IDM INSTITUTE FOR DISEASE MODELING

2023 IDM Annual Symposium

Advancing Simulation Methodology for Identifying Optimal Healthcare Policy During COVID-19 Pandemic

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Background

- Health behaviors are **complex** and can **change over time**
- **Modelling** studies provides insights into the relationship between **health behaviors** and **policy outcomes** for policymakers

Figure: https:// www.sycamoreinstitutetn.org /drivers-of-health/

Questions to tackle COVID-19 pandemic

In order to minimize the disease burden,

1. How effective are **non-pharmaceutical interventions (NPIs)** when vaccination is unavailable? Can we control the pandemic to the level of Washington state's objective? Are the results **robust** to model uncertainty?
2. When viruses keep **mutating**, will **vaccination** remain effective policies? Will **NPIs** remain effective policies?

To address vaccine hesitancy,

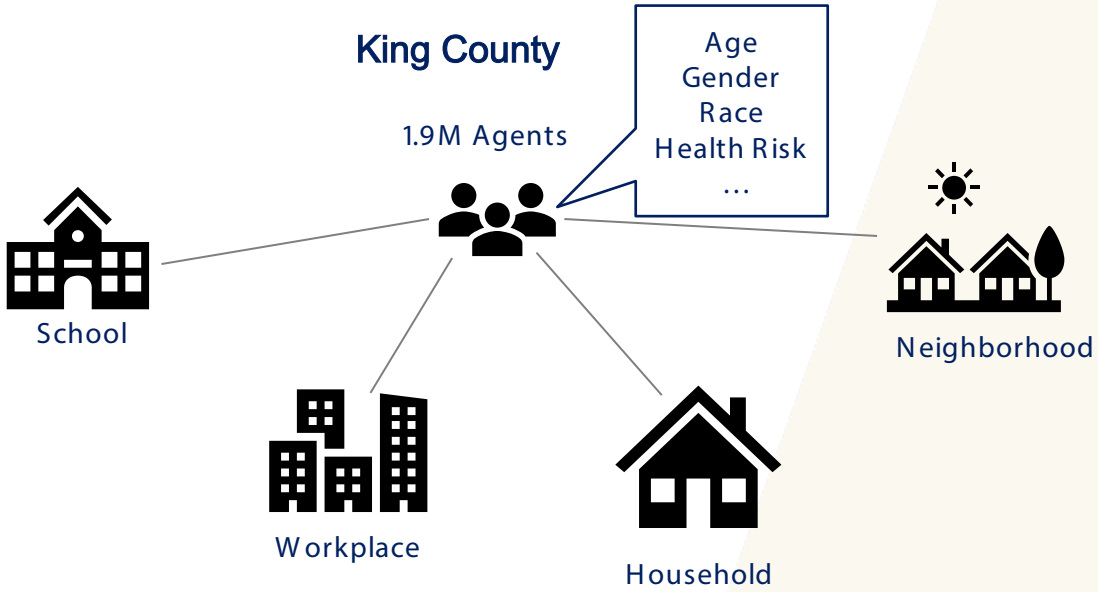
3. Given individuals make different **vaccination behavior decisions**, whom should be **targeted** to **promote vaccination**?

Research Question 1

- How effective are **non-pharmaceutical interventions (NPIs)** when vaccination is unavailable?
- Can we control the pandemic to the level of WA objective?
- Are the results **robust** to model uncertainty?

Lee S, Zabinsky ZB, Wasserheit JN, Kofsky SM, Liu S. COVID-19 pandemic response simulation in a large city: Impact of nonpharmaceutical interventions on reopening society. Medical Decision Making. 2021 May;41(4):419-29.

