

R shiny APP: an Agent Based Model - SEIR Simulation Platform

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2025 Fall PHP2560 Final Project Report

Dec 9, 2025

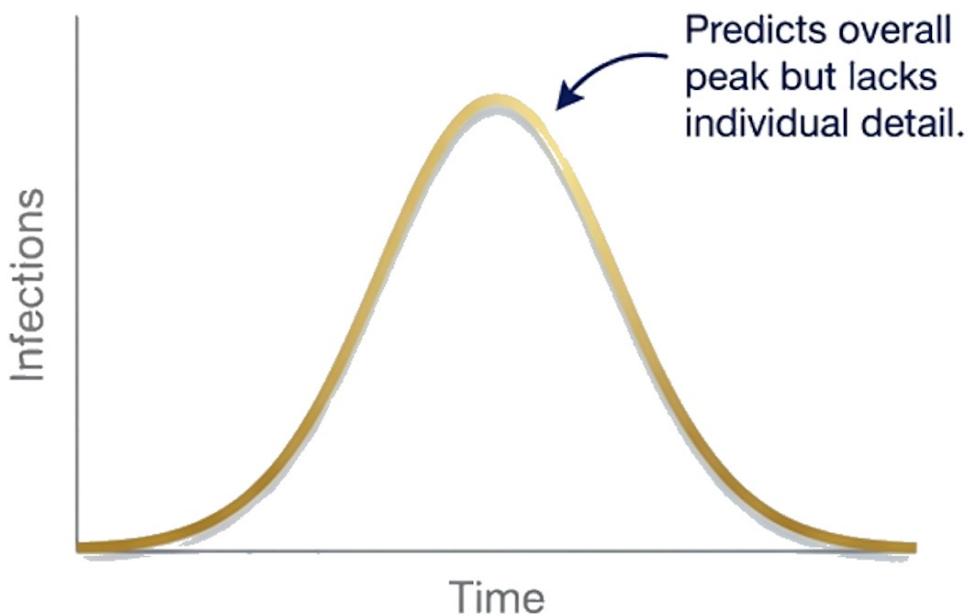


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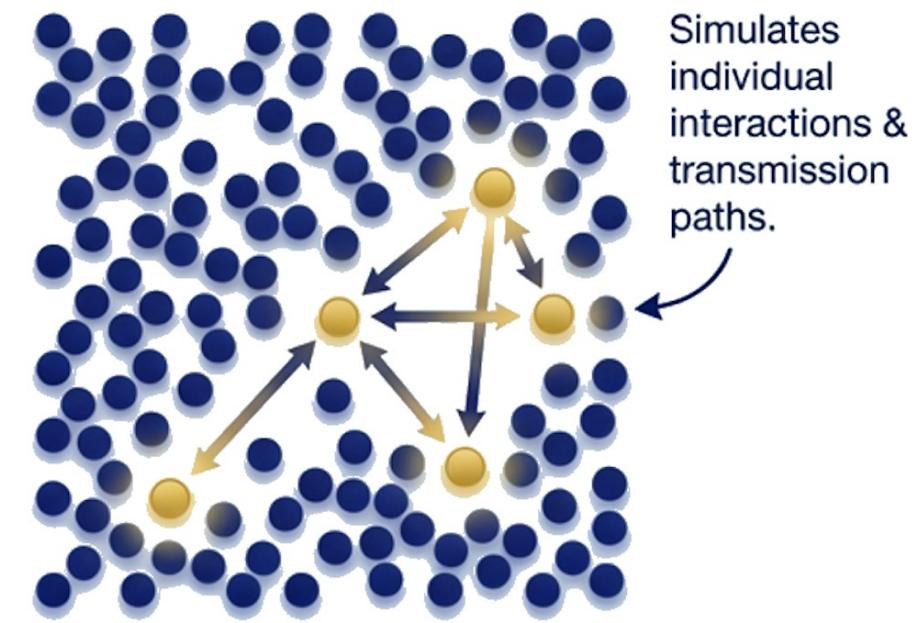
Step 1. Background & Methods

Aggregate Models



Aggregate equation-based models treat the population as a uniform whole. They are useful for broad trends but miss the granular, real-world dynamics that emerge from individual interactions.

