Indicative solution of the Mexican Flu case (EN)

dr. Erik Pruyt

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Exploratory SD models of the spread of the new (A/H1N1)v flu variant –also called Mexican flu or swine flu– were developed right after the first signs of the outbreak of a new flu variant in Mexico. Several months later, the models were used to make a good hot teaching/testing case for BSc and MSc students. The case is good because of the step-wise approach and the familiarity of students with the topic. The model is extended, explained and explored at length in (Pruyt and Hamarat 2010a), and used to illustrate ESDMA for informed crisis management in (Pruyt and Hamarat 2010b). The basic version of the model is available at `http://forio.com/simulate/simulation/e.pruyt/mexican-flu`.

[Case questions 1.1-1.3:] First, students need to make a very simple simulation model about a flu epidemic in the Western world (see Figure 1(a)), construct a complete CLD of the simulation model (see Figure 1(b)), simulate its behaviour and draw graphs of the evolution of the *susceptible population*, the *infections*, the *infected fraction*, and the *recovered population* (see Figure 1(c)).

[Case questions 2.1-2.2:] Second, students need to extend the simple model displayed in Figure 1(a) with a form of seasonal immunity. Although the extension is rather small, an additional flow (with a well-thought-out formulation[1]) and a time series or sinus function are required.

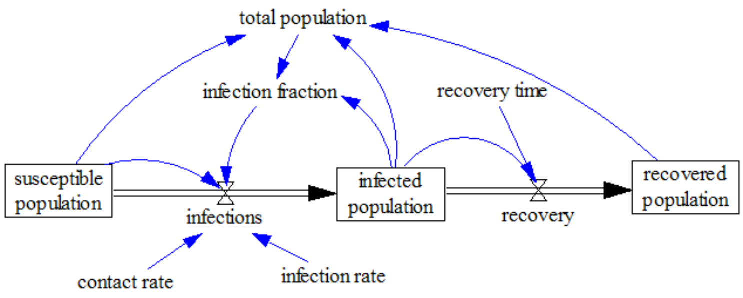
Students are asked to adapt the model and simulate it (see Figure 2(a)), draw graphs of the evolution of the *susceptible population*, the *infections*, the *infected fraction*, and the *recovered population* (see Figure 2(b)), and compare the outputs of this model with the outputs of the previous model. The epidemic now occurs later and is less catastrophic.

[Case questions 3.1-3.2:] Third, students are asked to duplicate the model and turn it into a bi-regional model comprising the Western world as well as the densely populated Developing World (see Figure 3(a)). Again, students are asked to simulate the model, make graphs of the evolution of the *susceptible population*, the *infections*, the *infected fraction*, and the *recovered population* of the Western World (see Figures 3(b) and 3(c)), and compare the graphs of the Western region with the previous ones. Students are expected to note that an early outbreak in the Developing World –because of a higher contact rate and a higher infection ratio in the Developing World– may actually lead to an early outbreak in the Western World, but with a lower infected fraction, followed by a more intensive outbreak in winter (when immunity is lower).

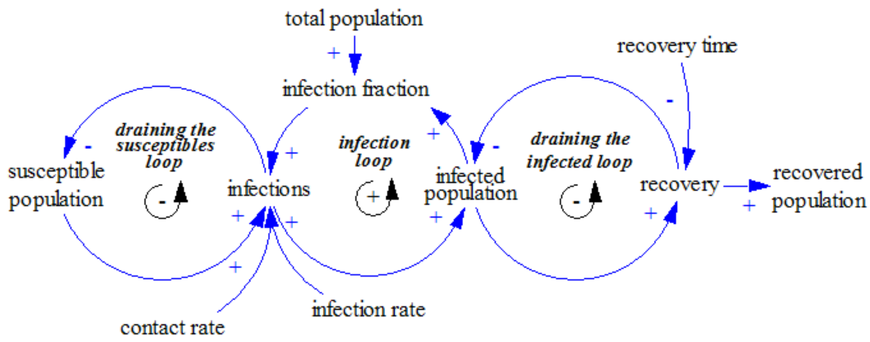
[Case questions 3.3-3.4:] Then students are asked to validate the model, investigate the sensitivity of the *infected fraction* of the Western World to small changes of *contact rate*, *infection ratio*, and *recovery time* of the developing world (see Figure 4(a)), and draw conclusions. Possible conclusions are that the infected fraction may not reach the feared third of the population, that the precise outbreak in the developing world may actually lead to a weaker or stronger second peak in the Western world, and that the size of the second peak is inversely proportional to the size of the first peak (which is not the case for other sets of parameter values).

