The Flu

Evan Christianson, David Kraemer, Caleb Leedy, and Will Royle

April 14, 2016

Problem statement

- Grinnell College has asked us to provide policy recommendations for dealing with flu season.
- It is interested in vaccination advice and whether quarantines are needed.
- There are four status levels with respect to the disease.

Susceptible	Not sick but could become sick
Infective	Infected with the disease
Remove	Not infected and immune from the disease
Dead	Dead

Problem statement

Population Interactions

- **Infectives** can spread the disease to **susceptibles**.
- **Infectives** can also recover and become **susceptible**.
- **Infectives** can also become **dead**.
- On recovery, **infectives** can gain immunization and become **remove**.
- **Removes** can lose their immunity.

Model overview

Variable	Meaning	Parameter	Meaning
s	Susceptible population	α	Contagion rate
f	Infective population	ρ	Recovery rate
r	Removes population	λ	Lost immunity rate
d	Dead people	β	Immunization rate
K	Total population	φ	Fatality rate

Model assumptions

- Homogeneous population
- A person interacts with every other person in the population each day
    - This interaction does not change when people get sick
- The total population is constant
- We treat the population as infinitely divisible

Model overview

Our model is a dynamical system of four equations:

$$f' = \alpha \cdot f \cdot s - \rho \cdot f - \varphi \cdot f \tag{1}$$
$$r' = \beta \cdot \rho \cdot f - \lambda \cdot r \tag{2}$$
$$d' = \varphi \cdot f \tag{3}$$
$$s' = -f' - r' - d' \tag{4}$$

subject to the population constraint:

$$K = f + r + d + s.$$

Modeling process

We can modify our model to incorporate different intensities of the flu:

- Non-fatal viruses from which people do not develop immunity
  - $\beta = 0, \lambda = 0, \varphi = 0$
- Non-fatal viruses from which people can develop immunity
  - $\lambda = 0, \varphi = 0$
- Non-fatal viruses from which people can develop immunity, but where immunity is not necessarily permanent.
  - $\varphi = 0$
- Fatal viruses from which people can develop immunity, but where immunity is not necessarily permanent.

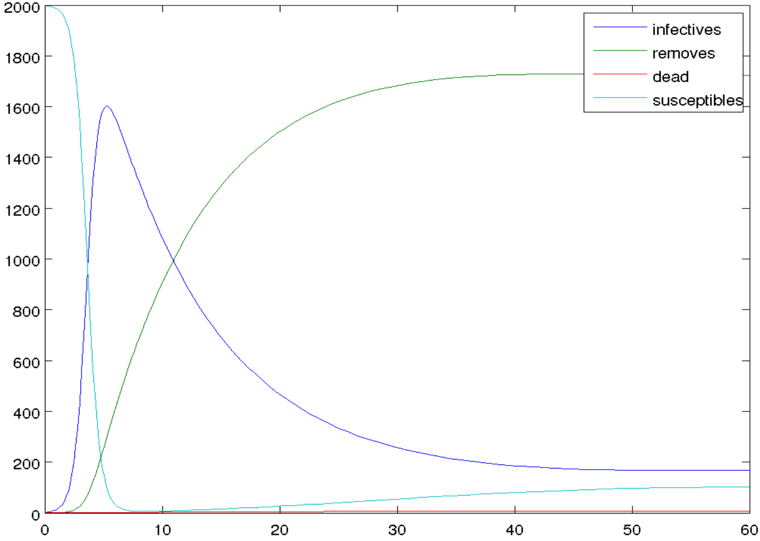
Cost function

We used the following equation to make policy recommendations to the college.

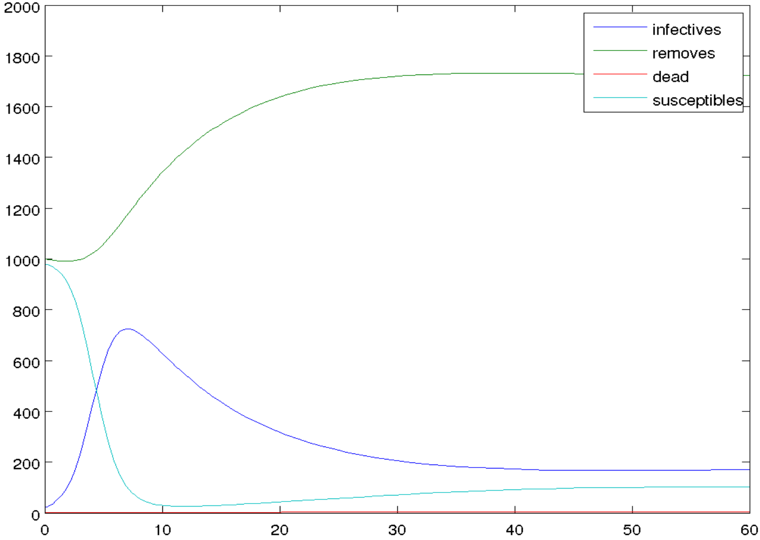
$$c(t) = r_0 c_v + c_m \int_0^T f(t)dt$$

Variable	Meaning
T	Total number of days in the simulation
c_v	The cost of a vaccination
c_m	The cost of treating sick people
t	Time (in days)

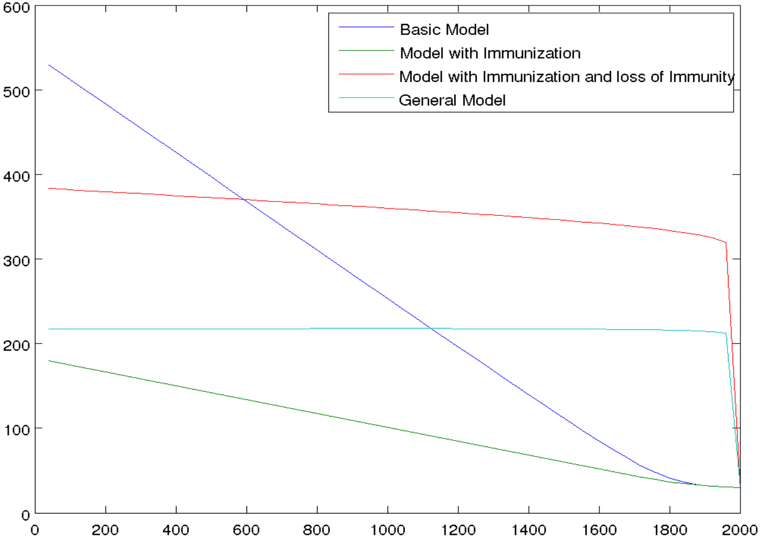
No Vaccinations



Half Vaccinations



Cost across scenarios



Recommendations and Limitations

Limitations:

- Does not account for the cost of death
- Only one type of influenza

Recommendations:

- Vaccinate everyone
- If someone dies implement a quarantine