Overview of large-scale agent-based model



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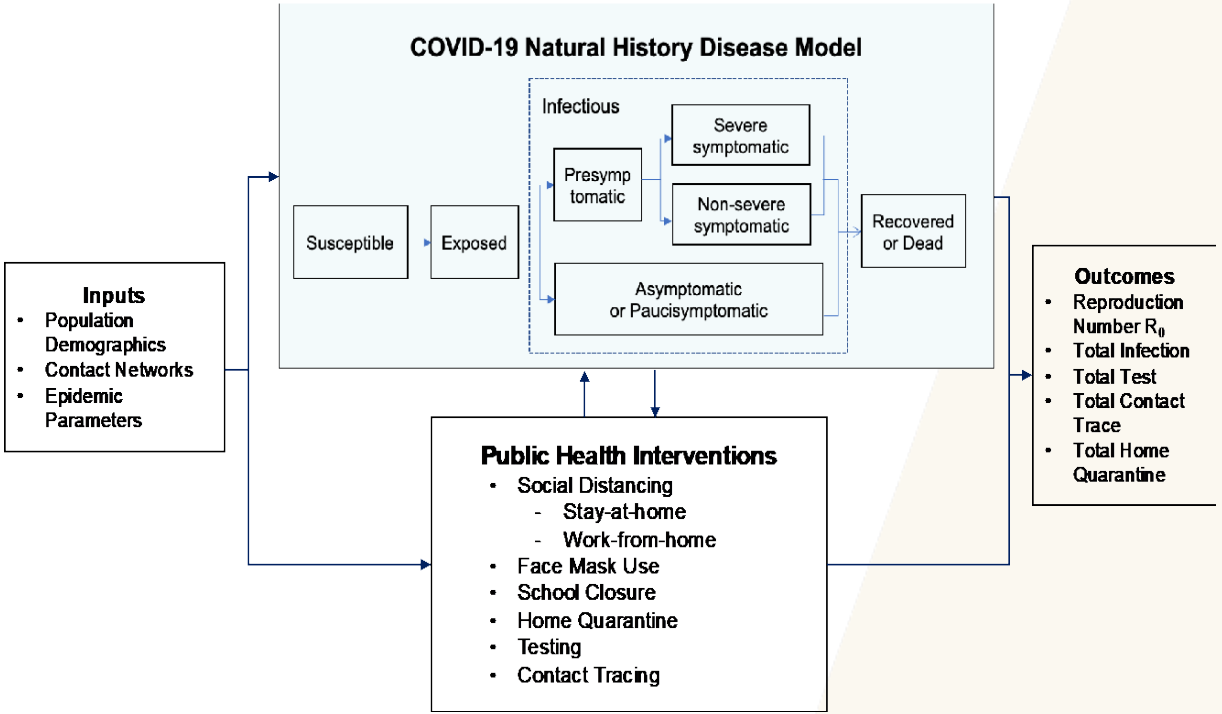
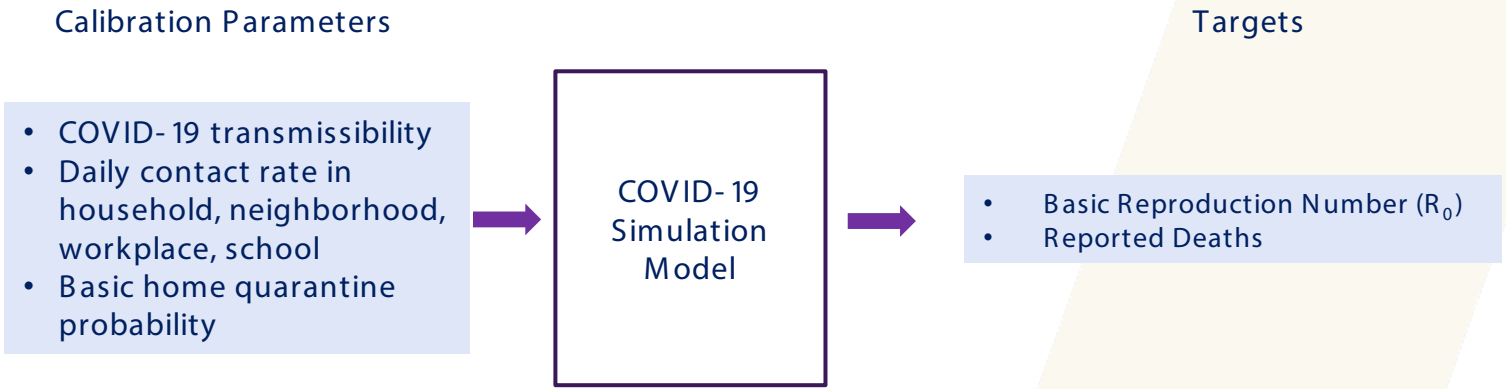


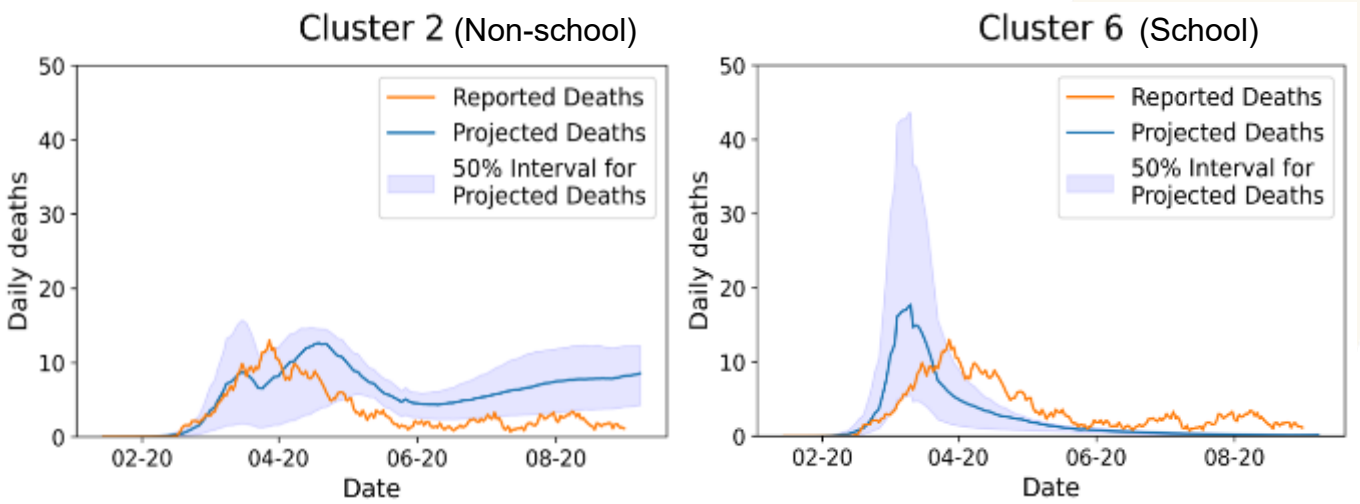
Model calibration



- Calibration period: January 15, 2020, to May 31, 2020
- Fit NPIs compliance history by observing Seattle's sequence of interventions
- Resulted in seven clusters, narrowed down to two parameter sets (Cluster 2 and Cluster 6)

Calibration results

- Cluster 2: High contacts in **non - school** places (household, neighborhood, workplace)
- Cluster 6: High contacts in **school** setting



