UNIVERSITY OF TWENTE.

# ABM3

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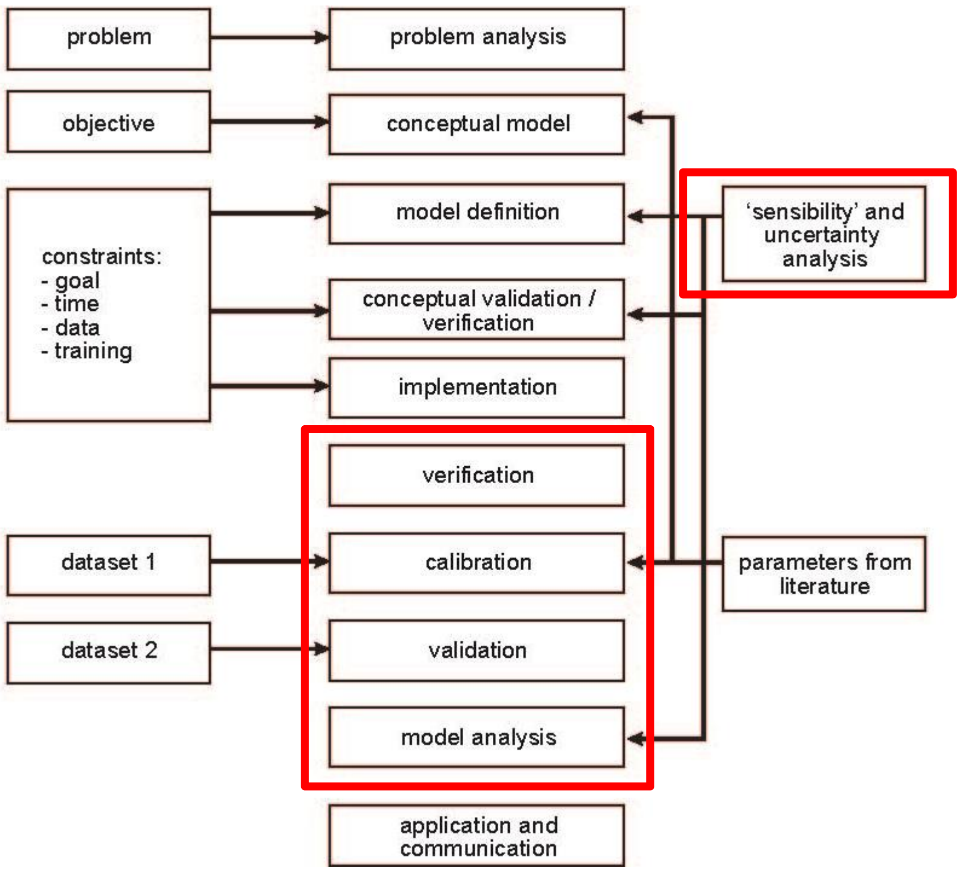
FACULTY OF GEO-INFORMATION SCIENCE AND EARTH OBSERVATION

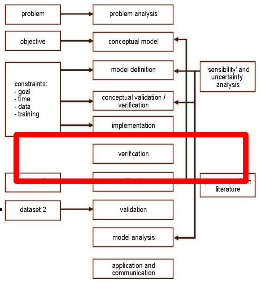
# OVERVIEW

- Verification
- Sensitivity Analysis
- Parameterization
  - Direct parameterization
  - Indirect Parameterization (Calibration)
    - One at a Time
    - All at a Time
- Validation
  - Input validation
  - Process validation
  - Descriptive output validation
  - Predictive output validation

- What about pattern-oriented Modelling?

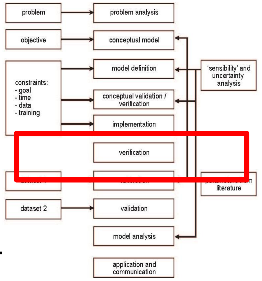


# VERIFICATION



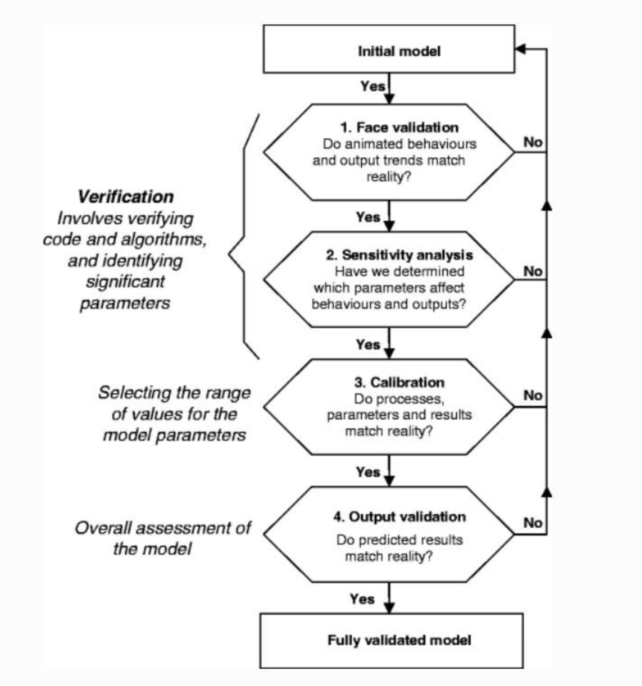

- To understand the output of an agent-based model it is often necessary to evaluate the details of a simulation 'history'.
- This can be done in three ways (Axelrod):
  - Key events in chronological order
  - History of one agent can be documented
  - History from a global viewpoint can be noted (distribution of pedestrians) –large scale patterns)

- Verification is the task of ensuring that a model satisfies the specifications




# VERIFICATION – FACE VALIDATION

- History of an individual agent can be “misleading” especially when the simulation contains random effects.
- To determine if the results are typical, it is necessary to repeat the simulation.
- Statistical analysis of the results is necessary.



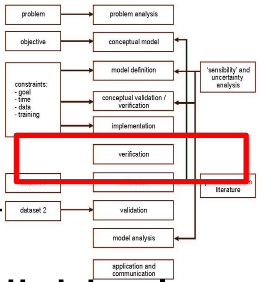

- Sensitivity analysis can proof if the output is sensitive to variation in initial conditions and parameters.
- The effect of different model versions can also be assessed by running controlled experiments.
- Difference in the logic of the model can be studied by comparison of different versions.

logic : different conditions, order in executing, how many simulation we need

Ngo, T.A., See, L. (2012). Calibration and Validation of Agent-Based Models of Land Cover Change. In: Heppenstall, A., Crooks, A., See, L., Batty, M. (eds) Agent-Based Models of Geographical Systems. Springer, Dordrecht. https://doi.org/10.1007/978-90-481-8927-4_10

Castle, C. J. E. and A. T. Crooks (2006). Principles and Concepts of Agent-Based Modelling for Developing Geospatial Simulations. Working paper series UCL - paper 110 - Sep 06.

# Local or global sensitivity analysis




- Local sensitivity analysis: test how sensitive the model is to the value of each individual parameter.
  - Does not allow us to capture parameter interactions: how the model's sensitivity to one parameter might change as other parameters change

one input at a time, while other inputs remain constant

- Global sensitivity analysis: test how sensitive the model is when varying all parameters at the same time.
  - Problem is that many different combinations are possible

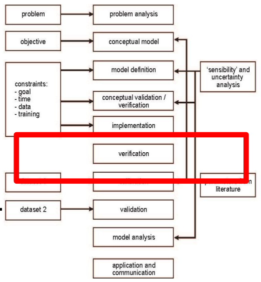
sensitivity : how sensitive our model to change the analysis
example : sugar scape

Local Sensitivity Analysis :
OAT : one at a time, jadi ubah 1 nilai parameter
OFAT : one factor at a time, broader range of input
limitation : only analyze one input silmutenously

Global Sensitive Analysis:
ubah beberapa input dalam satu waktu, misal A (ada 5) B ada 5 jadi ada 25 kombinasi
Analysis bisa menggunakan linear regression antara 2 input, is it influence positive or negative

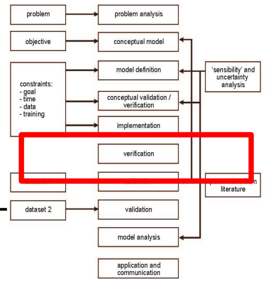
# Sensitivity analysis, uncertainty, robustness

ketidakpastian ketahanan




- Does the model reproduce patterns *robustly*, or are these results *sensitive* to changes in model *parameters*? The wolf model not reproduce patterns robustly, it is sensitive, because if we change the parameters then the bell pattern might be change
- How uncertain are the model's outputs? (would it produce the same results if different plausible parameter values are used)
- Uncertainty analysis (UA) looks at how uncertainty in parameter values affects the reliability of model results
- Robustness analysis (RA) explores the robustness of results and conclusions of a model to changes in its structure.

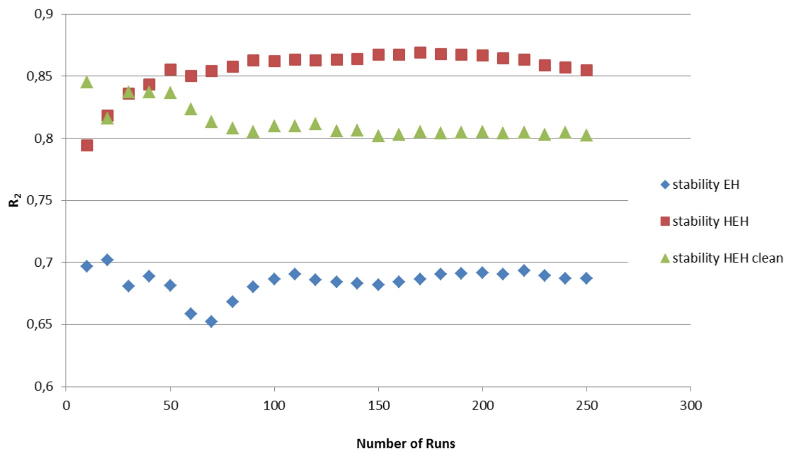
# Stability




Two methods to check stability (robustness):

- Plotting the accumulative average of the state variable (output) over an increasing number of runs.
- The coefficient of variation is defined as the ratio between the standard deviation of a sample and the mean of that sample resulting in the following formula: $Cv = \sigma \mu$

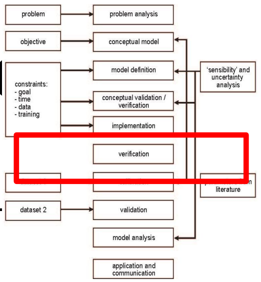
in which *Cv* is the coefficient of variation, *σ* the standard deviation of the sample and *μ* the mean of the sample



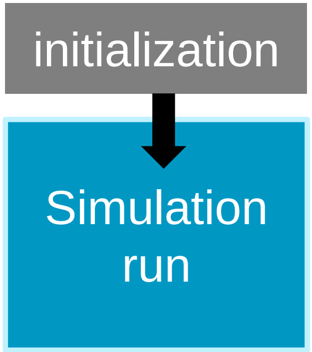

| N | Cv |
|---|---|
| 5 | 0.0022 |
| 10 | 0.0024 |
| 25 | 0.0024 |
| 50 | 0.0021 |
| 100 | 0.0021 |

(Lorscheid, Heine, & Meyer, 2012),

# Determine how many times a new population should be constructe




- Agent-based models use a re-created “synthetic population”
- The synthetic population is normally generated based on statistical data (CBS).



