Effectiveness of Nonpharmaceutical Interventions to Avert the Second COVID19 Surge in LA County: A Simulation Study

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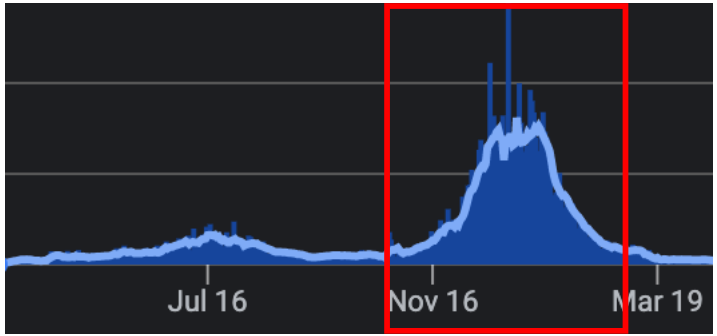
PRESENTATION OVERVIEW

- **Project Overview**
- **Methods**
- **Results**
  - Base Case Scenario
  - Overall Scenario Performance
  - Scenario Performance by Age Groups
  - Scenario Performance by Activity Types
- **Conclusions**
- **Limitation & Future Work**

Project Overview

A simulation that leveraged a detailed transit and activity model to explore the nonpharmaceutical interventions (NPIs) that could be implemented at the early stages of a COVID-19 surge to prevent or reduce a large wave of infections, deaths, and an overwhelmed hospital system.



Nonpharmaceutical Interventions (NPIs):

- Expanded use of cloth masks, N95 masks
- Restrictions to reduce contact intensities
- Antigen testing

Region/Population: Los Angeles County (LA County), 10 million individuals

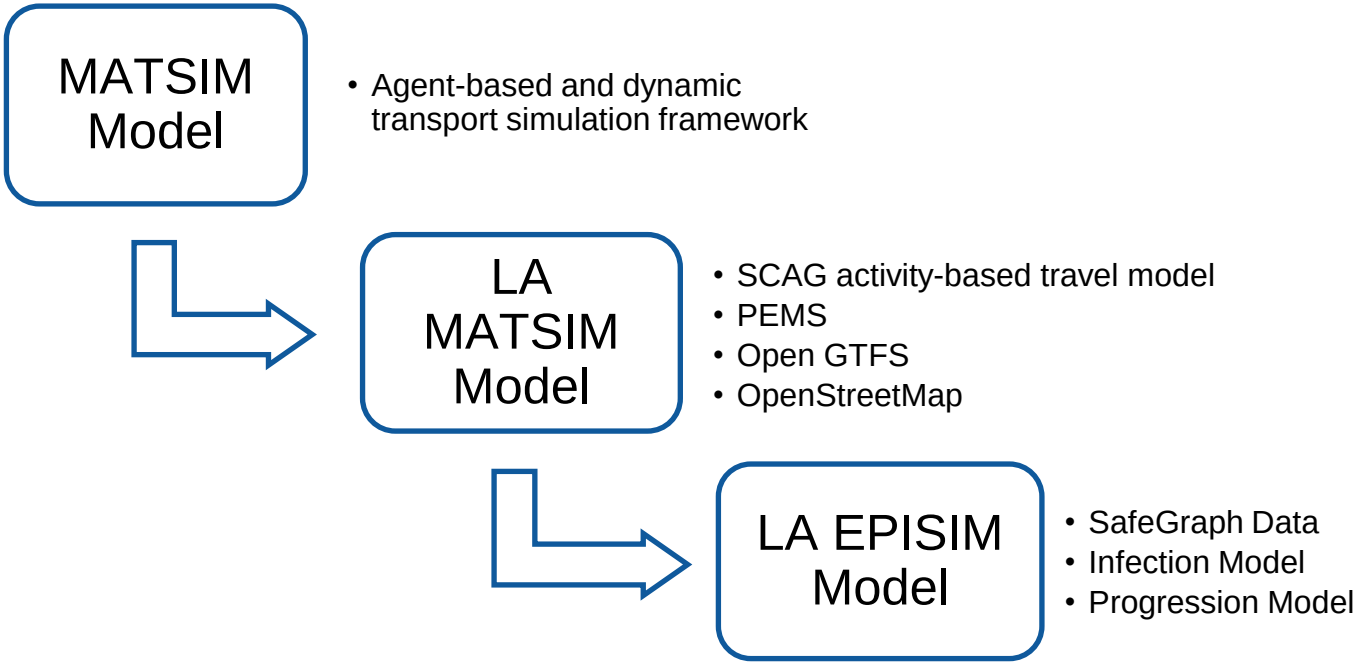
Simulation Period: Nov 1, 2020 to Feb 10, 2021

Project Overview

Simulation created through integrated layers of models and data:

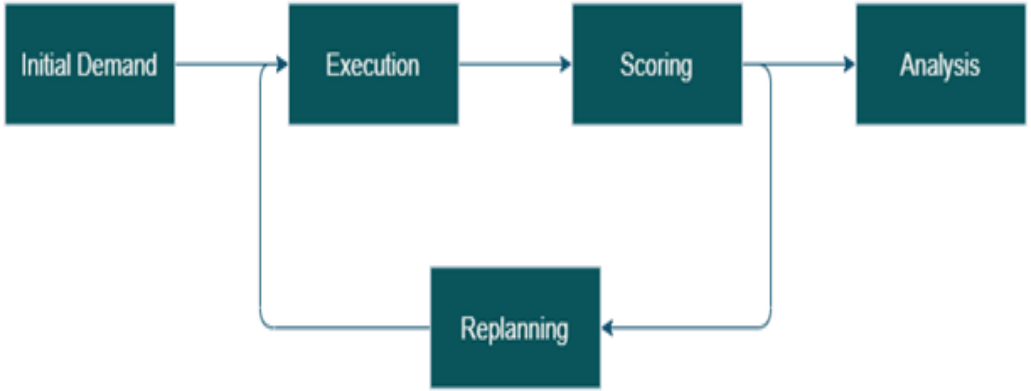
- **Transit, activity, and contact**: dynamic agent-based travel model, ***MATSim***
  - Reductions over time: **mobile device data**
- **Epidemic transmission**: Viral infection model, ***EpiSim***
  - Infections over time: **epidemiological data** from the LAC Department of Public Health

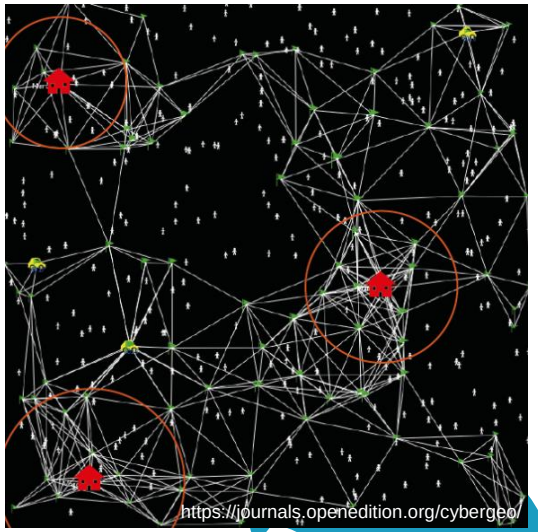
METHODS


MATSIM Model
• Agent-based and dynamic transport simulation framework
LA MATSIM Model
• SCAG activity-based travel model
• PEMS
• Open GTFS
• OpenStreetMap
LA EPISIM Model
• SafeGraph Data
• Infection Model
• Progression Model

MATSIM MODEL (www.matsim.org)

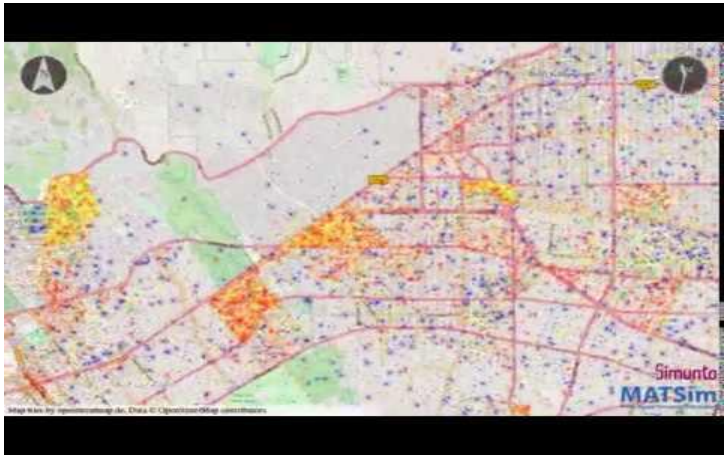
- An agent-based and dynamic transport simulation framework incorporating large-scale transport networks and detailed representation of travel demand for real-world applications.
- The framework is widely used by transport agencies and auto manufacturers, and increasily used for academic research in infectious disease transmission

