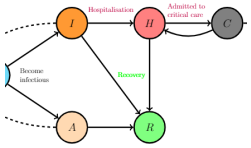
Covid Project



Nick Taylor

AI For Good

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Chapter 1

Covid Model

1.1 Model Structure

Below is a description of the compartmental model. We adapt the basic SEIR model to include age structure, asymptomatic infection, progression of severe infection and various control measures. For a full breakdown of variables and parameters used in the model, see Tables 1.1 and 1.2.

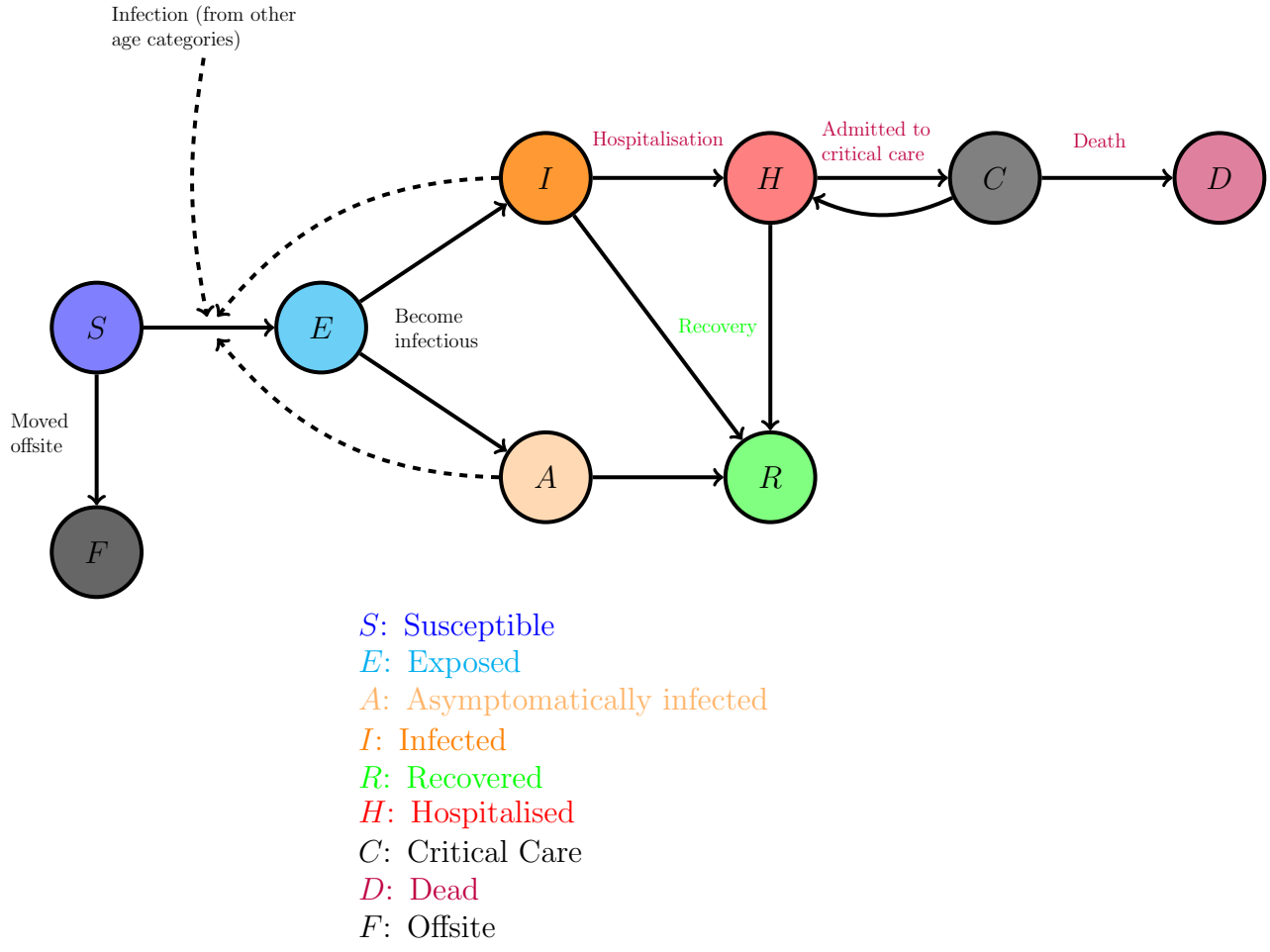

Figure 1.1: Model diagram (old! now also have Q and U compartments).

Variable symbol	**Name**
S_i	Susceptible (age category i)
E_i	Exposed (presymptomatic infection)
I_i	Infected (symptomatic and infectious)
A_i	Asymptomatic infected (infectious)
R_i	Recovered
H_i	Requiring hospital care
C_i	In intensive care
U_i	Requiring intensive care, don't receive (uncared)
D_i	Dead
F_i	Moved offsite (high risk categories only)
Q_i	Quarantined

Table 1.1: Variable names and symbols.

