Group 5: Controlling Measles Outbreaks in a confined setting

Presented by Natania, Neema,
Rachel, David & Wayne

24 July, 2024

Introduction

Measles is a highly infectious virus that is often associated with childhood. It is most common among children between the ages of 1 and 4 years old, but can infect individuals of any age who are not immune Vaccination with the measles, mumps, and rubella (MMR) vaccine

Research Gap:

- Limited understanding of measles outbreak dynamics in a fully susceptible population.
- Need for insights on the effectiveness of emergency vaccination campaigns and herd immunity thresholds.

Research Question:

- How long does it take to control a measles outbreak in a confined setting of 200,000 people?
- What is the impact of an emergency vaccination campaign on outbreak dynamics?
- What level of vaccine coverage is required to control the outbreak by day 50?

Population and Setting

Target Population and Subgroups:

- Population: 200,000 people.
- Subgroups: Age groups - Infants, Children, Adults.

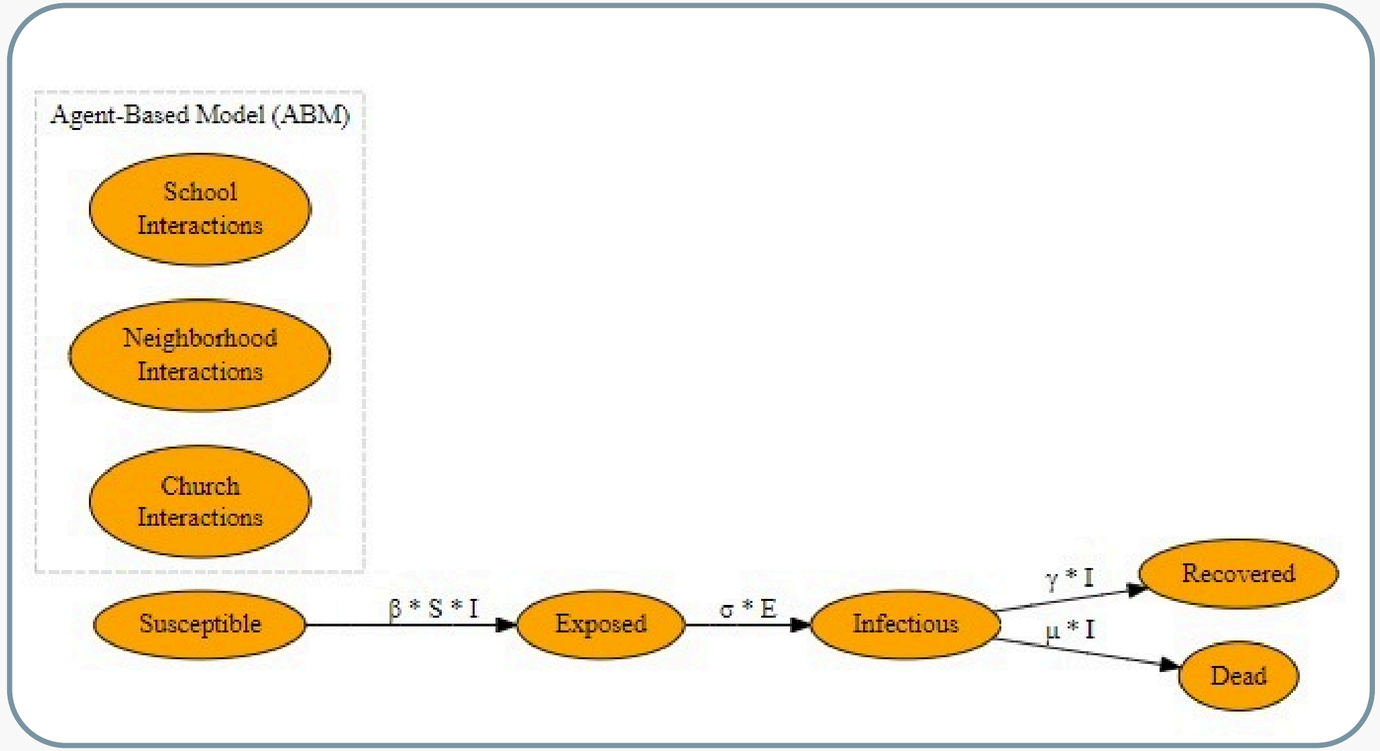
Setting and Location:

- Confined hypothetical city with no existing immunity.