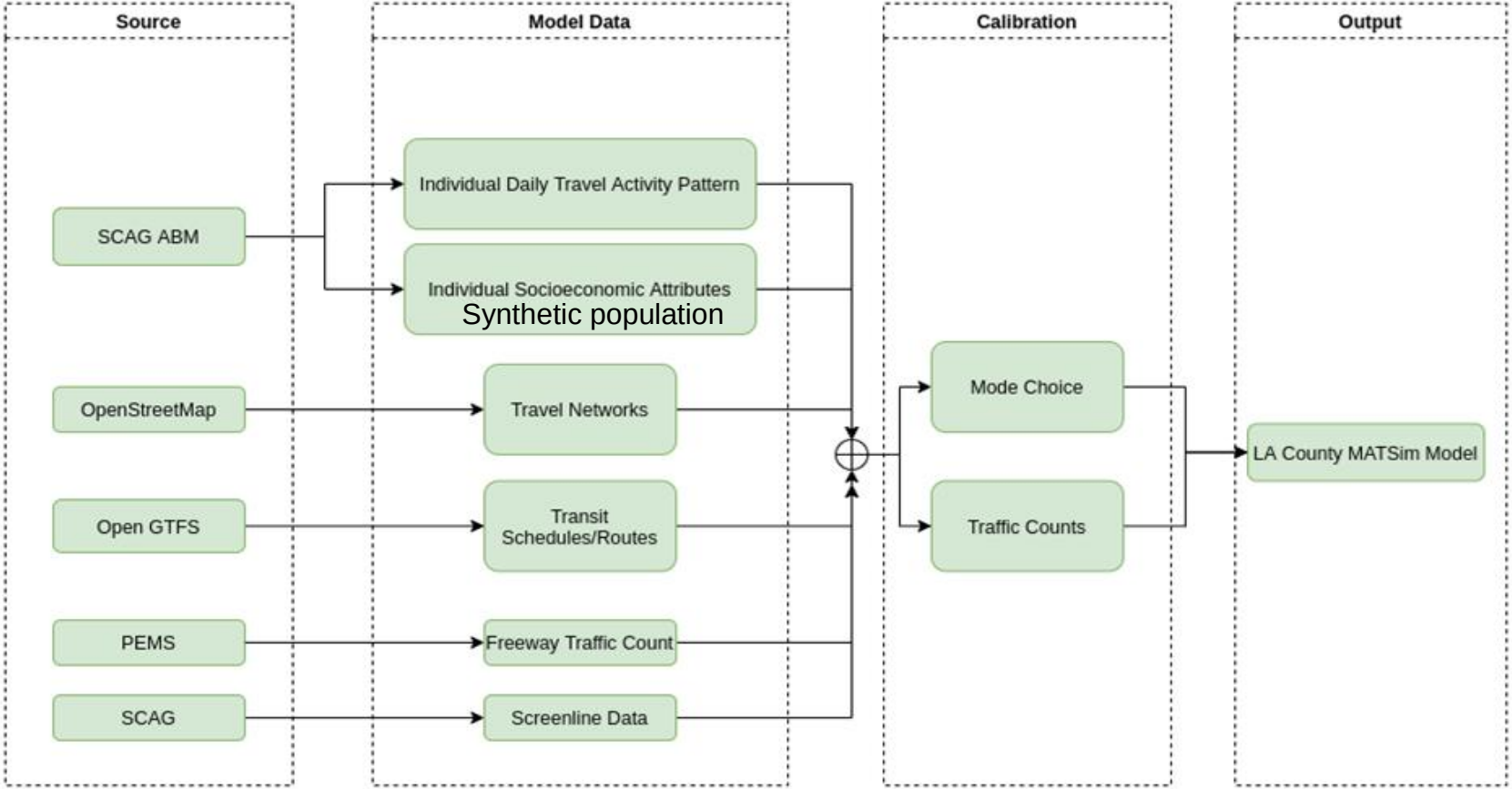




LA COUNTY MATSIM MODEL

- The MATSim model implemented in LA County with data from the official Southern California Association of Governments' (SCAG) new activity-based travel model and supplemented with other local data.
- LA MATSim model is open-source: https://github.com/matsim-scenarios/matsim-los-angeles.



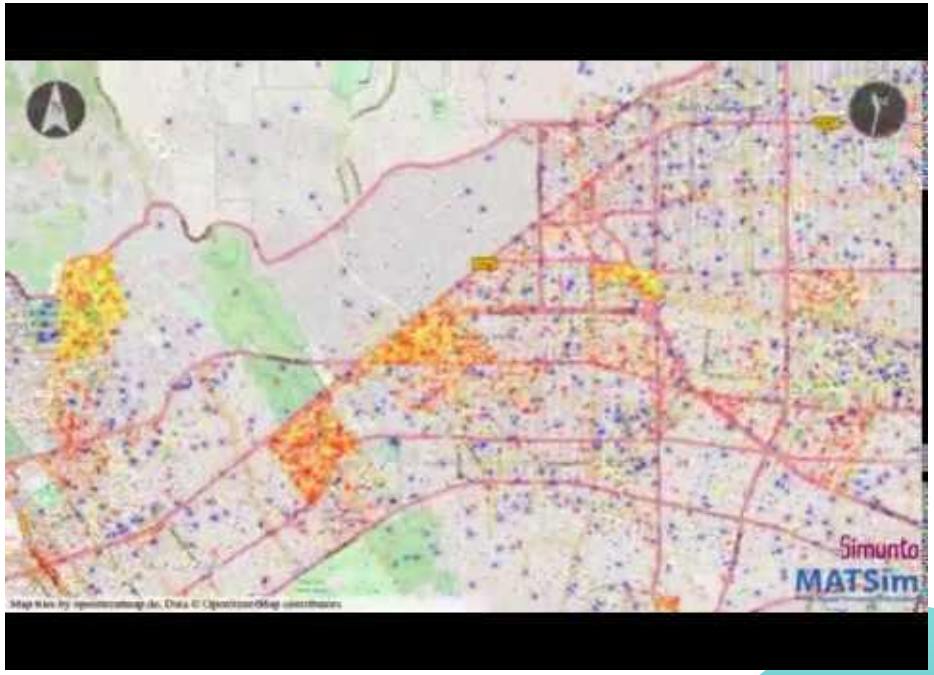


- Represents travel that begins and ends in greater SCAG region and passes through LAC
- Represents all trips made within 24 hours on a typical weekday for each individual
- Travel time and cost from roadway and transit network files by all modes

LA COUNTY MATSIM MODEL

Incorporation of fine-grained attributes:

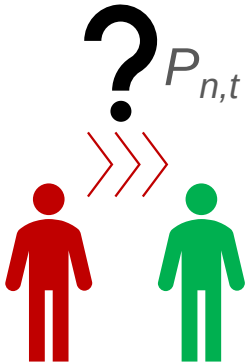
- **Households** (size, income, type, etc.)
- **Individuals** (age, gender, race/ethnicity, education, worker status, worker industry and occupation, etc.)
- **Trip Purpose** (home, work, shop, eat out, special event, etc.)
- **Trip Travel Mode** (SOV, HOV, bus, walk, etc.)

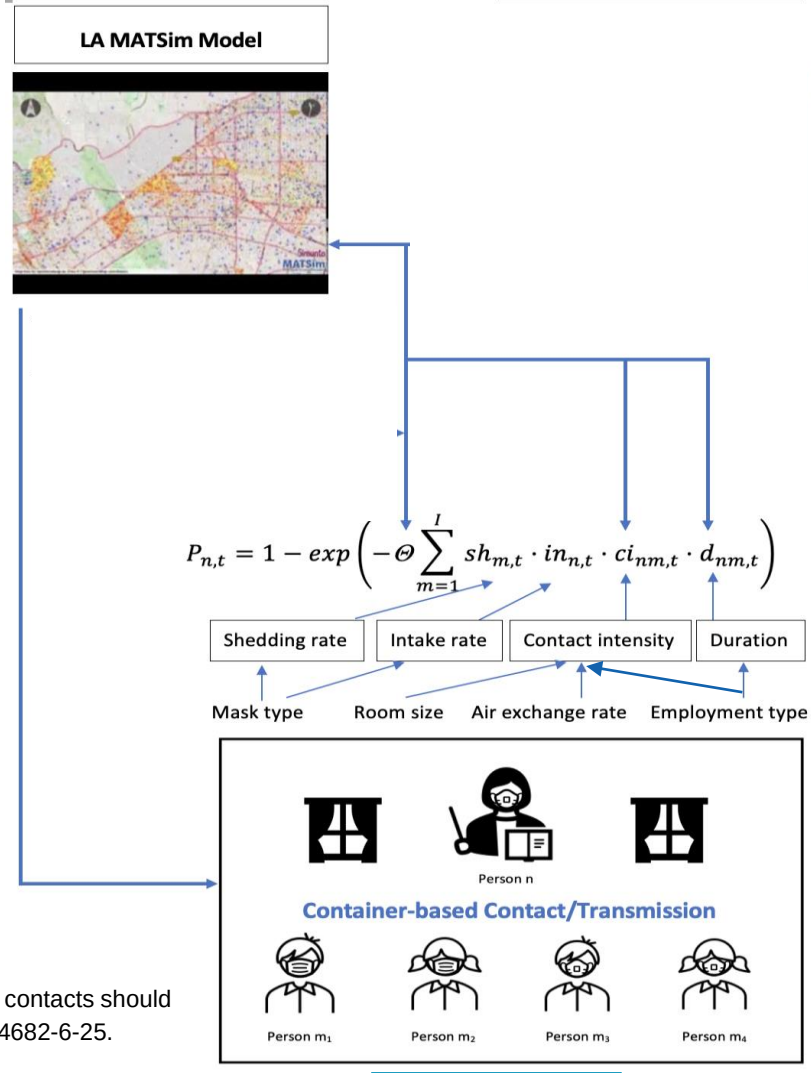


Activities: blue = home, red = work, yellow = leisure/shopping, and green = education

LA EPISIM MODEL: The idea

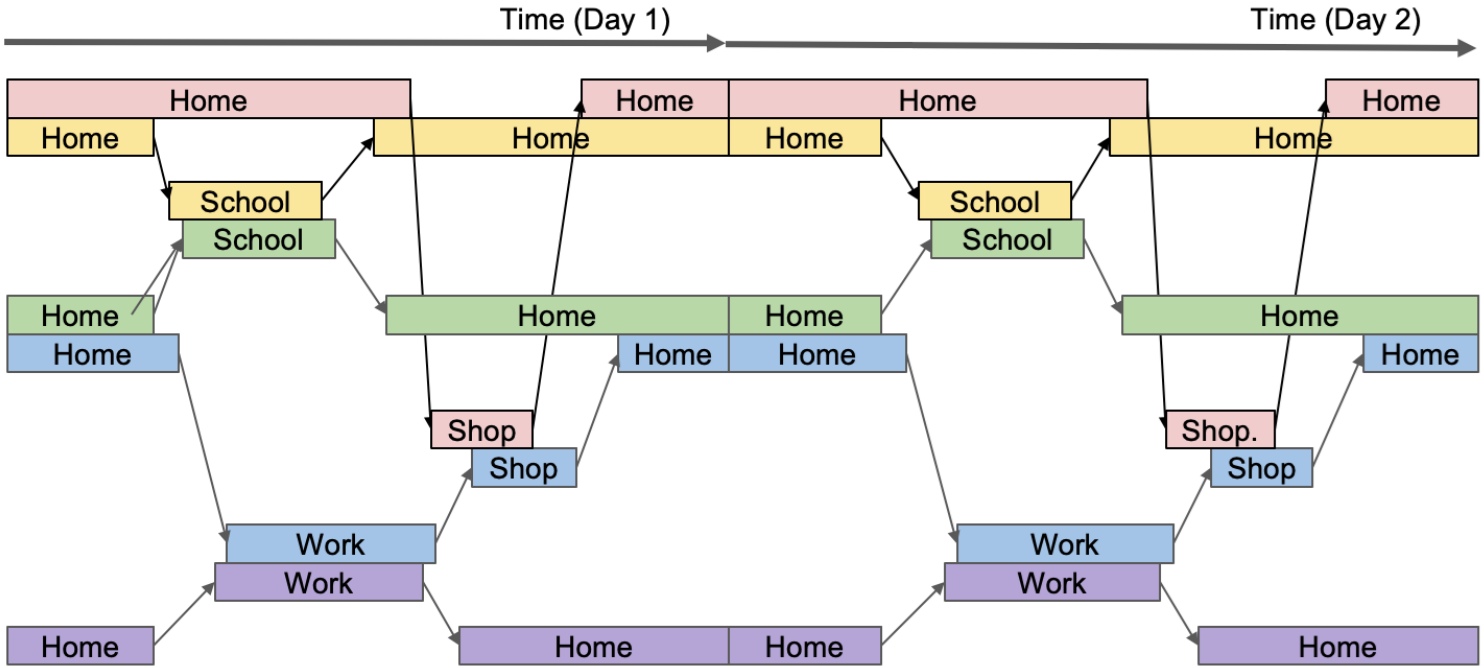
- Synthetic population and their activity patterns from transport activity model
- Synthetic persons in same location (“container”) can infect each other ***with some probability*** determined by multiple factors determined by the **individuals**, the **space** they share, the **activity** they are conducting