Research question 1

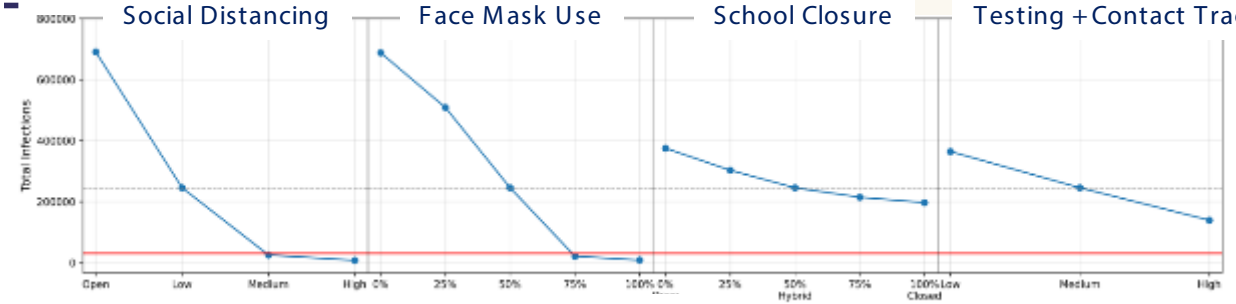
1. How effective are **non - pharmaceutical interventions (NPIs)** when vaccination is unavailable?
2. Can we control the pandemic to the level of Washington state's objective?
3. Are the results **robust** to model uncertainty?

NPIs	Parameter Settings
Social Distancing	Open (0%), **Low (20%),** Medium (50%), High (80%)
Face Mask Use	0%, 25%, **50%** , 75%, 100%
School Closure	Open (0%), 25%, **Hybrid (50%)** , 75%, Closed (100%)
Testing and Contact Tracing	Low, **Medium** , High

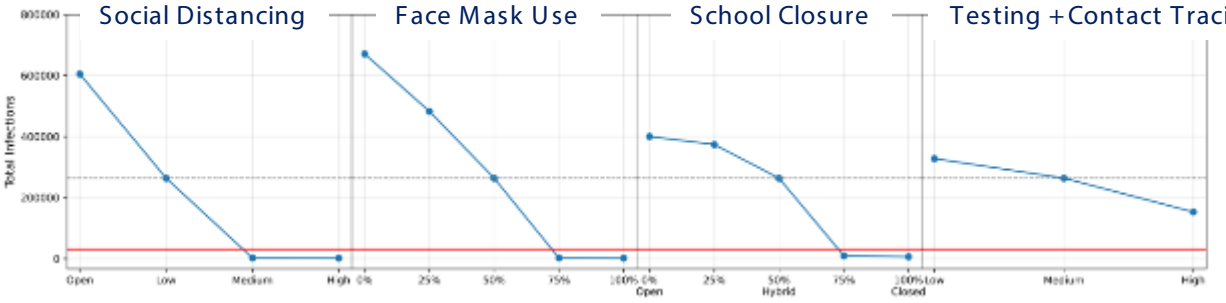
Research question 1-1

How effective are **non-pharmaceutical interventions (NPIs)** when vaccination is unavailable?

Cluster 2



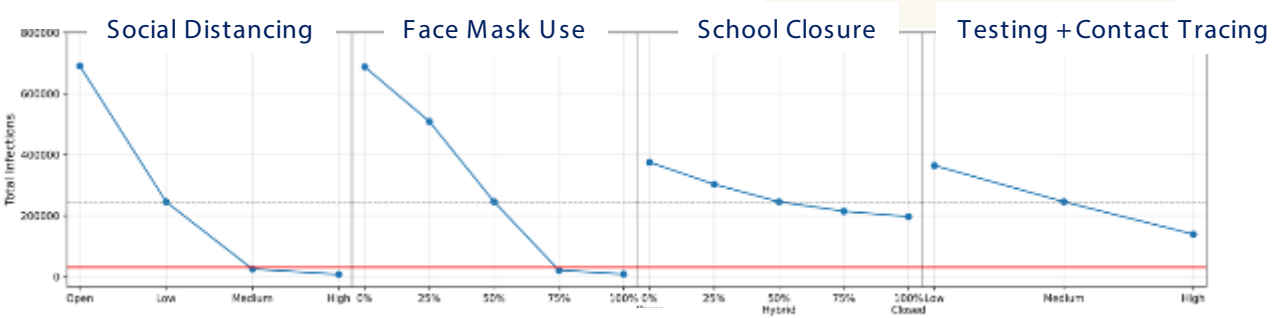
Cluster 6



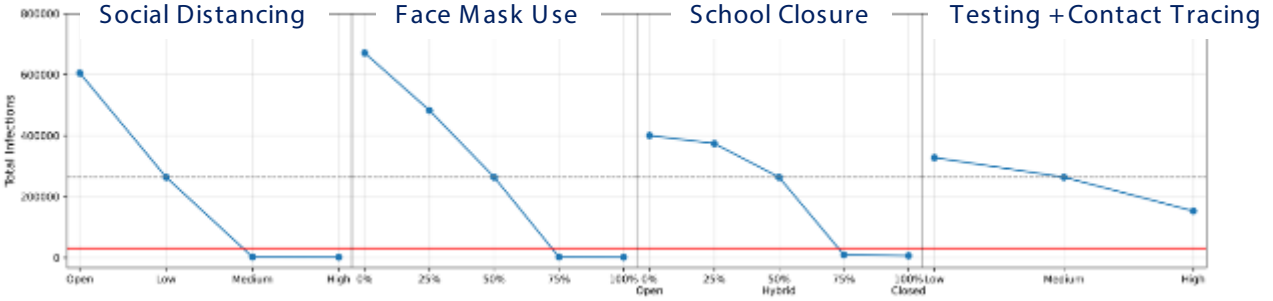
Research question 1-2

Can we control the pandemic to the level of **Washington** state's objective?

