MODELLING FOR PANDEMIC PREPAREDNESS

PANDEM-2
PANDEMIC PREPAREDNESS AND RESPONSE

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The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 883285. The material presented and views expressed here are the responsibility of the author(s) only. The EU Commission takes no responsibility for any use made of the information set out.

Introduction

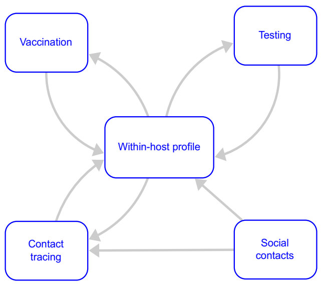
- Pandemics are large-scale outbreaks that lead to increases in morbidity and mortality over a wide geographic area. The risk of future pandemics has continued to increase over the past century due to global travel, land use changes, and natural environment exploitation. In the last two decades, transmissible pathogens have caused three pandemics (SARS, H1N1 & COVID-19) and various cross-border epidemics (Ebola & Mpox).

- The public health system employ countermeasures that aim to curtail transmission within a population. Policymakers avail themselves of simulations (obtained from compartmental models) to evaluate the likely efficacy of the proposed. In the literature, one can find several works showcasing methodologies to represent countermeasures such as testing, tracing and isolation, social distancing, and vaccination.

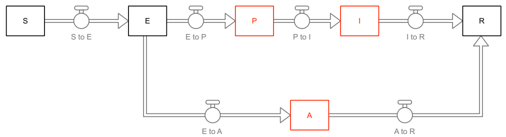
- However, such proposed models do not explicitly account for the resources that constrain the evaluated policies. Recall that resources are stock variables that accumulate over time at different speeds, and variation in performance relates to the number of resources that the public health system can accumulate at a given time. Such an accumulation is the result of the strategic planning conducted during the preparedness phase. Therefore, this work formulates and analyses a compartmental model with explicit structures that account for countermeasures constrained by finite resources.

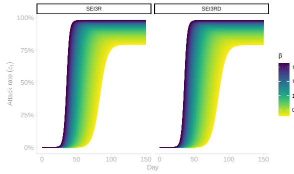
- We present this structure leveraging the concept of *small models*. We frame this work as a case-based modelling approach where we explore plausible scenarios of a hypothetical spread of a novel pandemic influenza virus in the Netherlands, drawing on empirical data collected by the Dutch public health system during the COVID-19 response.

Model overview



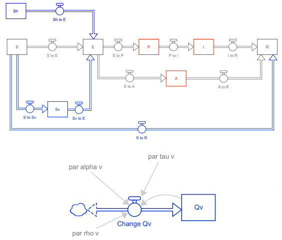
Within-host profile (SEI3R)

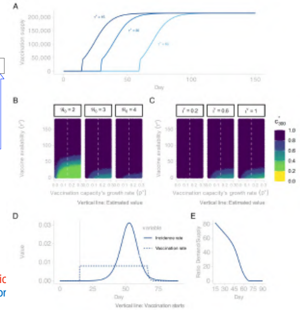




- Serves as baseline scenario (no intervention) assuming a constant contact rate.
- Attack rate (c_t): proportion of persons in a population who experience an acute health event over a defined period (t).

Vaccination

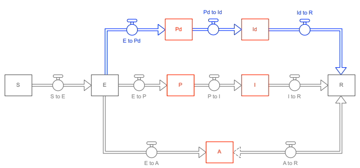


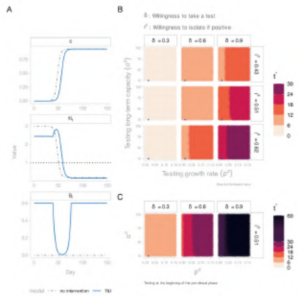


- Vaccination capacity is represented by the logistic growth structure coupled with an if-else function for availability.

$$c_t^* = \frac{c^{intervention}}{c^{baseline}}$$

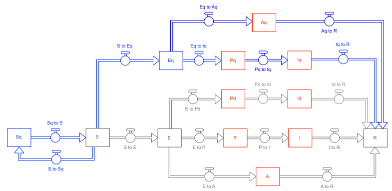
Testing and isolation

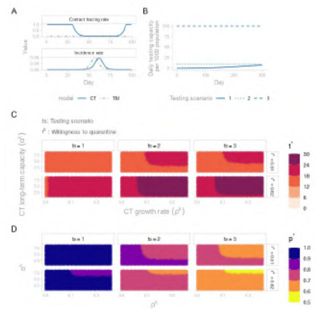




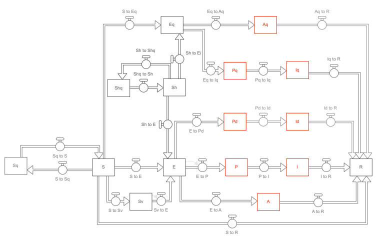
- Testing capacity is modelled using the logistic growth model
- t': Number of days by which the peak is delayed

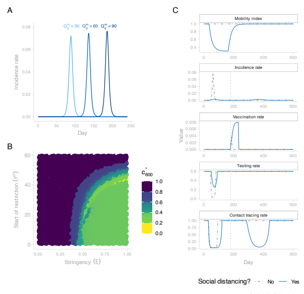
Contact tracing





Synthesis (including social distancing)





Dynamics in contacts are modelled using a first-order delay and can last only for a finite number of days.

Conclusions

- The simulation runs show that no single intervention can contain the spread of a highly-transmissible infectious disease such as pandemic influenza. In other words, pandemic management should not concentrate on which specific policy to deploy but on how to use the entire toolset effectively. Namely, deploying the tools at the right time and with enough strength.

- Since pandemic response critically depends upon available resources, and the accumulation of such resources is contingent on pandemic preparedness, we conclude that the success of pandemic response merely reflects the success of pandemic preparedness. In a sense, the outcome of a pandemic is determined before it starts. Therefore, the model built in this work serves a dual purpose. In addition to providing the means to test a broad range of policies, it also emphasises the need for improving preparedness plans.