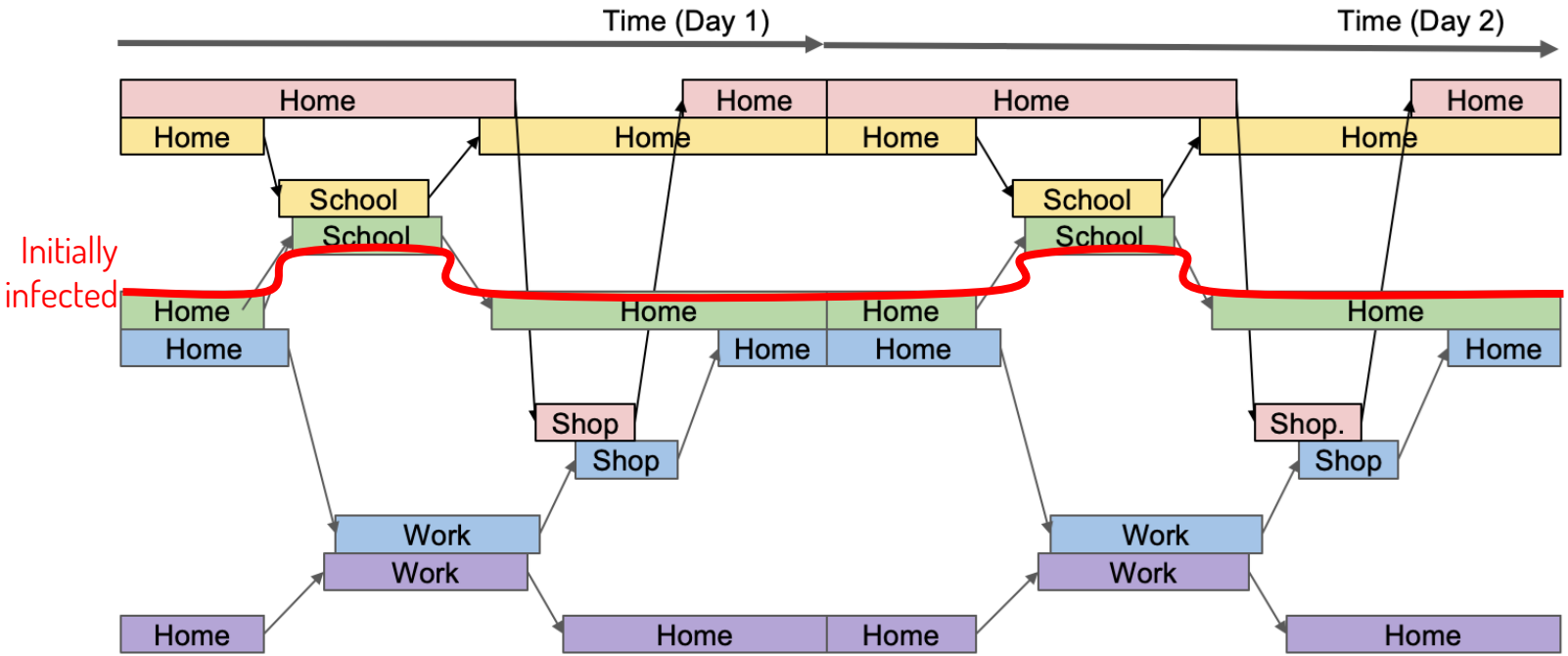


Infection model source: Smieszek T. A mechanistic model of infection: why duration and intensity of contacts should be included in models of disease spread. Theor Biol Med Model. 2009 Nov;6:25. doi:10.1186/1742-4682-6-25.

LA EPISIM MODEL: Activity-trip-chains

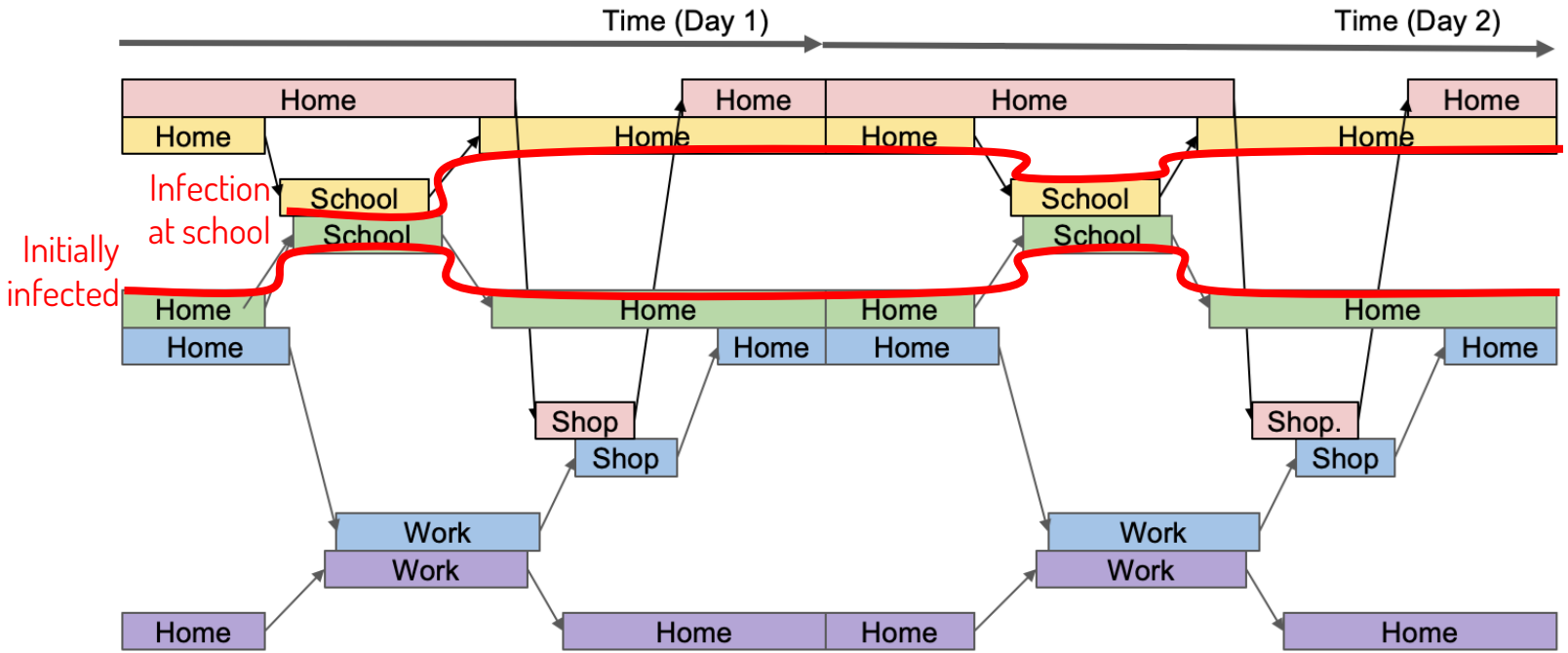


LA EPISIM MODEL: Infection chains (1)



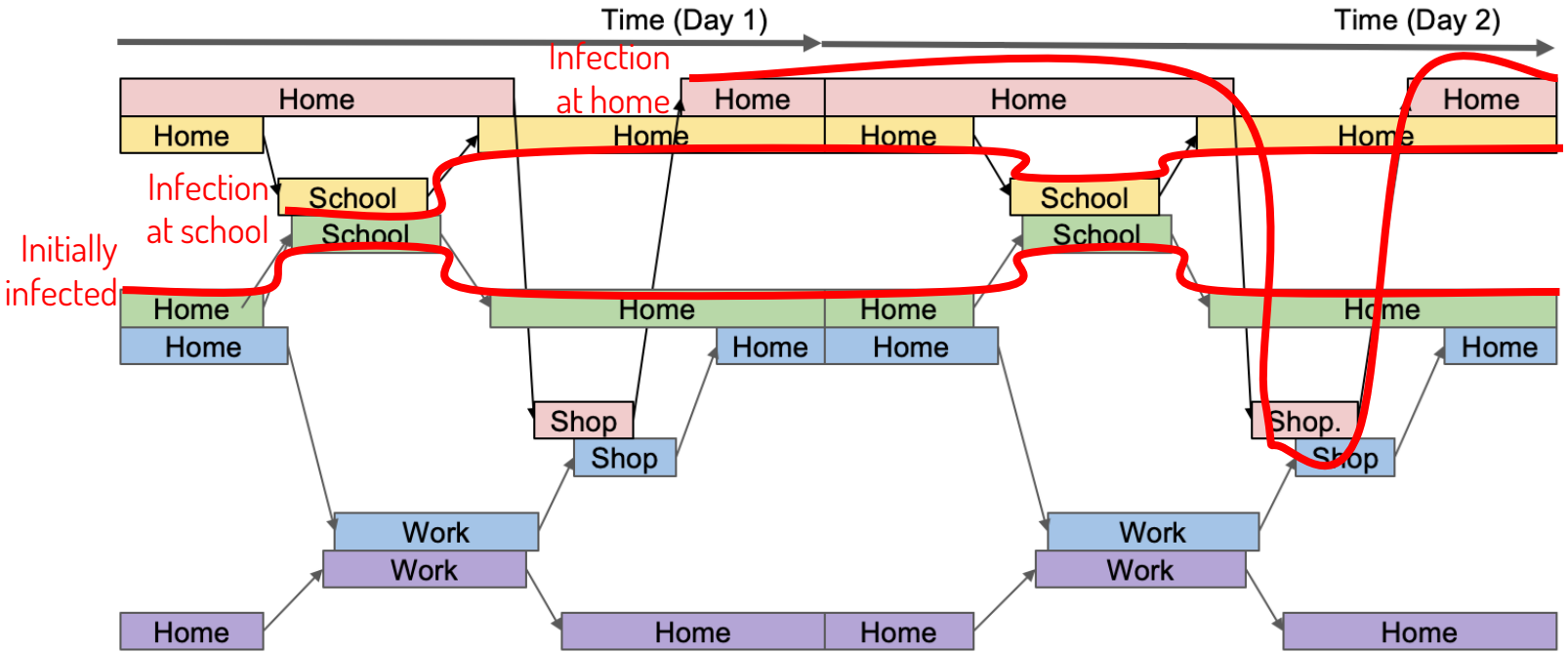
Infection chain: Person C

LA EPISIM MODEL: Infection chains (2)