Description of Outcomes:

- Time to epidemic peak.
- Duration until epidemic resolution.
- Total number of infected individuals.

Model Structure and Interventions



Flowchart of SEIR Model

Model Structure:

- Incorporation of social networks: schools, neighborhoods, churches.
- Parameters: Population size, initial infectious individuals, transmission probability, incubation period, infectious period, recovery rate, death rate..

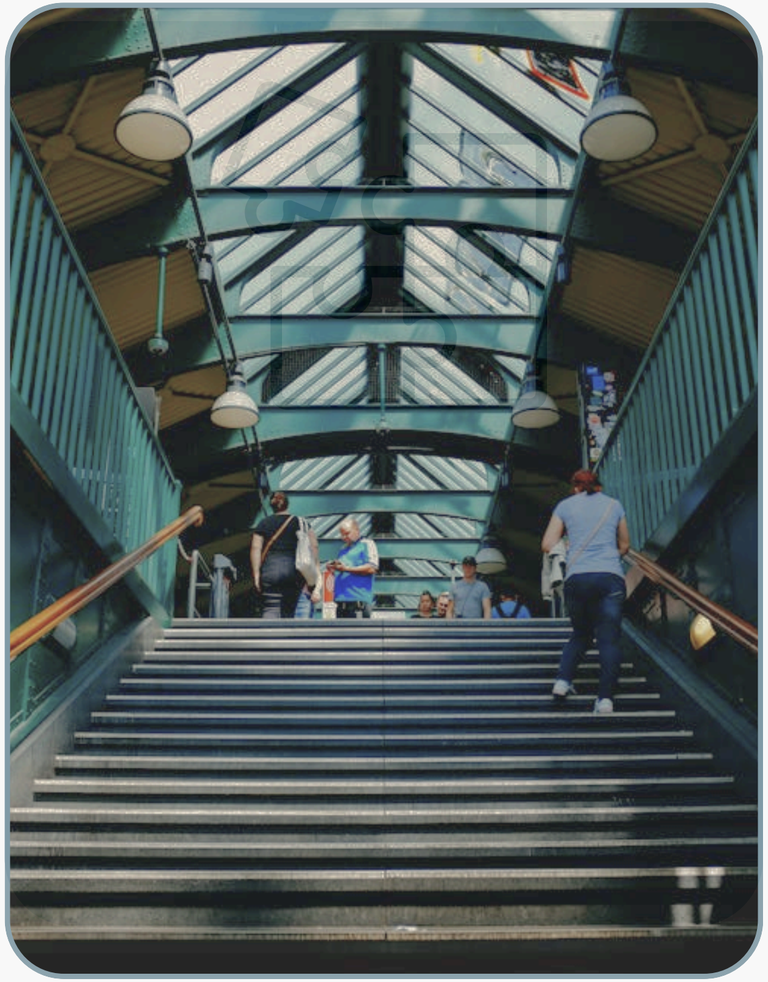
Interventions and Comparators:

- Emergency vaccination campaign on day 21 with 5,000 doses.
- Scenarios: No intervention, varying levels of vaccine coverage.

Social Dynamics

Uncertainity

- Variability in individual behaviors and contact rates.
- Stochastic nature of the agent-based model leading to different outcomes in each simulation run.



