unit agents initialize their `areaPerBuildingType` attribute from the shapefile attribute table. By reading the attribute table of the shapefile, a given number of Compartment agents is created to represent the population from the spatial unit.
3. For each compartment agent, the epidemiological attributes (latency status period, infectious period, death rate, etc.) are randomly drawn from the parameters.
4. Loading of the agenda. The agenda of each compartment is loaded from a file (a file per spatial area).
5. Initialize epidemic: a given number of Individual agents become infected: updating of the groups (and compartment) they belong.
6. Creation of the Authority agent with its Policy.

Synthetic population generator

Contrary to the Micro and Meso models, the population with its agenda has to be generated before running the simulation and cannot be generated on the fly. To generate the population, two models have to be used: the first one allows to generate the environment and the individuals, the second one the agenda.

Environment and synthetic population

The first model computes from the shapefile of spatial units and the shapefile of buildings the area of buildings per building types. Then, it relies on Gen* to generate a set of individuals from census data with the wanted attributes (e.g. sex, age, occupation, etc.). Once the population is generated and localized in the spatial units, the model aggregates the population of individuals and saves the resulting spatial units in a shapefile.

Synthetic agenda

Each compartment agent of the model has its own set of timely organized activities, i.e. a synthetic agenda. The generation of agendas is based on demographic attributes of the agent, such as sex, age and employment status, and the specification of workdays and days off during the week. For employed agents and students, typical working days will be made of work and school activity, with starting, lunching and ending hours being determined uniformly within parametric ranges. Working agents can lunch inside or outside the workplace according to the given probability parameter. Retired individuals have an agenda full of leisure days. Individuals that are too young have an empty agenda.

The choice of the activities outside of work and study will depend on the age and gender of the individual. It is indeed possible to parametrize (through a CSV file) the fact that young people will, for example, favor leisure activities or elders will favor shopping, home and visit to friends activities. After regular working hours, agents with allowed age to engage in evening activities can enroll friends to do collective activities. During days off all the agents will be assigned a parametric and probabilistic number of activities (decreasing with age) with relatives and friends. All the leisure activities are determined using a weighted activity list according to the age group given in the file parameters, Activity type weights.csv.

Contrary to the meso model, the agenda for a compartment agent corresponds to an aggregation of individuals' agenda. For a current time of the day, the compartment agent's agenda describes the number of individuals who are carrying each type of activity in each type of building.

Input Data

All the input data are summarized in **Table 1** and **Table2**.

Data file	Data Type	Description	Source
Spatial unit.shp	GIS shapefile	All the building geometries, with type and flats attributes.	OpenStreetMap, Google Maps, and hand digitalization from Google satellite image. For Ben Tre, the initial data come from the Land Use map (DONRE, 2010).
boundary.shp	GIS shapefile	The considered area (e.g. commune) boundary.	OpenStreetMap, GADM website: https://gadm.org/download_country_v3.html...
satellite.png	GIS raster file	The background satellite image. (for visualization only)	https://www.bing.com/maps (or other satellite image provider)
population.csv	csv tabular file	The synthetic population generated from a sample using the Gen* library. Each line corresponds to a single individual with age, sex, and household id.	https://international.ipums.org/international/ https://www.gso.gov.vn/default_en.aspx?tabid=774
Epidemiological	Csv tabular file	The set of epidemic parameters for	Various sources from the literature

Parameters.csv		the COVID-19.	(c.f. Annex 1 for more details)
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Table 1. Overview of the dataset (only the bold file names are mandatory)

Only three input data files are mandatory: boundary.shp and agenda data file for each spatial unit. The other ones can be omitted: as an example, when the synthetic population file is missing, COMOKIT will generate a population with an ad hoc generator. This generator (and this is the same for the activities and agendas generators) can be parametrized through additional files (c.f. **Table 2**).

Data file	Data Type	Description	Source
Population Records.csv	Csv tabular file	The mapping between variable in COMOKIT and variables values and names in population.csv	Annex 2
Population parameter.csv	Csv tabular file	The set of parameters to define the population of Individuals (used when no population.csv file is provided)	Annex 2
Activity parameter.csv	Csv tabular file	The set of parameters to define the activities of Individuals	Annex 3
Activity type weights.csv	Csv tabular file	According to the age (interval) and sex, the weight of the different activities	Annex 3
Building type weights.csv	Csv tabular file	According to the age (interval) and sex, the weight of the building type	Annex 3

Table 2. Overview of the files for additional parameters.