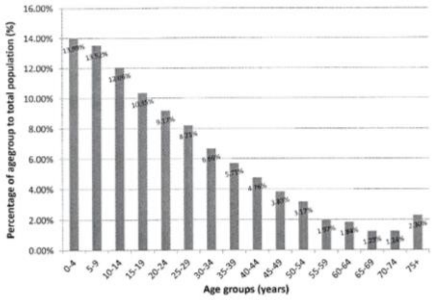




Figure D.4: *Ashanti region population divided by age and group (GSS, 2012)*

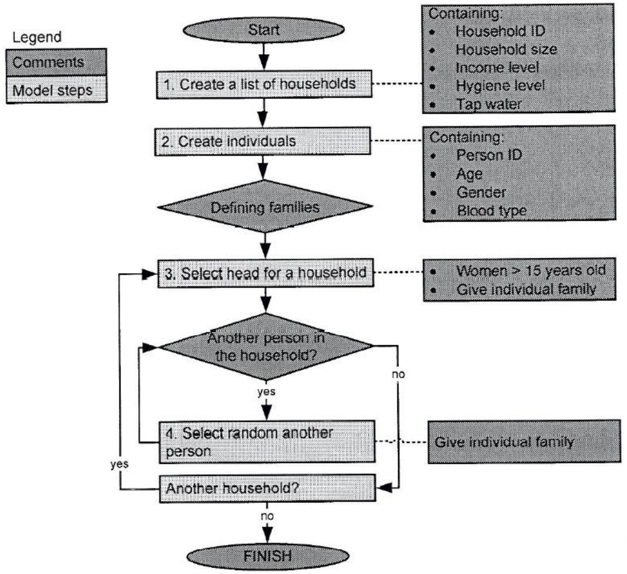
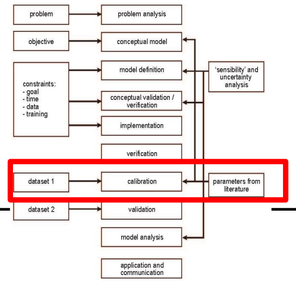
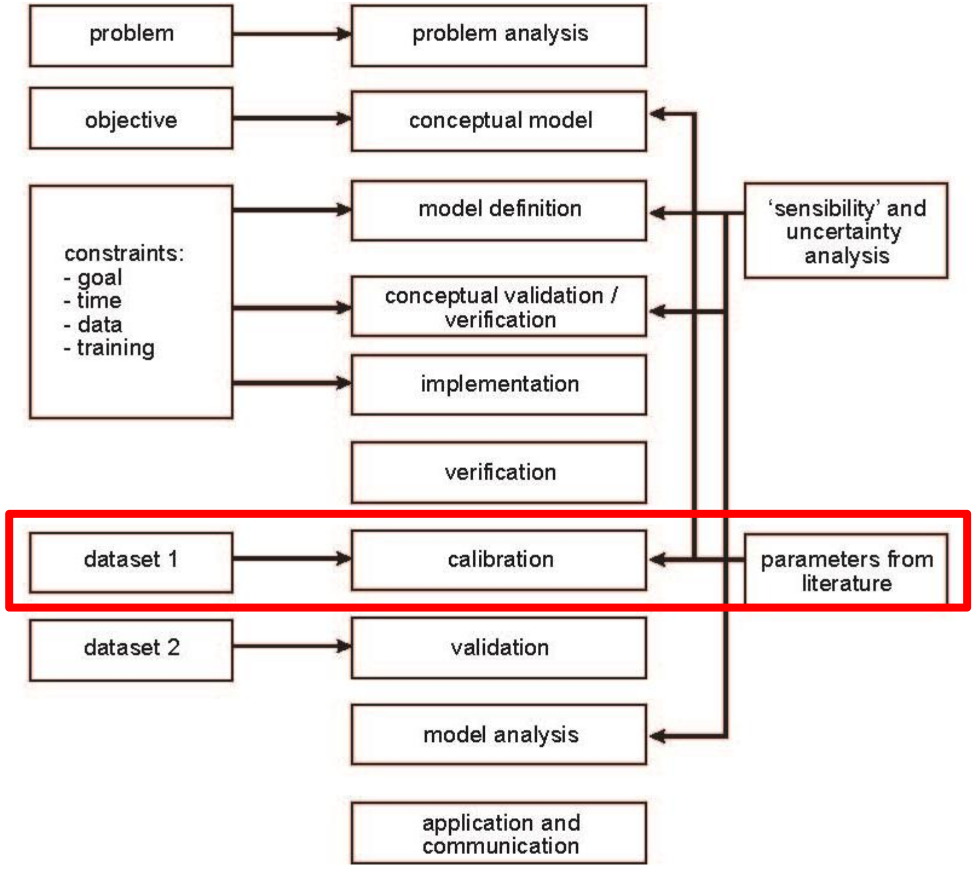



Figure 6.2: *Synthetic population generator after Moeckel (2003)*

# THE MODELLING PROCESS






Parameters are the constants in the equations and algorithms that are used in your model

Parameterization: selection of values for a model's parameters

Calibration: specific type of parameterization in which we try to find a set of values for important parameters.

Direct Prarameterization : literature, field work, experiments, experts, pembobotan berdasarkan resources (liteature, dll)
Indirect Parameterization (calibration)  : second best choice, don't know parameter at all, narrow value in certain range, or know the best value

# Purposes of model calibration

- Model calibration serves the following purposes:
  - Force the model to match empirical data
  - Estimate the value of parameters that cannot be evaluated (measured) directly
  - To test the model's structural realism: can we calibrate it to match the observations within a reasonable range?

- Calibrate each sub-model separately

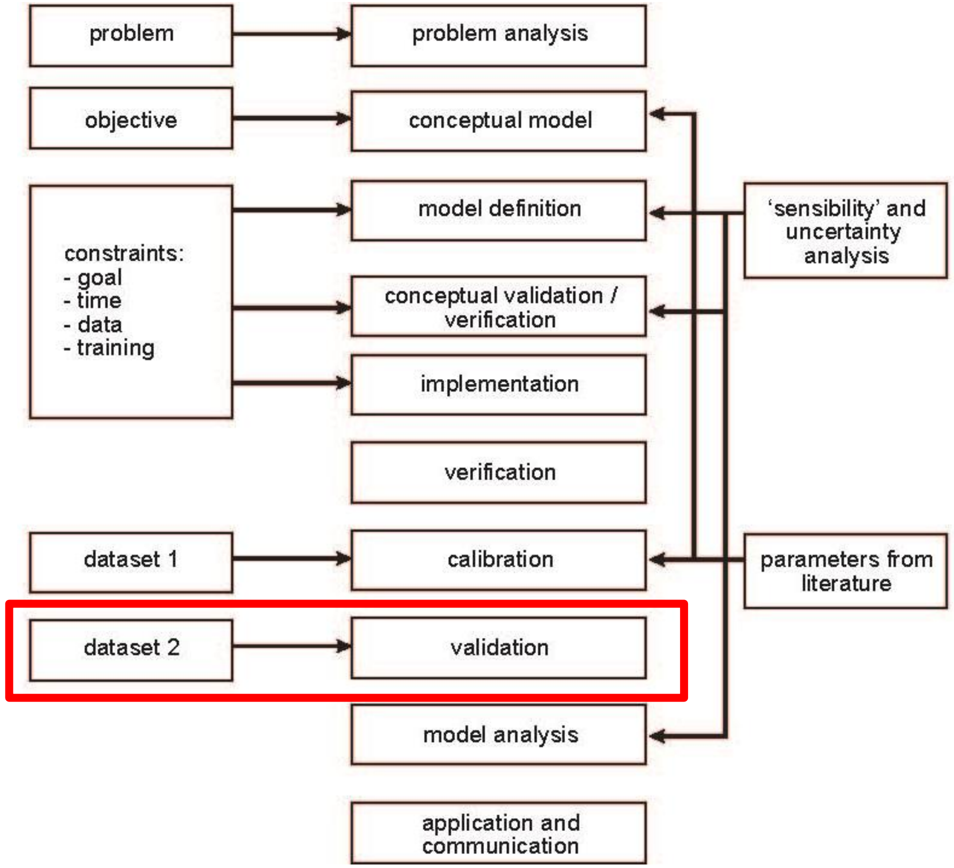
Workflow of calibration :
- define at least one model output as target
- run simulations varying unknown parameters
- analyse runs to identify parameter settings with desired output

# Categorical versus Best-fit Calibration

- *Categorical Calibration*: search for parameter values that produce model results within a category or range you defined as acceptable (mean number of agents between 120 and 150)
- *Best-fit Calibration* you search for one set of parameters that cause the model to best match some exact criteria (mean 135 agents)

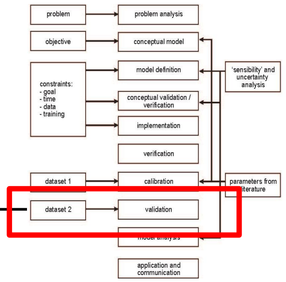
Calibration : Example Model
Calibrated parameters :
- number of plots within one district
-cost for enlarging house
Desired output : population growth in outer districts but still plots available at end

# THE MODELLING PROCESS




- Validation is checking if the model is a good model of the simulated phenomenon
  the most difficult step
- *Validation – the model shows the macro-level regularities (pattern) that the research is seeking to explain. If so, this is evidence that the interaction and behavior of the agents is the cause of the regularities (pattern).*
- After comparing the macro behavior it is desirable to compare the output of the model with empirical data.

# VALIDATION




- A model has a degree of <u>validity</u> (Law and Kelton, 1991)

*A model is valid to the extent that it adequately represents the system being modelled (Casti, 1997)*

maybe it can be valid in some patterns but not to others

**Casti, J.L.** (1997) Would-Be-Worlds: How Simulation is Changing the Frontiers of Science, John Wiley & Sons, New York, USA.
**Law A.M., and W.D. Kelton** (1991), Simulation modeling and analysis; Second Edition, McGraw-Hill, New York
**Axelrod, R.** (1997). Advancing the Art of Simulation in the Social Sciences. Simulating Social Phenomena, Berlin, Heidelberg, Springer Berlin Heidelberg.

# VALIDATION – POSSIBLE PROBLEMS

- Both model and system under analysis are likely to be stochastic.
- A model might be able to produce plausible future predictions but may not be able to recreate known past system states.

- Model could be correct but data from the real-world system may not.
- Many simulations are path dependant (i.e. the outcome of a simulation is dependant on the exact initial setup chosen) – history of a simulation is highly significant.

