Model M

Towards a faithful epidemiologiocal model of a city

Centre for Modelling of Biological and Social Processes

Prague, September 24, 2020

Basic structure

2 parts

1. Epidemiological model (SEIR)
2. Network modelling a real environment (in our case a small town, however we can put any structure here as a firm etc.)

Epidemiological model

- Based on traditional SEIR model
- But enhanced to capture Exposition, Deaths, Testing and detection, Symptomatic vs Asymptomatic progress, and COVID-like symptoms caused by other reasons.
- Probabilities of state transitions according to expert estimates, fine-tuned by fitting actual epidemic data
- Contact tracing and other measures algorithms

Epidemiological model

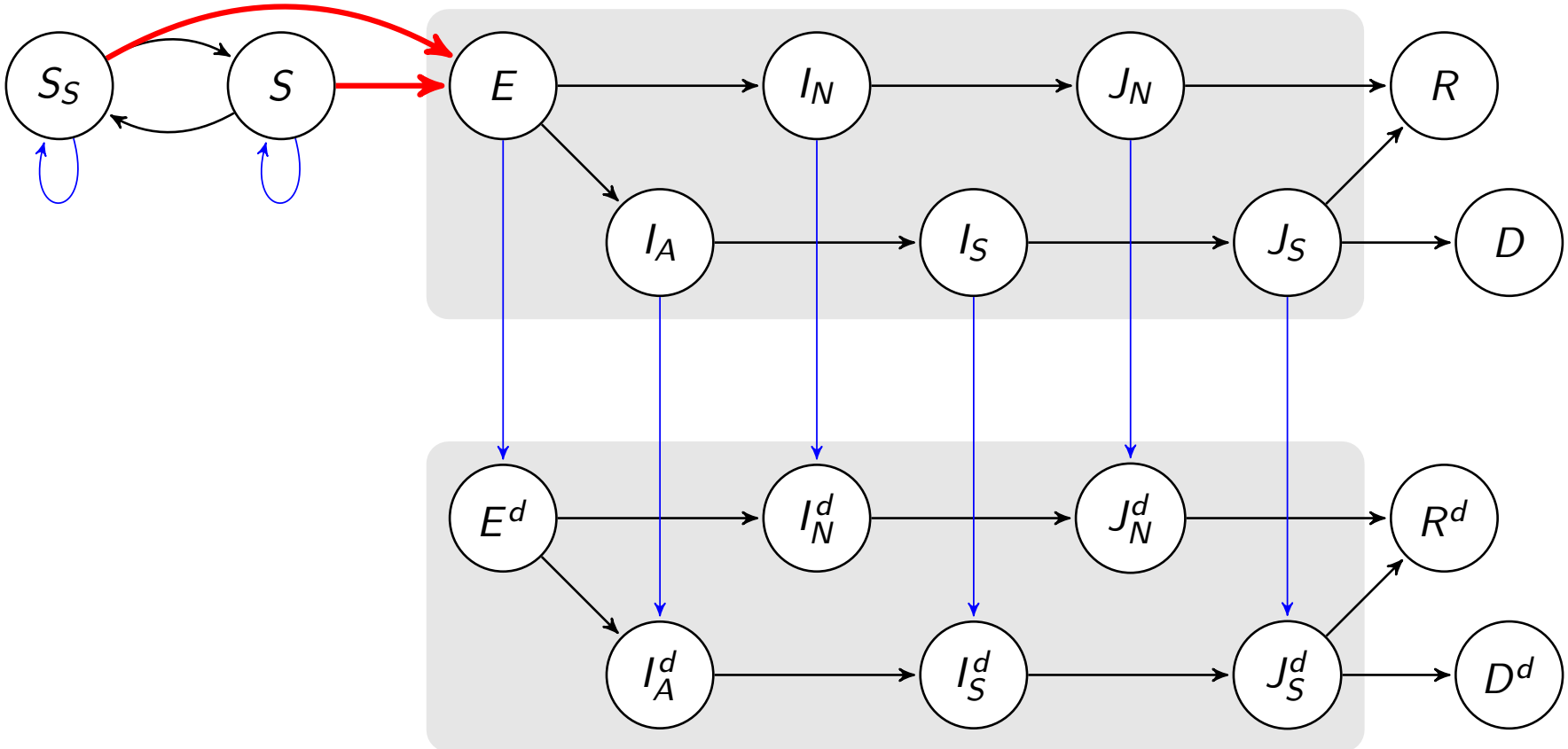
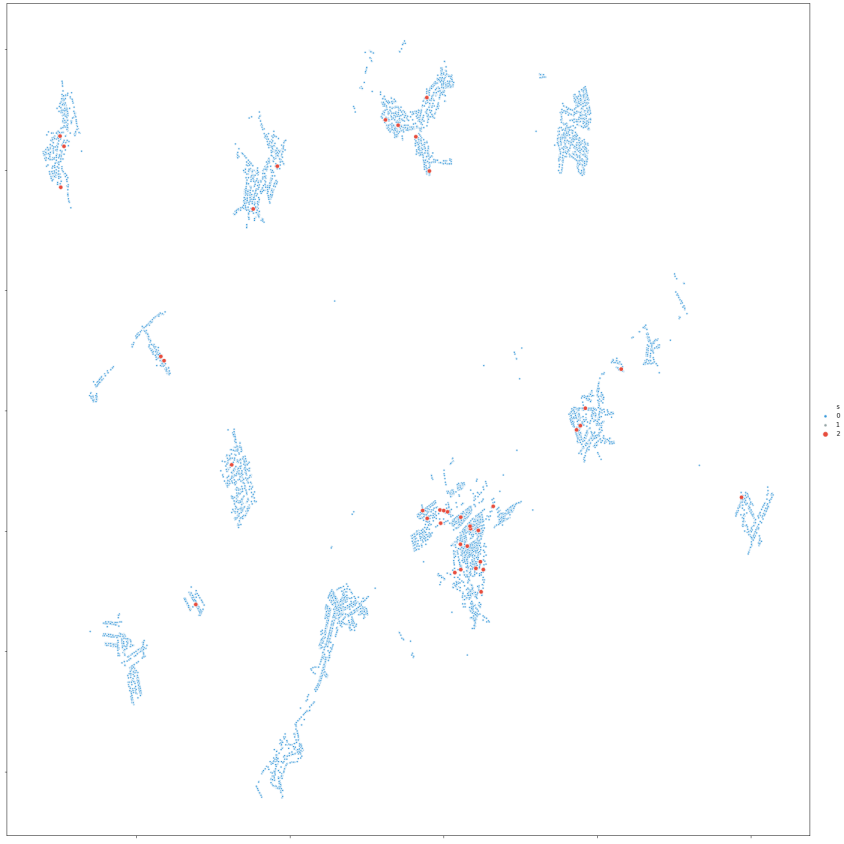