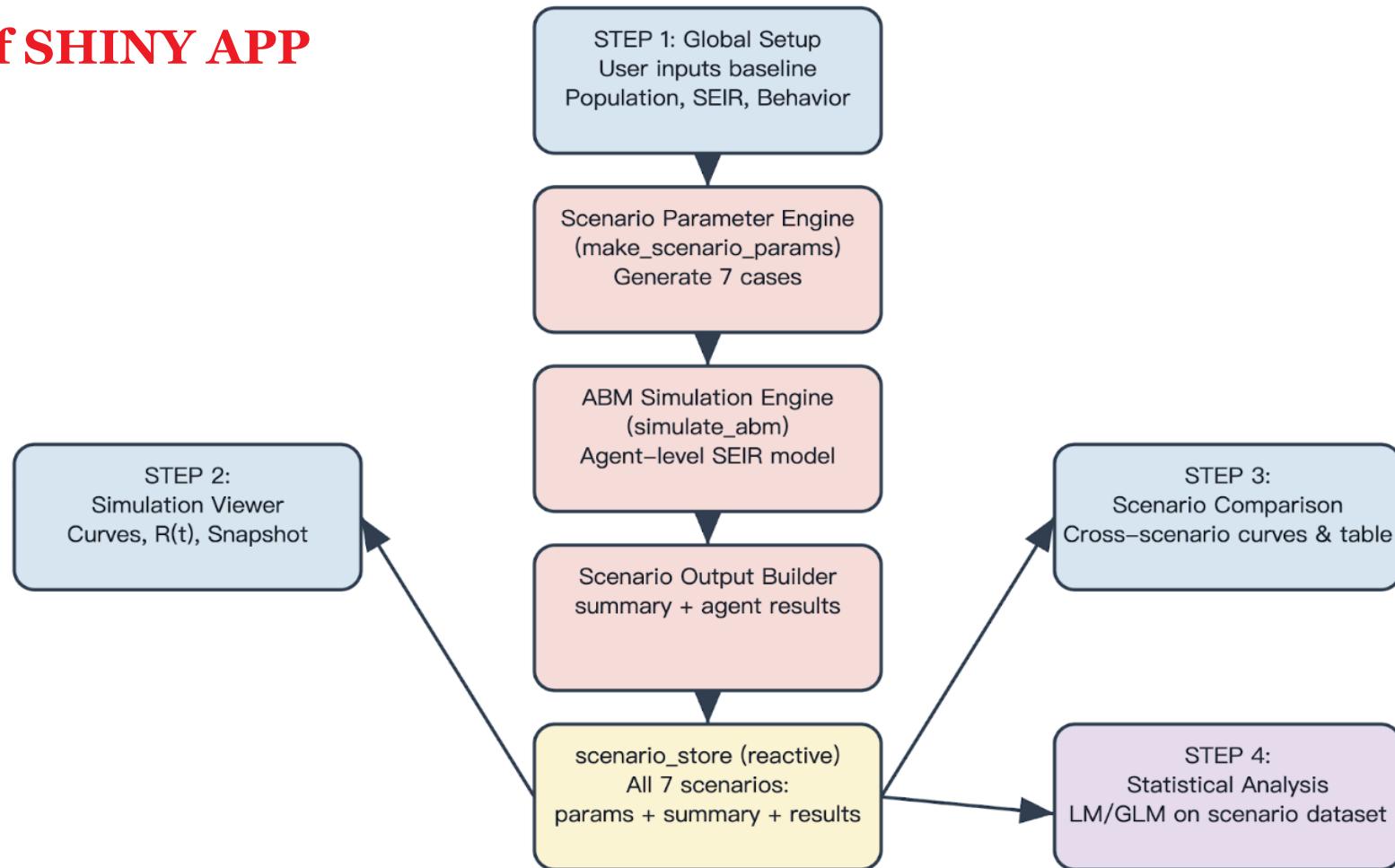
Our Approach: Agent-Based Models



Our framework simulates thousands of individual agents, each with unique states and interactions. This bottom-up approach creates more realistic, emergent patterns, moving beyond simple curves to capture complexity.