Infection chain: Person C → Person B

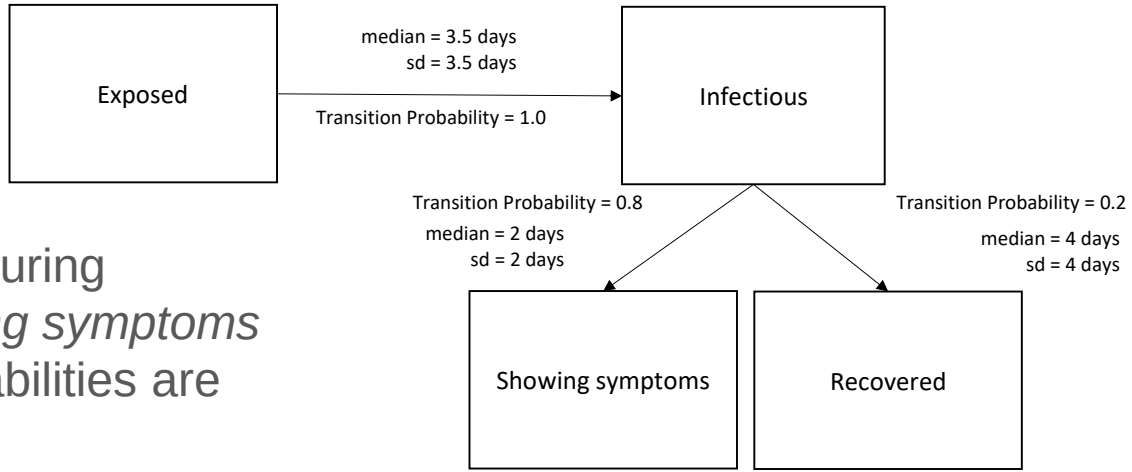
LA EPISIM MODEL: Infection chains (3)



Infection chain: Person C → Person B → Person A

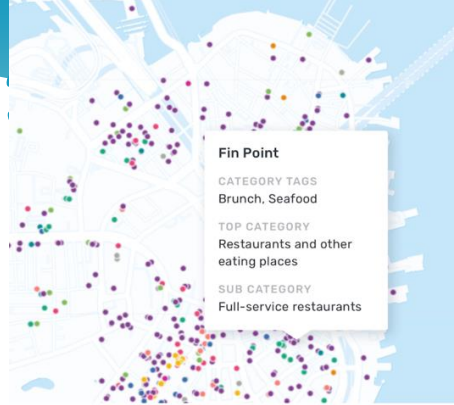
Progression model

- States:
  - *exposed*
  - *infectious*
  - *showing symptoms*
  - *recovered*



- infection is possible during *infectious* and *showing symptoms*
- some transition probabilities are age-dependent

Reductions in activity patterns: Geolocation mobility data



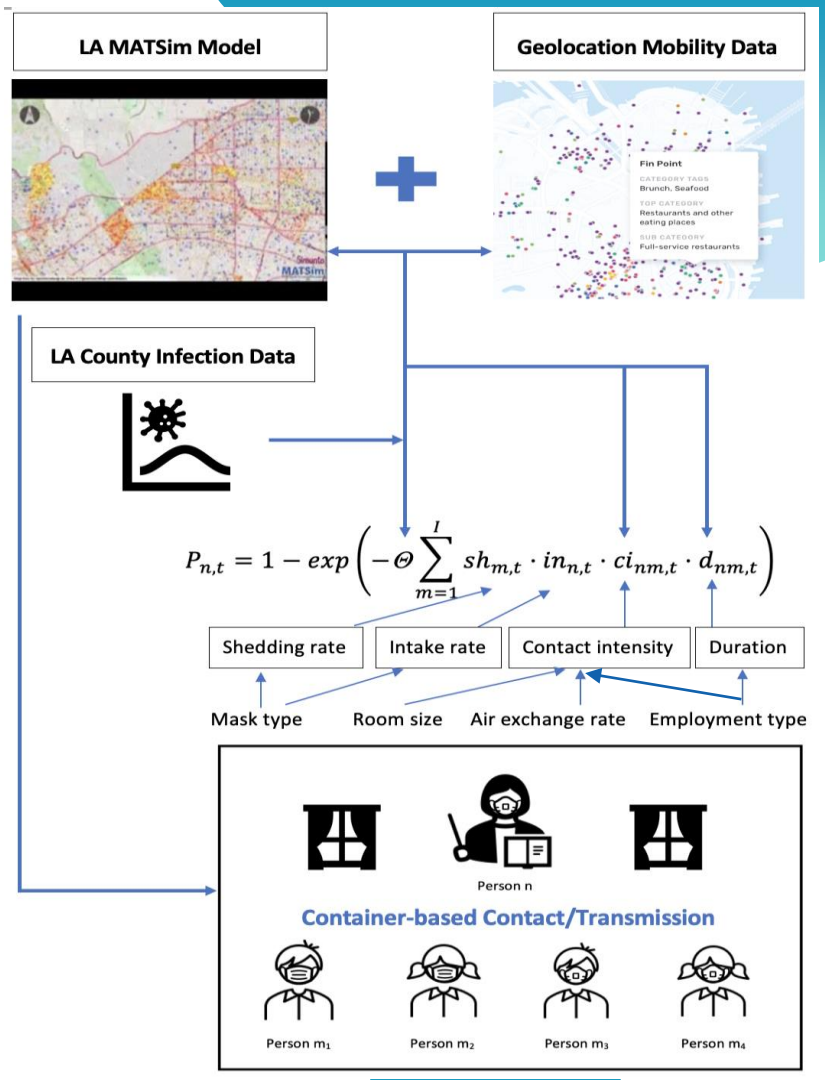
- Observed changes in contact patterns from SafeGraph geolocation mobility data used to determine the **% change in activities** by **census block group (and corresponding LA MATSim travel analysis zones)** for **each week post-pandemic** relative to a fixed pre-pandemic week (03/02/2020).

naics_code (SafeGraph)	sub_category (SafeGraph)	Description	Activity_Purpose (EpiSim Model)
5416	Management, Scientific, and Technical Consulting Services	This industry group comprises establishments primarily engaged in providing advice and assistance to businesses and other organizations on management, environmental, scientific, and technical issues.	work_54
5617	Services to Buildings and DwellingsT	This industry group comprises establishments primarily engaged in one of the following: (1) exterminating and pest control services; (2) janitorial services; (3) landscaping services; (4) carpet and upholstery cleaning services; or (5) other services to buildings and dwellings.	work_56/HHmaintenance
6233	Continuing Care Retirement Communities and Assisted Living Facilities for the Elderly	NULL	work_62/visiting

SAFEGRAPH

LA EPISIM MODEL: Calibration and simulation

- Incorporates changes in activity patterns from mobile device data
- Calibrated to epidemiological data
- Use model to explore the effect of interventions
  - Expanded use of cloth masks, N95 masks
  - Antigen testing
  - Restrictions to reduce contact intensities



METHODS – Key Contributions

Key contributions to existing agent-based models of infectious disease dynamics:

- **Incorporation of fine-grained detail on individual agents and their activity patterns**, including multiple **employment categories** (vs. SOTA, generally a single ‘work’ category)
- **Incorporation of fine-grained detail in observed reductions in activities due to pandemic restrictions**, informed by changes in contact patterns observed in mobility devices (vs. SOTA, which is to applied overall for the entire city/county)

SIMULATED INTERVENTION SCENARIOS

Base case scenario

- Parameter values resulting from the calibration process
- Accounts for activity reductions coming from mobile device data
- **65% cloth mask** compliance for **activities outside of the home**
- **30% cloth mask compliance** for **visiting activities** (e.g. visiting friends/family)

SIMULATED INTERVENTION SCENARIOS

Cloth masks

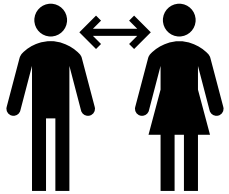
- Increase base case mask compliance (65%) to 75% (low), 85% (medium), 95% (high), and 100% (upper bound)
- Applied to all activities except for home and visiting with family/friends

N95 masks

- A fraction of all mask 65-100% of mask wearers use KN95/N95 masks
- We implement 25%, 50%, 75%, and 100% compliance for all activities except for home (0%), and visiting (max 30%)

Mask Type	Shedding rate	Intake rate	Reduction in Infection risk	Source
No mask	1	1	0%	
Cloth mask	0.8	0.7	44%	Konda, Abhiteja, et al., 2020
N95 mask	0.15	0.2	97%	Plana, D. et al., 2015; Yim, W. et al., 2020; Asadi et al., 2020

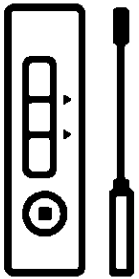
SIMULATED INTERVENTION SCENARIOS



Contact reductions

- Works by reducing contact intensity parameter
- Interpretation: interventions to reduce viral particle intensity, e.g. through:
  - Physical distancing
  - Improving ventilation
  - Moving to bigger rooms
- We implement *reductions* in contact intensity by 25%, 50%, 75%, and 100%