Figure: State transition diagram. E – exposed, I_a – infectious presymptomatic (later will exhibit symptoms), I_s – infectious symptomatic, J_s – non-infectious symptomatic, I_n – infectious asymptomatic (never will become symptomatic), J_n – non-infectious asymptomatic, R – recovered undetected, D – dead undetected, X_y^d – Y_y detected.

City M as a model

- 56102 nodes (inhabitants), 21 ext. nodes
- 2 million edges (contacts) in 31 layers
- interaction intensities correspond to weights of contact layers
- human behaviour is modelled by changes of parameters for state transitions
- we model testing, quarantine, contact tracing, partial closures



Faithful graph model

- Population:
  - The city (24k people)
  - Dozen of neighbouring municipalities (32k people)
- Data based on:
  - Czech Republic 2011 Census (Czech Statistical Institute)
  - Location and characteristics of properties (State Administration of Land Surveying and Cadastre)
- Contacts/social interactions:
  - Matrix of social contacts (Prem et al. 2017)
  - List of schools, shops, restaurants (Econlab z.s.)
  - Consumer habits (Media and Lifestyle, Median)
  - Shopping behaviour (Skala a Sulc)
  - Transport and mobility behaviour (Cesko v pohybu – Czechia in Motion)

Social contacts

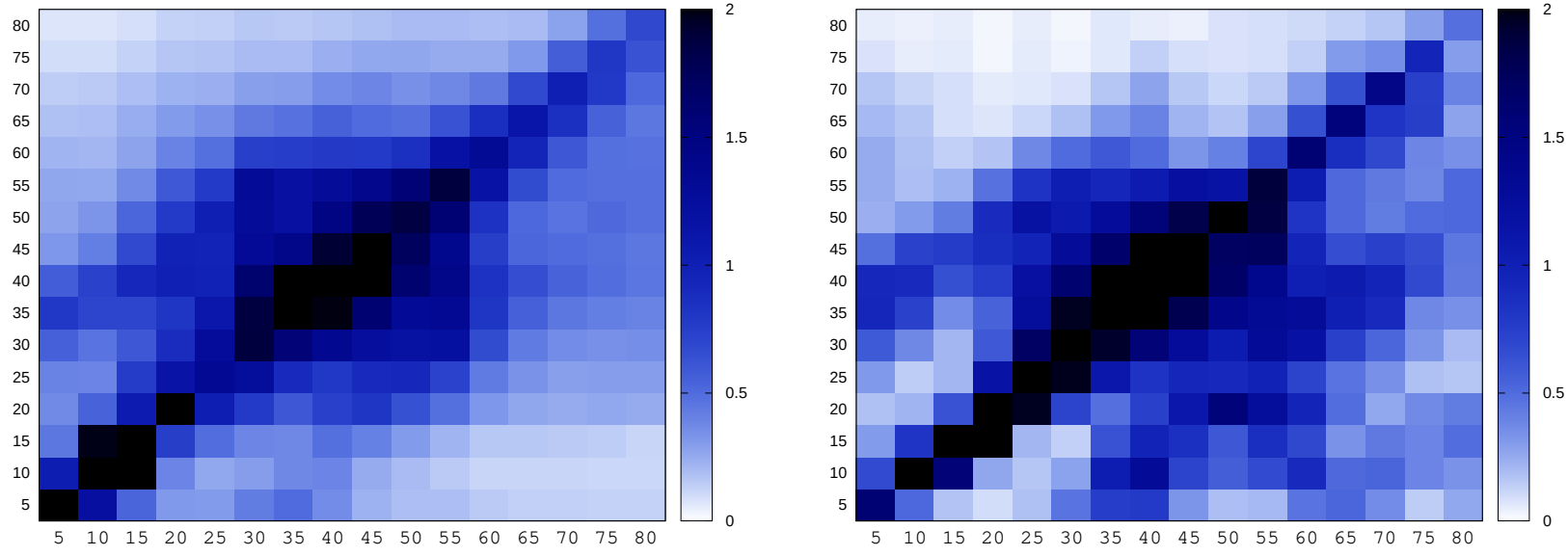


Figure: Frequency matrices for social contacts based on age: Our data (left), Prem et al. 2017 (right)

Faithful graph model - contd.

- Dynamics of interactions during pandemic
  - COVID-19 spread modelling (Median)
  - Epidemic Tracking (Life during pandemic - PaQ Research)
- Contagiousness of different contact types:
  - Survey of Czech leading experts
  - Literature meta-review

