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1. Introduction

This report presents a simulation of an infectious disease spreading through a population using an individual-based SIR (Susceptible-Infectious-Recovered) model. The main focus is on analyzing how different vaccination rates influence the spread and extinction of the disease. The simulation was implemented in C++ and configured via INI files. Two types of results were collected: per-day dynamics of disease spread and the overall effect of vaccination rates on the final number of recovered individuals.

2. Methodology

The simulation models a population of 30,000 individuals. Each individual can be in one of four states: susceptible, infectious, vaccinated, or recovered. The disease has the following parameters:

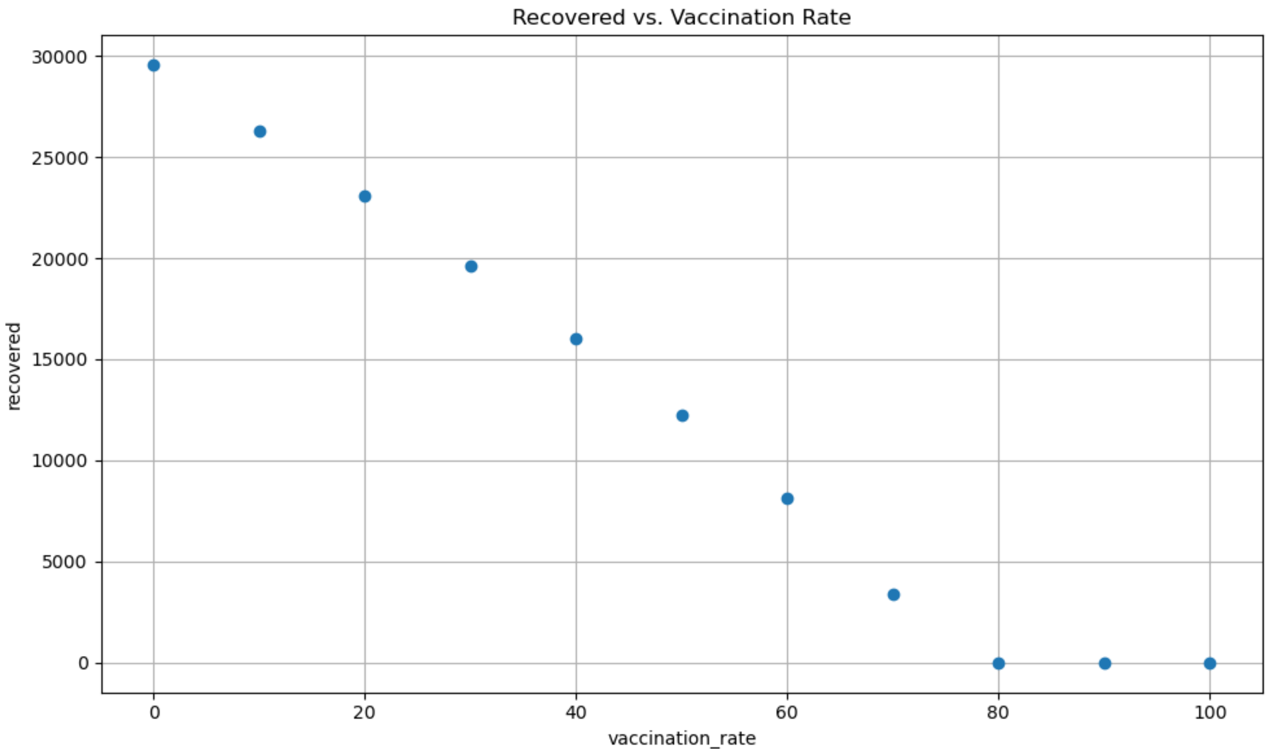
- Duration (D): 4 days
- Transmissibility (β): 0.2
- Contacts per day: 6 random persons
- Vaccination Rate: 0.1
- Population: 30000

Initially, a proportion of the population is vaccinated, and one person (patient zero) is infected. At each timestep (1 day), infectious individuals interact with 6 others. The infection spreads based on the transmission probability. The simulation stops when there are no infectious individuals left.

