# ECONOMIC IMPACT OF INFLUENZA EPIDEMICS:
## MODELLING INTERACTIONS OF INFECTIONS, TREATMENT PATHWAYS AND REIMBURSEMENT

dwh simulation services

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## Objectives

Infectious diseases spread through social contacts and affect people of all age groups. Traditional epidemic models consider these effects with the use of differential equations (e.g. SIR models), contact networks or explicit modelling of households and workplaces.

However past modelling studies did not implement structures of the health service system, like service providers (e.g. physicians) and their reimbursement. It is clear that patients do not only spread the disease further, but they also interact with health service providers and consume services, which lead to costs.

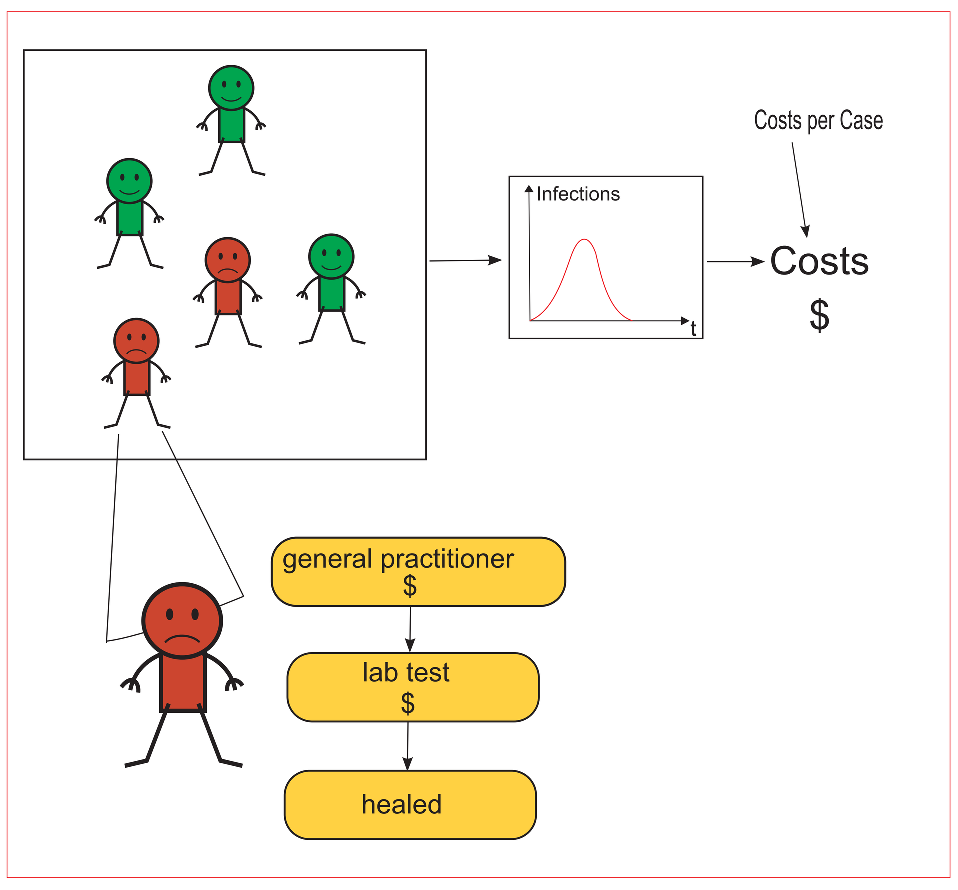


**Figure 1.** Models can calculate overall costs from the progress of the epidemic (i.e. how many people are infected) and the costs per case. On the other hand each infected patient visits healt care providers and consumes health services, which lead to costs.

These interactions have an impact on potentially limited resources (for example working hours of physicians through queuing effects) and the health system as a whole.

In traditional models this impact is only a function of the infections (or the amount of days that individuals are infected) – the simulation calculates costs from the time course of the epidemic model's output variables (see **figure 1**). This approach ignores the fact that the influence on resources and the expenditures of the health system might create feedback on the patients' provider consultations and their treatment.