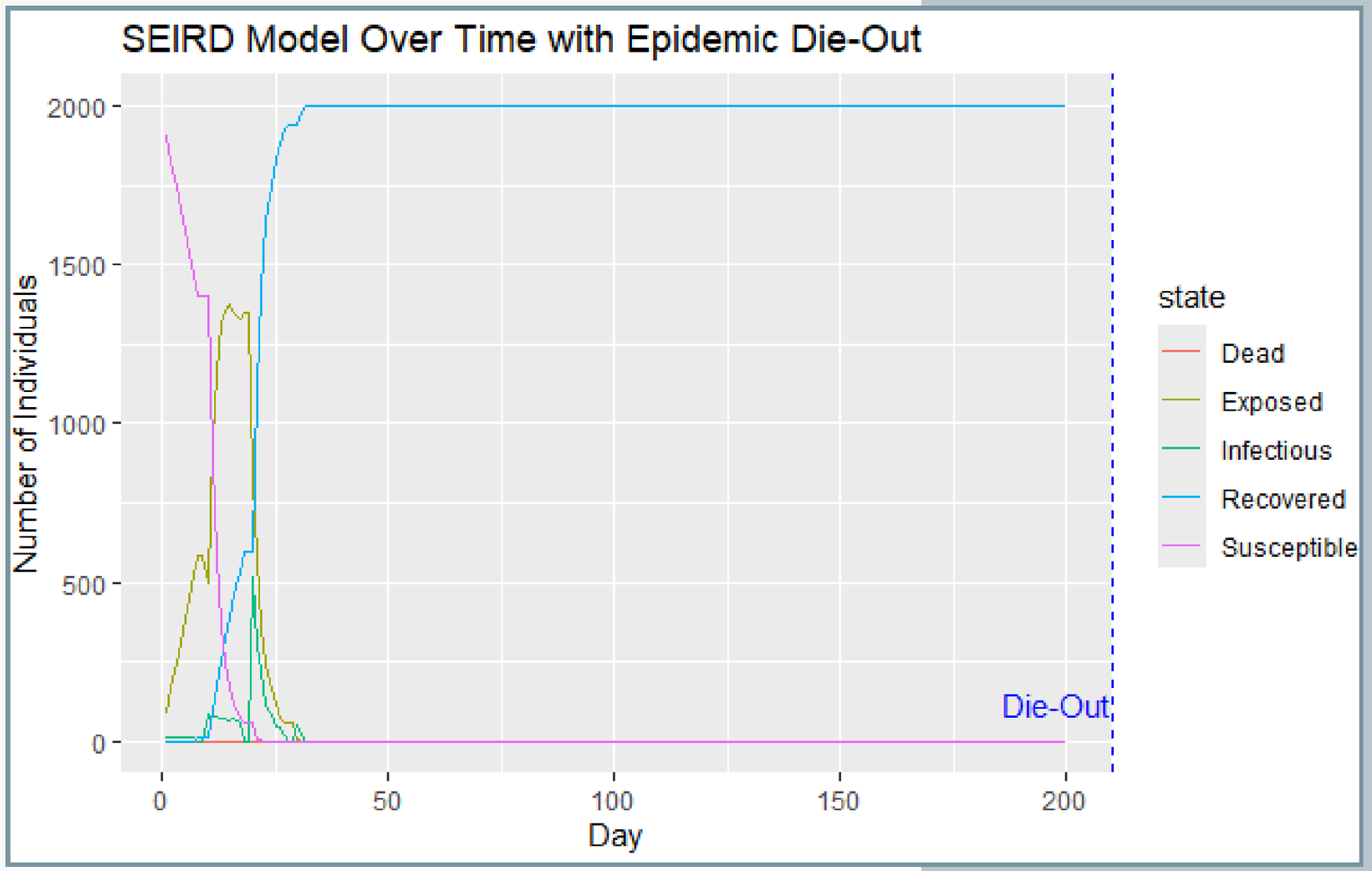
Heterogenity

- Differences in social interactions across age groups and social settings.
- Impact of different vaccination rates and pre-existing immunity levels on outbreak dynamics.