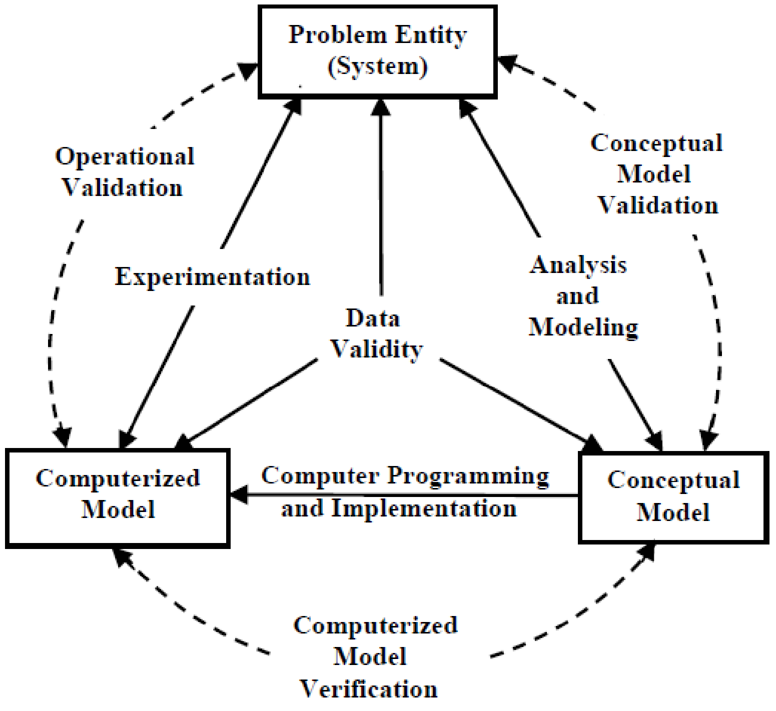



Figure 2: Simplified Version of the Modeling Process

Sargent, R. (2011). Verification and validation of simulation models.
January 2011, Proceedings - Winter Simulation Conference 37(2):166 - 183
DOI: 10.1109/WSC.2010.5679166

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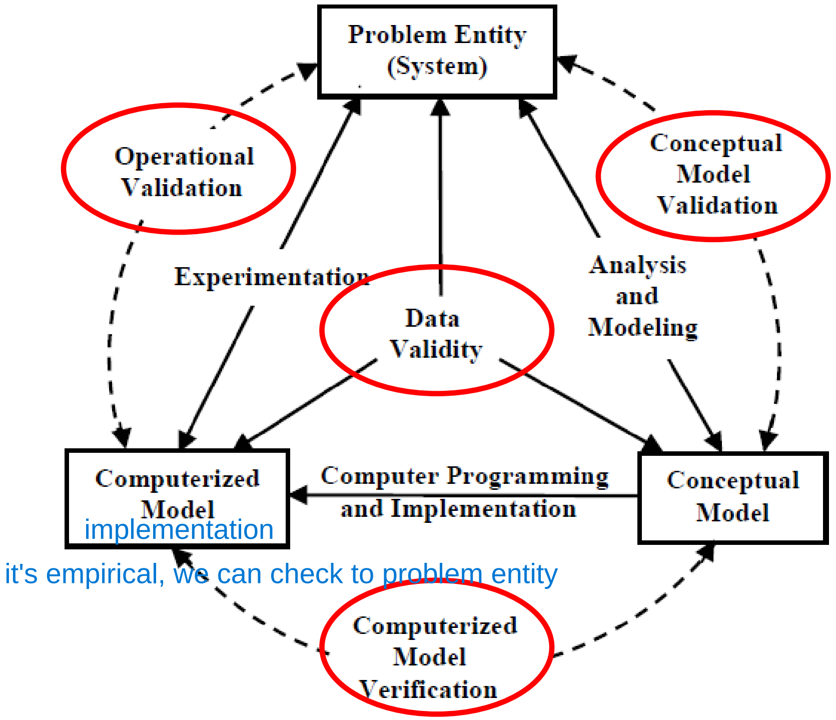


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# VALIDATION

- Validation
  - Input validation quantitative and qualitative data that used
  - Process validation how well the process is represented in the model reflected to the real world, include: scale, entities, interactions
  - Descriptive output validation how well the model output capture the features of the data used for the model simulate the real world
  - Predictive output validation

    to what degree that your simulation patterns

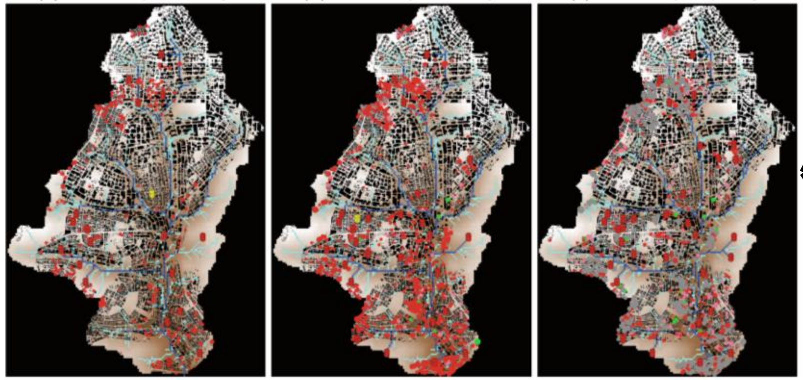
    no independent data available

    is the model able to forecast data not used for more building, or data only required later, or for another case study
  - Macro validation (at an aggregation level)
  - Micro validation comparing individual rules/agents
  - Face validation (do the general ideas about the behavior and properties compare to the real-word) versus empirical validations (data validation)

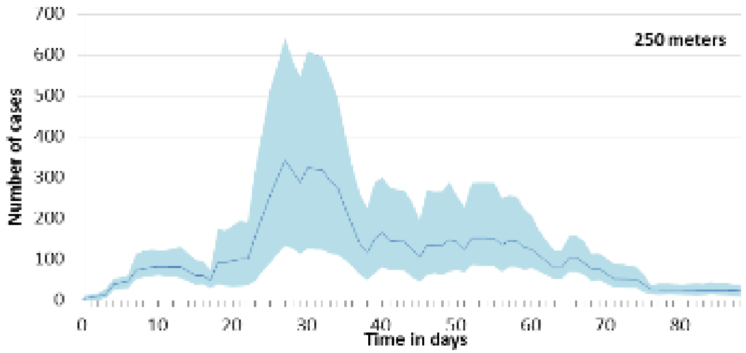
- Validity of a model is always related to the purpose of this model
- All models are simplifications, and all models are wrong

TRACE PROTOCOL : TRAnsparent and Comprehensive Ecological modelling documentation

# An Example: Using time series and spatial patterns



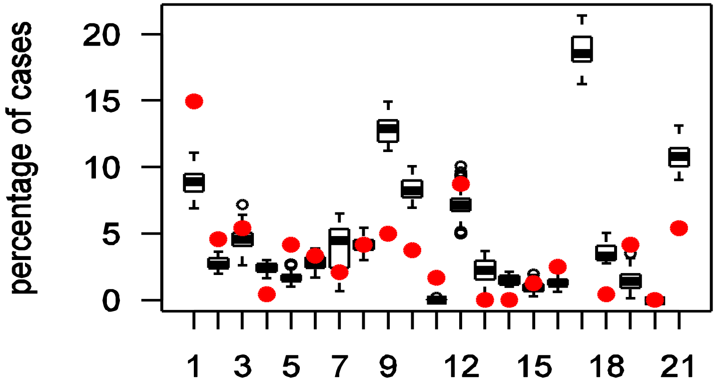

- Should your model be able to reproduce patterns of change over time?




variation quite substantial

- Should your model be able to reproduce patterns in space?

**HEH** : Human Environment Human



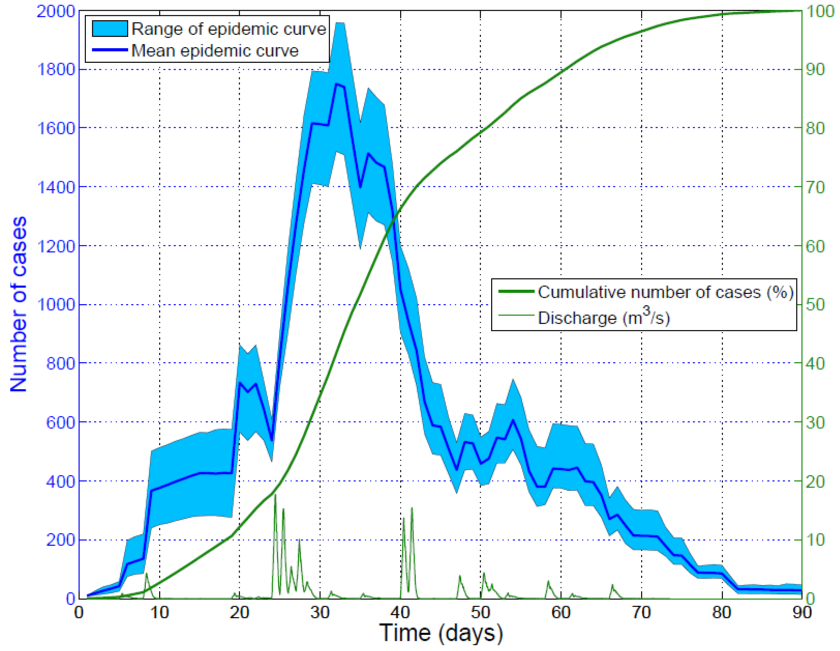

red dots: actual cases in the neighbourhood
black : simulation result

community

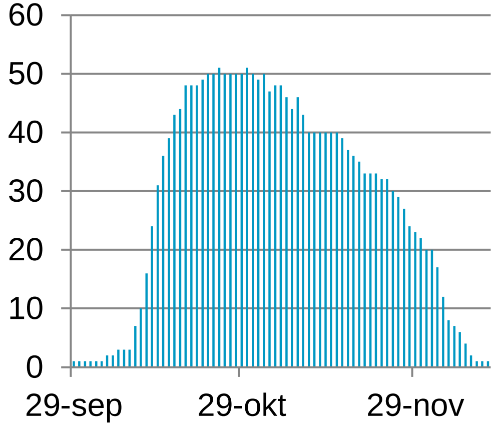
Augustijn, E.-W., et al. (2016). "Agent-based modelling of cholera diffusion." Stochastic Environmental Research and Risk Assessment **30**(8): 2079-2095.

# INTEGRATED MODEL

## RESULTS




Range of epidemic curves representing the minimum and maximum number of cases within a set of 90 runs.




| Transmission mechanism | HH | HEH | EH | VT |
|---|---|---|---|---|
| Average number of cases | 80 | 2461 | 683 | 22 |
| Minimum and maximum number of cases | 60-104 | 2237-2608 | 595-786 | 10-38 |
| Contribution to total number of cases (%) | 2.5 | 75.8 | 21.0 | 0.7 |

Augustijn, E.-W., et al. (2016). "Agent-based modelling of cholera diffusion." Stochastic Environmental Research and Risk Assessment **30**(8): 2079-2095.