All results were written to CSV files, and two graphs were generated:

- Recovered vs. Vaccination Rate (final recovered persons)
- Disease dynamics over time for a single vaccination rate

3. Results



📊 Figure 1: Recovered vs. Vaccination Rate

This graph shows how increasing the vaccination rate leads to fewer individuals recovering from the disease meaning the disease is less able to spread.

- Vaccination Rate: varied from 0.0 to 1.0 in 0.1 steps

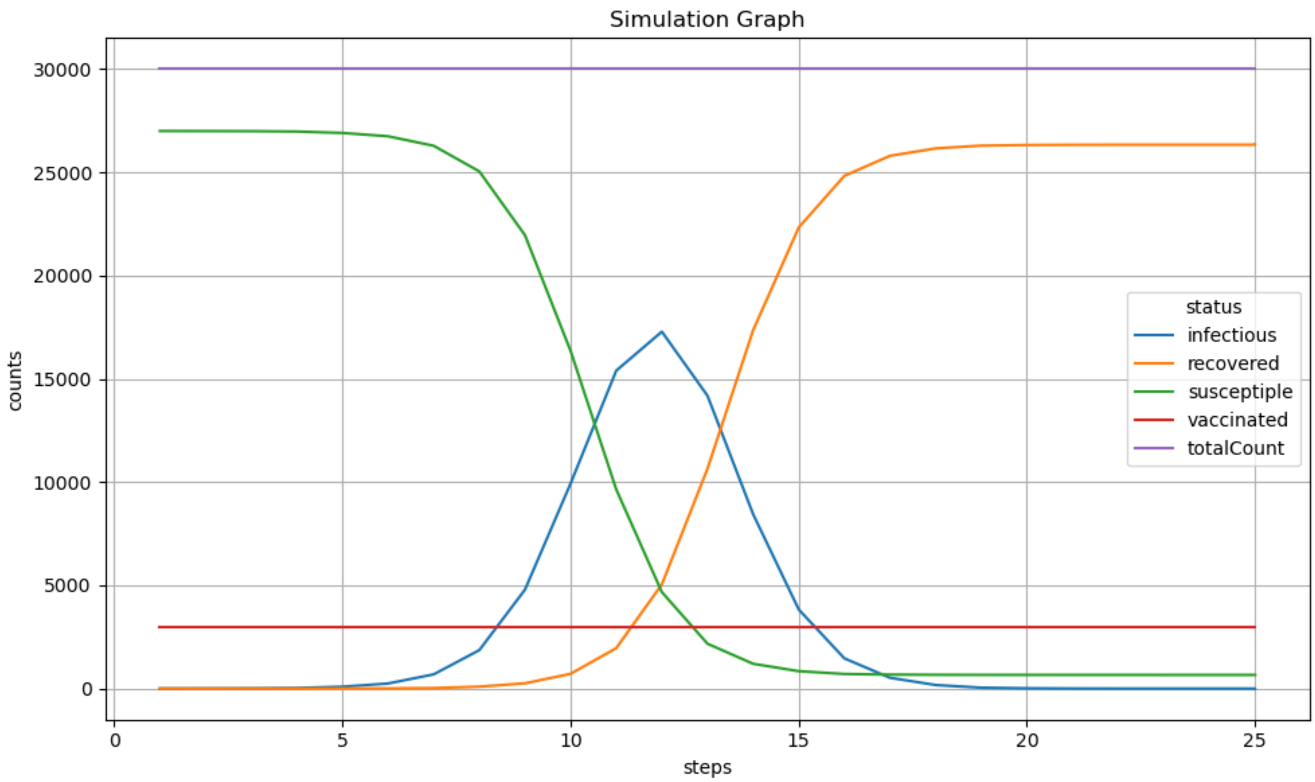


Figure 2: Disease dynamics over time for a single vaccination rate (vaccination rate = 0.1)

This figure presents the number of infectious, recovered, susceptible, vaccinated individuals over time. The disease spreads rapidly in the beginning, then declines as people recover or remain protected due to vaccination.