[Case question 3.5:] Students are also asked to investigate what happens in terms of the *infected population* in the Western World if a vaccine becomes available in month 6 and 50% of

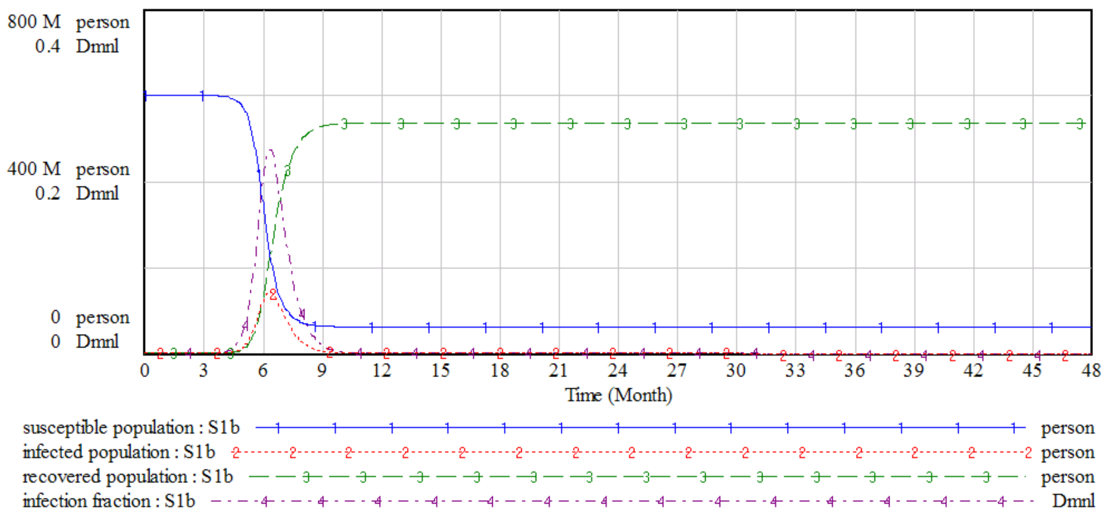
[1] The flow between these populations, the net '*susceptible to immune population flow*' is equal to: ('*normal immune population*' - '*immune population*')/'*susceptible to immune population delay time*', but the flow cannot be greater than the '*susceptible population*' divided by the '*susceptible to immune population delay time*' if there is a net flow towards the immune population, and the return flow cannot be greater than the '*immune population*' divided by the '*susceptible to immune population delay time*' if there is a net flow towards the susceptible population.



(a) SFD of the first version of the simulation model of the Mexican Flu case

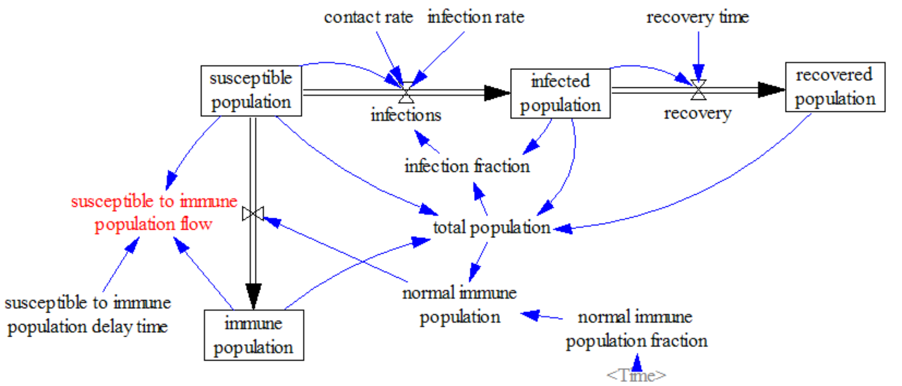


(b) Complete CLD of the first version of the simulation model of the Mexican Flu case