Cluster 2



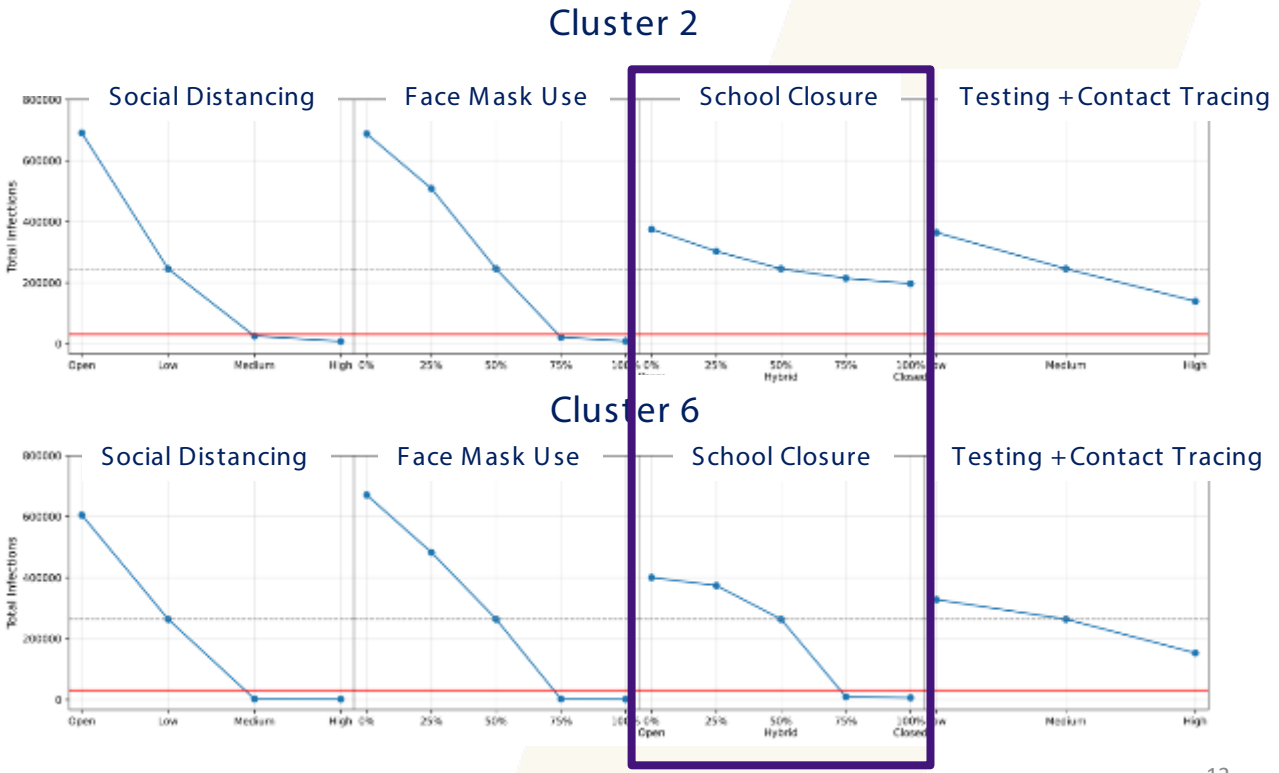
Cluster 6



Washington state's objective

Research question 1-3

Are the results **robust** to model uncertainty?