Step 1. Background & Methods

Workflow of SHINY APP



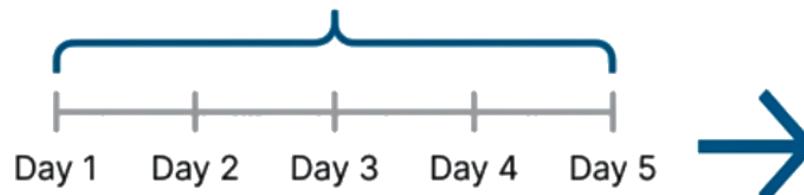
Step 2. Key Concepts & Parameters

Epidemiological Compartments

- **Susceptible (S): Vulnerable individuals.**
Probability of infection depends on local prevalence.
- **Exposed (E): Infected but not yet infectious (Latent period).**
- **Infected (I): Infectious individuals capable of transmitting the virus.**
- **Recovered (R): Immune individuals removed from the transmission chain.**

Step 2. Key Concepts & Parameters

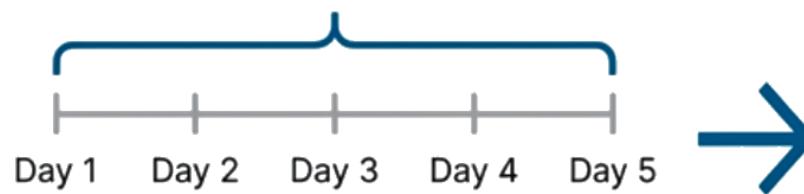
Incubation Period



$$\text{Incubation Rate } (\sigma) = \frac{1}{T_{\text{inc}}} = \frac{1}{5} = 0.2$$

A 20% daily probability of an Exposed agent becoming Infectious.

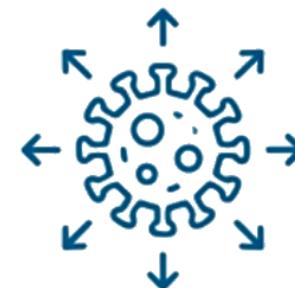
Infectious Period



$$\text{Recovery Rate } (\gamma) = \frac{1}{T_{\text{inf}}} = \frac{1}{5} = 0.2$$

A 20% daily probability of an Infectious agent Recovering.

Transmission



Transmission Rate (β)

The core driver of spread. Related to R_0 by $R_0 = \frac{\beta}{\gamma}$.
This is the parameter interventions will modify.

Step 3. Mathematical Framework

Stochastic SEIR Foundations (Discrete-Time Model)

- SEIR as Individual-Level Stochastic Transitions

Each individual evolves independently through the states:

$$\mathbf{S} \rightarrow \mathbf{E} \rightarrow \mathbf{I} \rightarrow \mathbf{R}$$

- Biological Durations → Rates → Daily Transition Probabilities

Empirical epidemiological durations are mapped into per-day transition rates, then converted into probabilities used in simulation.

Incubation (Latent) Transition

Average incubation period: T_{inc}

$$\sigma = \frac{1}{T_{\text{inc}}}$$

Daily probability that an Exposed agent becomes Infectious:

$$P(E \rightarrow I) = 1 - e^{-\sigma \Delta t}$$

Infectious (Recovery) Transition

Average infectious period: T_{inf}

$$\gamma = \frac{1}{T_{\text{inf}}}$$

Daily probability that an Infectious agent recovers:

$$P(I \rightarrow R) = 1 - e^{-\gamma \Delta t}$$

Step 3. Mathematical Framework

Transmission Dynamics: Effective β & Force of Infection

- Effective Transmission Rate (β_{eff}) Under Interventions

Interventions (masking, distancing) do not alter SEIR structure, but directly reduce transmissibility.