Epidemiological parameters

The epidemiological parameter file is a table of parameters. For each of them, the following values are provided: (i) the name of the parameter, (ii) the age category lower bound (the upper bound will be defined according to the lower bound of the next age category of the parameter), (iii) whether the parameter value is given or if it has to be picked in a given probability distribution, (iv) its value (if of type given value) or the first parameter for the distribution, and (v) the second parameter (of the distribution).

Submodels

The epidemiological submodel

In our model, the disease-related state of the Individual agents follows a slightly modified SEIR model (44) using a final state machine structure (c.f. **Figure 3**). We considered the traditional Exposed compartment as a Latent compartment, where individuals are not yet infectious. We

assumed the whole population starts the simulation in a **Susceptible** state (**S**) (as this is an emergent disease, nobody is immunised). When an Individual is in contact with an Infectious agent or located in an infected building, it can become infected and move to the **Latent** state (**L**), depending on the successful transmission rate. The successful transmission rate here is defined as the probability for one contact at a given step to be infected by an Individual. The *latent period* is defined as the time period between the exposition to the virus and the time the Individual becomes infectious, whereas the *incubation period* is the period between exposition and symptom onset. The Individual agent will stay in the Latent state for a given latent period computed according to the incubation period, and the *serial interval*, which is the period between the symptom onset of the newly infected individual and a future possible infection that it will cause. Due to presymptomatic infections, this serial interval can have a negative value, which is subtracted from the incubation period to obtain the possible latent period. In the case of having a positive value, we consider the latent period as equals to the incubation period (therefore, not using the serial interval), indicating infectivity of the Individual only once symptomatic (see **Figure 4**).

Once the latent period is expired, the Individual agent will move to one of the three infectious states (whereas the traditional SEIR model contains a single one): it can be **asymptomatic (Ia)**, **presymptomatic (Ip)** or **symptomatic (Is)**. If the serial interval value was negative, the Individual agent will be presymptomatic for a short period equals to the absolute value of the serial interval before moving to the symptomatic state, therefore having an incubation period equals to the latent period plus the presymptomatic period. The agent will stay in these states during the serial interval (for presymptomatic) and the infectious period for symptomatic and asymptomatic. The transmission risk of a susceptible individual will depend on being symptomatic or asymptomatic, and will be multiplied by a viral factor which is different for each Individual. We consider that asymptomatic and presymptomatic Individuals share the same transmission rate.

Once the infectious period is over, Individual agents reach the **Removed (R)** state, representing all individuals that have been infected, but are not infectious anymore. To represent deaths and recoveries, we decided to consider another variable, *clinical_status*, which represents the current clinical status of the Individual agent.

Individual agents begin with a clinical status set to not needing hospitalisation (**N_H**) (see **Figure 5**). Individuals in the asymptomatic, latent or presymptomatic states will still not need hospitalisation. However, symptomatic Individuals have a probability of needing to be hospitalised (and thus move to the clinical status need_hospitalisation **H_N**). Symptomatic individuals needing to be hospitalised have a probability of needing to be admitted in an Intensive Care Unit (ICU) (and thus to be in the clinical status need_ICU **H_I**), and therefore, die from the disease (corresponding to the clinical status dead **R_D**). If the Individual agent is not being taken to a hospital before the end of its expected period needing ICU, it will be considered as dead due to lack of treatment. In the case the agent will never need ICU and has not been taken to a hospital, it will be considered as recovered (**R_R**). For Individuals taken by hospitals, the hospital will decide on the clinical status according to the probability of dying for ICU cases. For hospitalised cases,

they are considered recovered once they do not show any symptoms (i.e. not in the state symptomatic) and are tested negative for x consecutive days.