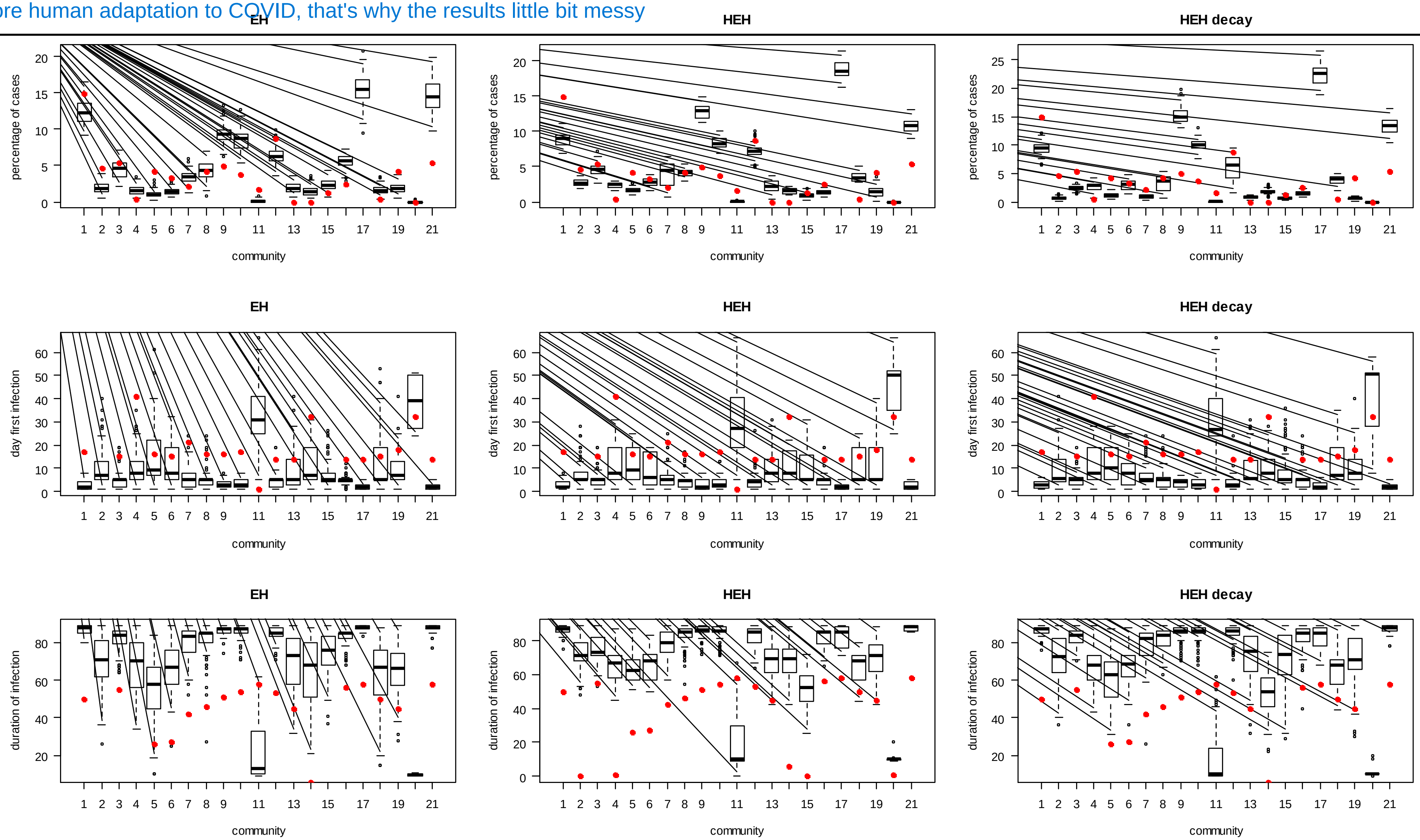
# EXPERIMENT 1: EVALUATION SPATIAL PATTERNS

These is the results before human adaptation to COVID, that's why the results little bit messy

Disease cases

Day first infection

Duration of infection

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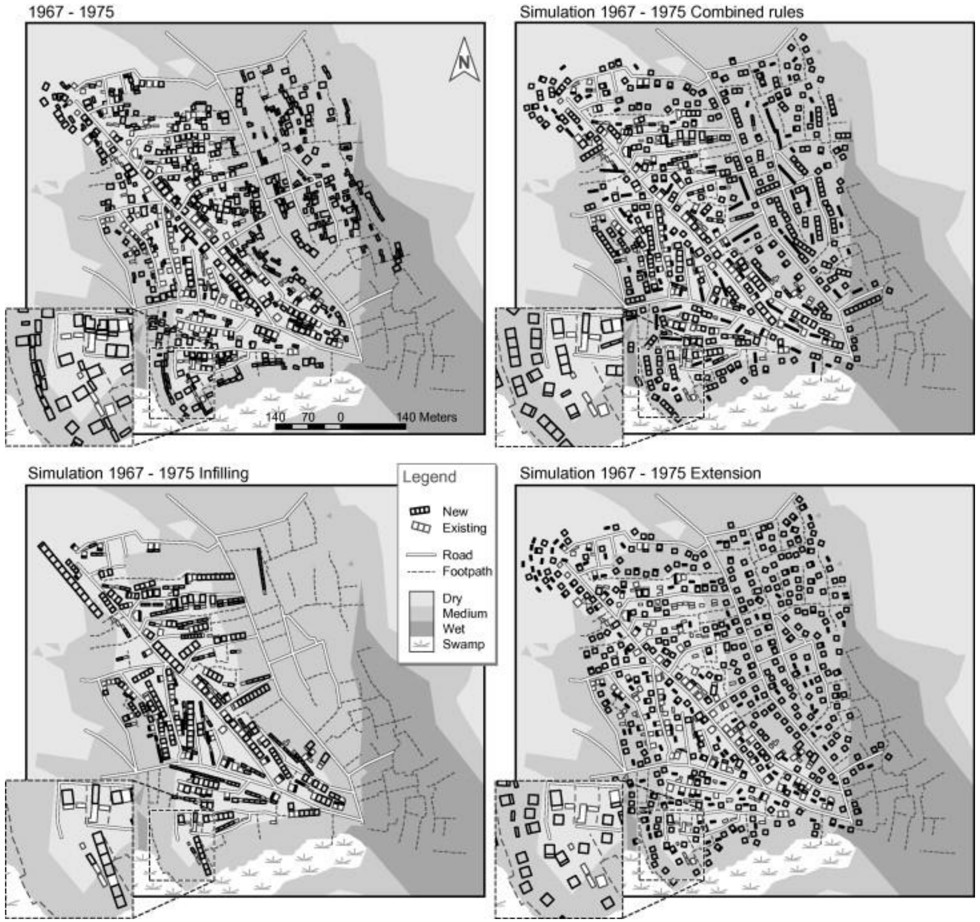
Augustijn, E.-W., et al. (2016). "Agent-based modelling of cholera diffusion." Stochastic Environmental Research and Risk Assessment **30**(8): 2079-2095.

# PATTERN ORIENTED MODELING

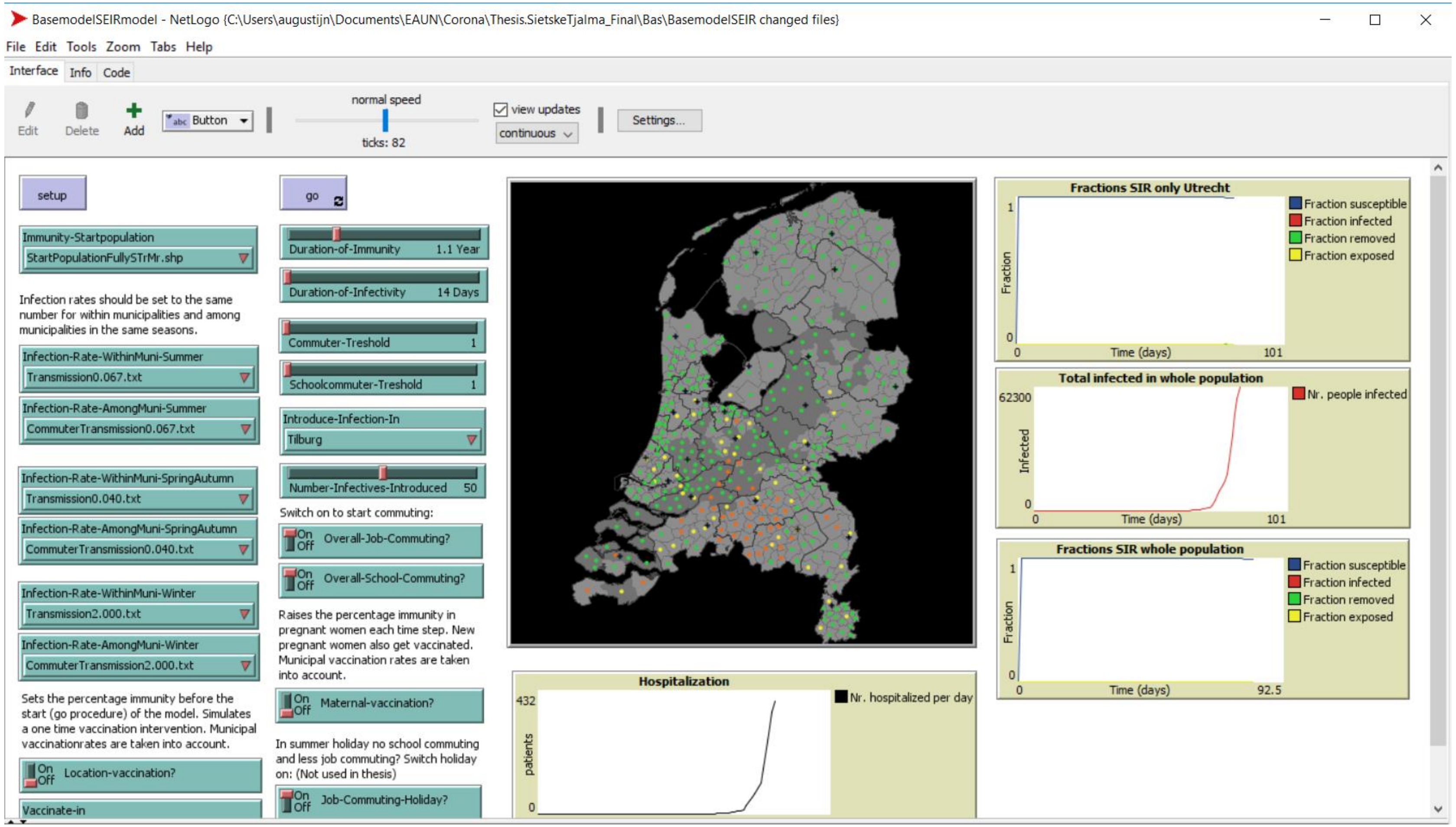
- Two differen/alternative hypothesis

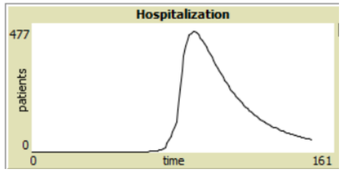
- Extension: use the complete area to find the optimal location
- Infilling: try to align to existing buildings