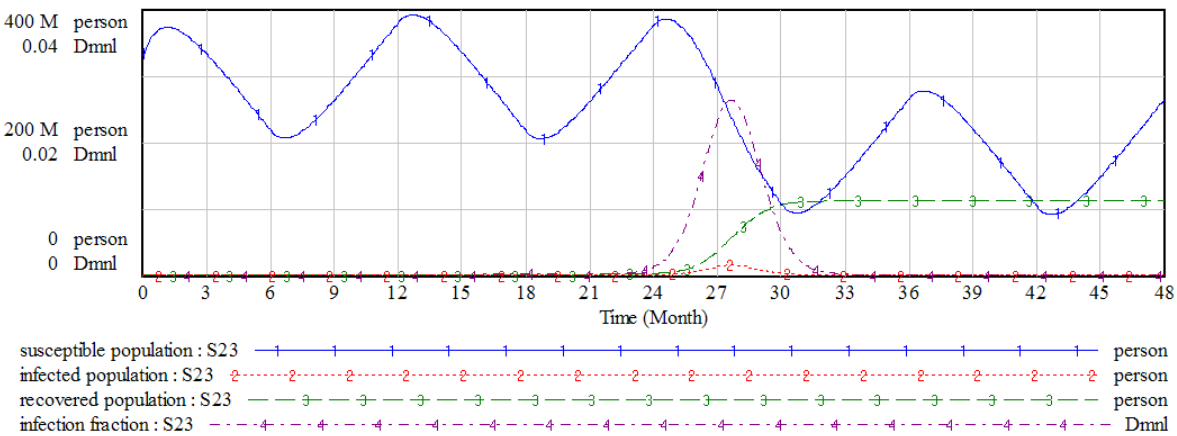


(c) Behaviour of four key variables for the first version of the Mexican Flu model

Figure 1: SFD, complete CLD, and behaviour of the first version of the Mexican Flu model