SIMULATED INTERVENTION SCENARIOS



Antigen (rapid) testing

- Harmon, A. et al., 2021, *JAMA*: sensitivity of self-administered antigen is 96.3% sensitive during days zero to three of symptoms, which are the most contagious days
- We assume a 100% accuracy of antigen testing once agents show symptoms
- We assume individuals isolate after a positive result, with a 1-day delay
- Testing frequencies implemented: **Every 1, 3, 5, 7, 10 days**

SIMULATED INTERVENTION SCENARIOS

Implemented intervention scenarios and work categories

- Applied to **all population and work categories** OR **select high-risk work categories** only
- These include healthcare and social support, retail shops and personal care shops, transport operators, educators, food service, entertainment

NAICS	Work Industry
44	**Retail Trade**, Including Store, Shop, Dealer (e.g., Auto Dealer)
48	**Transportation**, Bus or Train Company, Airline, Postal Service, Warehouse or Storage
51	Information, Including Publisher, Phone Company, Movie Company, Internet Company, Library, Data Processing, Computer Company
52	**Finance** and Insurance such as **Bank**, Insurance Company, Credit Union, Finance Company
53	Real Estate Company, Any Rental or Leasing Company Including Auto or Video Rental
54	Professional Scientific or Technical Services, Including Law, Accounting, Design, Engineering, Consulting or Advertising, Firm or Company, and Veterinary Services, Management of Companies and Enterprises
55	Management of Companies and Enterprises
56	Administrative Support, Including Employment Agency, Travel Agency, Security Guard Company, Waste Management (Trash) Company, Remediation Services
61	Educational Services, Including School, University, Training School
62	**Health Care and Social Assistance**, Including Hospital, Doctors Office, Assisted Living Home, Day Care Center
71	Arts, Entertainment and Recreation, Including Art Gallery, Museum, Theatre, Bowling Alley, Casino
72	**Accommodation or Food Services,** Including Hotel, Restaurant
81	Other Services (Except Public Administration) such as Auto Repair, Hair or Nail Salon, Barber Shop, Funeral Home, Labor Union
92	Public Administration, such as Government Agency, City or County Department, Military

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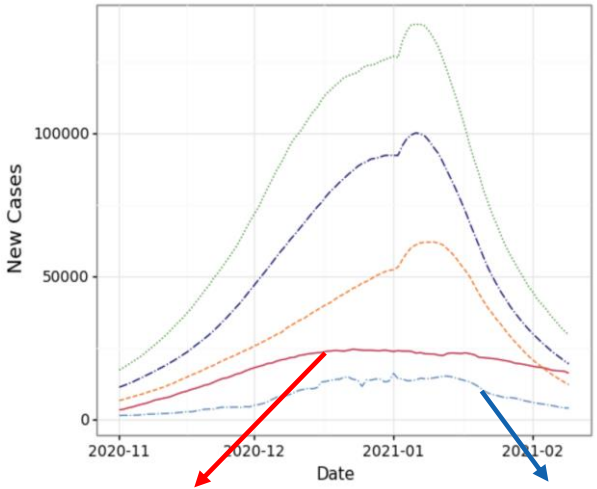
  - **Scenario Performance by Age Groups**
  - **Scenario Performance by Activity Types**
- Conclusions
- Limitation & Future Work

RESULTS

01 Base Case Scenario – Comparison between observed and modeled data

Epidemiological data used to calibrate the EpiSim Model and simulation results



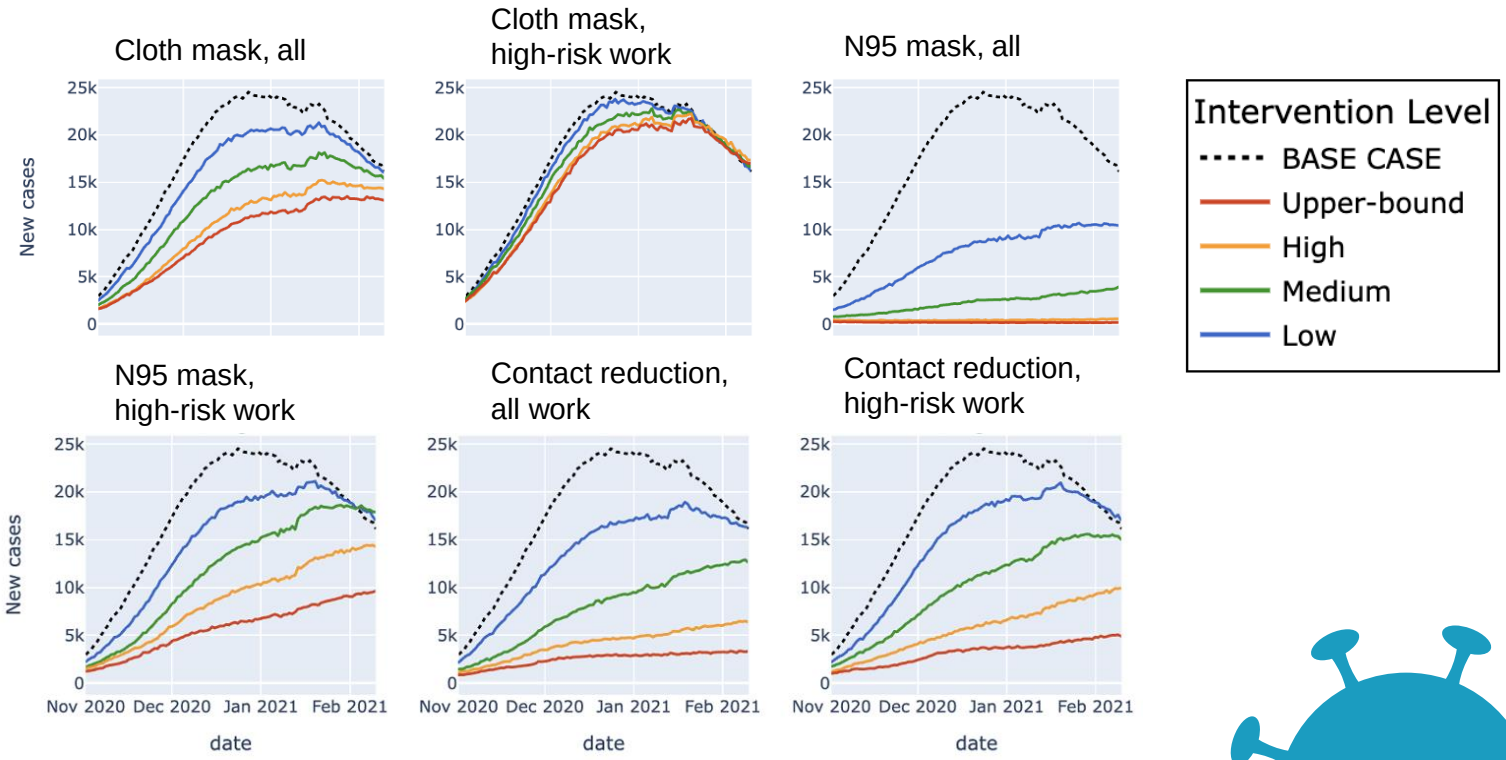
Modeled Data

Observed LA County Data

Proportion of New Cases by Age over time

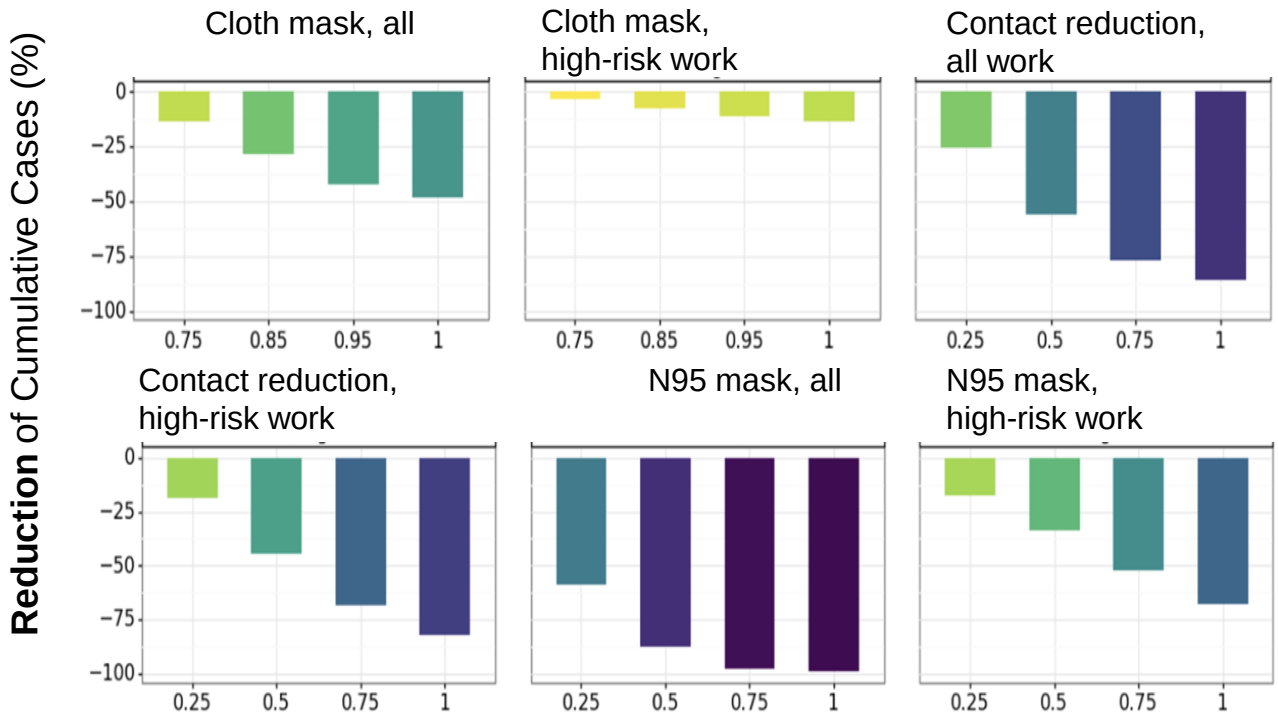
RESULTS

02 New Cases Over Time with Mask Compliance and Distancing at Different Levels



RESULTS

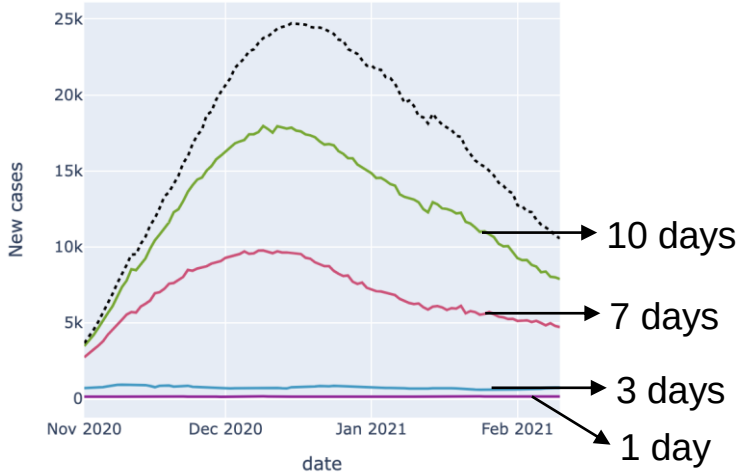
03 Reduction of Cumulative Cases for Single-Intervention Scenarios