Contacts and contagiousness

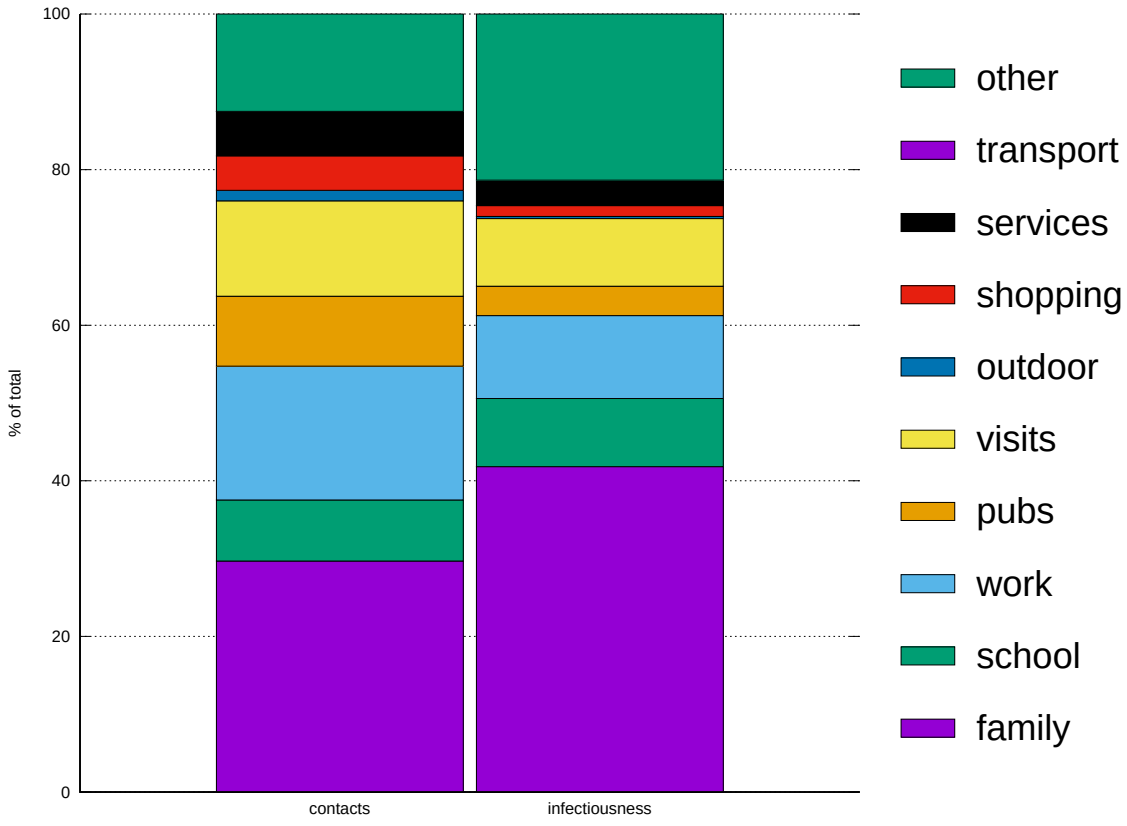


Figure: Relative contact intensities and contagiousness levels based on interaction types.

