CARTEEH

Center for Advancing Research in Transportation Emissions, Energy, and Health

A USDOT University Transportation Center

COVID-19 Impacts on Transportation, Air Quality, and Health

Agenda

Welcome and Introduction
Dr. Joe Zietsman, Texas A&M Transportation Institute

Simulation of COVID Impacts on Transit and Air Quality in Baltimore
Dr. Tak Igusa, John Hopkins University

Influence of COVID on Regional Transportation Planning
Dr. Michael O. Rodgers, Georgia Institute of Technology

Toward a Better Understanding of Recent Emissions and Meteorological Impacts on Air Quality in the South Coast Air Basin
Dr. Cesunica Ivey, University of California, Riverside

Exposures to COVID-19 in a Small Transportation Environment
Dr. Wen-Whai Li, University of Texas at El Paso

Moving Toward a More Sustainable "New Normal": An El Paso, Texas Case Study
Dr. Ann Xu, Texas A&M Transportation Institute

Questions, Answers, and Discussion Session

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WHITING SCHOOL of ENGINEERING

Impact of COVID-19 on mobility and transportation systems

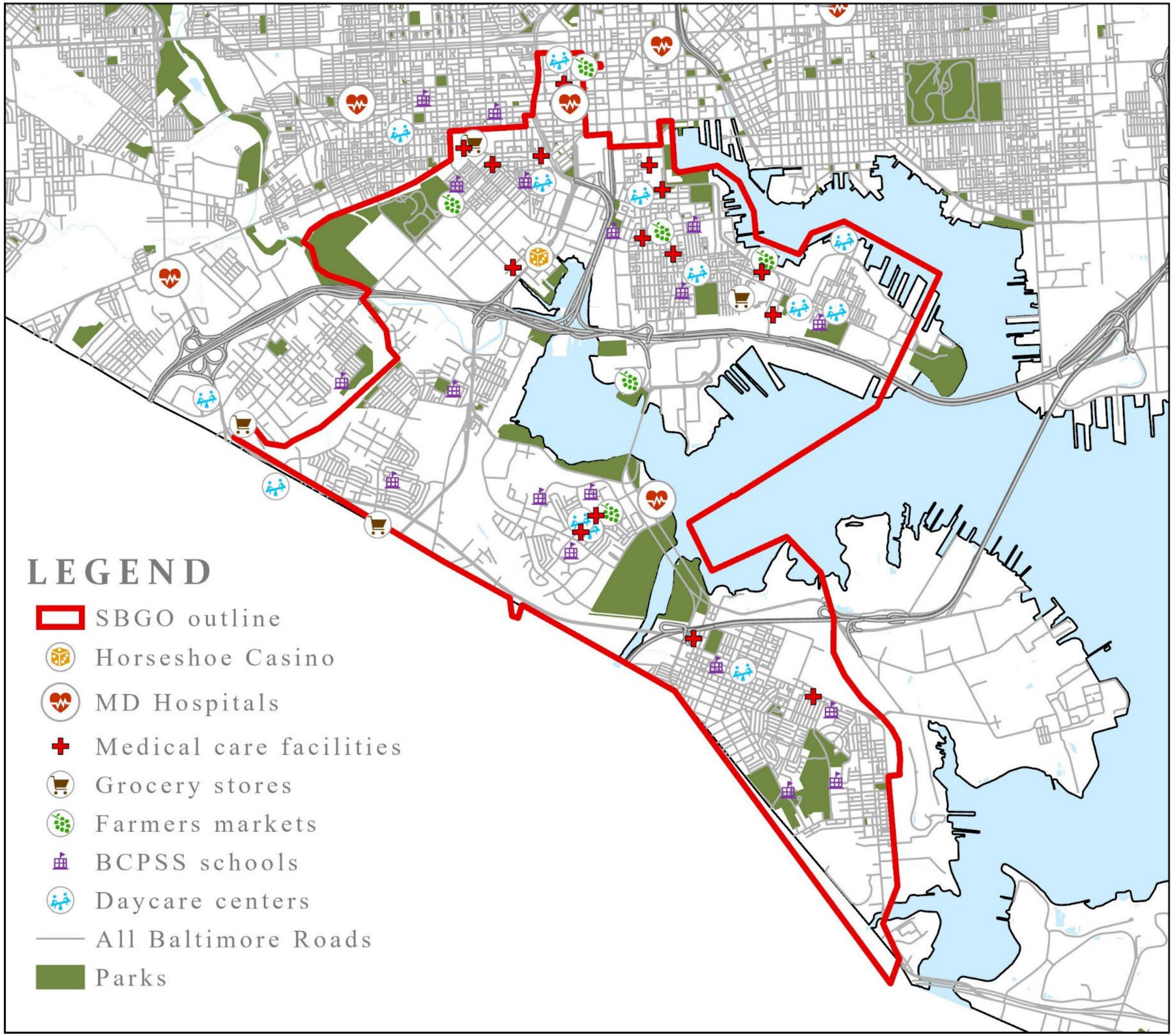
Tak Igusa, Professor of Civil & Systems Engineering
PhD student: Todd Chang