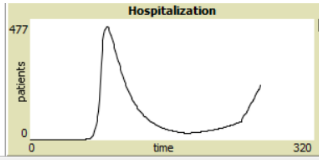



Augustijn-Beckers, P., Flacke, J., & Retsios, V. (2011). Simulating informal settlement growth in Dar es Salaam, Tanzania : an agent - based housing model. *Computers, environment and urban systems*, *35*(2), 93-103. https://doi.org/10.1016/j.compenvurbsys.2011.01.001

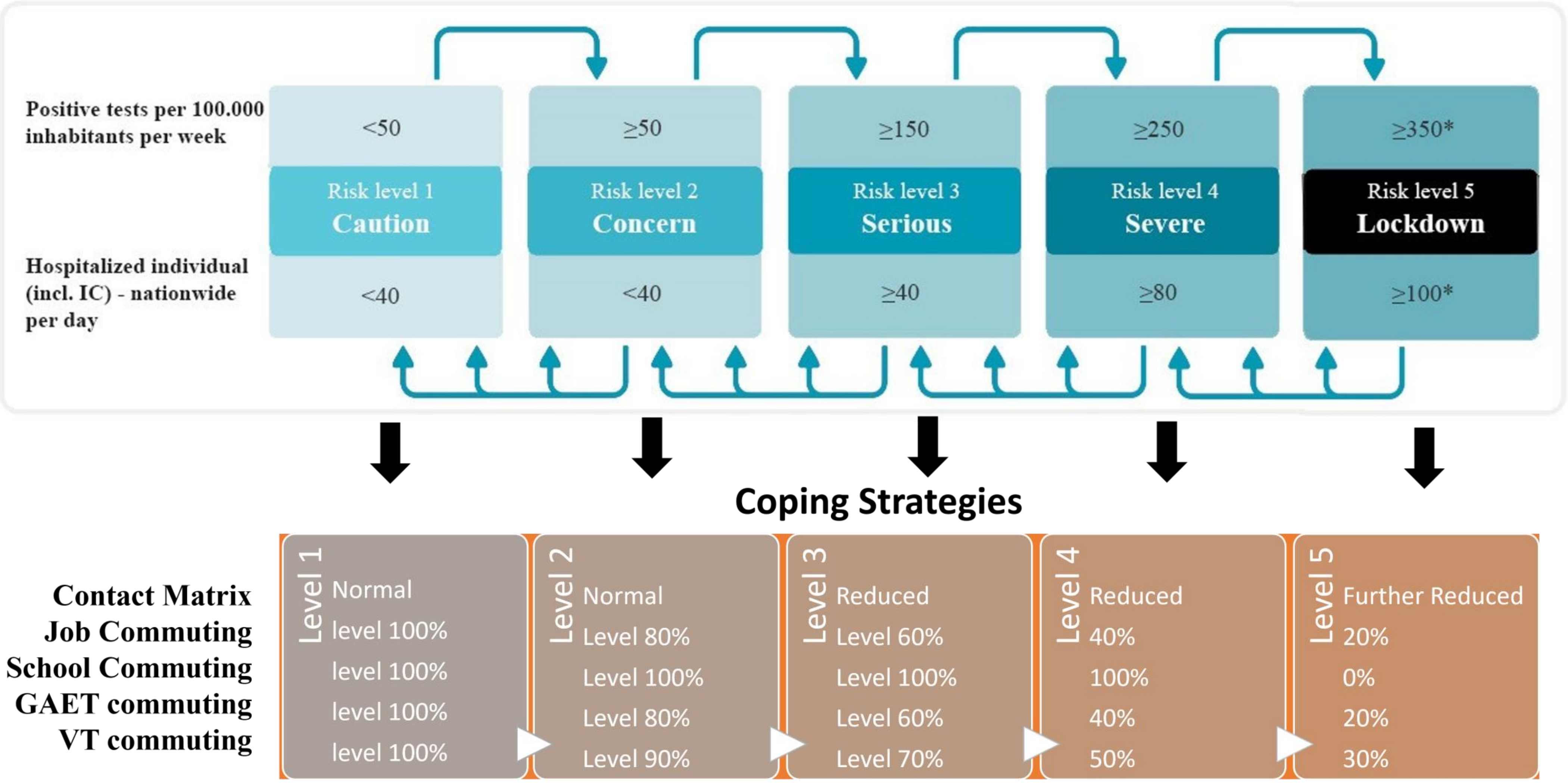
# Covid-19 model



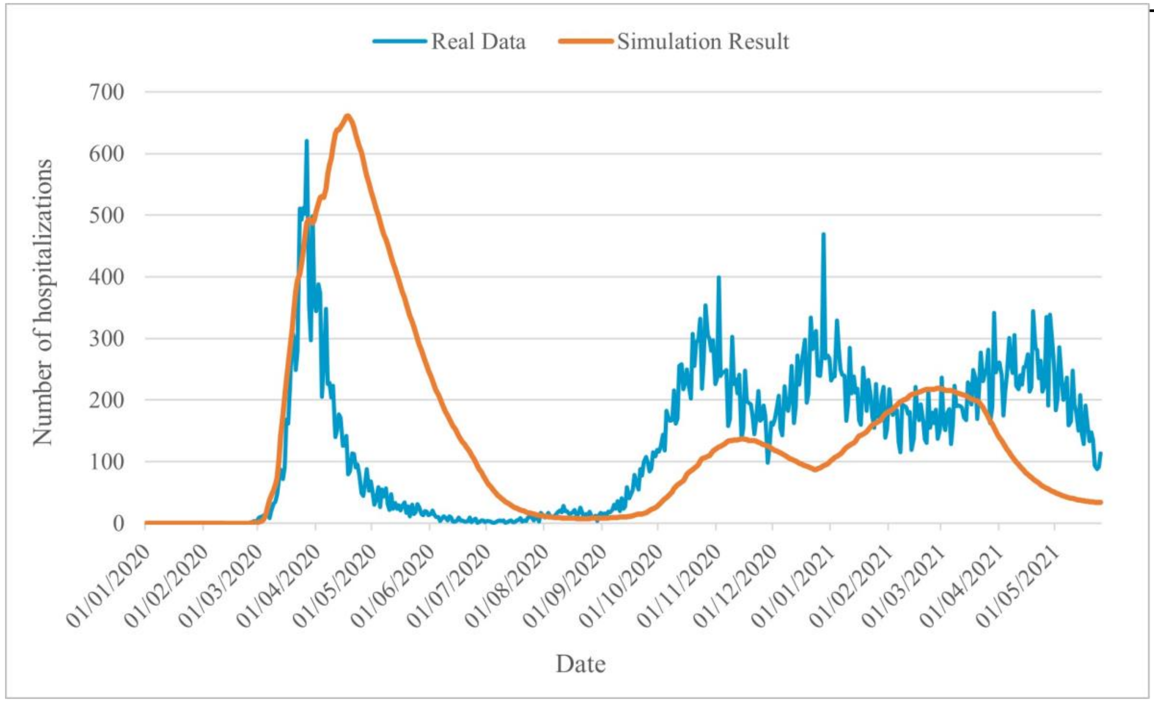
# Risk perception

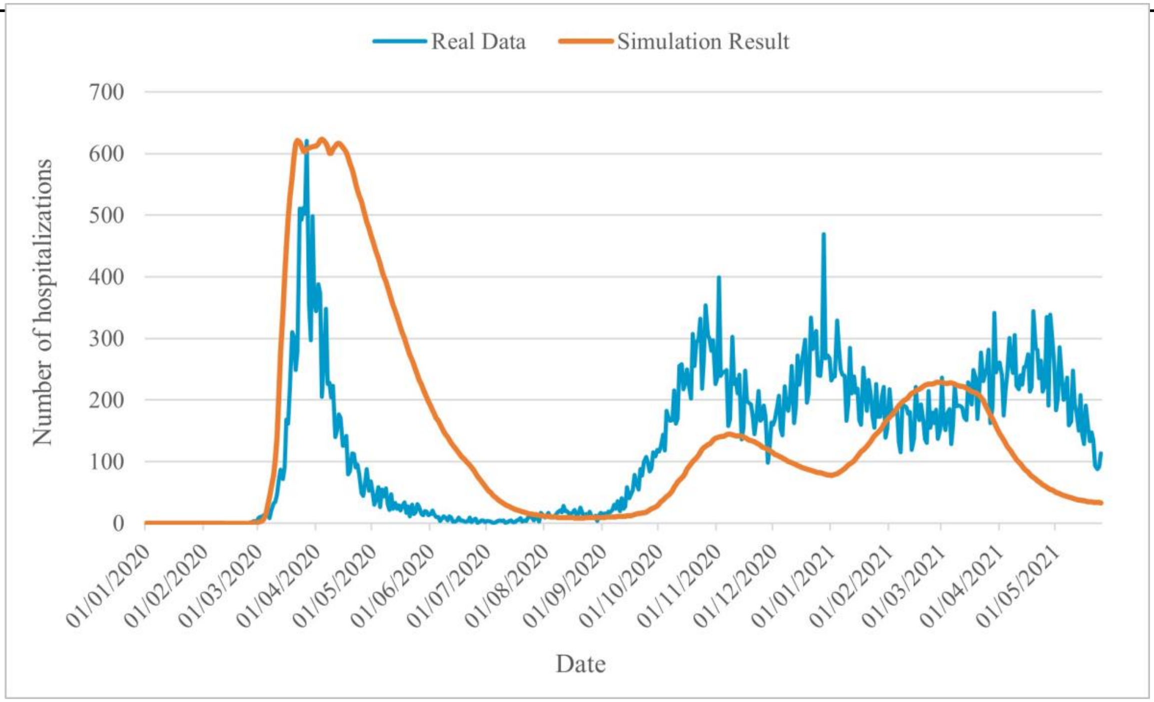



Augustijn et al. (2022) Integration of governmental risk perception into a Covid-19 model for the Netherlands, 2022 VFGG
Ministerie van Volksgezondheid, 2020