Contacts dynamics

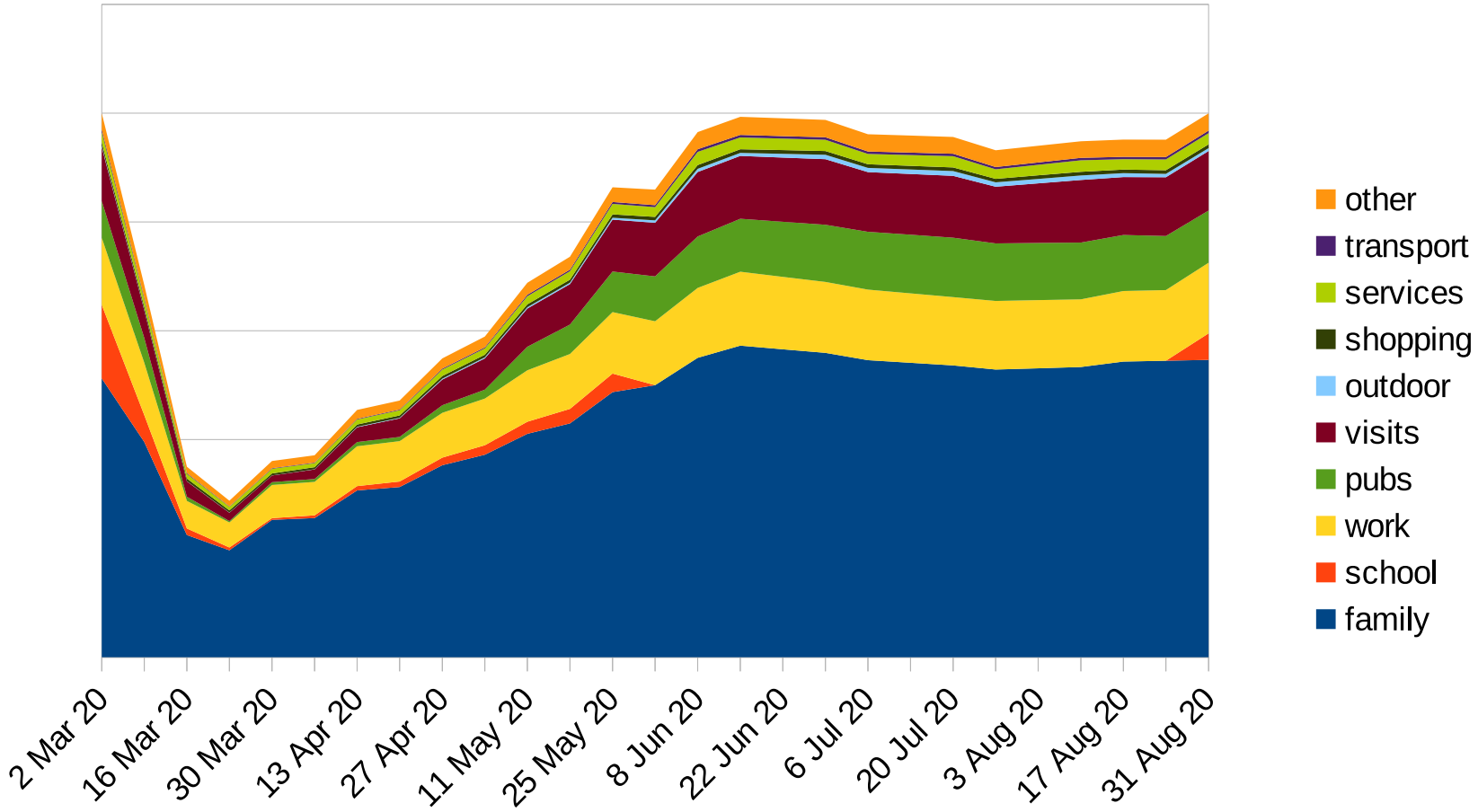
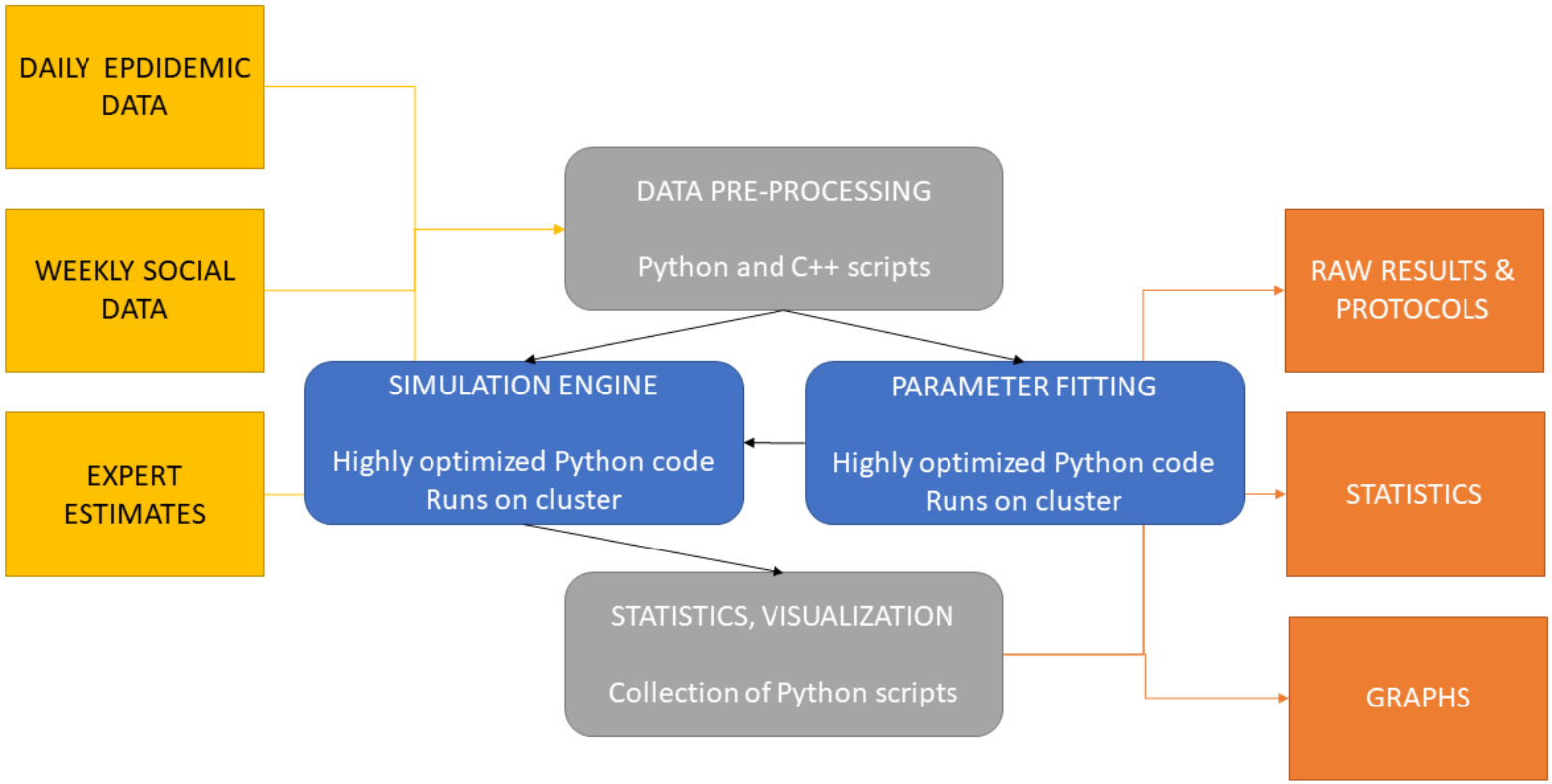


Figure: Contact intensities based on interaction types – weekly dynamics since March.