To take account of this increased complexity we investigate the integration of an epidemic contact model for one particular disease, namely influenza, into a framework for modelling treatment pathways of patients and reimbursement of service providers [1].

The focus is not on correct parametrization with real data and expert knowledge, but on the proposed model structure.

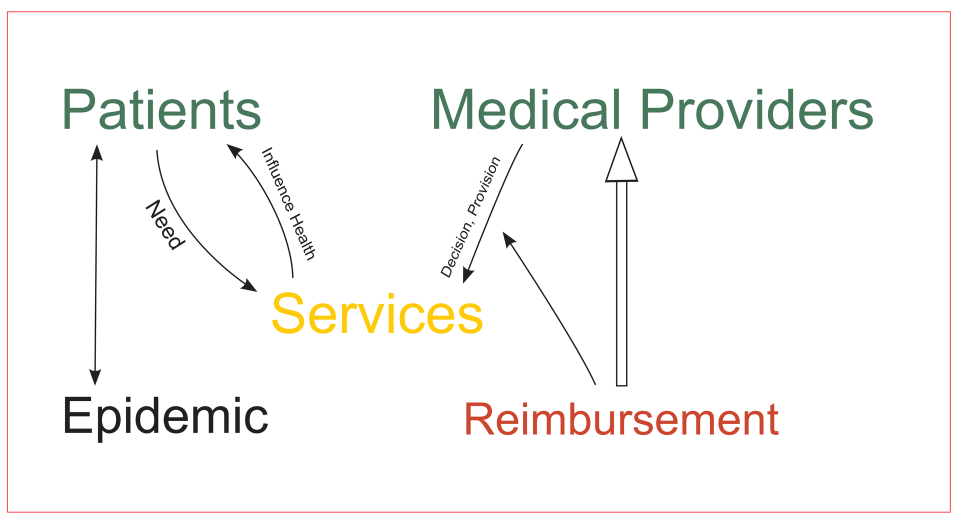


**Figure 2.** Basic structure of the problem to model. Epidemics spread between patients, who consult medical providers according to their medical problems and their need. Together with provider decisions this leads to provision of medical services, which are reimbursed to the providers. Patients and medical providers are the main agent classes in the model.

## Methods

The model framework is of object-oriented and agent based type. It incorporates patients and providers as spatially distributed agents (**figure 2**).

Objects that represent medical problems and diseases (e.g. influenza or diabetes) control the progression of a patient's disease and store possible treatment pathways in the form of statecharts (see **figure 3**). Examples of such medical problem classes could be an "Influenza" class or a "Diabetes" class. Patients developing a disease generate and store one medical problem object of the corresponding type.