Parameter symbol	**Name**
T_L	Time latent
T_I	Time infectious
T_H	Time in hospital
T_C	Time in critical condition if care received
T_U	Time in critical condition if care not received
T_Q	Time in isolation if isolated
a	Proportion asymptomatic
h	Proportion requiring hospital care
c	Proportion requiring critical care
d	Probability of death if critical and care is received
C	Contact matrix (age-structured)
β	Transmission rate
M_i	Rate of removal of susceptible high risk people
L	Rate of removal/isolation of infected individuals
r	Number of people to receive critical care
B	ICU bed capacity

Table 1.2: Parameter names and symbols.

The model consists of the following system, for a given age category i:

$$\dot{S}_i = -S_i\beta\mathbf{C_i}\cdot(\mathbf{I}+\mathbf{A}) - M_iS_i, \tag{1.1}$$
$$\dot{E}_i = S_i\beta\mathbf{C_i}\cdot(\mathbf{I}+\mathbf{A}) - E_i/T_L, \tag{1.2}$$
$$\dot{I}_i = (1-a_i)E_i/T_L - I_i/T_I - LI_i, \tag{1.3}$$
$$\dot{A}_i = a_iE_i/T_L - A_i/T_I, \tag{1.4}$$
$$\dot{R}_i = A_i/T_I + (1-h_i)I_i/T_I + (1-c_i)H_i/T_H + (1-h_i)I_i/T_Q, \tag{1.5}$$
$$\dot{H}_i = h_iI_i/T_I - H_i/T_H + (1-d)C_i/T_C + h_iI_i/T_Q, \tag{1.6}$$
$$\dot{C}_i = c_ir/T_H - C_i/T_C, \tag{1.7}$$
$$\dot{U}_i = c_i(H_i-r)/T_H - U_i/T_U, \tag{1.8}$$
$$\dot{D}_i = dC_i/T_C + U_i/T_U, \tag{1.9}$$
$$\dot{F}_i = M_iS_i, \tag{1.10}$$
$$\dot{Q}_i = LI_i - I_i/T_Q. \tag{1.11}$$

We have a recovery pathway, a hospital pathway and we have control measures. We use $\mathbf{C}_i$ to denote the ith row of the contact matrix C, and $\mathbf{I}$, $\mathbf{A}$ are vectors containing the numbers of symptomatic and asymptomatic people with each element corresponding to an age category.

We will now explain how the following functions work: r, M_i and L.

1.1.1 Critical care

Here our rate of receiving critical care, r is given by:

$$r(H_i, C_i) = \min[H_i, N_i]. \tag{1.12}$$

Here N_i (the number of new patients that can receive critical care in this age group) is given by:

$$N_i = B_i - C_i + C_i/T_C, \tag{1.13}$$

where B_i is the number of beds that exist for this age group (which is just split proportionally, i.e. no preferential allocation of beds occurs, they are allocated on a first come first served basis).

The maximum number N_i of beds that can be given is: the number that exist for that age group, minus those currently occupied, plus those recently freed up by death/recovery of a previous patient.

We have d is the probability of survival given a bed, and that all who don't receive a bed (but need one) die.

1.1.2 Moving vulnerable people offsite

The rate of moving offsite due to risk status is given by:

$$M_i = \min(M, S^*)/S^*, \tag{1.14}$$

for the time that each control is implemented (and 0 otherwise). $S^*(t)$ is the total number of susceptible people in the risk categories we are removing. This corresponds to random selection of people within these categories. We cannot remove more people than we have, which is why we need the minimum of M and S^*.

1.1.3 Moving infectious people offsite

Similarly, the rate of moving offsite due to symptomatic infection is given by:

$$L = L^*/I^*, \tag{1.15}$$

where $I^*(t)$ is the total number of symptomatic people at that time. This corresponds to removal of symptomatic people on a random basis, removing L^* people per day.

1.2 Control measures

1.2.1 Improve hygiene/sanitation provision

Reduces the transmission rate β.

1.2.2 Shielding

Restructuring the camp so that the young and old have reduced contact. This corresponds to reducing contacts between these groups in the contact matrix C, but increasing contacts within the groups.

1.2.3 Move vulnerable offsite

Move a maximum of M high risk susceptible people offsite per day.

1.2.4 Remove symptomatic infectious people

Move a maximum of L^* infectious people offsite per day.

1.2.5 Increase number of intensive care beds

Increasing B increases the number of people who can recover if they reach the critical stage of infection.

1.3 Useful Links

- LSHTM Africa:

  https://cmmid.github.io/topics/covid19/reports/
  LSHTM-CMMID-20200419-Covid19-Africa-strategies.pdf

- Age-dependent effects in the transmission and control of COVID-19 epidemic:

  https://www.medrxiv.org/content/10.1101/2020.03.24.20043018v2.full.pdf

- Projecting social contact matrices in 152 countries using contact surveys and demographic data:

  https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5609774/#!po=63.3333

- Imperial College UK paper:

  https://www.imperial.ac.uk/media/imperial-college/medicine/mrc-gida/
  2020-03-16-COVID19-Report-9.pdf