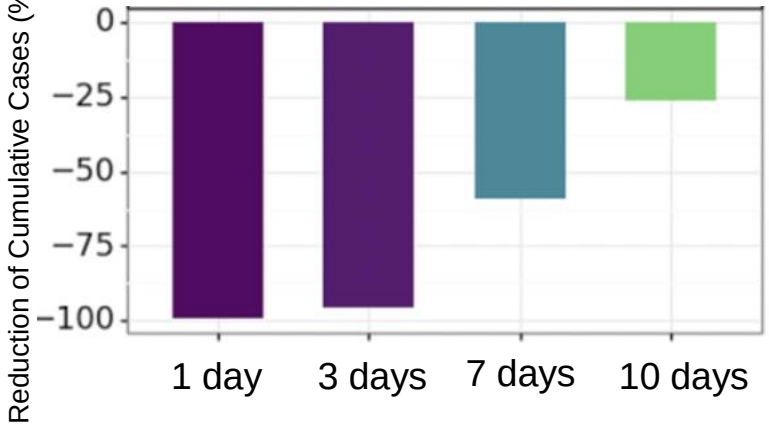
RESULTS

04 Testing scenario results

Overtime New Case By Testing Frequency

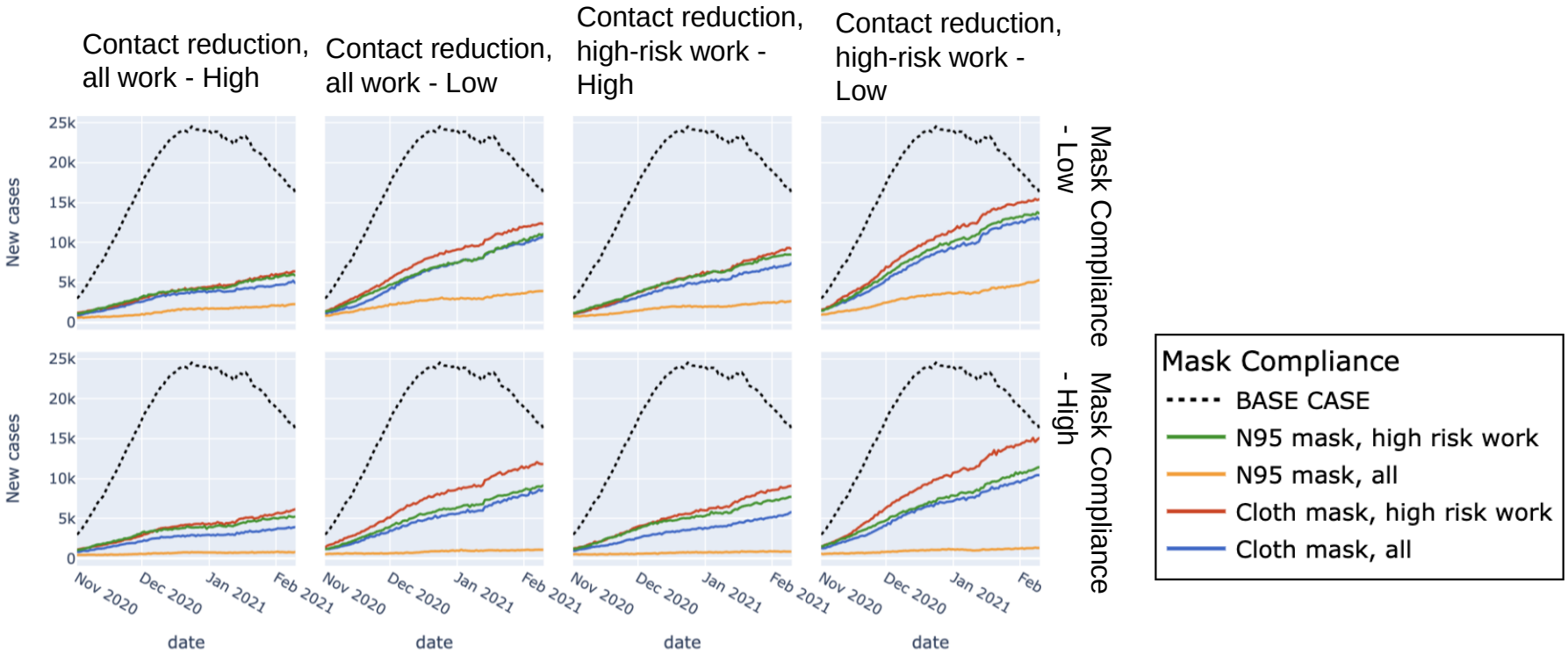


Reduction of Cumulative Cases (%) By Testing Frequency



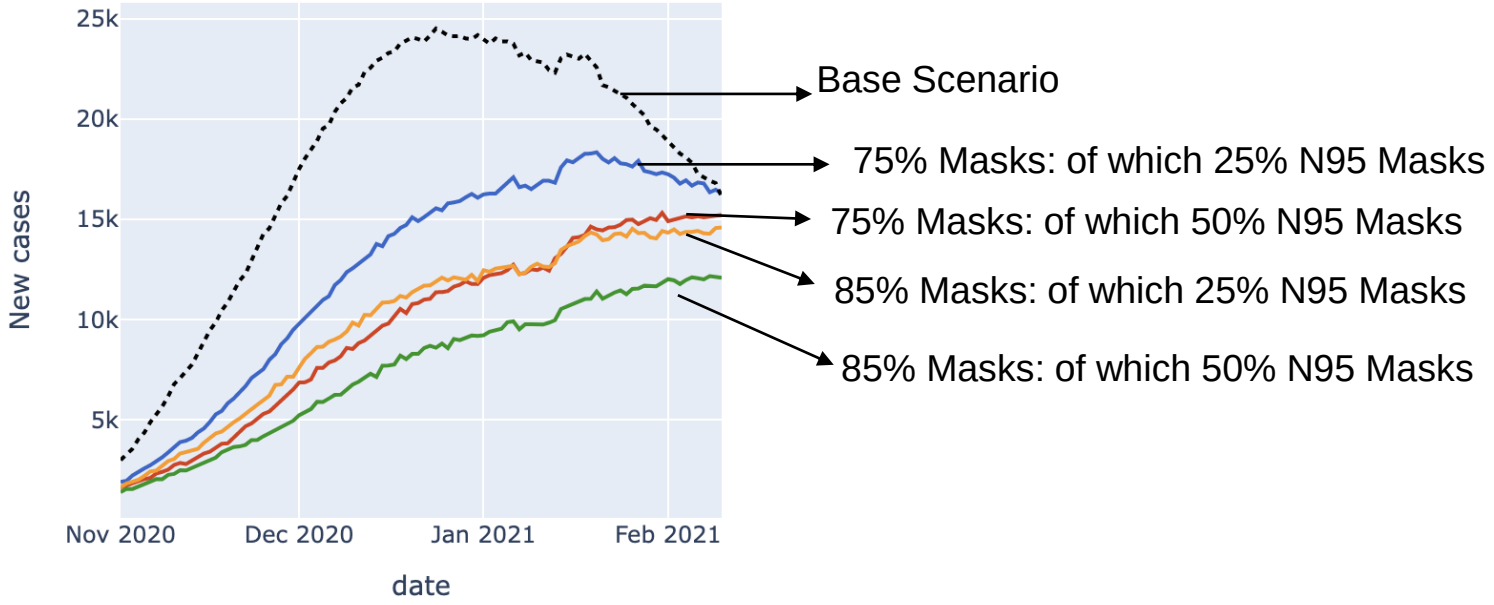
RESULTS

05 Combination scenarios – Contact Reduction AND Cloth / N95 Masks



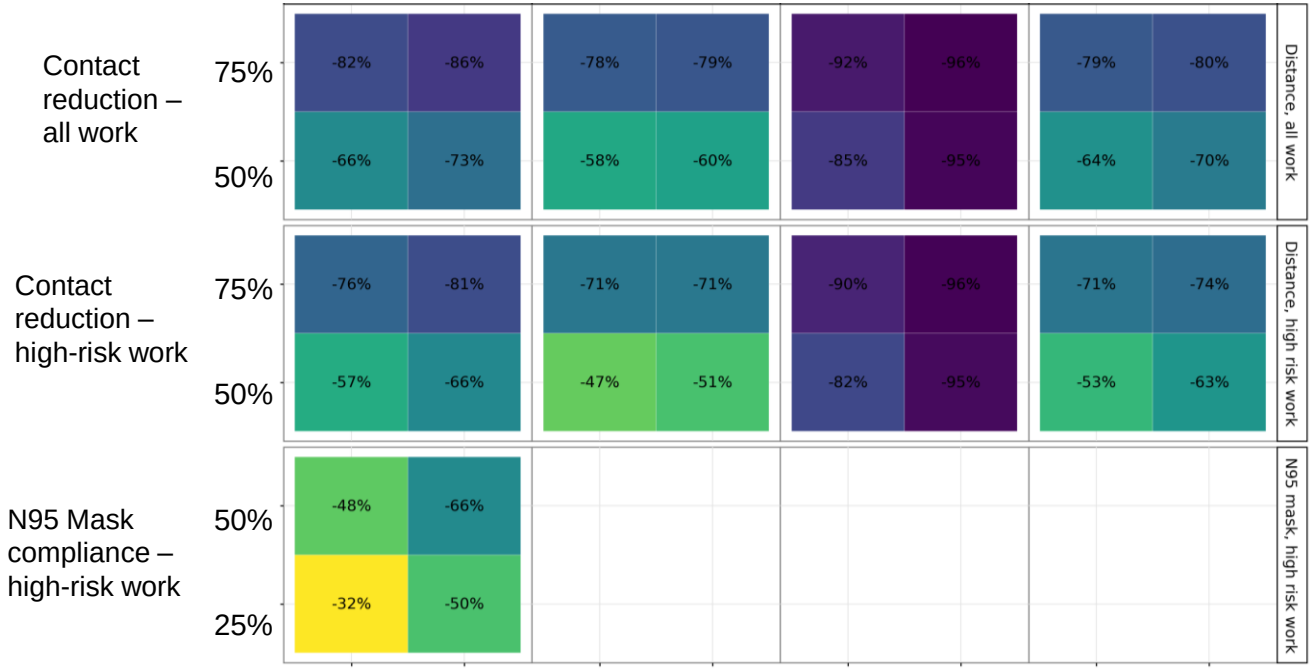
RESULTS

06 Combination scenarios – different levels combining cloth and N95 masks



RESULTS

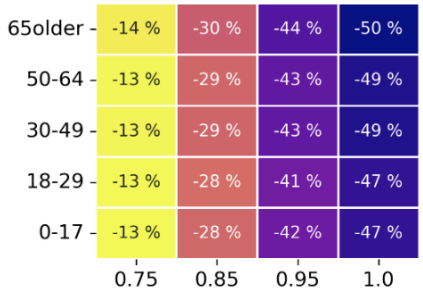
07 Reduction of Cumulative Cases for Combined-Intervention Scenarios



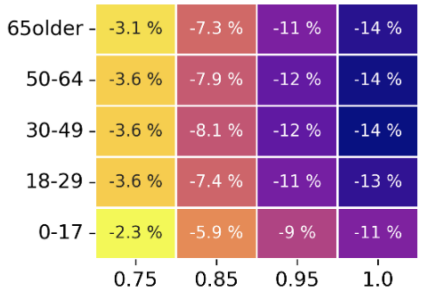
RESULTS