Findings for research question 1

When the wild strain of SARS-CoV-2 spread and vaccination is unavailable,

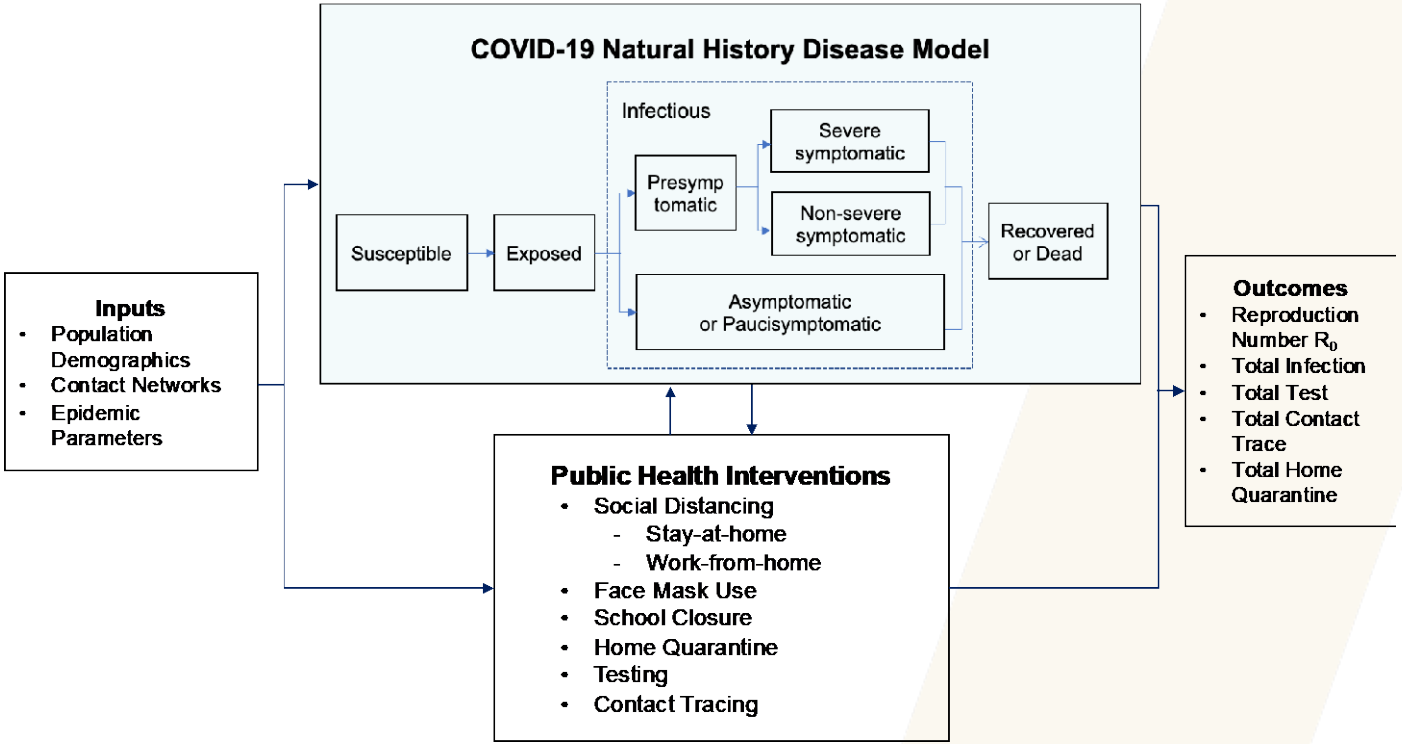
- **Face mask use** and **social distancing** are important regardless of model uncertainty
- **Strong school closure** may be effective only when a society's student contacts are high
- Current projections of **testing** and **contact tracing** are insufficient to contain COVID-19 without other NPIs

Research Question 2

- When viruses keep **mutating** , will **vaccination** remain effective policies?
- When viruses keep **mutating** , will **NPIs** remain effective policies?

LEE S, Zabinsky ZB, Wasserheit JN, Ross J, Chen S, Liu S. Impact of Vaccination and Non-Pharmaceutical Interventions with Possible COVID-19 Viral Evolutions Using an Agent-Based Simulation. Available at SSRN 4382858. 2023 Mar 22.

Updated large-scale agent-based model



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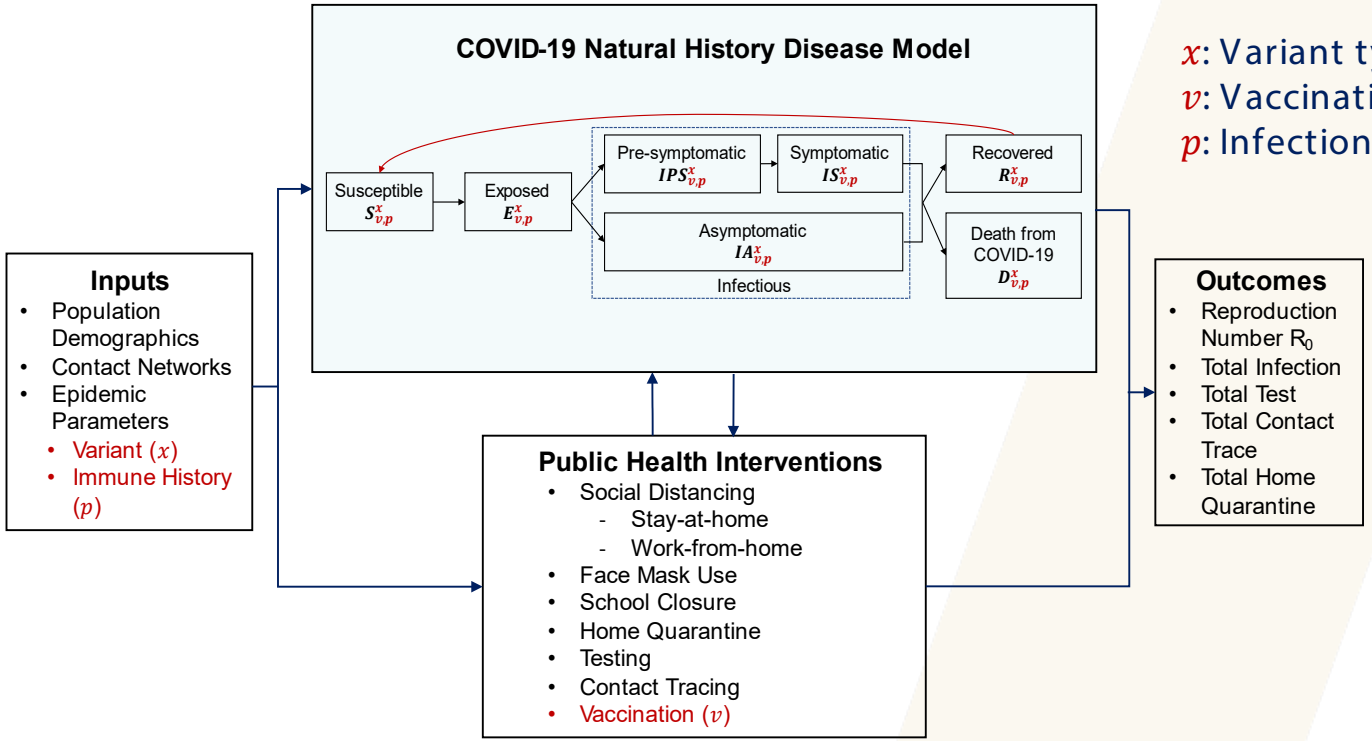
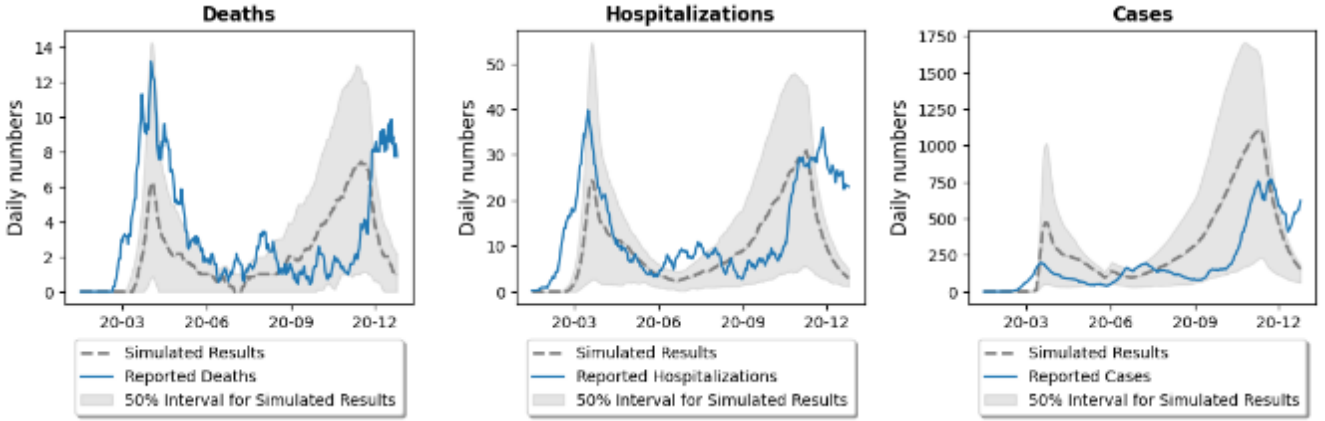