With closing of schools

Without closing of schools

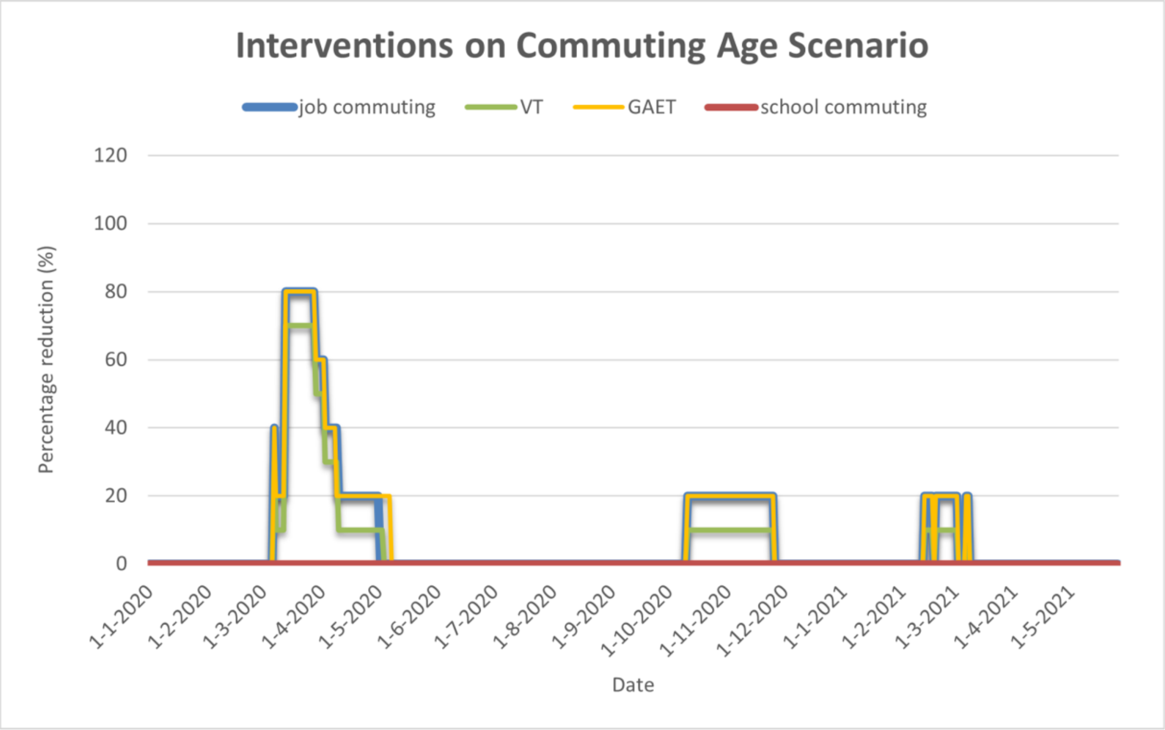



Number of hospitalized cases for the RoadMap Scenario

Number of hospitalized cases for the age-specific

Augustijn et al. (2022) Integration of governmental risk perception into a Covid-19 model for the Netherlands, 2022 VFGG (in press)



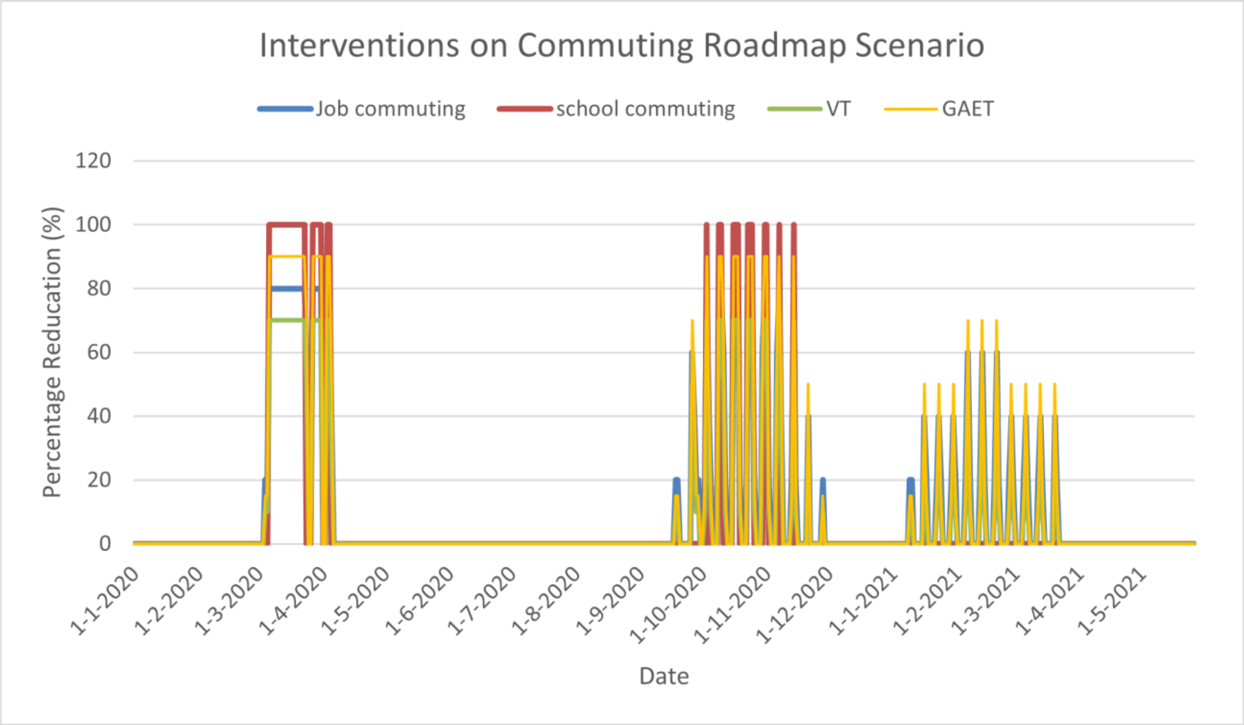
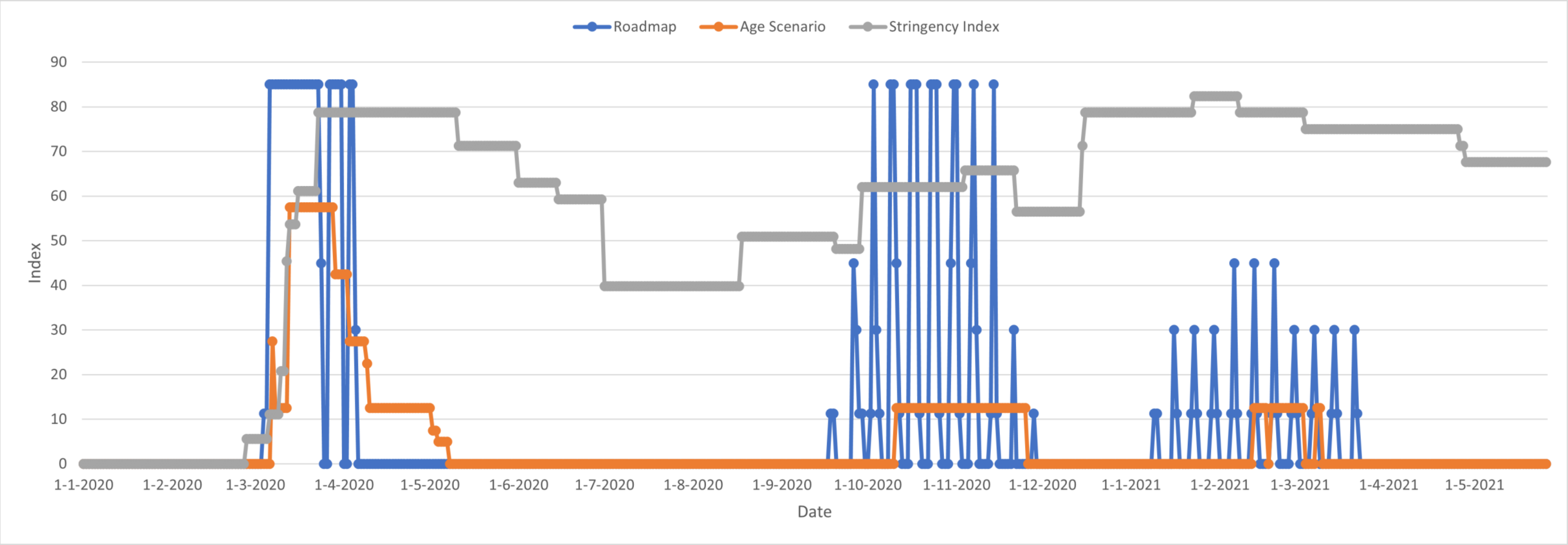




Figure 7: Interventions on Commuting for the RoadMap Scenario (a) and the Age Scenario (b).

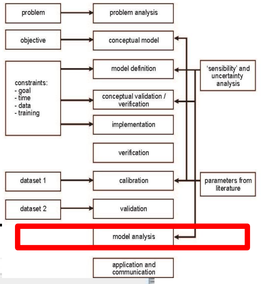


Augustijn et al. (2022) Integration of governmental risk perception into a Covid-19 model for the Netherlands, 2022 VFGG (in press)

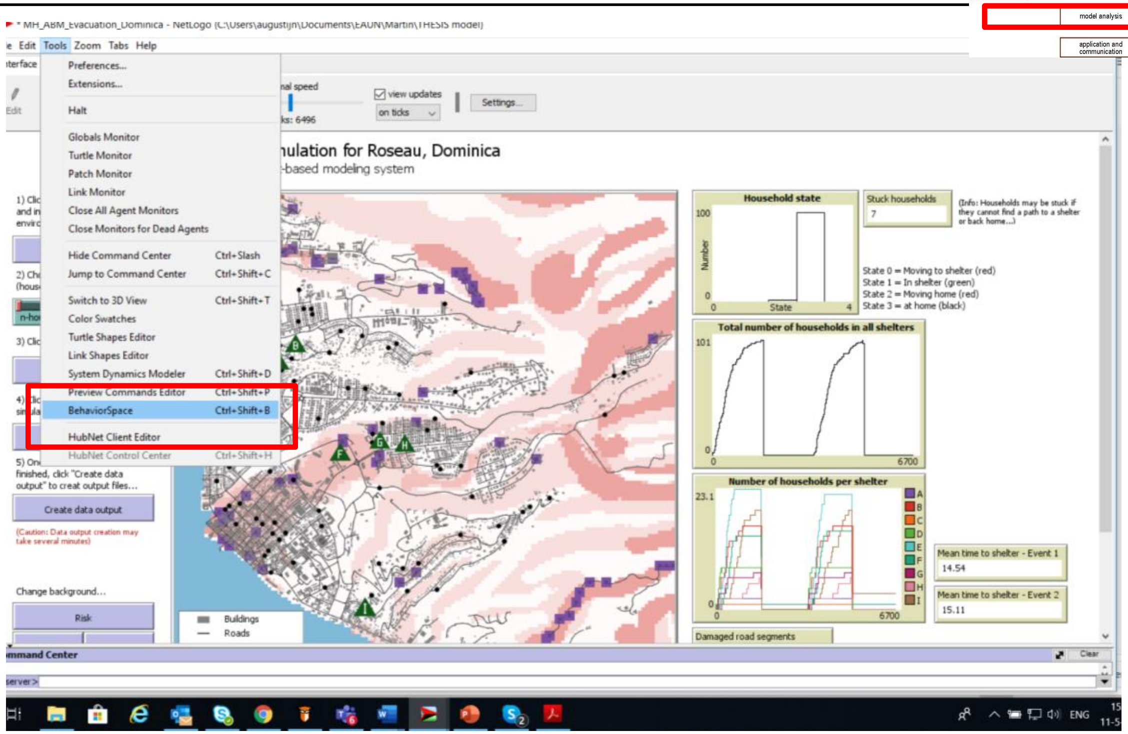
# MODELING COVID-19



# BEHAVIOR SPACE



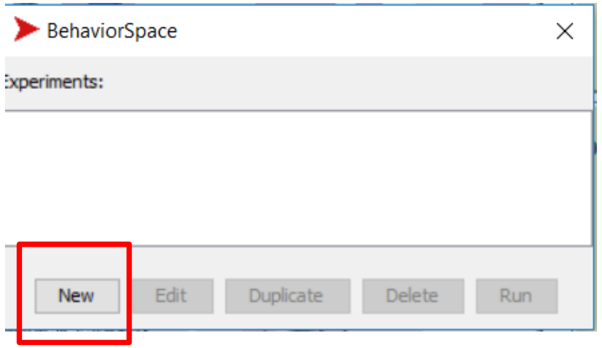

- Open behavior space via the **Tools menu**
- Create a new experiment
- Edit an existing experiment
- Run an experiment



