# Modeling Intervention Strategies for TB Control in the United States

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## Introduction

The most common epidemiological models are compartmental models, in which a system of differential equations describes how parts of the population move between different disease states, or *compartments*. The canonical example of such a model is the SIR model, which has three compartments: Susceptible, Infected, and Recovered. The dynamics of a population modeled by this framework are shown in figure 1, with associated system of differential equations 2.

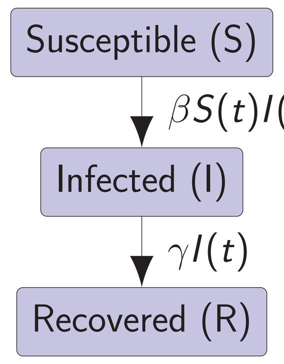


Figure : This flowchart depicts the standard SIR epidemiological model. It is accomponanied by the system of differential equations 2.

$$\begin{aligned}
\frac{dS}{dt} &= -\beta S(t)I(t)\\
\frac{dI}{dt} &= \beta S(t)I(t) - \gamma I(t)\\
\frac{dR}{dt} &= \gamma I(t)\\
N &= S(t) + I(t) + R(t)
\end{aligned}$$

Figure : The system of differential equations governing the SIR model.

The SIR system, though very informative about basic disease dynamics, fails to capture the intricacies of more complicated diseases. This project examines the spread of tuberculosis (TB) in the United States (US) via compartmental models and stochastic, agent-based models. These explorations allow one to explore the impact, both epidemiological and economic, of various intervention strategies. These models are based on a 2012 compartmental model of TB in the US created by A. N. Hill, J. E. Becerra, and K. G. Castro.

## The Basic Hill Model

The Hill model is another compartmental model, illustrated in figure 3.

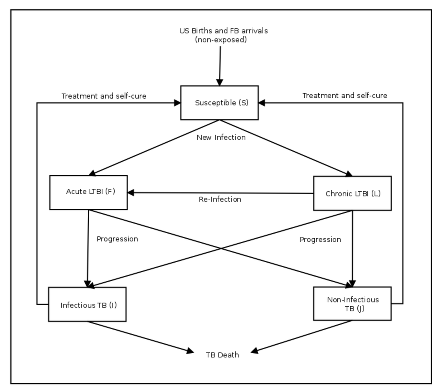

Figure : A flow chart representing the compartments of the Hill Model.

The illustration of this model is not full, as there are two subpopulations in the Hill Model. TB dynamics in the US differ radically between US born (USB) individuals and foreign born (FB) individuals, so this model maintains two distinct populations in which the disease can spread. There is a near identical diagram to describe the dynamics of the model for the FB population. Further, each compartment in this model also loses people to do natural death. The system of differential equations for this model is naturally more complex and is provided in an appendix. In order to implement this model, Hill, Becerra, and Castro used the `R` programming language, with the `lsoda` routine to numerically solve the differential equations.

For this implementation, various numerical solvers were implemented, including an Eulerian Method, a Quadratic Method, a Fourth-order runge kutta method, and the `lsoda` routine. Once the basic Hill model was implemented, further tracking capabilities were added as well as economic modeling. This implementation tracks total active TB cases, entering cases of LTBI, and treatment costs for active and latent disease for all populations. Tracking was used to evaluate various interventions explored in Hill, Becerra, and Castro's work, as well as interventions exploring the possibility of treating incoming LTBI cases.

## Economic Modeling

We extended our basic implementation of the Hill model to incorporate economic data of treatment costs for Active and Latent Tuberculosis. In our model, we estimate the average heath care costs to be $14,014.90 and $403.45 to treat a single case of Active or Latent TB respectively. Given these costs and the average treatment rates for Active and Latent TB in the USA, we modeled the expected economic burden of Tuberculosis projected over the next hundred years.

## Intervention Analysis

Intervention Analysis

## An Agent Based Implementation

Implementing an Agent Based Framework