x: Variant type
v: Vaccination history
p: Infection history

Model calibration

- Calibration period: January 15, 2020, to December 31, 2020
- Fit NPIs compliance history by observing Seattle's sequence of interventions
- Resulted in one parameter set



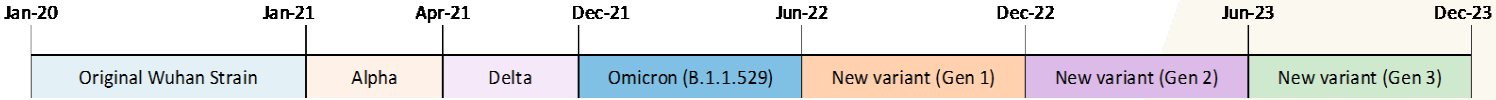
Research question 2

1. When viruses keep **mutating** , will **vaccination** remain effective policies?
2. When viruses keep **mutating** , will **NPIs** remain effective policies?

Policy Scenarios	Parameter Settings
Vaccination willingness reduction for each additional dose	50% less, **25% less** , Same
NPI Policy	**Timeline 1** , Timeline 2, Threshold

Research question 2

Virus **mutation** scenarios

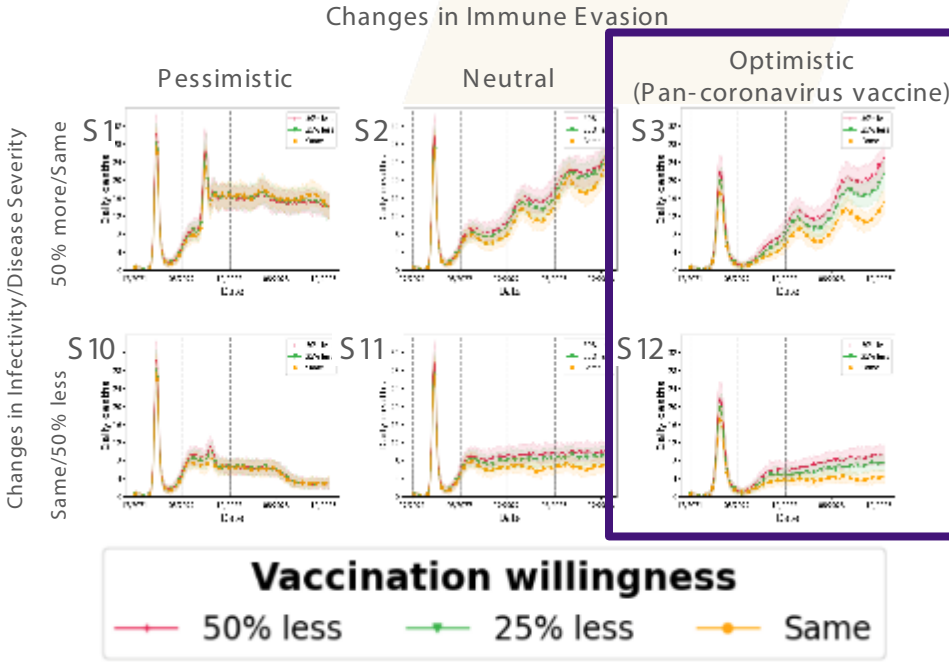


Mutation Scenarios	Changes in infectivity	Changes in disease severity	Changes in immune evasion
S1	50% more infectious	Same	Pessimistic
S2			Neutral
S3			Optimistic (Pan-coronavirus vaccine)
S4		50% less severe	Pessimistic
S5			Neutral
S6			Optimistic (Pan-coronavirus vaccine)
S7	Same	Same	Pessimistic
S8			Neutral
S9			Optimistic (Pan-coronavirus vaccine)
S10		50% less severe	Pessimistic
S11			Neutral
S12			Optimistic (Pan-coronavirus vaccine)

Research question 2 - 1

When viruses keep **mutating** , will **vaccination** remain effective policies?