Dec. 3, 2020

Public-private partnership meeting on improving mobility in low--income neighborhoods
Todd Chang presenting

SOUTH BALTIMORE
GATEWAY PARTNERSHIP

Study Area


LEGEND
SBGO outline
Horseshoe Casino
MD Hospitals
Medical care facilities
Grocery stores
Farmers markets
BCPSS schools
Daycare centers
All Baltimore Roads
Parks

Cherry Hill, South Baltimore

- Most residents do not have a car.
- Bus service is limited and not frequent (before the pandemic).
- Low accessibility to **healthy food** and **public transit**.

TABLE 2: Transportation trends among respondents, Cherry Hill Needs Assessment Survey, 2015.

CHARACTERISTIC	NUMBER	PERCENT
How often do you travel to other parts of Baltimore City?		
Daily	10	24.4
Every other day	6	14.6
As and when needed	25	61.0
Type of transportation used most often		
Drive car	20	43.5
Take bus	24	52.2
Take taxi	2	4.3
What is the frequency of the bus? (among those using public transportation)		
Every hour	8	30.8
Irregular	2	7.7
Other	16	61.5
Purpose of travel (multiple selections allowed)		
For work	5	8.5
For shopping	6	10.2
For health services	4	6.8
For other business	5	8.5
To buy groceries	7	11.9
To visiting friends or to attend church	1	1.7
All of the above	31	52.4

From Winbush, R., Ahmed, A., Anyadike, C., Churchill, J., Menzise, J., Robinson, G., and Rone, T. (2015). A Comprehensive Demographic Profile of the Cherry Hill Community in Baltimore City. The Institute for Urban Research, Morgan State University.