Results over time (No Intervention)

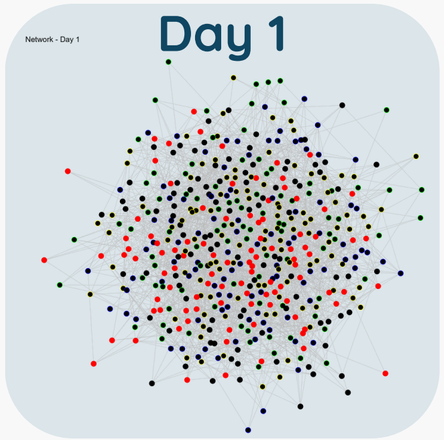
Current scenario:

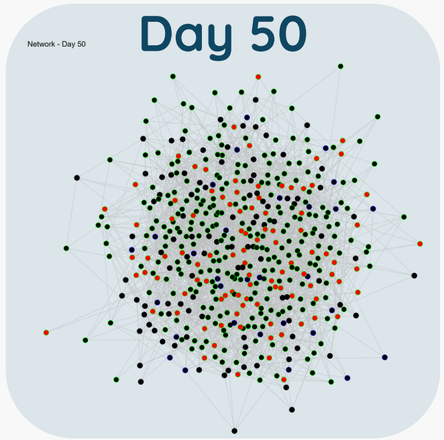
Recovery happens relatively quickly, and the death rate remains low throughout the simulation. By the end of the 50-day period, the majority of the population has either recovered or, to a lesser extent, died, with very few individuals remaining susceptible. This simulation effectively demonstrates the dynamics of measles spread and the impact of recovery and low mortality rates.

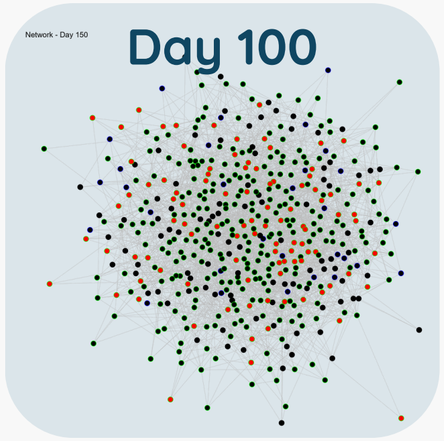


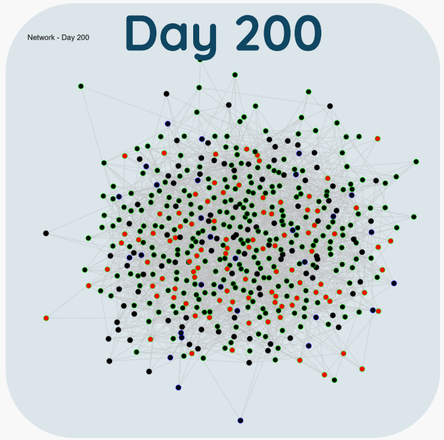
Introduction of Interaction Dynamics

Evolution of Network Dynamics









Day 1 Dynamics:

- Sparse connections
- Initial small clusters around key nodes (schools, neighborhoods, churches)

Mid-Term Dynamics(Day 50-100):