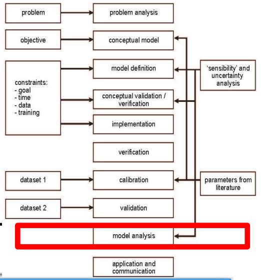

what tools/methods are available to capture model outcomes?
-via the user interface : monitors, graphs, inspecting elements\
- by writing information to an output file
- via behaviour space

what types of output ABM models can we produce?
-agents, environments, time
- count, behavior and interaction

at what aggregation level can you capture outputs?
- for and individual agent or an individual patch
-all agents, complete environments



# BEHAVIOR SPACE




- Variables that are automatically added come from the user interface
- For models that are stochastic, increase the number of repetitions
- Carefully check the outputs → number of households per shelter
- Make sure your model does not keep on running for ever

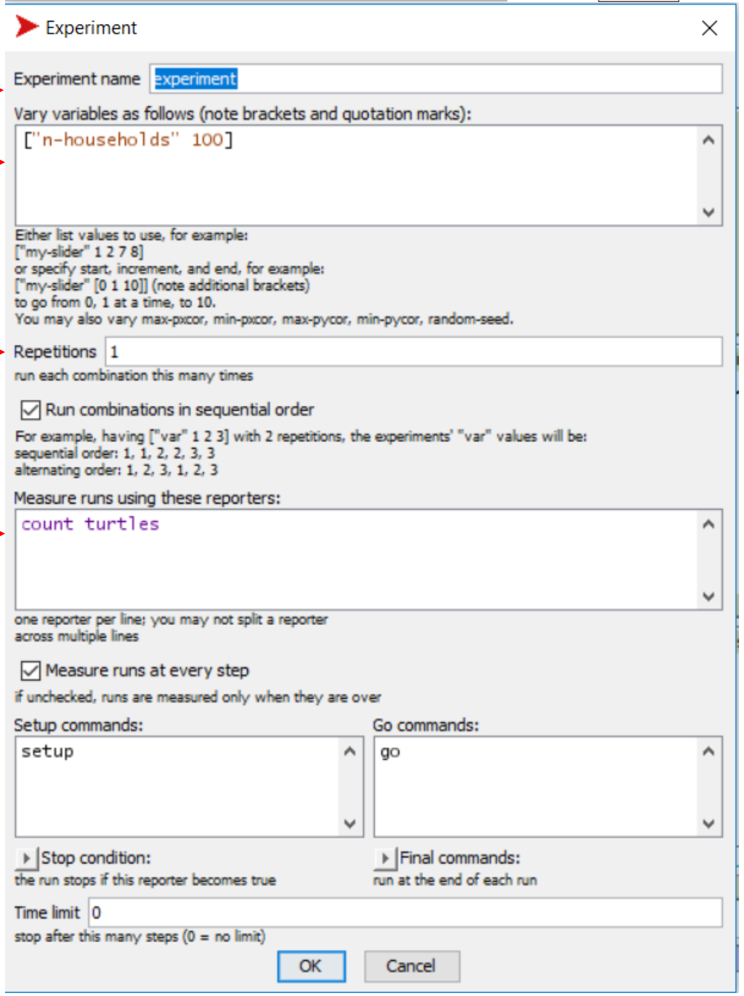
names

variables

repetitions

outputs

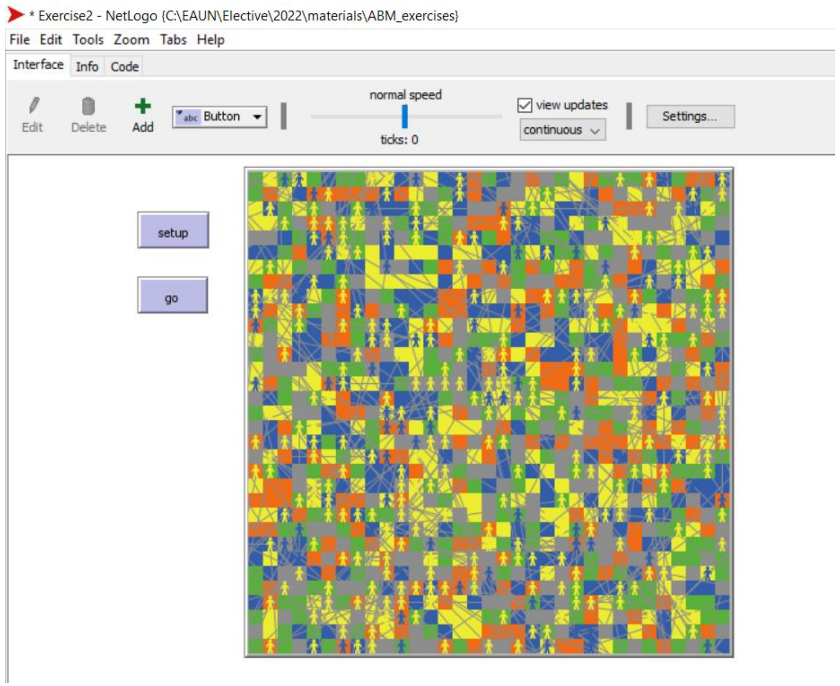
Stopping the model



# CODE EXAMPLES

# CREATING LINKS

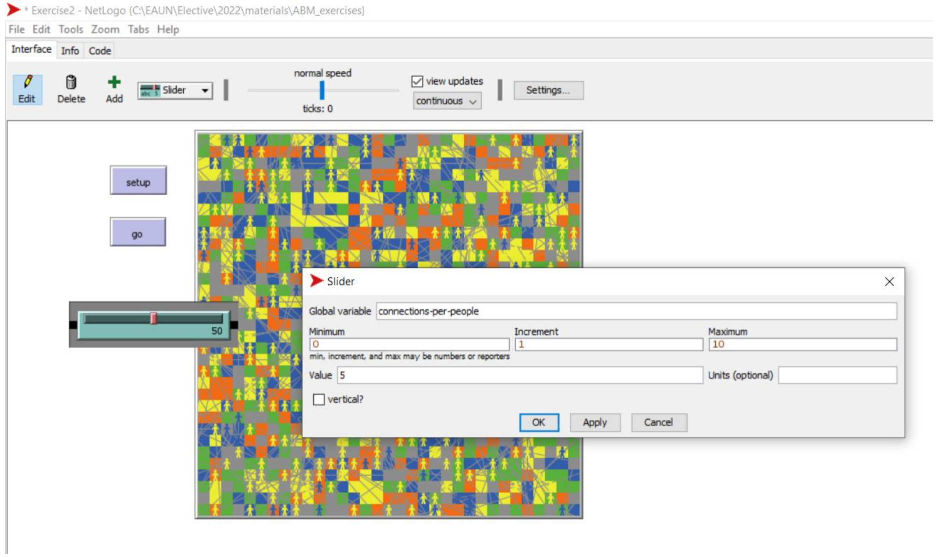
```
to setup-agents
  create-residents 100
  ask residents [move-to one-of patches set color blue set shape "person"]
  create-tourists 300
  ask tourists [move-to one-of patches set color yellow set shape "person" set stay-duration (random 10 + 1) create-link-with one-of residents]
end
```

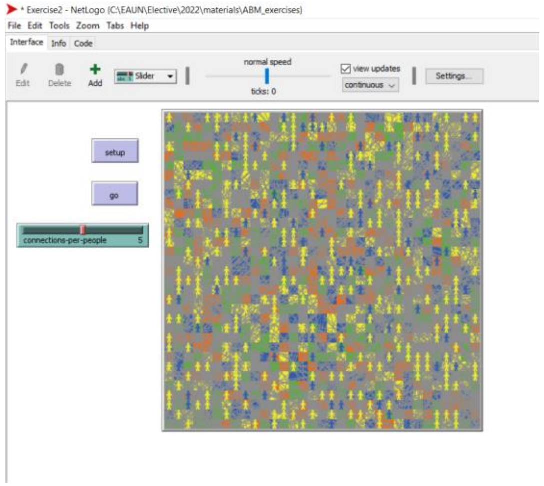



- You now see lines between the tourists and the residents when you run the setup