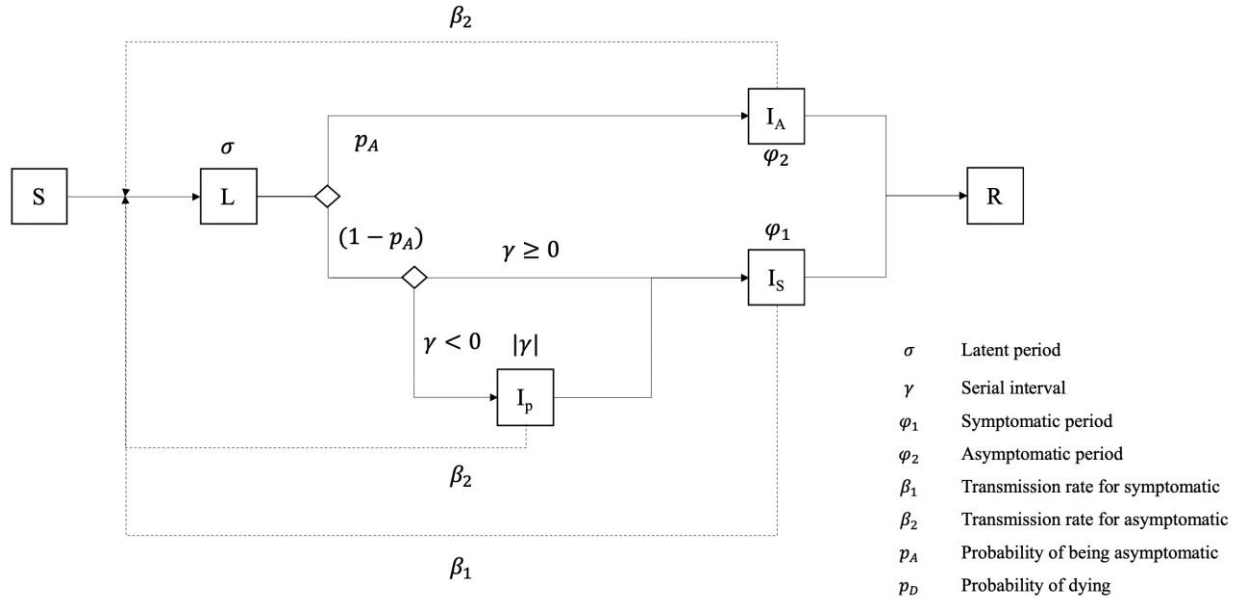


Figure 3. Epidemiological model of the Individual agent.

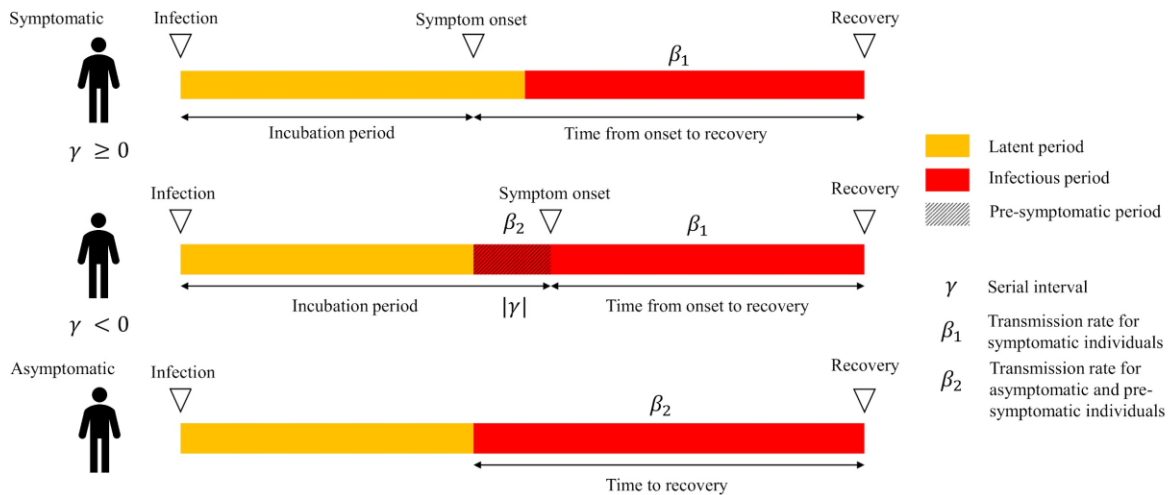


Figure 4. Illustration of the durations in different states (and the associated transmission rates) for both Symptomatic and Asymptomatic Individuals.