08 Reduction of Cumulative Cases By Age Group

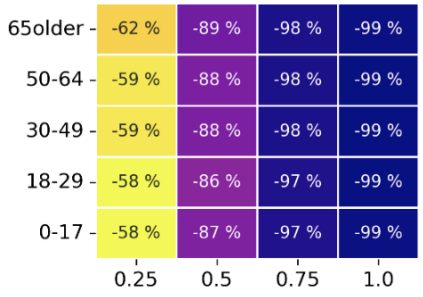
Cloth mask, all



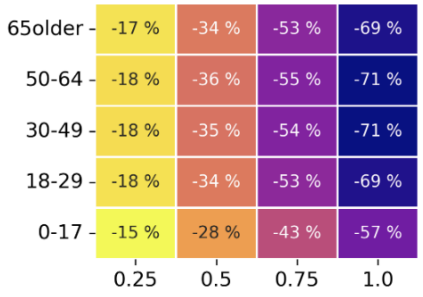
Cloth mask, high-risk work



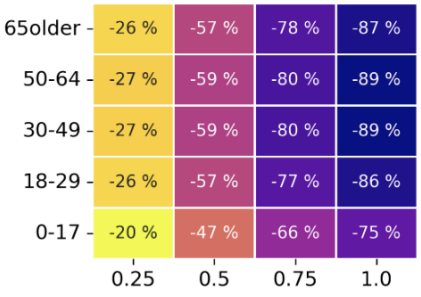
N95 mask, all



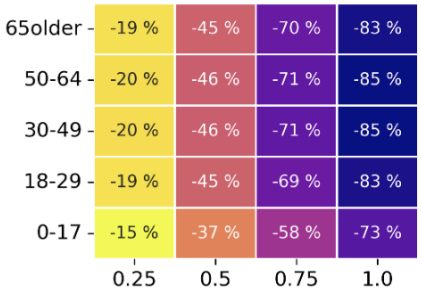
N95 mask, high-risk work



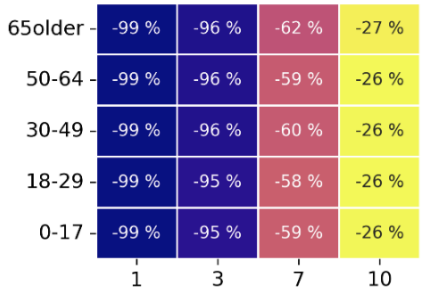
Contact reduction, all work



Contact reduction, high-risk work

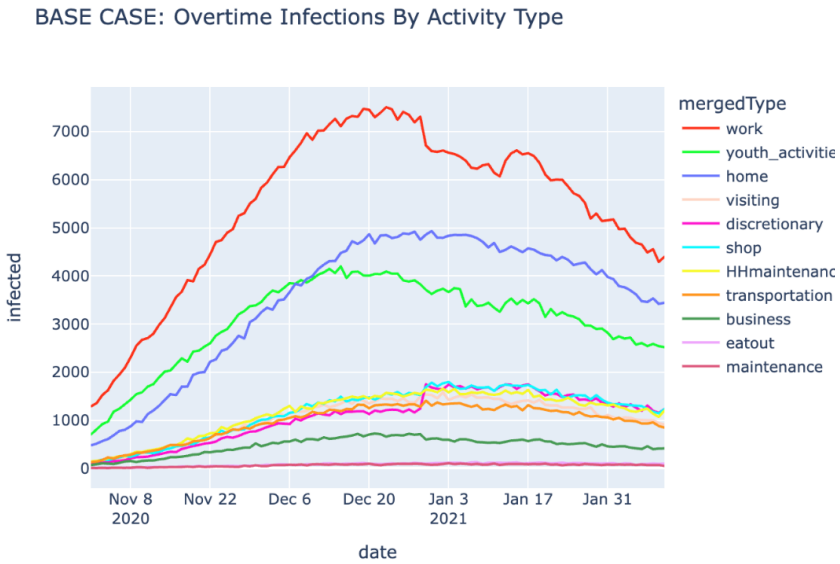


Testing frequency (days)



RESULTS

09 Scenario Performance by Activity Types



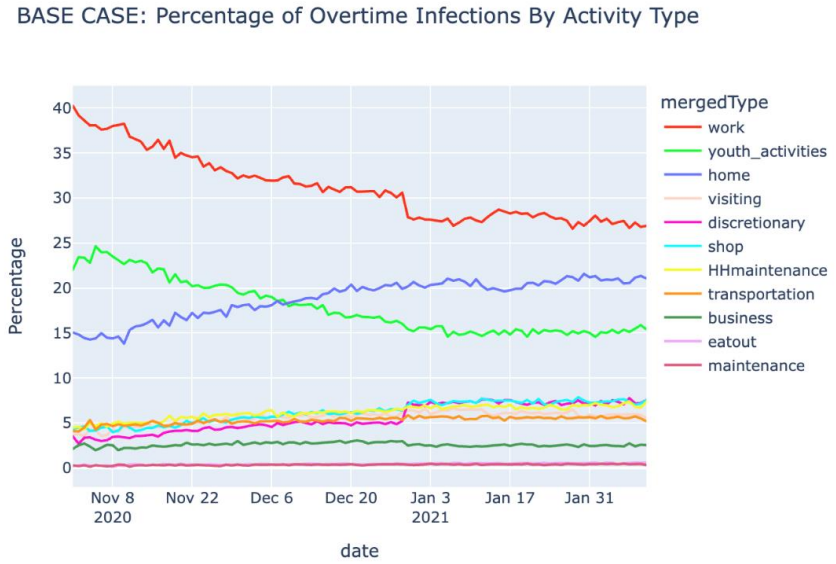


Figure 11. Base Case: Infections Over Time by Merged Activity Type.

