Model 1: Mask efficiency vs Percentage Population

Before incorporating facemask utilisation into the SIRS model, changes in the effective reproduction number (Re) as a result of facemask population coverage and mask effectiveness is explored. Re refers to the average number of secondary infections caused by an infected individual in a non-fully susceptible population. Re values and their associated representations are shown in Table 1.

Table : Highlights the possible Re values and what these values represent in the context of infection transmission.

|  |  |
| --- | --- |
| **Re Value** | **Representation** |
| Re > 1 | Each infected individual infects more than one other person on average. Infection is likely to spread. |
| Re = 1 | Infection level remains stable. |
| Re < 1 | Each infected individual infects fewer than one person on average. Infection will gradually decline and end. |

The code to explore facemask coverage against effectiveness is shown in Figure 1:

A screenshot of a computer code

Description automatically generatedThis loop iterates over different values of R0 values against different combinations of facemask coverage (***‘mask\_coverage\_range’***) and effectiveness (***‘mask\_effectiveness\_range’***). This loop adjusts the R0 value based on these mask variables to produce an updated Re value.

Figure : Function used to calculate the Re for different facemask coverage and effectiveness values.

The R0 represents the average number of new infections caused by an infected individual in a fully susceptible population. The R0 values are prescribed as 2.2 and 4.0, in line with Stutt et al (2020), to show the range of possible values as the true value is uncertain. Both mask ranges are prescribed a range from 0-1 in steps of 0.1, which represents 0-100% coverage and effectiveness.

Model 2: SIRS

A Susceptible-Infected-Recovered-Susceptible (SIRS) model is developed and utilised for mathematically modelling the transmission of Covid-19 across 540 days, with the consideration of lockdowns and mask wearing protocols being followed. The population is shown proportionally, with the initial conditions being set at 0.99, 0.01 and 0.0 for the Susceptible, Infected and Recovered respectively.

The developed SIRS model uses three core differential equations to simulate the change in the proportion of Susceptible, Infected and Recovered people in a given population. These equations were modelled in JupyterLab and are given in Figure 2 below:

A close-up of a white background

Description automatically generated

Figure 2: SIRS differential equations used in the model.

The terms in these equations are described as followed:

* ***‘dS\_dt’***, ***‘dI\_dt’***, ***‘dR\_dt’*** = rates of change of the Susceptible, Infected and Recovered population respectively.
* ***‘S’, ‘I’, ‘R’*** = proportion of the population that is Susceptible, Infected and Recovered respectively.
* ***‘beta’*** = transmission rate.
* ***‘delta’*** = rate of immunity loss.
* ***‘gamma’*** = recovery rate.

The SIRS requires prescribed parameters, which are shown in Figure 3 (below) and described in further detail in Table 2:

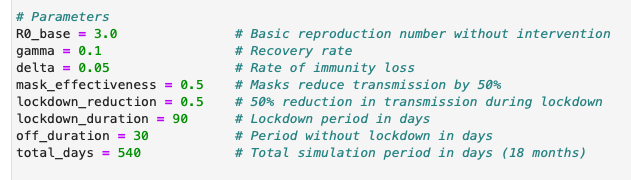


Figure 3: Parameters prescribed to the SIRS model. The parameters that are not highlighted are given in all modelling scenarios. The variables highlighted in red are removed in the scenarios where lockdowns are not considered.

Table 2: Outlines the various parameters used in the SIRS simulations. Basic descriptions of each parameter is provided, along with their associated value used in the model. The reasoning or source for the chosen values is also given.

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Description** | **Value** | **Source / Reasoning** |
| R0\_base | Basic reproduction rate | 3.0 | Consistent with Stutt et al (2020). |
| gamma | Recovery rate | 0.1 | Assumed due to lack of detailed data |
| delta | rate of immunity loss | 0.05 | Assumed due to lack of detailed data |
| mask\_effectiveness | Proportion of transmission reduction due to facemasks | 0.5 | Consistent with Stutt et al (2020) |
| lockdown\_reduction | Proportion of transmission reduction due to lockdown | 0.5 | Consistent with Stutt et al (2020) |
| lockdown\_duration | Lockdown duration (days) | 90 | Consistent with Stutt et al (2020) |
| off\_duration | Duration without lockdown (days) | 30 | Consistent with Stutt et al (2020) |
| total\_days | Total simulation duration (days) | 540 | Consistent with Stutt et al (2020) |

For all scenarios, the effect of facemasks is considered, however this is not the case for lockdowns. For both of these considerations, the transmission rate (***‘beta’***) is adjusted.

The function to model lockdowns is shown in Figure 4:

A screen shot of a computer code

Description automatically generated

Figure 4: Defined function used to model lockdowns effectively in the model.

It is important to note that the lockdown always starts on the 45th day for any given scenario(***‘first\_lockdown\_start’****=45*), in line with the work of Stutt et al (2020). The lockdown durations and cycles remain constant at the values given in Table 2.

For each day, the function calculates an the ***‘day\_adjusted’***  by subtracting the initial lockdown day. If this value is negative, and therefore falls before day 45, a lockdown is not triggered. The function then calculates the cycle duration of the lockdowns and uses modular arithmetic to identify where the day lies within the cycle. If the day falls within the lockdown duration, the function returns a True value which indicates that the lockdown is active. If the day falls outside of the lockdown period, the function returns a False value and the infection rate remains at its base level.

To model the effects of facemasks and lockdown implementation on the transmission of the virus, the base infection rate is adjusted accordingly. The base beta value represents the infection rate without any interventions and is calculated using the equation shown in Figure 5, and the given values in Table 2:

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Figure 5: Equation used to calculate the base transmission rate without any interventions.

This base value is then dynamically adjusted via the following equation (Figure 6):

A close up of text

Description automatically generated

Figure 6: Equations used to calculate the dynamic transmission rate, with the effects of facemasks and lockdowns considered.

The first stage of the code adjusts the beta value based on the populations facemask coverage (***‘mask\_coverage’***) and the masks’ effectiveness (***‘mask\_effectiveness’***). The mask effectiveness was kept constant (Table 2), with coverage values of 0, 0.25, 0.5 and 1.0 prescribed to represent a masked population of 0%, 25%, 50% and 100% respectively.

The second stage of the code determines whether the day is in a lockdown period using the function in Figure 4. If so, the facemask adjusted beta value is halved during these periods, in line with the value prescribed in Table 2. This suggests that lockdowns reduce transmission rates by 50%. If a lockdown scenario is not considered, then this section is not included.

The resultant dynamic beta value is then processed through the SIRS differential equations mentioned previously.