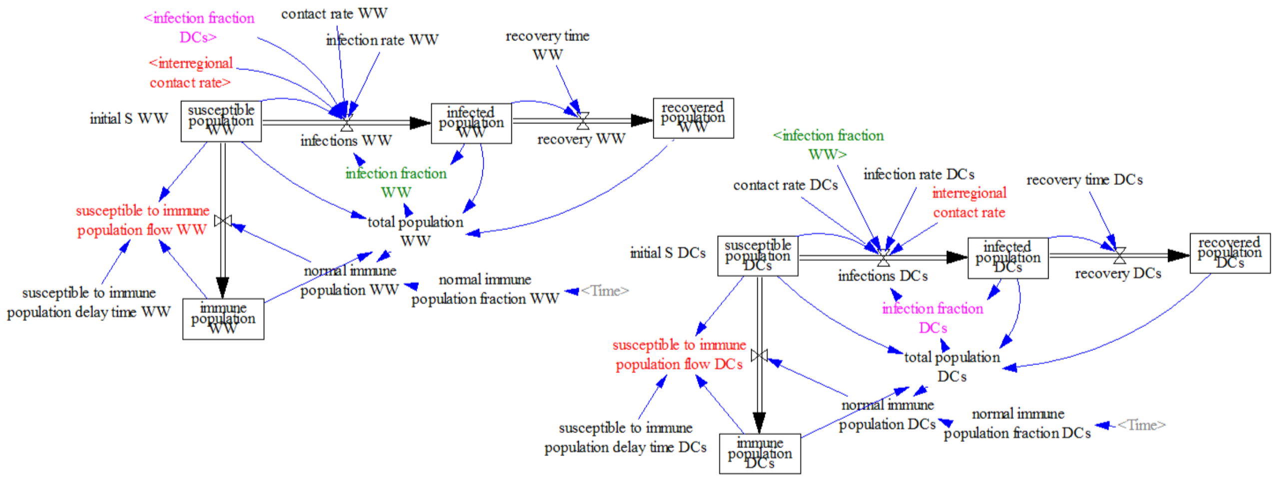


(a) SFD of the second version of the simulation model of the Mexican Flu case

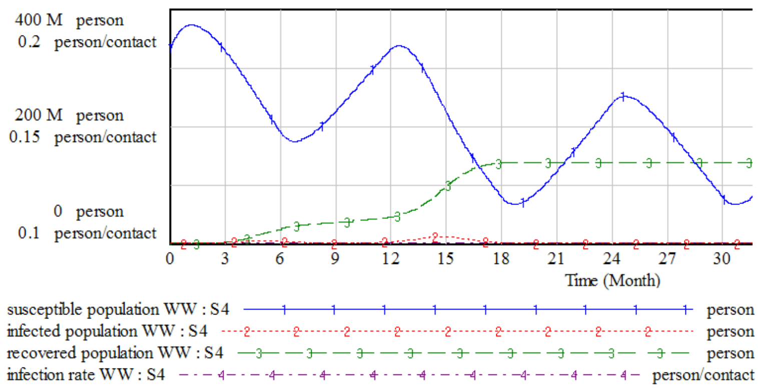


(b) Behaviour of four key variables for the second version of the Mexican Flu model

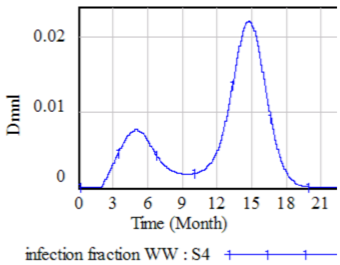
Figure 2: SFD and behaviour of the second version of the Mexican Flu model



(a) SFD of the third version of the simulation model of the Mexican Flu case



(b) Behaviour of four key variables for the third version of the Mexican Flu model



(c) Detail: the *infected fraction*

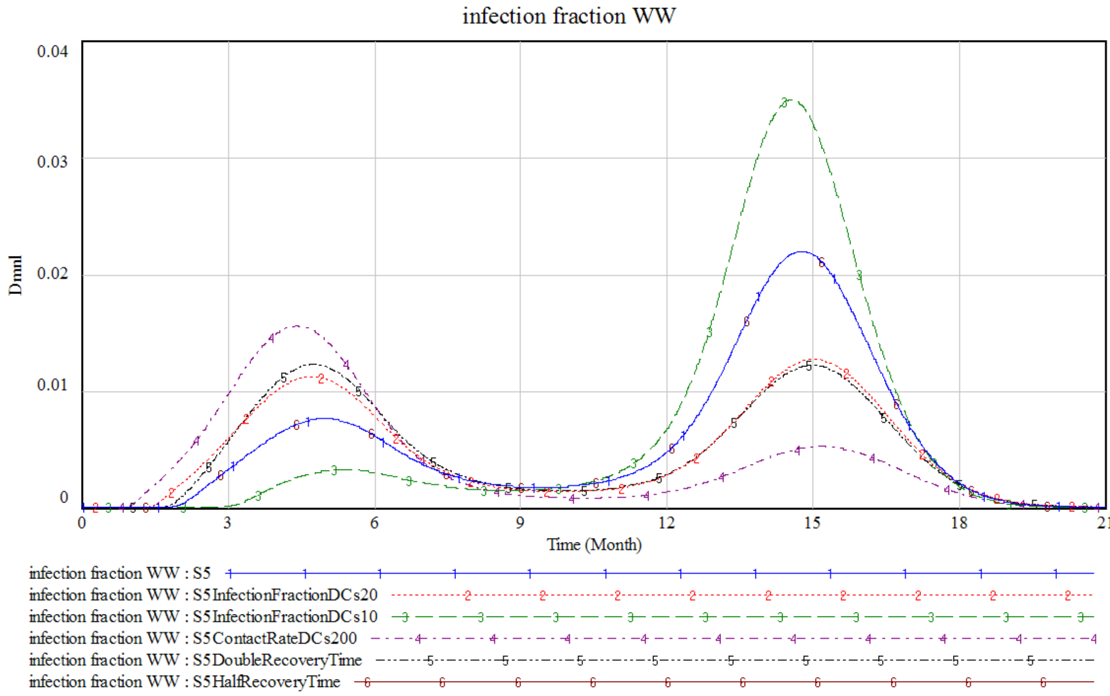
Figure 3: SFD and behaviour of the third, bi-regional, version of the Mexican Flu model