Baseline transmission rate: β

Intervention-adjusted rate: $\beta_{\text{eff}} = \beta(1 - \text{MaskEffect})(1 - \text{SocialDistancing})$

- Force of Infection (λ): Linking Exposure to Prevalence

For each susceptible agent, infection risk depends on:

- effective transmissibility β_{eff}
- average contact rate c
- current infection prevalence I/N
- The instantaneous force of infection:

$$\lambda = \beta_{\text{eff}} c \frac{I}{N}$$

- Daily Probability of Infection for Susceptible Agents

Using the exponential survival form: $P(S \rightarrow E) = 1 - e^{-\lambda \Delta t}$

Step 3. Mathematical Framework

Stochastic Transition Kernel & Emergent Dynamics

- Summary of Transition Probabilities

Transition	Formula	Meaning
S → E	$1 - e^{-\lambda}$	Infection probability
E → I	$1 - e^{-\sigma}$	End of incubation
I → R	$1 - e^{-\gamma}$	Recovery probability

- From Micro-Level Stochasticity to Macro-Level Epidemic Waves

Aggregating thousands of agents produces:

- epidemic curves
- peak prevalence
- timing of outbreak
- scenario differences driven by β_{ef}

Monte Carlo repetitions further estimate **mean trajectories and confidence intervals.**

Step 4. Statistical Analysis

$$Y = \beta_0 + \underbrace{\beta_1 SD + \beta_2 Mask + \beta_3 Lockdown}_{\text{Main Effects}} + \underbrace{\beta_{ij}(X_i \times X_j)}_{\text{Interaction Terms}} + \epsilon$$

Model Fitting

- Fitting **linear regression model** to the aggregate dataset ($N = \text{Scenarios} \times \text{Repetitions}$). Outcome Variables includes `Peak Prevalence` and `Day of Peak`.
- To capture the potential effects of combined interventions, the model includes pairwise interaction terms between all selected **predictors (Social Distancing, Mask Usage, and Lockdown)**.

Step 4. Statistical Analysis

$$Y = \beta_0 + \underbrace{\beta_1 SD + \beta_2 Mask + \beta_3 Lockdown}_{\text{Main Effects}} + \underbrace{\beta_{ij}(X_i \times X_j)}_{\text{Interaction Terms}} + \epsilon$$

Notes for Interaction Terms

- **Baseline Trap:** In models with interactions, the main effect coefficient represents the outcome only when the interacting variable is zero.
- **Avoid Isolated Interpretation:** When an interaction term is significant, coefficients cannot be interpreted in isolation.
- **Focus on Net Effect:** Evaluate true effectiveness based on the net effect under specific conditions.

5. Limitations & Future Work

While this simulation provides valuable insights, the following limitations should be considered and may improved in future:

- **Computational Constraints (Population Size):** Agent-Based Models require significant memory. To ensure this app runs smoothly in the browser, we limited the simulation to a maximum of 5,000 individuals.

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- **Limited Scenarios & Data:** Our simulation follows the setting in Silva et al. (2020). This means we are limited to the 7 specific scenarios and parameters defined in that paper, resulting in a relatively small dataset.

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- **Limited Scenarios & Data:** Our simulation follows the setting in Silva et al. (2020). This means we are limited to the 7 specific scenarios and parameters defined in that paper, resulting in a relatively small dataset.
- **Modeling Assumptions:** We used a basic linear regression model to analyze the results. While useful for general trends, a more advance model might be needed to capture the complicated details of viral transmission.

6. Resources & References

Our Project Resource:

- GitHub: <https://github.com/fan-zhongyu/ABM-SEIR-Simulation>
- R shiny APP: <https://zhongyu.shinyapps.io/2560FinalProject/>

Other Interesting Related Resources:

- Epidemic Calculator by Goh: https://gabgoh.github.io/COVID/?utm_source=catalyzex.com
- Interactive Agent-Based Model Visualization for COVID-19 Masking: <https://dek.ai/masksim/>

6. Resources & References

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R Shiny APP Demonstration



Thank You



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