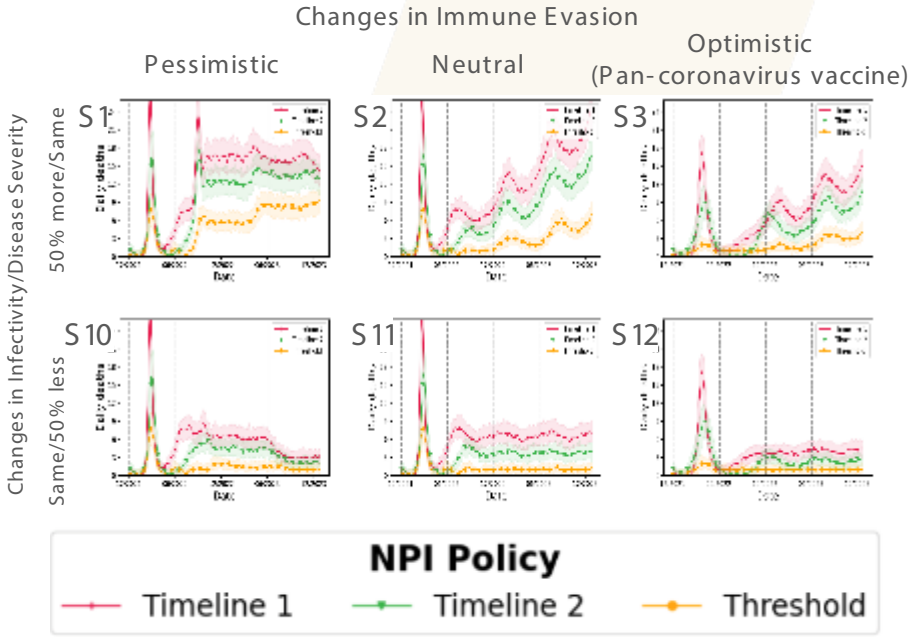
- 6 mutation scenarios, 3 vaccine willingness
- Increasing vaccination willingness is **effective** with optimistic immune evasion **(pan - coronavirus vaccine, S3 and S12)**



Research question 2 - 2

When viruses keep **mutating** , will **NPI policy** remain effective policies?

- 6 mutation scenarios, 3 NPI policies
- Strengthening NPI policy **always reduce mortality** , regardless of virus mutation scenarios



Findings for research question 2

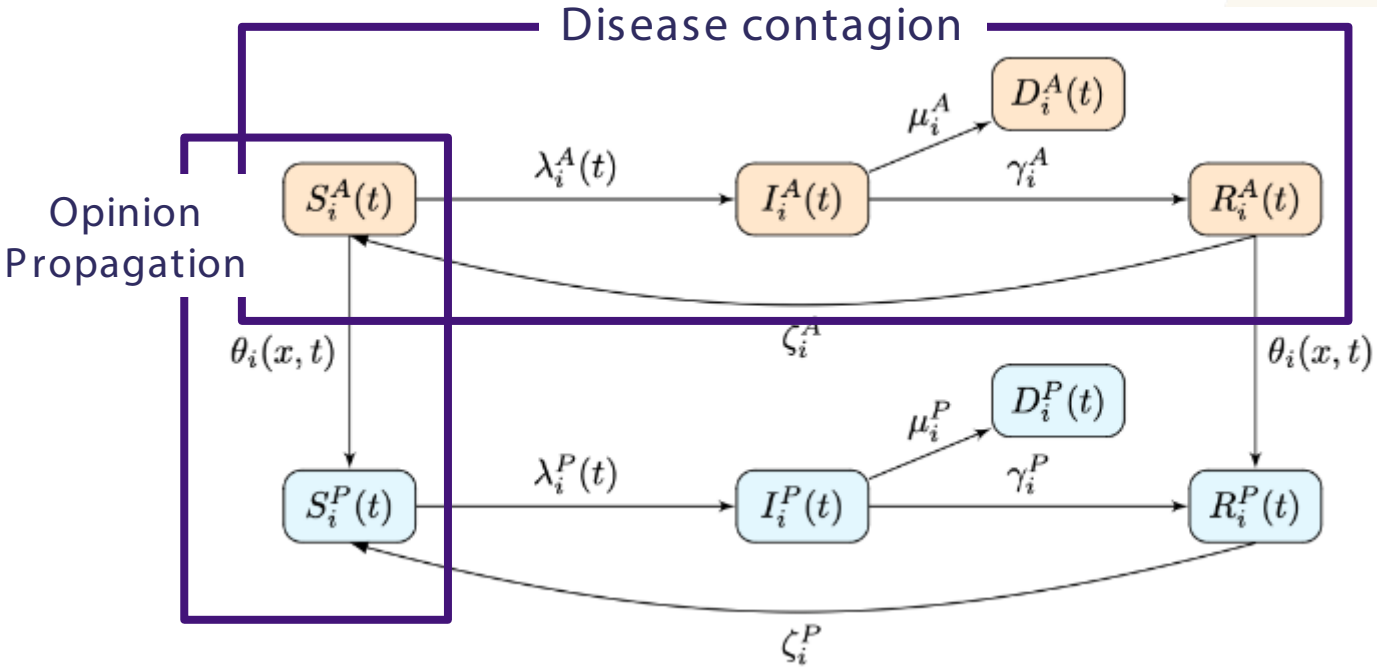
When the SARS-CoV-2 keep mutates,

- Developing **pan-coronavirus vaccine** has high potential in reducing death toll with increased vaccination willingness
- Strengthening **NPI policy** is **robust** to viral mutation