the Western population gets vaccinated almost immediately after the vaccine has been developed. Figure 4(b) shows that one of the consequences for the *infected population* in the Western World is the elimination of the second outbreak.

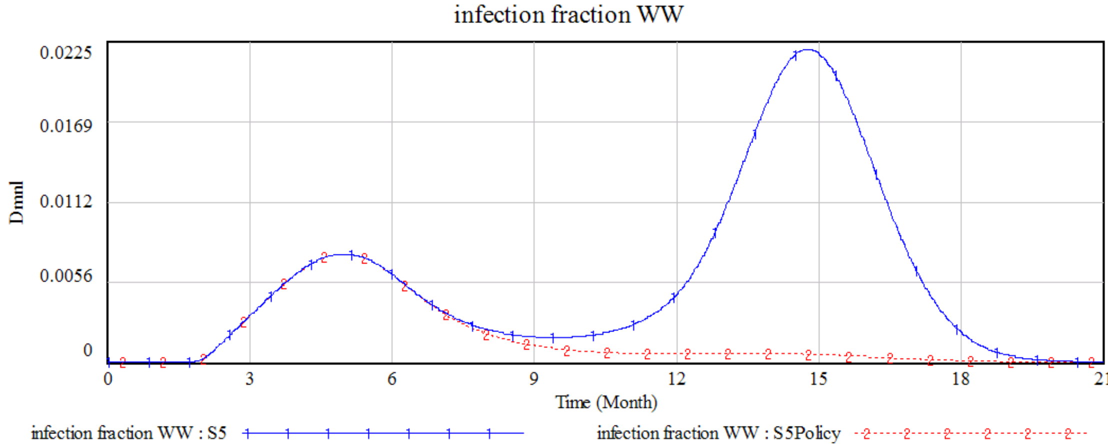
[Case question 3.6:] Finally, students are asked to formulate a 1-sentence policy recommendation to the European Commission concerning this flu and what to do about it. Students could then for example conclude that: If a vaccine can be made before the second peak, then a heavy first outbreak should be avoided (e.g. by taking the necessary social measures), but if a vaccine cannot be made before the second peak is likely to occur, then it would even make sense to amplify the first peak (e.g. by organising flu parties).

Building blocks addressed in this case include stock-flow modelling and causal loop diagramming of aging chains, formulating special functions (lookup functions, time series and/or sinus functions, MIN/MAX functions, well-thought-out flows), and exploring different model and policy behaviours.

In teaching, this case is used at the end of week four (see curriculum in (Pruyt et al. 2009)) or at the end of day two of a three-day workshop.



(a) Sensitivity of the infected fraction of the Western World to changes in the *infected fraction* of the Western World to small changes of *contact rate*, *infection ratio*, and *recovery time* of the developing world



(b) Effect of sufficient vaccination before the second flu peak

Figure 4: Sensitivity and policy analyses

References

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