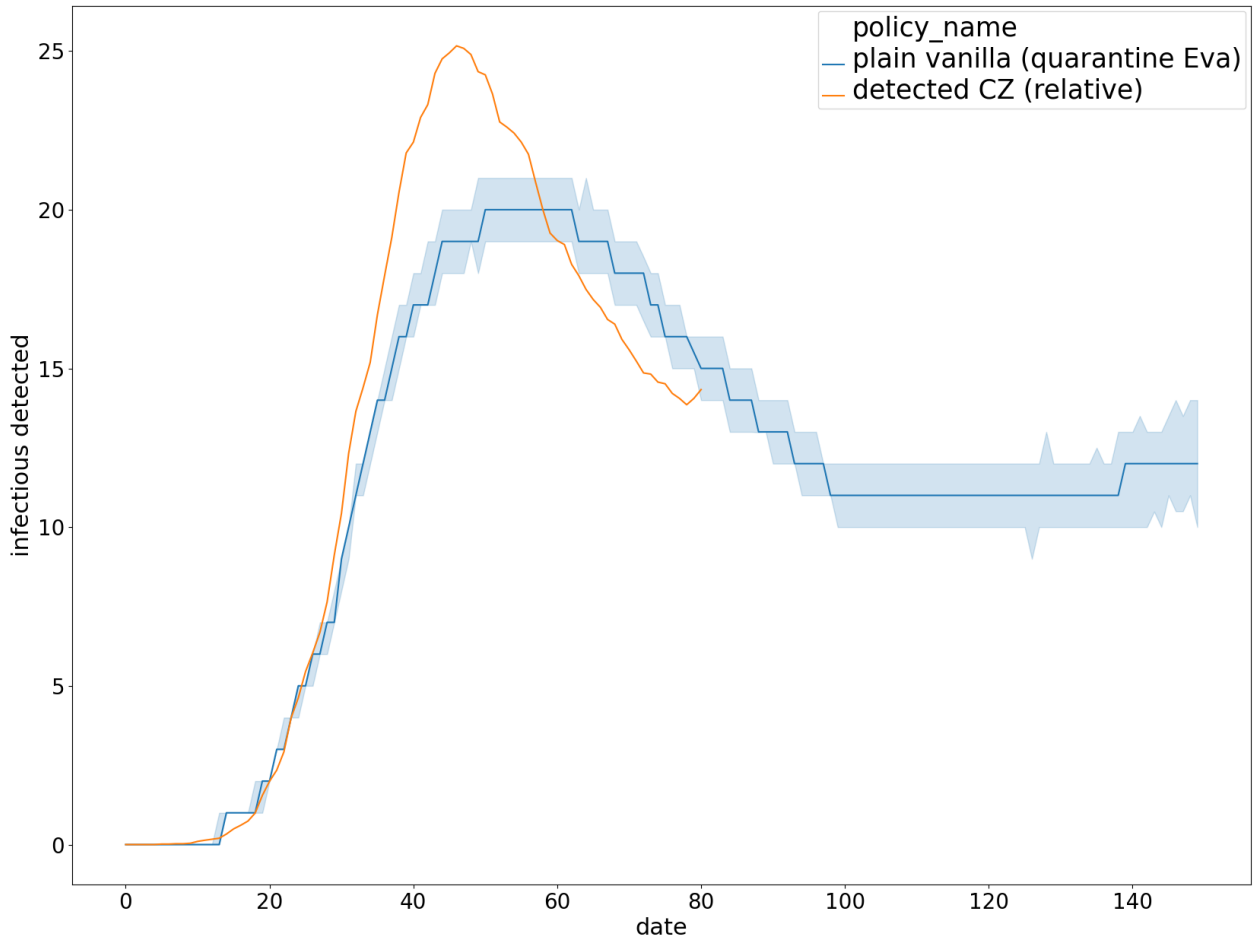
Gabriela-29691 - a node in City M

ID: 29691
sex: female
age: 19
occupation: student
address: -566848,-1195260
apartment: 3196
233 contacts
(household, family, school, shops, sport, cafes, restaurants)