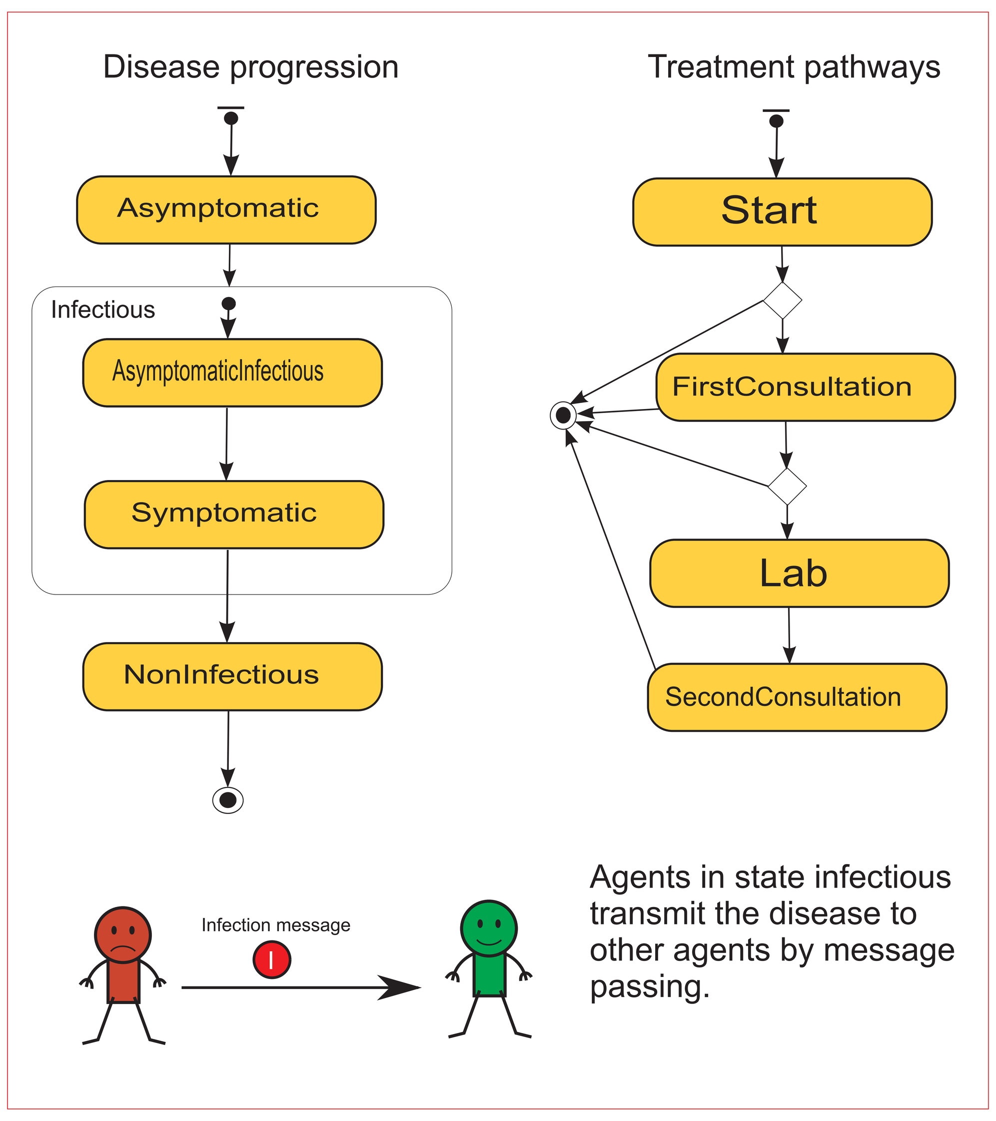


**Figure 3.** Statecharts that control the progression and possible treatment pathways of a disease. Patients with influenza will transit through various states where they can be infectious and/or can have symptoms. Additionally they transit through the statechart modelling treatment pathways, where each state stands for a provider visit the patient will make. In state infectious, patients can transmit the disease,

We added an epidemic model to this framework by modelling influenza epidemics as objects (in all experiments different epidemic objects represent epidemics with completely different virus strains) that are generated at specific points of time, for example once in a year as for seasonal influenza.

An influenza epidemic object initially infects a short number of patients, which means that the patient stores a reference to the epidemic object and creates a medical problem object of type influenza.

Each patient has contact with several other patients (contact network), and every contact transmits the infection with a certain rate. In case of infection the infectious patient sends a message with a reference to the corresponding epidemic object to the agent they infect. Patients store the epidemic objects that infected them once already as "past epidemics", and they cannot get an infection from the same epidemic twice (this substitutes for the state "recovered" in a SIR-model).

The reimbursement system in the model stores all visits that are made during simulation. After specific time intervals (usually a quarter of the year) it calculates reimbursement for the providers by summing up the provided services.
In the shown scenario the possible services included lab tests at the laboratory, lump compensations for the general practitioners, and optionally costs for prescribed neuraminidase inhibitors.