RESULTS

10 Scenario Performance by Activity Types – N95 all work categories

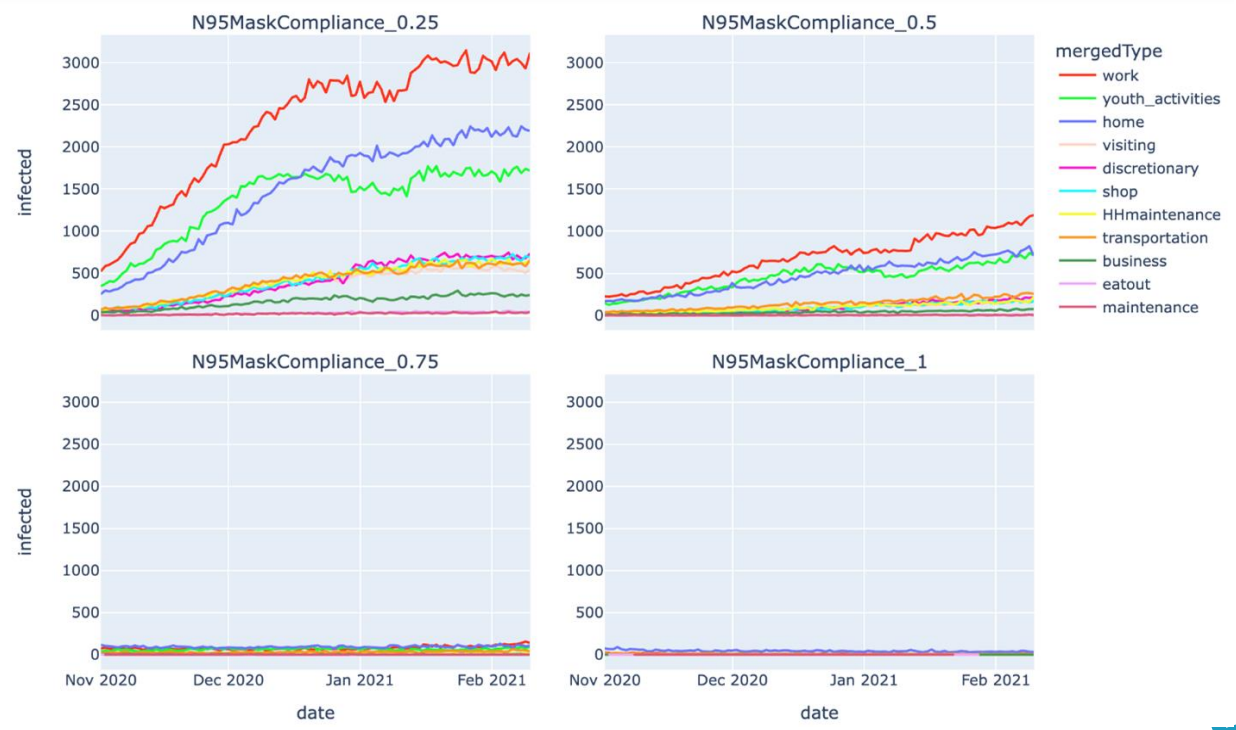


Figure 13a. N95 mask, all

RESULTS

11 Scenario Performance by Activity Types – N95 high risk work only

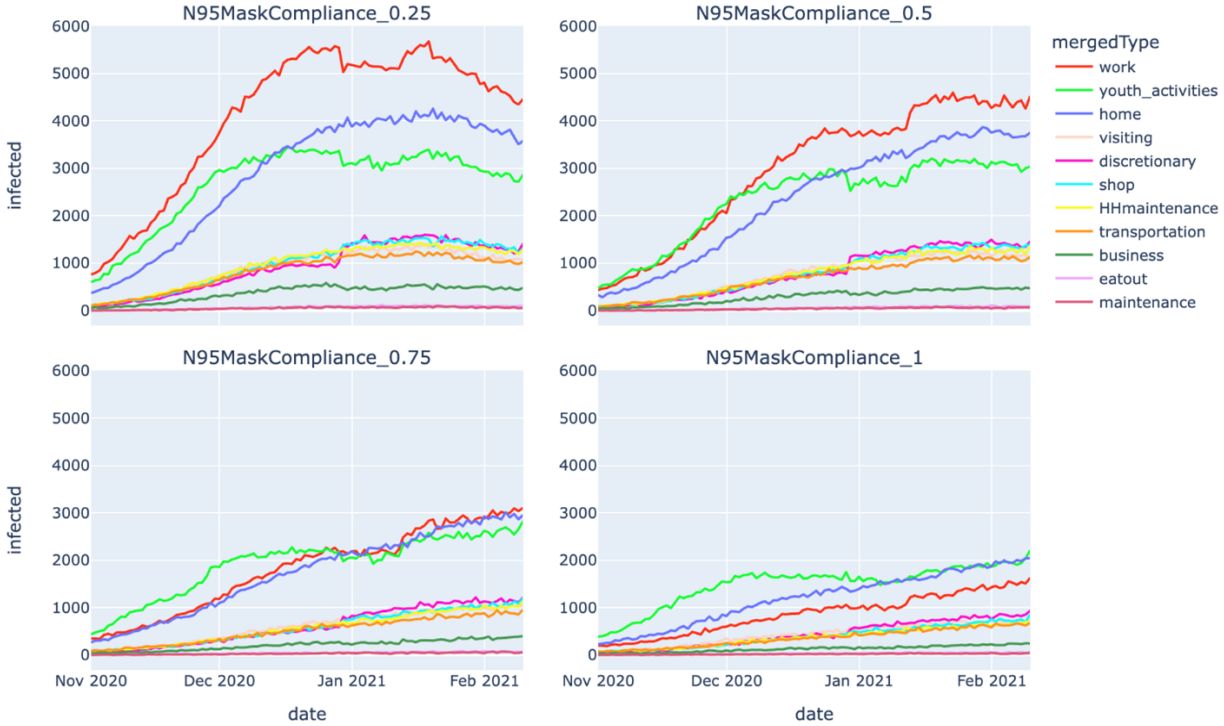


Figure 13b. N95 mask, high risk work

CONCLUSIONS

1. **Reasonable substitutions of N95 masks for cloth masks at baseline use levels significantly reduced cumulative infections**. If only 25% and 50% of the 65% base cloth mask compliance rate are substituted for N95 masks across all activities, then cumulative reductions are 59% and 87%.
2. **N95 masks should be worn during all types of interactions and not just high contact intensity work activities**. When N95 masks interventions are only applied to selective work activities, they are less impactful, with percentage reductions from 18% to 67%.
3. **Shutdown and capacity restrictions should be focused on high contact intensity work types rather than required for all types of work**. The contact intensity reduction scenarios applied to all work activities reduced cumulative cases from 26% to 86%. When applied to selected work activities, they had almost the same effect, with cases decreasing from 19% to 82%.
4. **Antigen testing is also very effective at reducing cumulative infections**. At the higher end of testing frequency (every day and three days), the COVID-19 surge is almost eliminated. However, the more realistic scenario levels (everyone testing every seven and ten days) show percentage reductions in cumulative cases of 59% and 26%, respectively.
5. **The most effective and least restrictive scenario included a 50% decrease in contact intensity and 25% N95 mask compliance to only selective work activities and reduced cumulative infections by 53%.**
    - When N95 masks are applied to all activities instead of just selected activities in this scenario, the reduction in cumulative infections increases to 82%.
    - If N95 mask compliance increases from 25% to 50% for all activities, then the reduction in inflections increases to 95%.

LIMITATIONS & FUTURE WORK

- Capturing heterogeneities in infection by socio-demographics and employment category. This should be done by including observed stratified infection data in the model calibration process.

- Addressing area density and area deprivation, which both have been shown in other research to contribute to increased exposure to COVID-19. These aspects were not addressed by our modeling approach, despite the inclusion of the finely spatially resolved SCAG data the LA MATSim model runs on.

- Addressing holiday behavior, which explained a lot of the observed trend in cases in L.A. County during the modeled period, which covered Thanksgiving, Christmas, and New Year's holidays, but was not addressed by the activity model.

Key Methodological Contributions

Key contributions to existing agent-based models of infectious disease dynamics:

- **Fine-grained detail on individual agents and their activity patterns is incorporated**, including multiple **employment categories** (vs. a single 'work' category), each with their own contact intensity
- **Reductions in activities due to pandemic restrictions are fine-grained neighborhood specific**, informed by changes in contact patterns observed in mobility devices (vs. applied overall for the entire city/county)

Key Public Health Takeaways

- **Workplace-specific policies (social distancing, N95-mask wearing) can exacerbate health inequities** (older adults do not benefit). Enforcement is difficult and requires a combination of policies around restrictions and paid leave for workers
- **Extra benefit of N95 masks above cloth masks: N95 masks in the workplace and community (e.g., shops, grocery stores) has major impact in reducing spread**. To be effective, implementation requires a strong network of action between local health departments and CBOs to enforce in the community
- More generally: Fine-grained modeling approach provides insights into the impact of different levels of implementation and enforcement of interventions implemented at the **workplace** and in the **community** on infection spread for a large population and subpopulations

THANKS!

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Backup: Contact intensity

	floor size	number people	floor area (per Person)	air exchange rate	share old buildings	1/(floor_pp* airX)	contact intensity	Notes
Home	20	4	5	1	1	0.2	1.000	Average floor size of dining room in a house in L.A. is 20m^2, assuming 4 people in family
work, business, errands	90	10	9	1	0.5	0.222	1.111	Average m^2 per employee in office space is 9m^21
schools & kindergarten	60	30	2	0.5	1	1	5.000	Same assumptions
universities	60	30	1	0.5	1	1	5.000	Classes only
public transport	30	30	1	1	0.5	2	10.000	Assumed buses (predominant public transport in LA: 1.3 million boardings/weekday vs. 308,653 boardings / weekday for metrorail), nobody standing (29 seats) and 30m^222
leisure	150	200	0.75	2	0.5	1.333	6.667	Average size for a restaurant dining area is 300m^2 for a capacity of 2003
shop	1500	200	7.5	1	0.5	0.267	1.333	Average grocery store size is 1500m^2 with 200 customers

[1] How much office space do we need. Mike Petrusky. Office+SpaceIQ. November 24, 2020 accessed 5/17/2022 https://www.iofficecorp.com/blog/office-space-per-employee#:~:text=In%20previous%20years%2C%20workplace%20design,2020%20was%20196%20square%20feet; [2] City/Transit Buses. Dimensions.com, 2021 accessed 5/17/2022, https://www.dimensions.com/element/city-transit-buses; [3] How to Create a Restaurant Floor Plan. Total Food Service. July 25, 2013 access 5/17/2022 https://totalfood.com/how-to-create-a-restaurant-floor-plan/

Single-Intervention Scenarios

Scenario Name.	Intervention	Low Level	Medium Level	High Level	Upper-bound Level
Cloth mask, all	Increases cloth mask compliance for all activities from .65 base rate	0.75	0.85	0.95	1.0
Cloth mask, high-risk work	Increases cloth mask compliance for high-risk work activities from .65 base rate	0.75	0.85	0.95	1.0
N95 mask, all	Share of N95 masks for all activities	0.25 N95 /0.40 Cloth	0.5 N95/0.15 Cloth	0.75 N95	1. N95
N95 mask, high-risk work	Share of N95 masks for high-risk work activities	0.25 N95 /0.40 Cloth	0.5 N95 /0.15 Cloth	.075 N95	1.0 N95
Distance, all work	Reduce contact intensities for all work activities	0.25	0.5	0.75	1.0
Distance, high-risk work	Reduce contact intensities for high-risk work activities	0.25	0.5	0.75	1.0
Testing	Testing Frequency for all activities	10	7	3	1

Combined-Intervention Scenarios

	Cloth mask compliance, all default activities	**Cloth mask compliance, high-risk work activities**	**N95 mask compliance, all default activities**	**N95 mask compliance, high-risk work activities**
N95 mask compliance, high-risk work activities	- N95 mask, high-risk work: 0.25, 0.5 - Cloth mask, all (beyond those with N95's): 0.75, 0.85			
Distance, all work activities	- Distance, all: 0.5, 0.75 - Cloth mask, all: 0.75, 0.85	- Distance, all: 0.5, 0.75 - Cloth mask, high-risk work: 0.75, 0.85	- Distance, all: 0.5, 0.75 - N95 mask, all: 0.25, 0.5	- Distance, all: 0.5, 0.75 - N95 mask, high-risk work: 0.25, 0.5
Distance, high-risk work activities	- Distance, high-risk work: 0.5, 0.75 - Cloth mask, all: 0.75, 0.85	- Distance, high-risk work: 0.5, 0.75 - Cloth mask, high-risk work: 0.75, 0.85	- Distance, high-risk work: 0.5, 0.75 - N95 mask, all: 0.25, 0.5	- Distance, high-risk work: 0.5, 0.75 - N95 mask, high-risk work: 0.25, 0.5