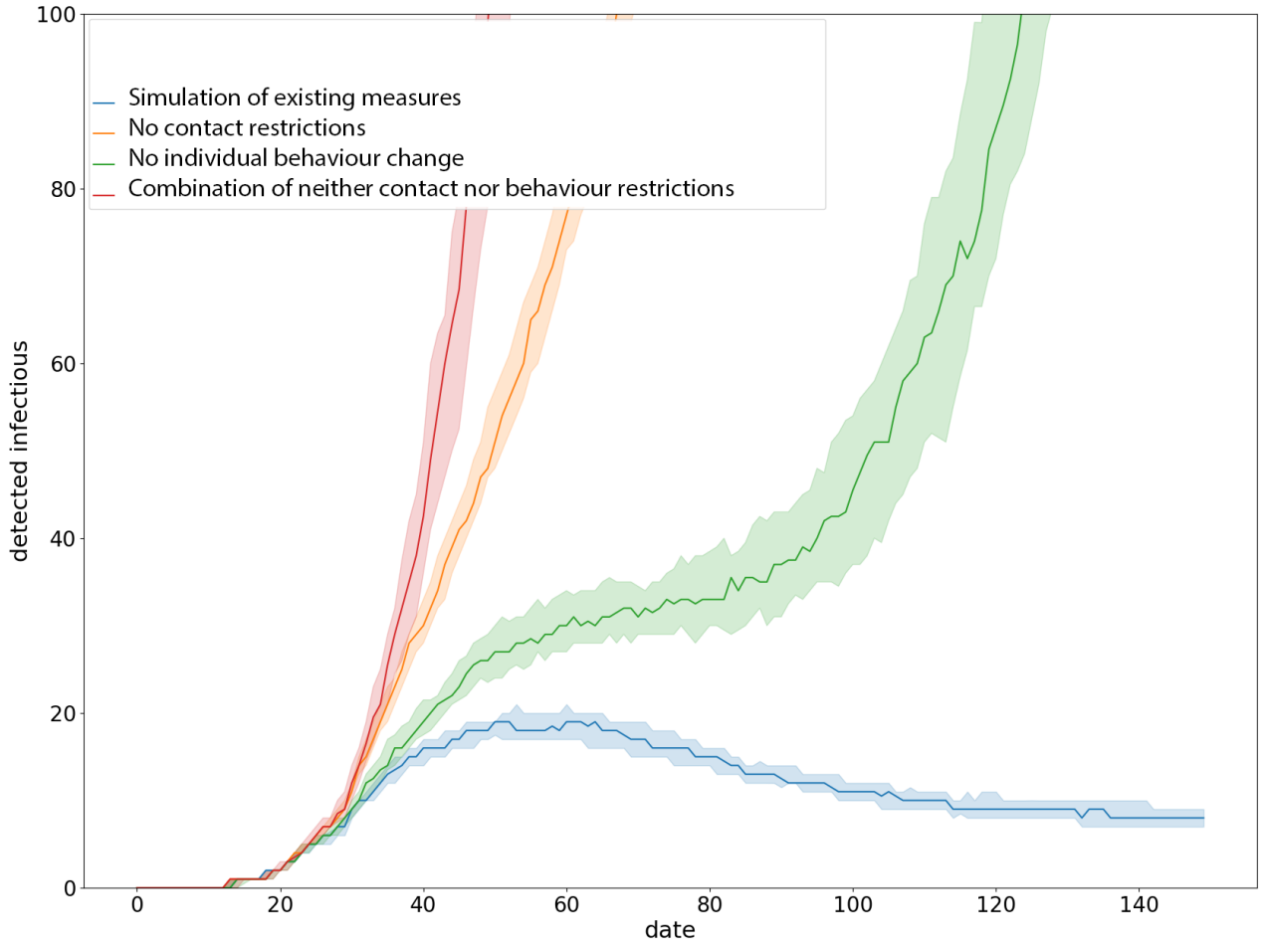
Model as software



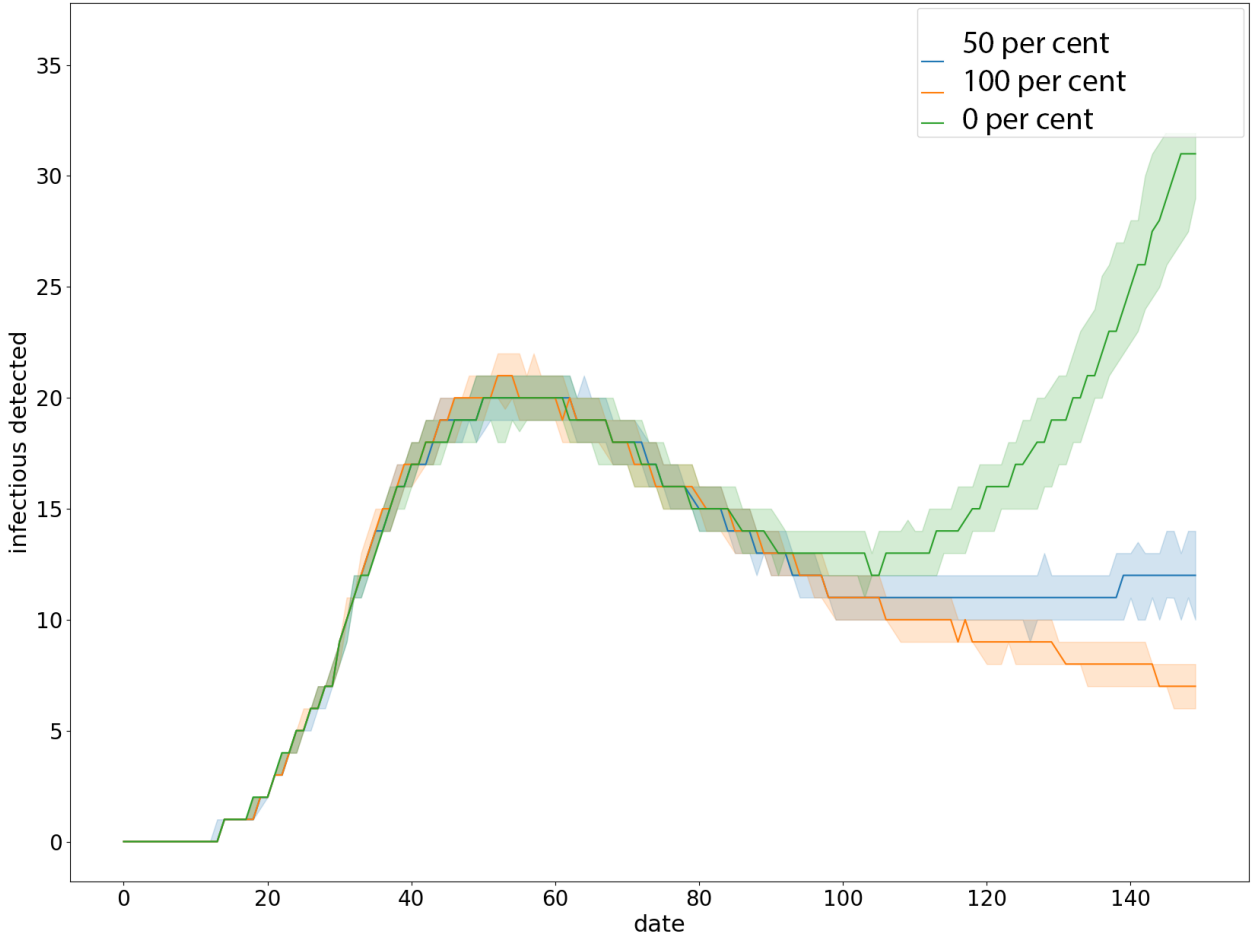