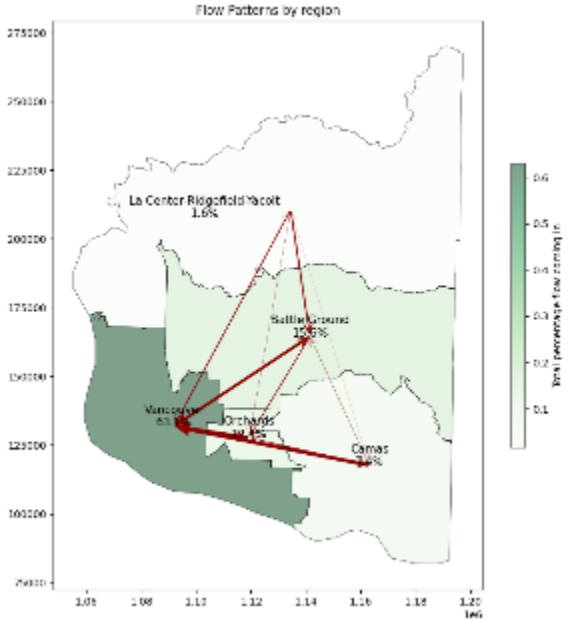
Research Question 3

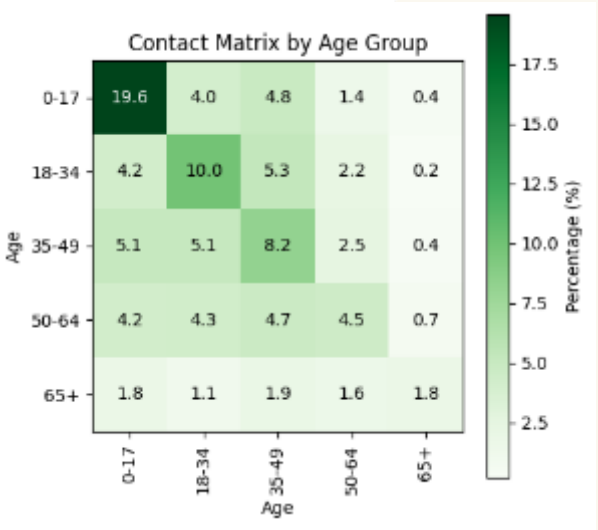
- To address vaccine hesitancy, given individuals make different **vaccination behavior decisions,** whom should be **targeted** to **promote vaccination** ?

Networked compartmental model



Networked compartmental model





Regional Group

Age Group

Research question 3

Given individuals make different **vaccination behavior decisions** ,
whom should be **targeted** to **promote vaccination** ?

Ongoing research approach

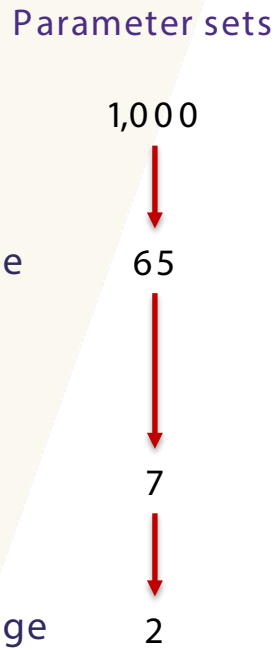
- Vaccination behavior decision depends on rational and emotional judgement and **active pro - vaccination neighbors** who share opinions
- Allocate resources by age and geographic groups
- Get **near - optimal solutions** while considering **fairness**

Thank you! Questions?

Appendix

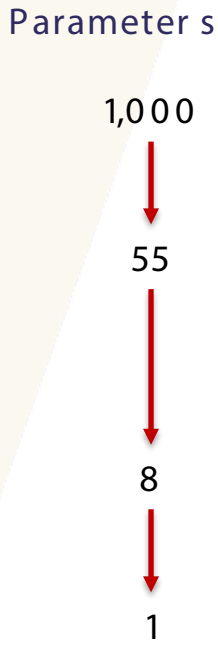
Model calibration

- Step 1
  - Use Latin hypercube sampling method to generate 1,000 parameter sets.
  - Randomly infect 10 random people and simulate for 30 days.
  - Select parameter sets whose basic reproduction number (R_0) is within range (1.5-3.5)
- Step 2
  - Cluster the selected parameter sets and get centroid of each cluster
  - With the centroid points, simulate for the full calibration period.
  - Select centroid points whose simulated infection-fatality ratio is within range (0.005-0.008)



Model calibration

- Step 1
  - Use Latin hypercube sampling method to generate 1,000 parameter sets.
  - Randomly infect 10 random people and simulate for 30 days.
  - Select parameter sets whose basic reproduction number (R_0) is within range (2-4)
- Step 2
  - Cluster the selected parameter sets and get centroid of each cluster
  - With the centroid points, simulate for the full calibration period.
  - Select centroid points with the lowest mean absolute error on health outcomes



Bivalent vaccination rate

King County, WA (May 10, 2023)