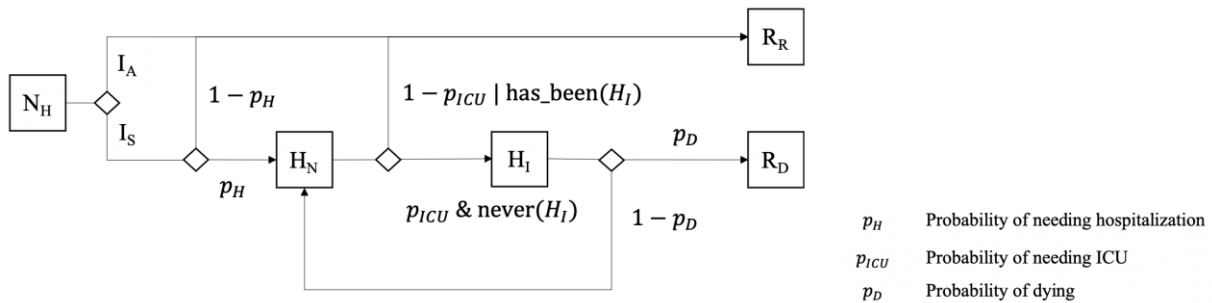


Figure 5. Hospitalisation model of the Individual agent.

The various incubation, serial and infectious periods are Individual dependent and are randomly picked following various distributions.

Given a lack of data, we made several assumptions in the model related to parameters (and in particular to their heterogeneity in the population):

- The incubation period does not differ for different age categories.
- The successful contact rate for human to human and environment transmission (i.e. the rate of Individuals becoming Latent after being in contact with an infectious one) does not differ for different age categories.
- The proportion of asymptomatic does not differ for different age categories.
- The successful contact rate does not differ during the infectious period.
- Asymptomatic and symptomatic individuals share the same infectious period distribution.
- The individual factor of the transmission risk does not differ for different age categories

Finally this model of the epidemic states evolution makes also several assumptions:

- The serial interval can be used as a proxy to get the presymptomatic part of the infectious period.
- Individuals could be infected by a contaminated environment, and for a maximal viral contamination in one building, the successful transmission rate is the same as one infectious Individual.
- Sex does not have an impact on the epidemiological model.
- The viral release of an individual in the environment (in our model, in Buildings) is the same for all infectious individuals.
- Presymptomatic and asymptomatic individuals share the same transmission successful contact rate.
- Masks do not deliver any protection, but rather reduce the successful contact rate of an infectious individual and its viral release in the environment.
- Recovered Individuals are totally immunised against the infection.

- Infection can lead to death only for Individuals expressing a need for intensive care.
- Testing is performed only for virus isolation, not antibodies, therefore, recovered people are not considered positive.

Daily Activities

Once weekly and daily agendas have been created at initialization, Individual agents have only to get, at each simulation step, the Activity corresponding to the current day and current hour, asks the Authority agent's authorization to perform it, finds a building associated with the Activity, and moves in it. In addition, the agent will ask the Authority for the number of individuals it can perform the Activity with. It will then pick randomly this number among its possible Activity followers, and store them during the Activity period. This set of agents will be used in the disease spread as possible infections with a higher probability.

The time is managed internally by the GAMA platform: from the simulation step duration set to 1 hour and a simulation starting date, the simulation will automatically compute the current day and hour.

Institutions

The Authority agent is in charge of applying one or several mitigation policies on the whole case study or on some local spaces. The policies can impact the simulation in two ways. Every step, the Authority can proactively perform some actions encoded in the policy, e.g. conduct a given number of tests on the population. On the other hand, each Individual agent asks the Authority whether it is allowed to execute a given Activity. In this case, the Authority will make its choice based on what is allowed by its policies that are currently applied.

Technically, any Policy agent has two main actions: `apply()` and `is_allowed(Individual, Activity)`. `apply()` is called repetitively every time step by the Authority and can consist in anything relevant to this policy, for instance conducting tests. `is_allowed(Individual, Activity)` is called every time an Individual wants to undertake an Activity and should return whether this policy allows it or not. In addition, `is_active()` tells whether or not the policy is currently active (i.e. its conditions are fulfilled, for instance). It is used by some restricting policies.

We chose a modular approach to define policies: a policy is based on a small set of simple concrete policies (e.g. *DetectionPolicy* that allows all the activities, but conducts tests at each step or *ActivitiesListingPolicy* that restricts activities in a given set of allowed ones) that are composed using the composite (implemented through the *CompoundPolicy*) and nesting (through the *ForwardingPolicy*) design patterns:

- *CompoundPolicy* is a policy composed of a list of other policies. When applied, it applies the listed policies in sequence, and allows an activity for a given individual if and only if it is allowed by all the policies.