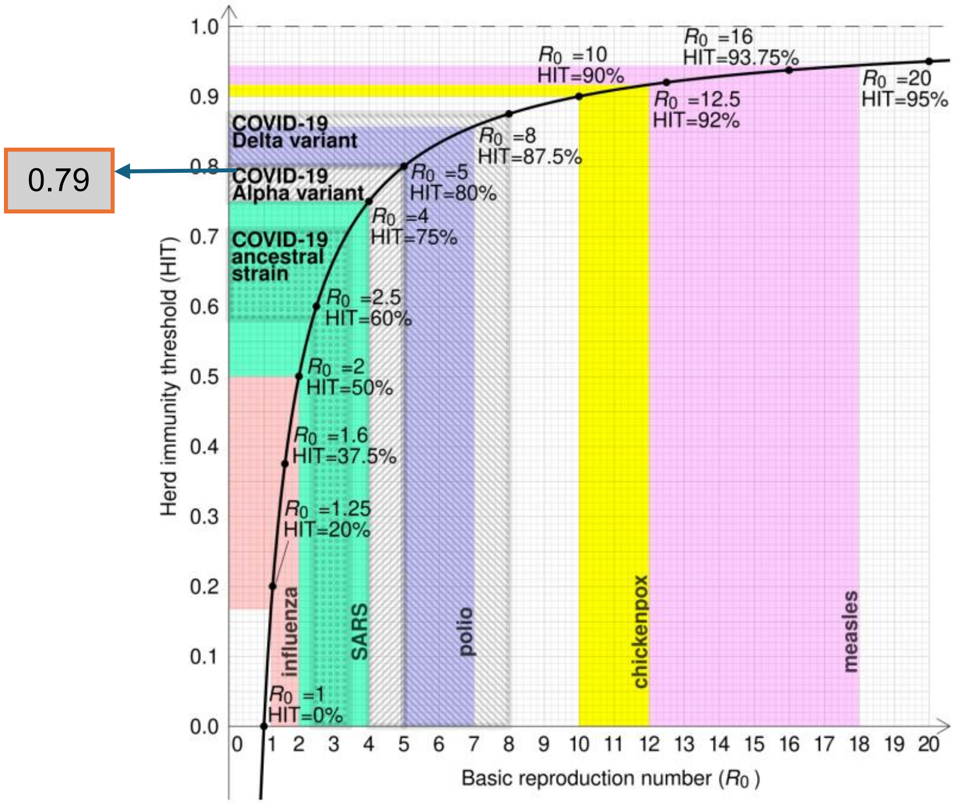
4. Discussion

The simulated results show a strong correlation between vaccination rate and the number of recovered people. At low vaccination rates, a large portion of the population gets infected and recovers, leading to high numbers of “recovered”. As the vaccination rate increases, fewer people get infected in the first place, so fewer need to recover.

The simulated threshold aligns closely with the theoretical herd immunity threshold:

$$\mathbf{HIT = 1 - 1/R_0 \text{ , where } R_0 = \beta \times \text{contacts per day} \times D}$$

$$\mathbf{R_0 = 0.2 \times 6 \times 4 = 4.8 \;\Rightarrow\; HIT \approx 1 - 1/4.8 \approx 0.79}$$



📊 Figure 3: Herd Immunity Threshold

The close match between the simulation result (~0.8) and the theoretical value (~0.79) suggests that the implemented model captures the herd immunity effect realistically. Minor deviations may result from randomness in the infection spread process, the stochastic nature of contact selection, or the finite size of the population (30,000 people). These factors introduce variability in how quickly infections die out, even at the same vaccination level.

5. Conclusion

The simulation successfully models the spread of an infectious disease and the impact of vaccination. The results confirm theoretical expectations: high vaccination rates can prevent the disease from spreading and reduce the number of people who must recover. The simulation provides a useful visual and statistical tool to understand herd immunity.