Cherry Hill, South Baltimore

- Most residents do not have a car.
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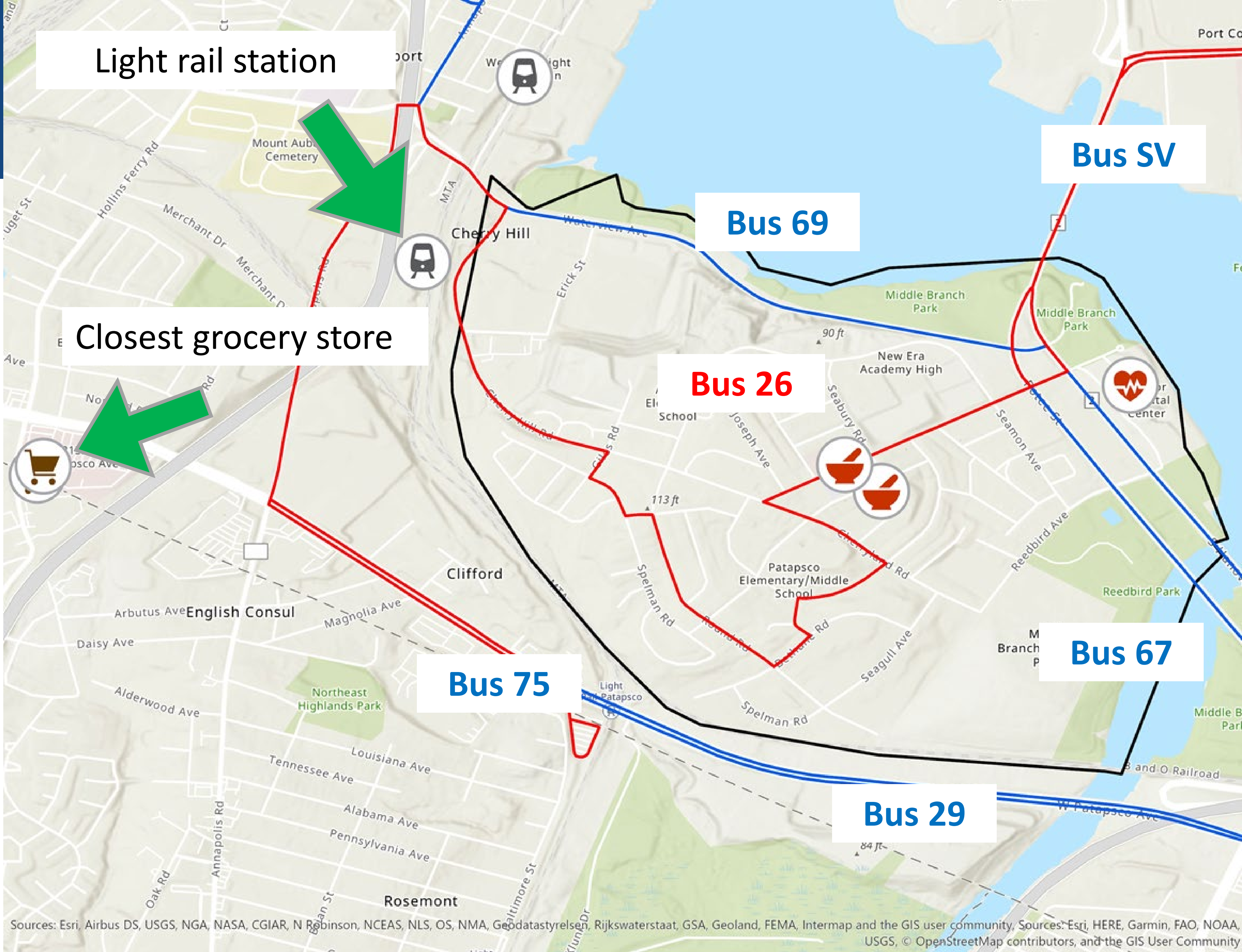
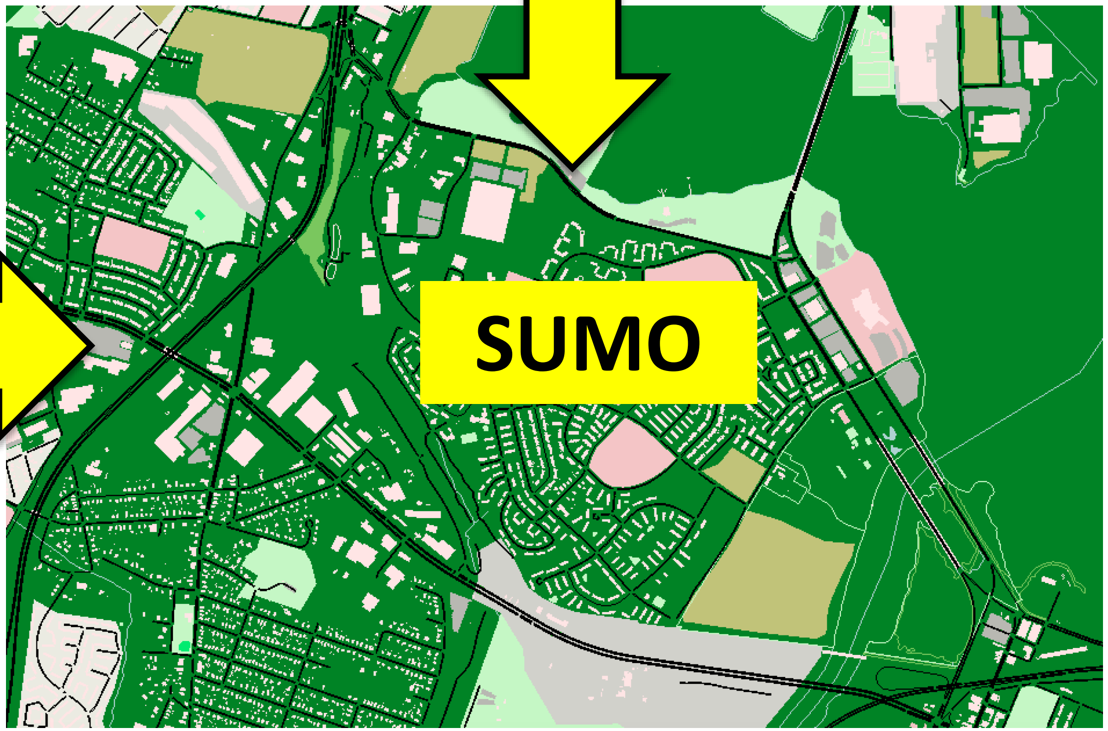