- *ForwardingPolicy* is a policy that embeds another policy. It can modify the nested policy allowance (for example *SpatialPolicy* restricts the application of its target policy in a given geographical space, and *TemporaryPolicy* in a limited time period).

The full class diagram of all the defined Policy species is shown in Figure 6.

Several Forwarding policies have been defined to restrict or expand other ones:

- *PartialPolicy*: a policy that accepts, given a probability, a proportion of couples of individuals - activity normally forbidden by its target policy.
- *SpatialPolicy*: a policy that restricts the application of its target policy to a given geographical area. If outside, it allows everything.
- *TemporaryPolicy*: a policy that restricts the duration of its target policy. If before, or after, everything is allowed. This policy becomes active (i.e. delegates to its target and runs the countdown) only when its target has become active.
- *AllowedIndividualsPolicy*: a policy that allows certain individuals to undertake activities no matter what. They can be defined by a percentage or by an explicit map. Outside of the list, it asks its target policy for allowance.
- *CaseRangePolicy*: a forwarding policy that activates its target policy only after a number of reported cases and stops after another one. Outside of this range, everything is allowed.

Finally several concrete policies are available:

- *ActivitiesListingPolicy*: a policy described by a map of activities names and boolean values representing, for each, whether they are globally allowed or disallowed. Not explicitly disallowed activities are considered as allowed.
- *PositiveAtHome*: the policy that forbids any activity to any Individual agent who has been tested positive.
- *FamilyOfPositiveAtHome*: the policy that forbids any activity to any Individual agent who has been tested positive and whose any relative has been tested positive.
- *DetectionPolicy*: the policy used to conduct a given number of tests at every step. It allows everything.
- *HospitalisationPolicy*: The policy used to use hospitals for cure.
- *noPolicy*: an empty policy that allows any activity to everyone.

As an example, a “realistic lockdown” experiment has been created to apply a 60 days lockdown policy, where positive people are not allowed to move, others are only allowed to stay home or go shopping, and only 10% of the total population is allowed to go working. This policy is thus built as a *TemporalPolicy*, limiting the application of a *CompoundPolicy* in a period of 60 days.

The nested policy is composed of:

- A policy applying a given number of tests at each simulation step (this policy allows any Activity).
- A policy forbidding any activity but shopping and going back home. This policy is nested in another policy that limits its application to 90 of the population (the remaining 10% are allowed to do any activities).
- A policy forbidding any activity to Individuals who have been tested positive.

The associated GAML code is the following one:

```
ask Authority {
  AbstractPolicy d <- create_detection_policy(number_of_tests_, false, true);
  AbstractPolicy l <- create_lockdown_policy_except([act_home, act_shopping]);
  AbstractPolicy p <- create_positive_at_home_policy();
  l <- with_percentage_of_allowed_individual(l, percentage_);
  l <- during(l, 60);
  policy <- combination([d, p, l]);
}
```

Note that the policy used by the authority can be dynamically adapted or changed anytime during the simulation.