Example: Fitting the real situation



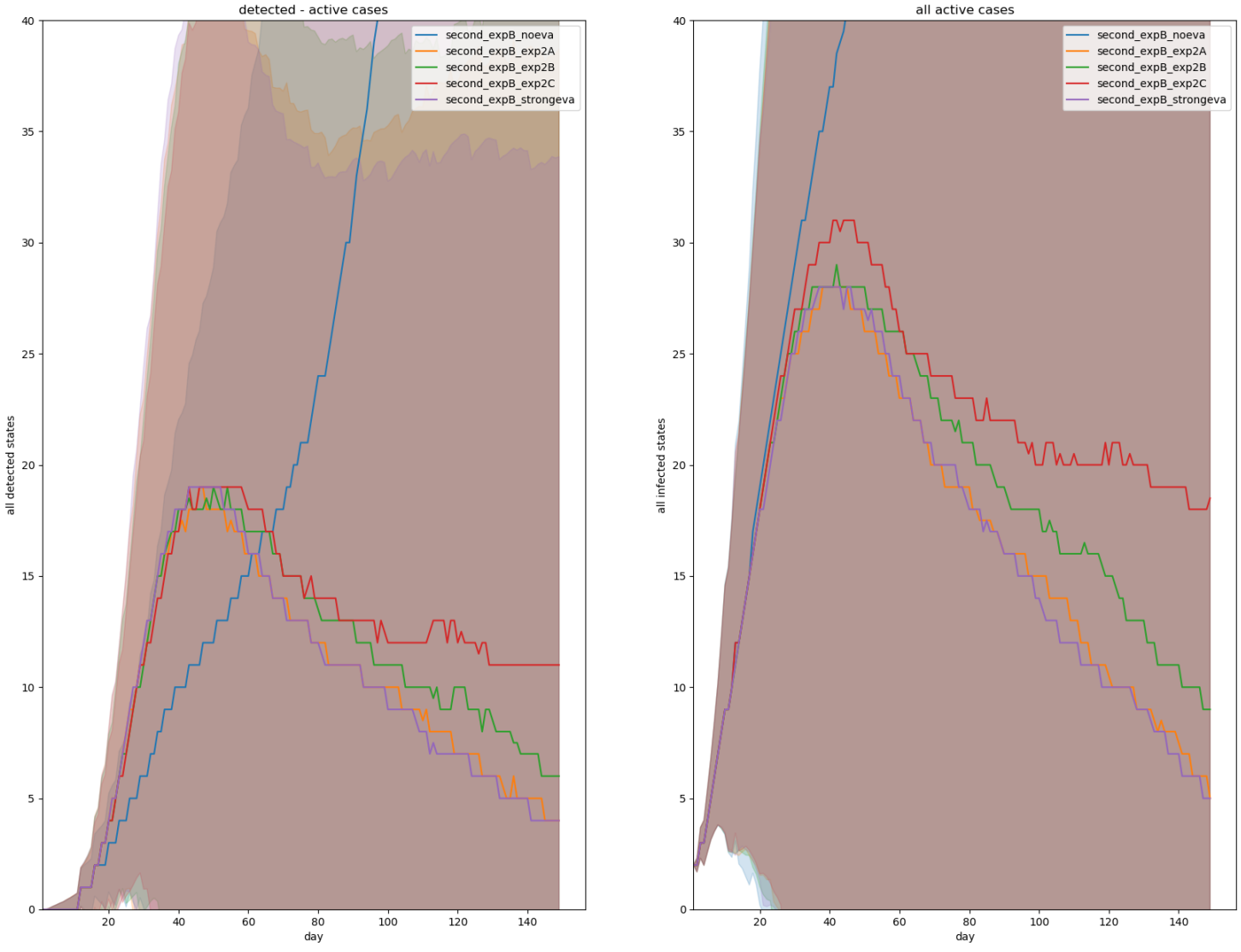
Example: Contact vs. individual behaviour restrictions