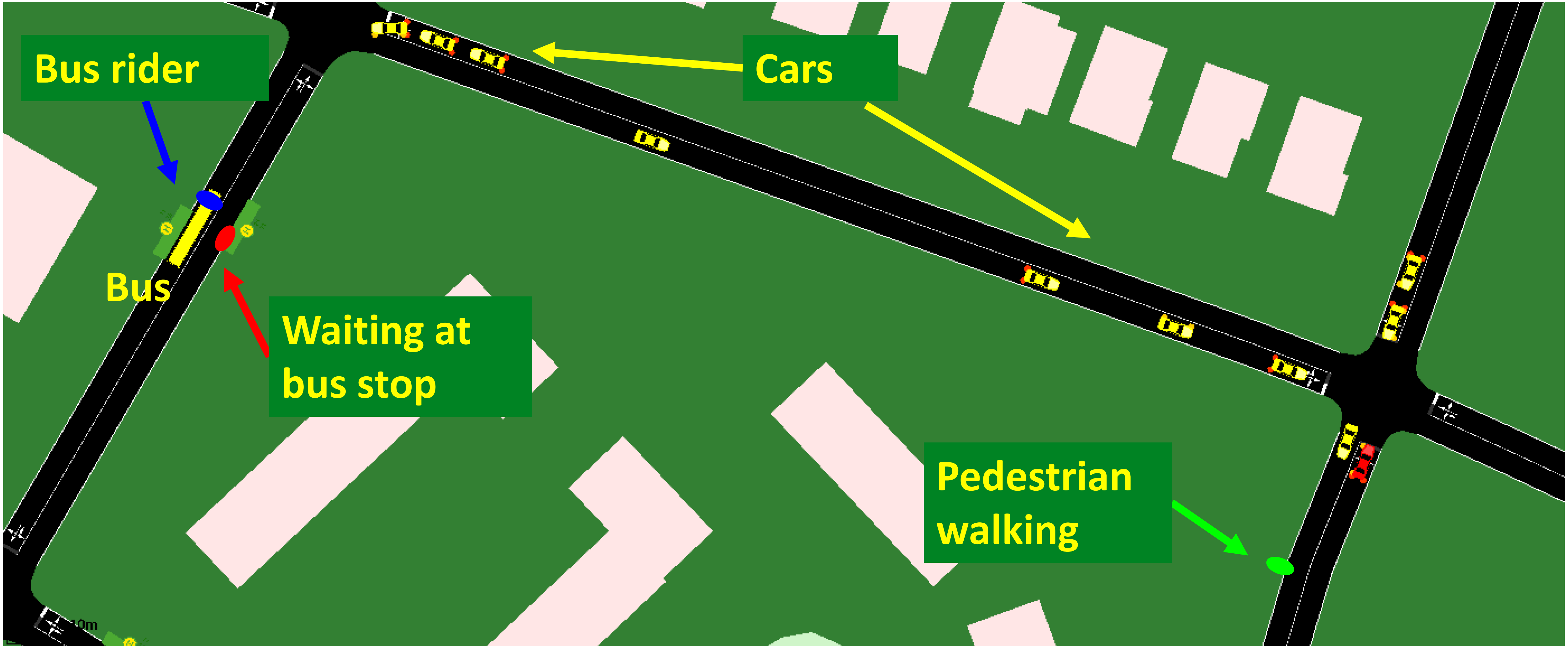
Simulation of Urban MObility (SUMO)