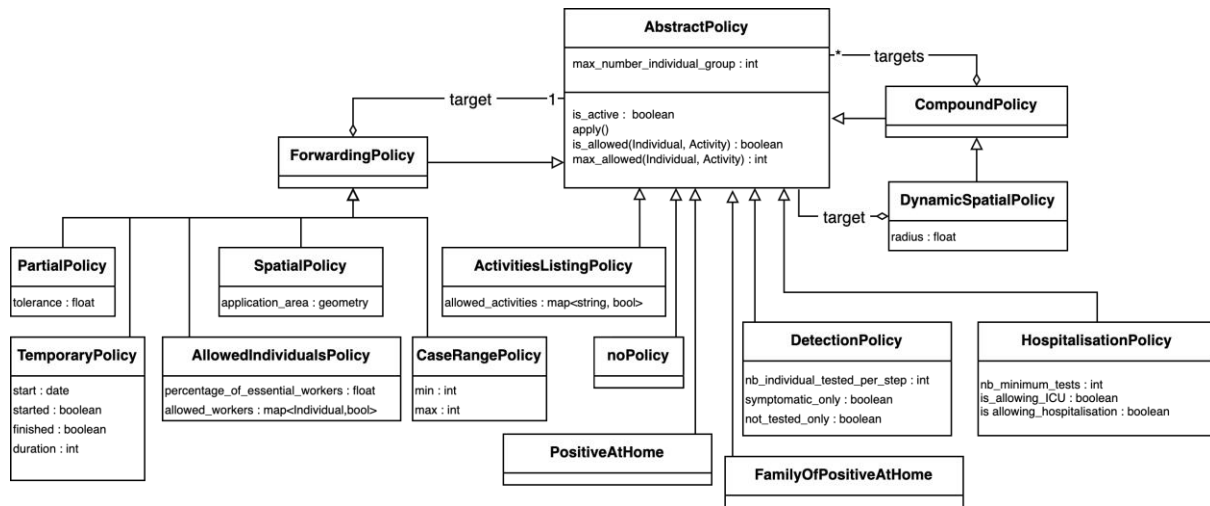


Figure 6. Full class diagram of the built-in policies.

Annex 1: Description of epidemiological parameters and input data related to COVID-19 used in the COMOKIT model

We make here a distinction between **parameters** (whose values are modified to define an experiment scenario) and **input data** (whose values are given from the literature).

Parameters

The parameters can either be used to define an exploration (e.g. to compare epidemics with and without transmission in buildings), or are only assumed and need to be investigated through a sensitivity analysis.

Parameter	Detail	Parameter_1	Parameter_2	Used for
Transmission_human	Fixed	true		Exploration
Transmission_building	Fixed	true		Exploration
Successful_contact_rate_building	Fixed	0.170071		Sensitivity
Basic_viral_release	Fixed	3		Sensitivity
Basic_viral_decrease	Fixed	0.01375		Sensitivity
Proportion_wearing_mask	Fixed	0		Exploration
Reduction_wearing_mask	Fixed	0.5		Exploration
proba_outside_contamination_per_hour	Fixed	0.0		Sensitivity

Input data

Parameter	Age	Detail	Parameter_1	Parameter_2	Region	Source
Successful_contact_rate_human	0	Fixed	0.034014			Derived from R0
Reduction_asymptomatic	0	Fixed	0.45		China	(1)
Proportion_asymptomatic	0	Fixed	0.28		Japan cruise	(2)
Probability_true_positive	0	Fixed	1.0			(3)
Probability_true_negative	0	Fixed	0.91			(3)
Incubation_period_symptomatic	0	Lognormal	1.57	0.65	China, Shenzhen	(4)
Incubation_period_asymptomatic	0	Lognormal	1.57	0.65		Assumed
Serial_interval	0	Normal	3.96	4.75	China not Hubei	(5)
Proportion_hospitalization	0	Fixed	0.025		USA	(6)
Proportion_hospitalization	20	Fixed	0.208		USA	(6)
Proportion_hospitalization	45	Fixed	0.283		USA	(6)
Proportion_hospitalization	55	Fixed	0.301		USA	(6)
Proportion_hospitalization	65	Fixed	0.435		USA	(6)