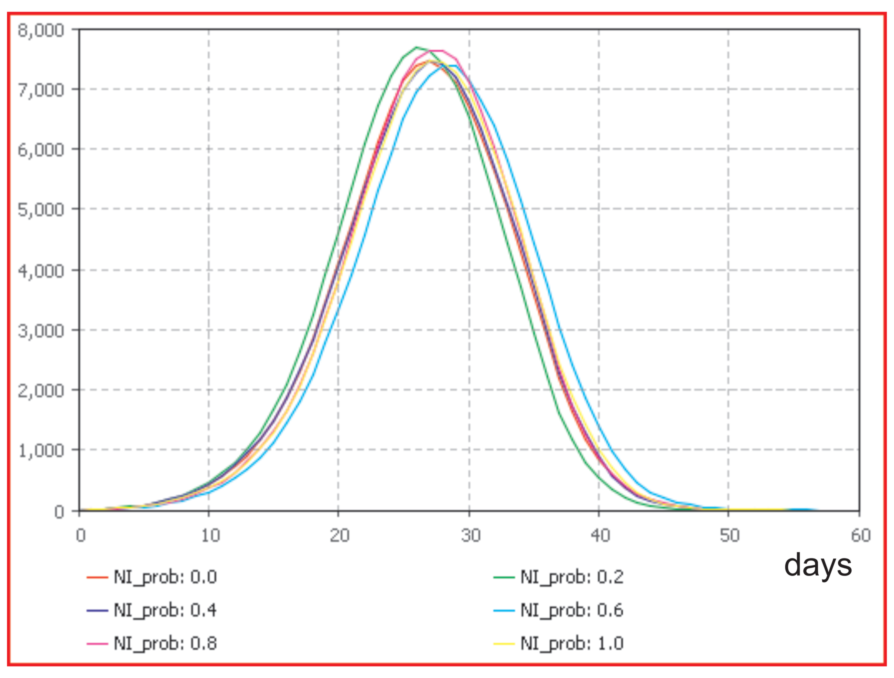


**Figure 4.** Results - number of infected people over time in days - of the parameter variation experiment with different probabilities (with steps of 0.2) for neuraminidase inhibitor prescription.

## Results

All simulation runs took place with 10.000 patients and 150 general practitioners as agents. Each patient had contact with 20 other patients and infection rate per contact was set to 0.05 (mean time of 20 days to transmit the disease).

Modelled epidemics show the well-known behaviour of SIR-type models in baserun. In simulation runs reduced capacity of service providers provokes that many patients do not consult them due to queuing effects.

According to literature, the prescription of neuraminidase inhibitors can shorten the length of an influenza infection by about a day on average [2]. Results of parameter variation experiment on prescription probability (**figure 4**) show that neuraminidase inhibitors can at most slightly delay an epidemic. **Table 1** lists costs for lump compensations and neuraminidase inhibitors in the parameter variation experiment.

| NI_probability | Costs LC | Costs NI |
|---|---|---|
| 0.0 | 160854.7 | 0.0 |
| 0.2 | 160347.9 | 28805.2 |
| 0.4 | 161162.4 | 63185.6 |
| 0.6 | 160402.2 | 82375.6 |
| 0.8 | 159967.8 | 114736.0 |
| 1.0 | 160782.3 | 147500.4 |

**Table 1.** Results of the parameter variation experiment. For each run with different probability of neuraminidase inhibitor prescription (NI_probability), costs for lump compensations and neuraminidase inhibitors are given.

## Conclusions

The integration of epidemic models with models of health service processes and reimbursement can lead towards a broader understanding of the influence of epidemics on health care systems. It is possible to investigate feedback of health service structure changes and reimbursement decisions on prevalence and effects of infectious diseases.

Further research should use treatment pathways identified by experts and on the basis of actual data, so that the model can be validated. In the future other diseases will be implemented as well, in order to show the whole complexity and interaction of diseases, health service consumption and reimbursement.

### References

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