- Commercial, open-source code for simulating traffic
- Detailed, individual travel behaviors

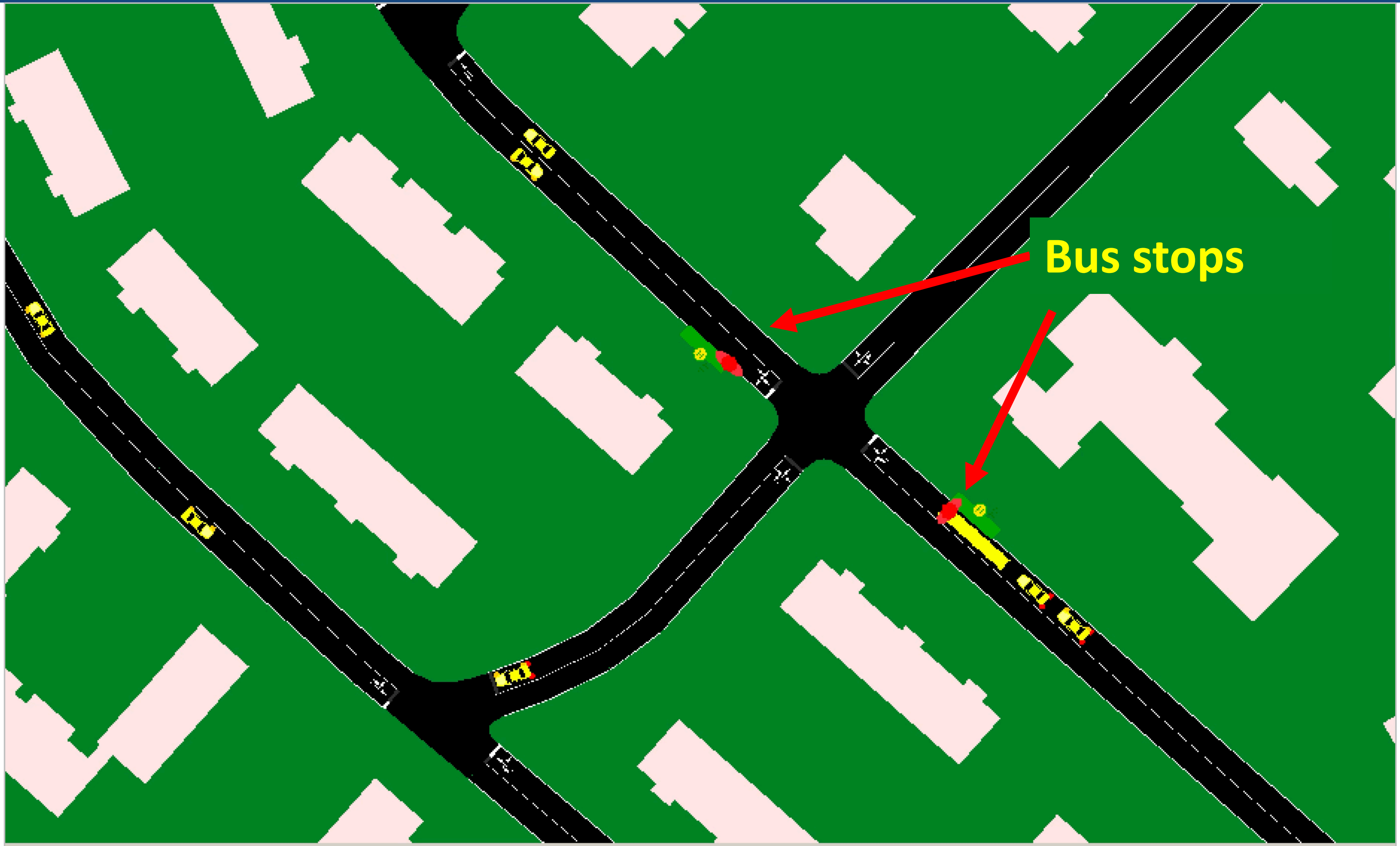
Demographics + traffic data



Visualization of traffic simulation

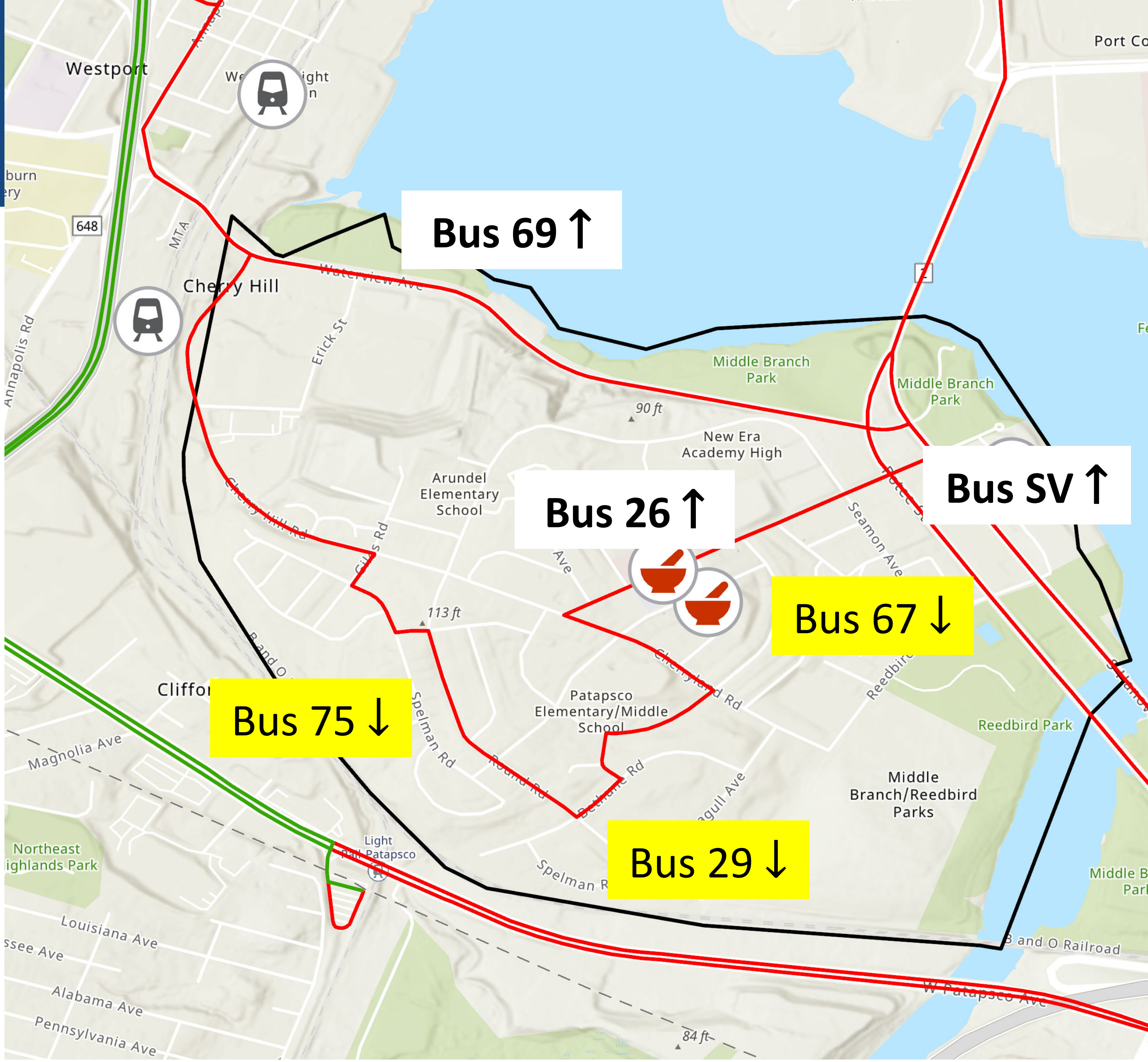


Simulation Detail of Pedestrians at Bus Stops



Influence of the COVID pandemic

- **Public transit ridership reduced by up to 90% in some areas of the U.S.**
- **Ridership dropped by only 60% in Baltimore.**
- **Average bus services in Baltimore will be reduced by 20% in 2021.**
  - Some bus lines will be cancelled or reduced
  - Some bus lines will have increased service to cover gaps.