# CREATE MORE LINKS

- Create a slider to define the number of links to create

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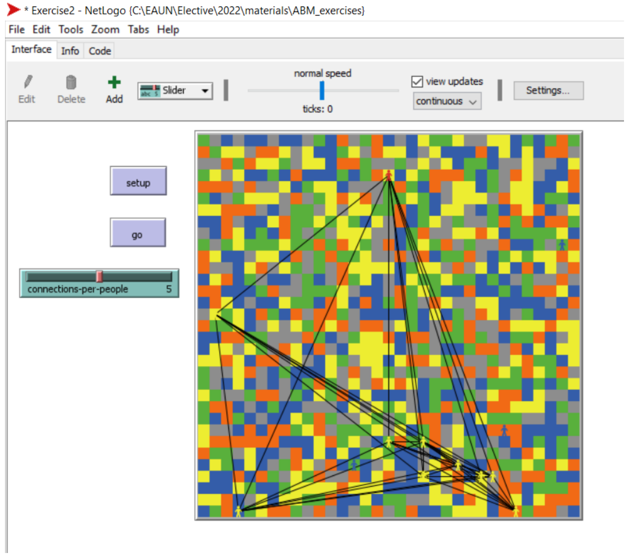
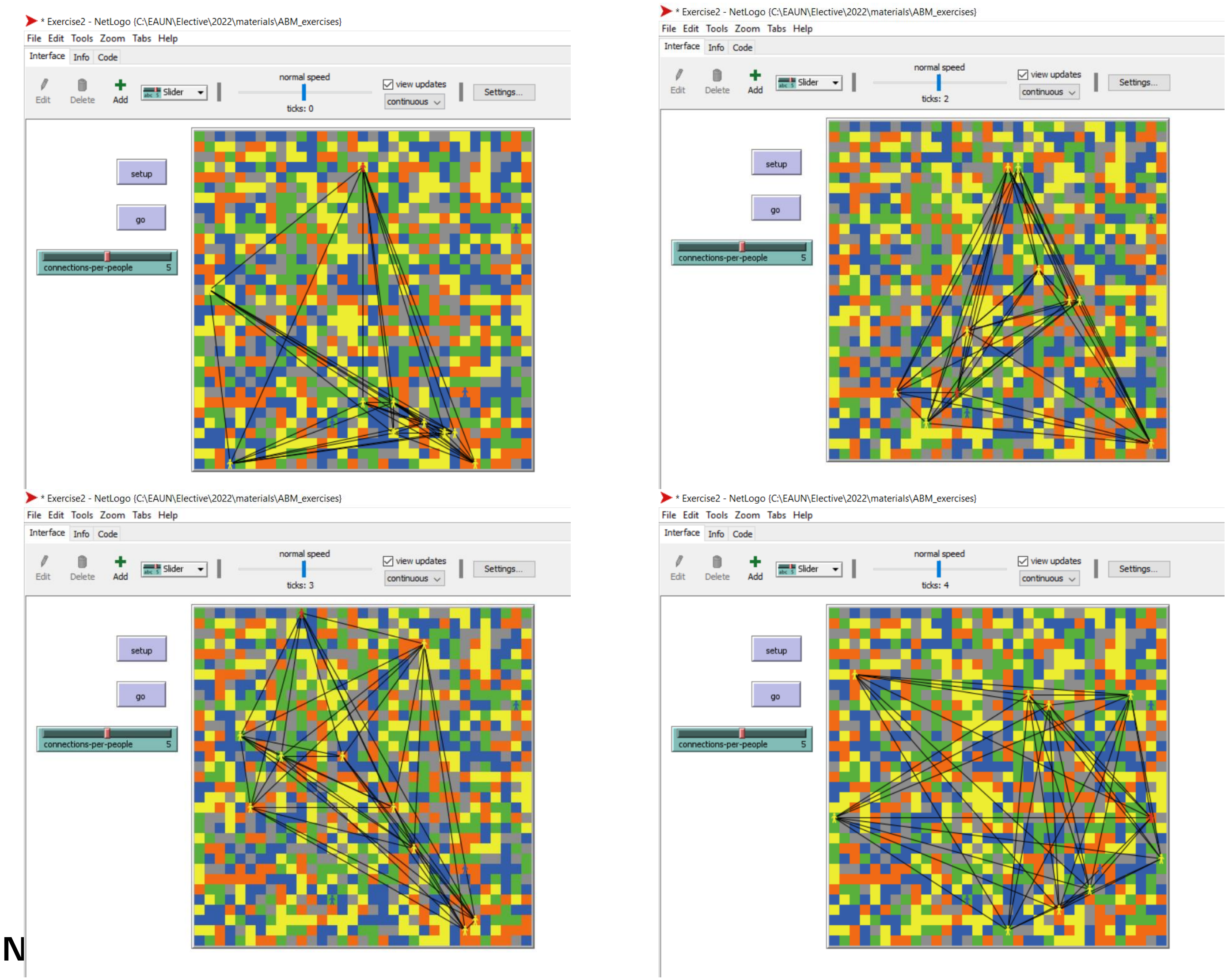
  create-residents 100
  ask residents [move-to one-of patches set color blue set shape "person"]
  create-tourists 300
  ask tourists [move-to one-of patches set color yellow set shape "person" set stay-duration (random 10 + 1) create-links-with n-of connections-per-people other tourists]
end
```




```
to setup-agents
  create-residents 5
  ask residents [move-to one-of patches set color blue set shape "person"]
  create-tourists 10
  ask tourists [move-to one-of patches set color yellow set shape "person" set stay-duration (random 10 + 1) create-links-with n-of connections-per-people other tourists]
  ask one-of tourists [
    set color red
  ]
  ask links [set color black]
end
```

- Give the links another color
- Reduce the number of agents to see the links

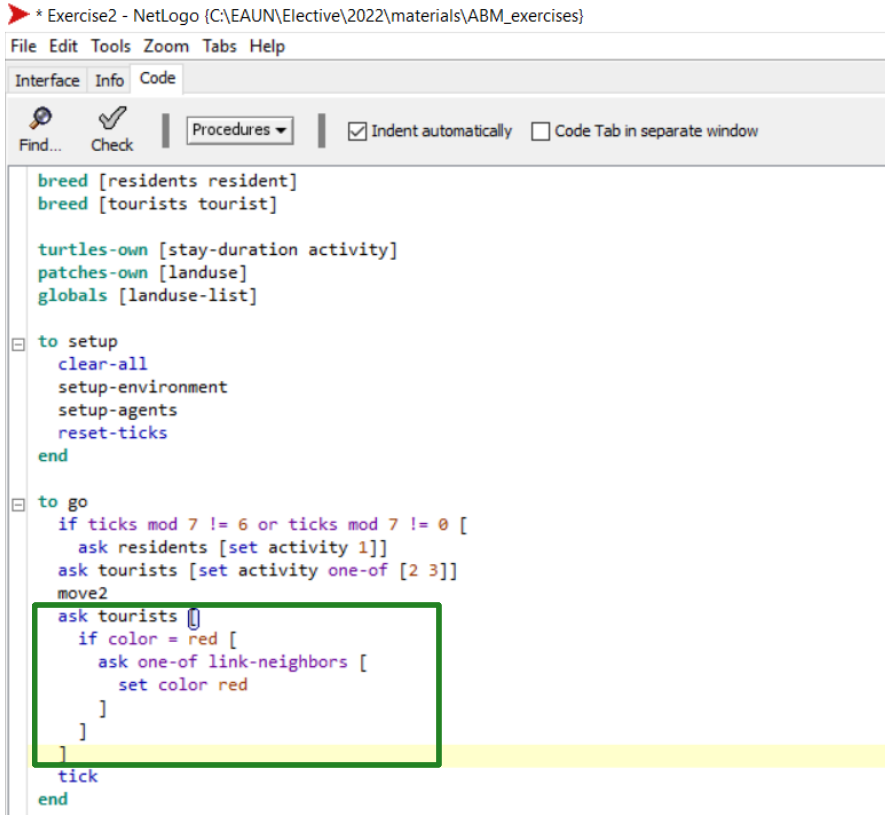
# MOVING THE TURTLES




- When we run the go, and our turtles move, the network will remain as is (the links will move with the turtles)

UN

# SPREAD MESSAGE

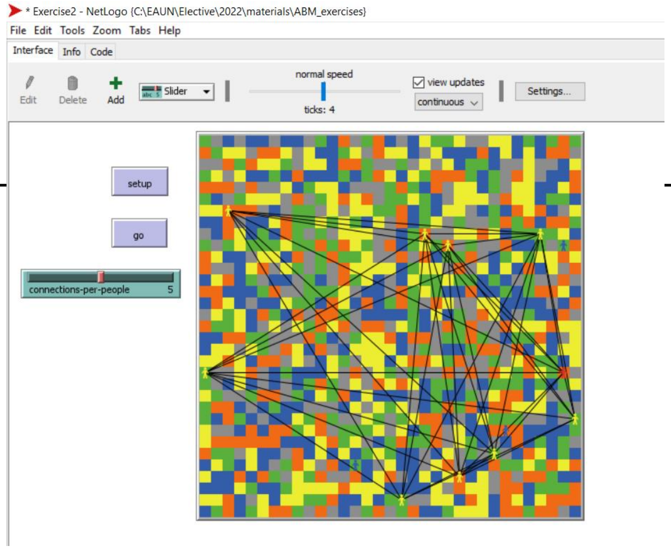


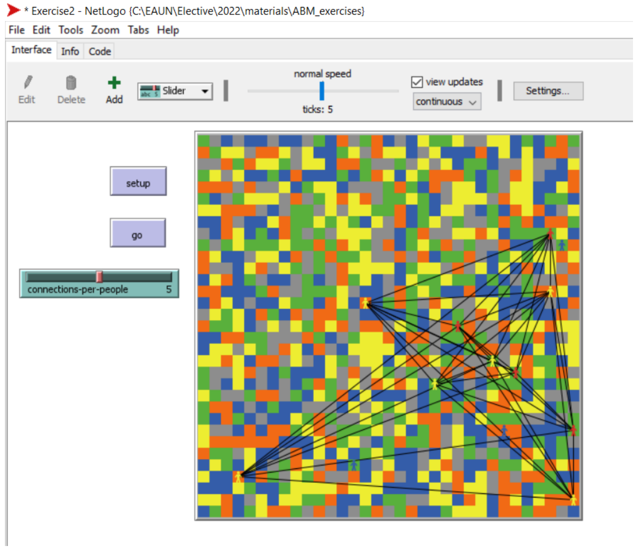

```
breed [residents resident]
breed [tourists tourist]

turtles-own [stay-duration activity]
patches-own [landuse]
globals [landuse-list]

to setup
  clear-all
  setup-environment
  setup-agents
  reset-ticks
end

to go
  if ticks mod 7 != 6 or ticks mod 7 != 0 [
    ask residents [set activity 1]]
  ask tourists [set activity one-of [2 3]]
  move2
  ask tourists [
    if color = red [
      ask one-of link-neighbors [
        set color red
      ]
    ]
  ]
  tick
end
```




- We see all turtles turn red
- Spread the fact that you should be aware of tick risk

UNIVERSITY OF TWENTE.

# TEAM BASED LEARNING 2

QUESTIONS VALIDATION

FACULTY OF GEO-INFORMATION SCIENCE AND EARTH OBSERVATION

Validation is regarded to be the most difficult part of ABMs. Which step in the validation process is the most difficult part of validating the Evacuation model? You can select multiple answers.

a. **Input validation**, as we cannot set a building to fire to collect data that is correct/valid.
we can collect data but it will never be same with real

b. **Process validation**, as we do not know what people in a building are doing at the time an evacuation starts.

c. **Descriptive validation,** as there are no patterns that we can replicate.

d. **Predictive validation,** as there is no independent data available

To check the validity of a model, you should know the purpose of the model. Which of the statements below about the Wolf-Sheep-Grass model is correct?

a. This model does not have a purpose, and therefore, it cannot be validated.

b. The purpose of this model is to show that wolf-sheep dynamics is a complex system. Therefore, descriptive output validation is the most important aspect of the validation process.

c. The purpose of this model is to predict how many sheep can survive with a given number of wolves in a neighborhood. Therefore, predictive output validation is the most important aspect of the validation process. the model is never predict, it just show the patterns

d. The problem with this model is that not all processes, like flocking of sheep, are implemented, and therefore, the model cannot be validated.

In the Living Textbook, you find the concept “validation” as one of the steps in the ABM design steps. Under challenges, various issues are listed that might apply to the evacuation model. Select all correct statements below.

a. The stochastic nature susah dibandingin sama real world

b. Predictive versus retrodictive capability we don't predict future but we predict the past

datanya experiment, fake

c. Data Quality datanya fake makanya harus divalidate

d. Path Dependency agentnya lokasinya random, kerandomnya ngefek model

Stochastic model : essential for risk assessment, decision making under uncertainity and understanding system whre randomness plays a crucial role
Deterministic models are useful for scenarios where precision is critical, and variability is minimal or can be ignored