Example: Overall contact tracing efficiency

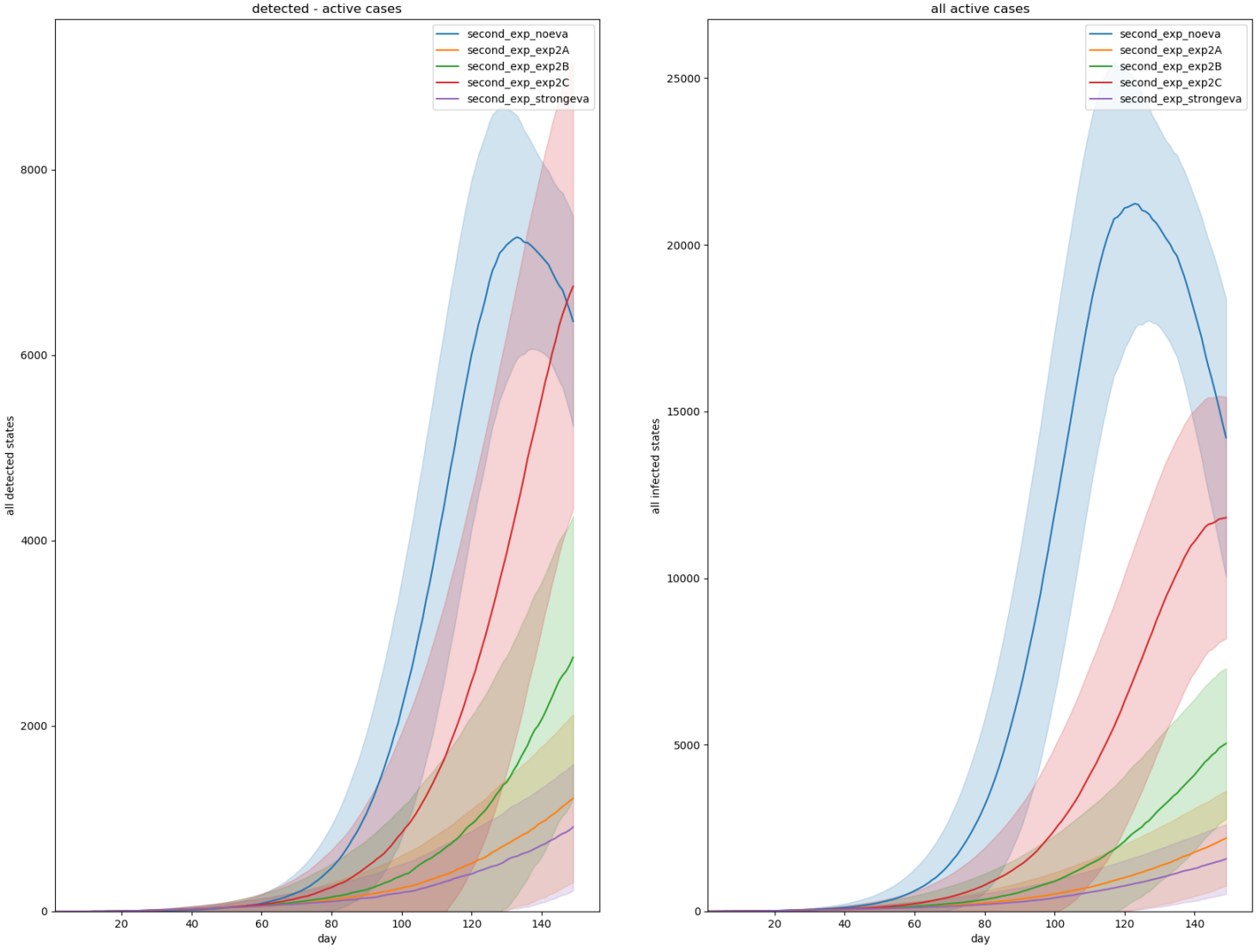


Example: Contact tracing on different layers - no closures



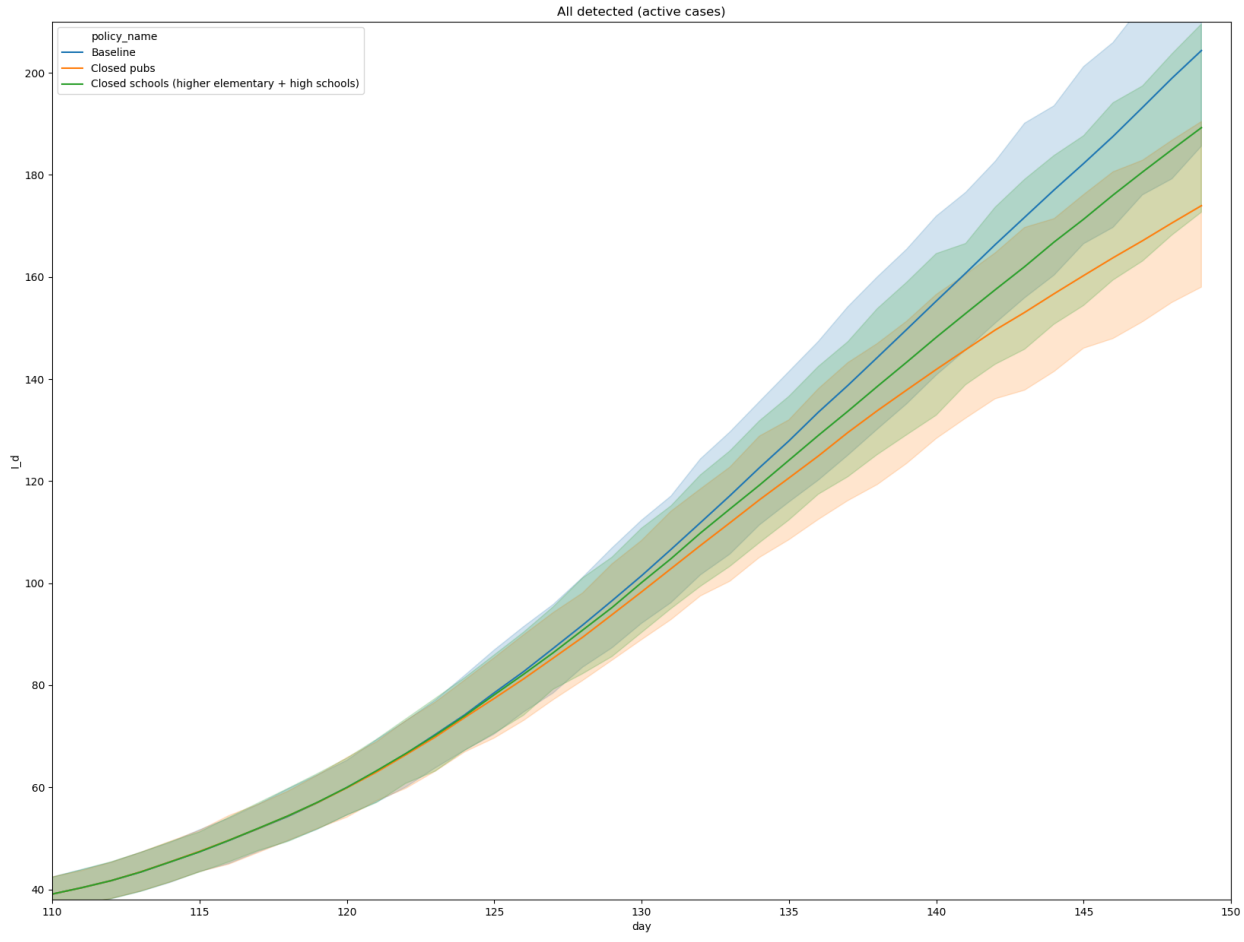
Blue: no tracing, Red: families only, Green: + school and work, Orange: + friends and leisure, Violet: complete tracing

Example: Contact tracing on different layers - closures



Blue: no tracing, Red: families only, Green: + school and work, Orange: + friends and leisure, Violet: complete tracing

Example: Closing pubs vs schools



Blue: current baseline (masks inside), Green: closed higher elementary schools and high schools, Orange: closed pubs and bars

Example: Gabriela-29691 goes to a party - story-000.txt

```
LOG(92): node 29691 enters the party - exposed
LOG(100): node 29691 changing state to I_n
LOG(118): node 29691 changing state to R_u
```

Example: Gabriela-29691 goes to a party - story-001.txt

```
LOG(92): node 29691 enters the party - exposed
LOG(99): node 29691 changing state to I_a
LOG(103): node 29691 changing state to I_s
LOG(106): node 29691 changing state to I_d
LOG(106): node 29691 was detected and is quarantined by Eva
    and asked for contacts.
LOG(108): node 29691 changing state to R_d
LOG(121): node 29691 was released from quarantine by Eva.
```

Example: Gabriela-29691 goes to a party - story-729.txt

```
LOG(92): node 29691 enters the party - exposed
LOG(96): node 29691 changing state to I_a
LOG(97): node 29691 changing state to I_s
LOG(97): node 29691 does not feel well and stays home.
LOG(100): node 29691 was marked as contact.
LOG(101): node 29691 was quarantined by Eva (because being contact).
LOG(102): node 29691 changing state to R_u
LOG(106): node 29691 was marked as contact.
LOG(116): node 29691 was released from quarantine by Eva.
```

What we can (and cannot) do

- Fine-grain scenarios on individual level within a county with realistic epidemiological parameters
- Effect of measures and individual behaviour changes with respect to contact types
- The model requires good graph of contacts and good estimates of disease parameters
- The model is a research tool, not out-of-the box solution
- The research team has experts covering all problem domains from epidemiology to statistics and mutli-agent systems.
- But our resources are limited.