nd-mta-plans-to-reduce-bus-marc-service-next-year-amid-coronavirus-losses

Source: https://www.thejakartapost.com/life/2020/03/12/whats-the-difference-between-pandemic-epidemic-and-outbreak.html

Traffic simulation scenarios

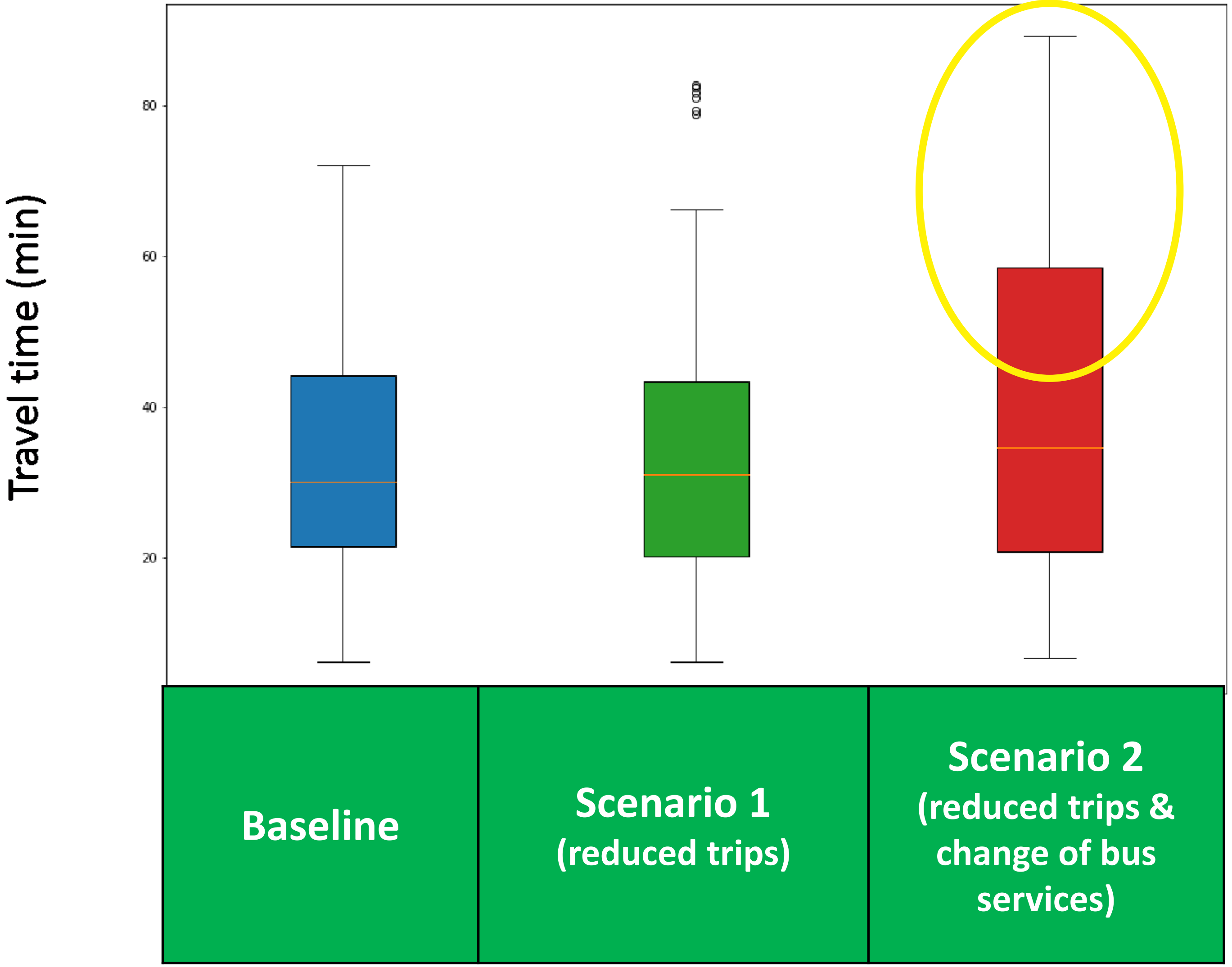
- **Track a representative sample of pedestrians traveling to**
  - Grocery store
  - Light rail station
  - Health care facility
- **Simulate mobility and air quality impacts on the residents**