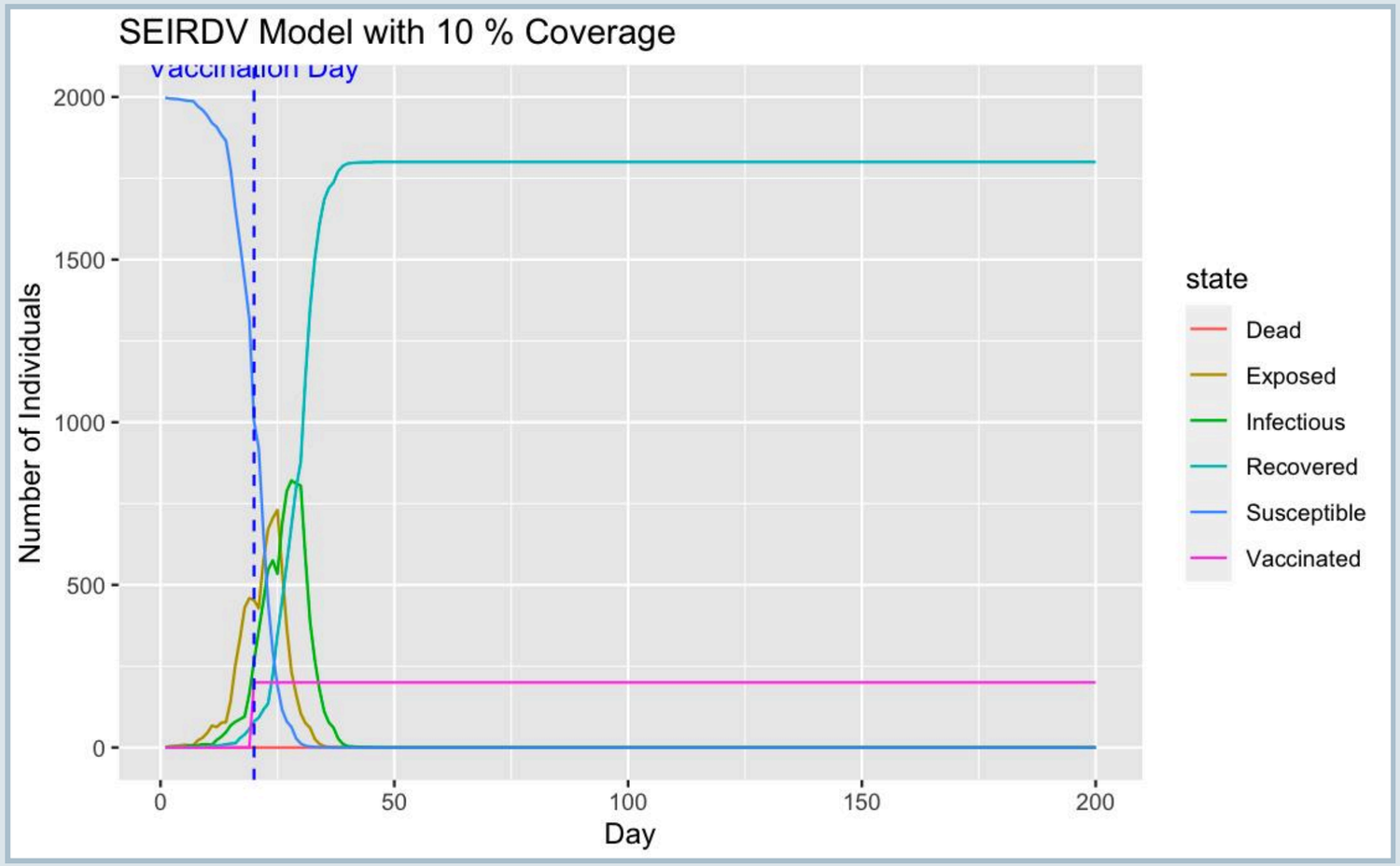
- Increased connectivity
- Defined clusters forming
- Denser interactions

Long-Term Dynamics (Day 100-200):

- Stabilization or further intensification
- Persistent social clusters
- Key highly connected nodes identified
- Patterns of inter-domain interactions (school, neighborhood, church)

Understanding these dynamics can inform targeted intervention strategies

Results Over Time: Emergency Vaccination



Insights:

- Rapid decline in the susceptible population
- Spike in exposed, infectious, individuals following the introduction of the virus,
- Subsequent recovery after vaccination day.
- Vaccinated population remains constant post-vaccination, showing the impact of vaccination in controlling the outbreak.

Vaccine Coverage and Pre-existing Immunity

Plot 1

- SEIRDV Model with Required Vaccine Coverage

Plot 2

- SEIRDV Model Over Time with Pre-existing Immunity

Plot 3

- SEIRDV Model Over Time with Ring Vaccination Strategy

Conclusion & Limitations

Conclusions

- The SEIR model effectively captures measles outbreak dynamics.
- Emergency vaccination campaigns significantly reduce infections and control the outbreak.
- A vaccination coverage of approximately 94.5% is required to achieve herd immunity and control the outbreak by day 50.
- Pre-existing immunity and ring vaccination strategies also significantly impact outbreak control.

Limitations

- Simplified assumptions about population behavior and social interactions.
- Lack of real-world demographic data in the hypothetical model.
- Variability in model outcomes due to stochastic nature and assumptions.
- Computational power

References

- [Hunter et al., 2018](Simplified assumptions about population behavior and social interactions.
- OutbreakTools, 2018