Proportion_hospitalization	75	Fixed	0.587		USA	(6)
Proportion_hospitalization	85	Fixed	0.703		USA	(6)
Proportion_icu	0	Fixed	0		USA	(6)
Proportion_icu	20	Fixed	0.2019		USA	(6)
Proportion_icu	45	Fixed	0.3675		USA	(6)
Proportion_icu	55	Fixed	0.3721		USA	(6)
Proportion_icu	65	Fixed	0.4322		USA	(6)
Proportion_icu	75	Fixed	0.5281		USA	(6)
Proportion_icu	85	Fixed	0.4125		USA	(6)
Proportion_death_symptomatic	0	Fixed	0		USA	(6)
Proportion_death_symptomatic	20	Fixed	0.0476		USA	(6)
Proportion_death_symptomatic	45	Fixed	0.0769		USA	(6)
Proportion_death_symptomatic	55	Fixed	0.2321		USA	(6)
Proportion_death_symptomatic	65	Fixed	0.2606		USA	(6)
Proportion_death_symptomatic	75	Fixed	0.3387		USA	(6)
Proportion_death_symptomatic	85	Fixed	0.9414		USA	(6)
Infectious_period_symptomatic	0	Lognormal	2.8622	0.0685	China, Shenzhen	(4)
Infectious_period_symptomatic	10	Lognormal	2.949688	0.094	China, Shenzhen	(4)
Infectious_period_symptomatic	20	Lognormal	2.95491	0.047	China, Shenzhen	(4)
Infectious_period_symptomatic	30	Lognormal	2.95491	0.033	China, Shenzhen	(4)
Infectious_period_symptomatic	40	Lognormal	3.072693	0.04	China, Shenzhen	(4)
Infectious_period_symptomatic	50	Lognormal	3.109061	0.037	China, Shenzhen	(4)
Infectious_period_symptomatic	60	Lognormal	3.131137	0.039	China, Shenzhen	(4)
Infectious_period_symptomatic	70	Lognormal	3.113515	0.08	China, Shenzhen	(4)
Infectious_period_asymptomatic	0	Lognormal	2.8622	0.0685		Assumed
Infectious_period_asymptomatic	10	Lognormal	2.949688	0.094		Assumed
Infectious_period_asymptomatic	20	Lognormal	2.95491	0.047		Assumed
Infectious_period_asymptomatic	30	Lognormal	2.95491	0.033		Assumed
Infectious_period_asymptomatic	40	Lognormal	3.072693	0.04		Assumed
Infectious_period_asymptomatic	50	Lognormal	3.109061	0.037		Assumed
Infectious_period_asymptomatic	60	Lognormal	3.131137	0.039		Assumed
Infectious_period_asymptomatic	70	Lognormal	3.113515	0.08		Assumed
Onset_to_hospitalization	0	Lognormal	1.23	0.79		
Hospitalization_to_ICU	0	Normal	7	5.9	China, Wuhan	(7)
Stay_ICU	0	Normal	8	5.9	China, Wuhan	(8)

References

1. Li R, Pei S, Chen B, Song Y, Zhang T, Yang W, et al. Substantial undocumented infection facilitates the rapid dissemination of novel coronavirus (SARS-CoV2). *Science* [Internet]. 2020 Mar 16 [cited 2020 Apr 4]; Available from: <https://science.sciencemag.org/content/early/2020/03/24/science.abb3221>
2. Mizumoto K, Kagaya K, Zarebski A, Chowell G. Estimating the asymptomatic proportion of coronavirus disease 2019 (COVID-19) cases on board the Diamond Princess cruise ship, Yokohama, Japan, 2020. *Euro Surveill.* 2020 Mar;25(10).
3. Lassaunière R, Frische A, Harboe ZB, Nielsen AC, Fomsgaard A, Kroghfelt KA, et al. Evaluation of nine commercial SARS-CoV-2 immunoassays. *medRxiv.* 2020 Apr 10;2020.04.09.20056325.
4. Bi Q, Wu Y, Mei S, Ye C, Zou X, Zhang Z, et al. Epidemiology and Transmission of COVID-19 in Shenzhen China: Analysis of 391 cases and 1,286 of their close contacts. *medRxiv.* 2020 Mar 27;2020.03.03.20028423.
5. Nishiura H, Linton NM, Akhmetzhanov AR. Serial interval of novel coronavirus (COVID-19) infections. *Int J Infect Dis.* 2020 Mar 4;
6. CDCMMWR. Severe Outcomes Among Patients with Coronavirus Disease 2019 (COVID-19) — United States, February 12–March 16, 2020. *MMWR Morb Mortal Wkly Rep* [Internet]. 2020 [cited 2020 Apr 21];69. Available from: <https://www.cdc.gov/mmwr/volumes/69/wr/mm6912e2.htm>
7. Yang X, Yu Y, Xu J, Shu H, Xia J, Liu H, et al. Clinical course and outcomes of critically ill patients with SARS-CoV-2 pneumonia in Wuhan, China: a single-centered, retrospective, observational study. *The Lancet Respiratory Medicine* [Internet]. 2020 Feb 24 [cited 2020 Apr 21];0(0). Available from: [https://www.thelancet.com/journals/lanres/article/PIIS2213-2600\(20\)30079-5/abstract](https://www.thelancet.com/journals/lanres/article/PIIS2213-2600(20)30079-5/abstract)
8. Zhou F, Yu T, Du R, Fan G, Liu Y, Liu Z, et al. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. *The Lancet.* 2020 Mar 28;395(10229):1054–62.