Baseline	Scenario 1	Scenario 2
Normal status	Resident trips reduced by 40%	Reduced trips & change of bus services

Simulation results: Emissions during peak traffic

Emissions	Baseline	Scenario 1 (reduced trips)	Scenario 2 (reduced trips & change of bus services)
CO	1.54 kg/hr	0.91 kg/hr	0.83 kg/hr
CO2	180 kg/hr	134 kg/hr	147 kg/hr
PMx	40 g/hr	31 g/hr	34 g/hr

Simulation of average travel times



For further information

- Tak Igusa (tigusa@jhu.edu)
- Todd Chang (cchiahs1@jhu.edu)

Center for Systems Science and Engineering
Department of Civil & Systems Engineering
Johns Hopkins University

Influence of COVID-19 on Regional Transportation Planning

DR. MICHAEL O. RODGERS
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING
GEORGIA INSTITUTE OF TECHNOLOGY

Regional Transportation Planning

- Metropolitan Areas
  - Metropolitan Planning Organizations (MPOs)
  - Regional Transportation Plans (RTP), Transportation Improvement Program (TIP)
- Non-metropolitan and Rural Areas
  - Regional Transportation Planning Organizations (RTPO)
  - Also Produce RTP and TIP plans
  - In many states tied to Regional Economic Development Organizations
- State DOTs
  - Statewide Planning
  - Coordination between planning organizations within states

COVID-19 Pandemic Impacts

- Tremendous Increase in Telecommuting Activity
  - Education
  - Service Industries
  - Administrative Functions
- Acceleration of On-line Shopping Trends
  - Small Package Delivery
  - Curb-side Pickup
  - Food Takeout and Delivery Services
- Significant Alteration of Daily and Weekly Traffic Patterns
- Significant Differences in Impacts on Virtually All Spatial Scales

COVID-19 Pandemic Impacts (cont.)

- Dramatic Impacts on Transit and Ride Hailing Services
  - Uber® and Lyft® shift from Ride Hailing to Food Delivery
  - Severe Impacts on Transit and Commuter Rail Ridership
  - Smaller but Substantial Impacts on Transit Bus Ridership
- Severe Impacts on some Non-Highway Modes
  - Riverboats and Cruise Ships
  - Passenger Aviation
- Challenges in Manufacturing and Freight Transportation
  - Supply Chain Disruptions
  - Low Inventory and Limited Reserve Production Capacity

Questions for Long-Range Transportation Planning

- How will these short-term impacts extend into a Post-Pandemic Era?
  - Organizational Impacts
    - Investment and Experience in Online Tools
    - Experience with Decentralization
  - Individual Impacts
    - Consumer Behavior
    - Consumer Preferences
  - Social Impacts
    - Impacts on Social Behavior
    - Impacts on Social Organizations
- What emergent trends will develop based on collective experience?

Long Range Planning Questions

- The End of "New Urbanism"?
  - Encouragement of Higher Densities
  - Transit-Oriented Development
  - Bicycle and Pedestrian Infrastructure
  - "Back to the City" Trends
- What is the Future of Transit and Shared-Mobility?
- Will Access to Health Care Advantage Smaller Cites Relative to Rural Areas and Major Cities for Future Growth?
- Potential Reluctance to Abandon Personal Vehicles.
- Changes in Consumer Behavior.

Toward a Better Understanding of Recent Emissions and Meteorological Impacts on Air Quality in the South Coast Air Basin

Cesunica E. Ivey
Chemical and Environmental Engineering
Center for Environmental Research and Technology

Thursday, December 3, 2020

COVID-19 impacts on Transportation, Air Quality, and Health
WEBINAR

Acknowledgements

Sponsors and Contributors

- **UC Riverside & CE-CERT**: Shams Tanvir, Matthew Barth, Kanok Bariboonsomsin, Barry Wallerstein, Dwaraknath Ravichandran, Ji Luo, Khanh Do, Arash Kashfi Yeganeh
- **Georgia Tech**: Ted Russell, Yongtao Hu, Ziqi Gao, Nash Skipper
- **Envair**: Charles Blanchard

Motivation (1)

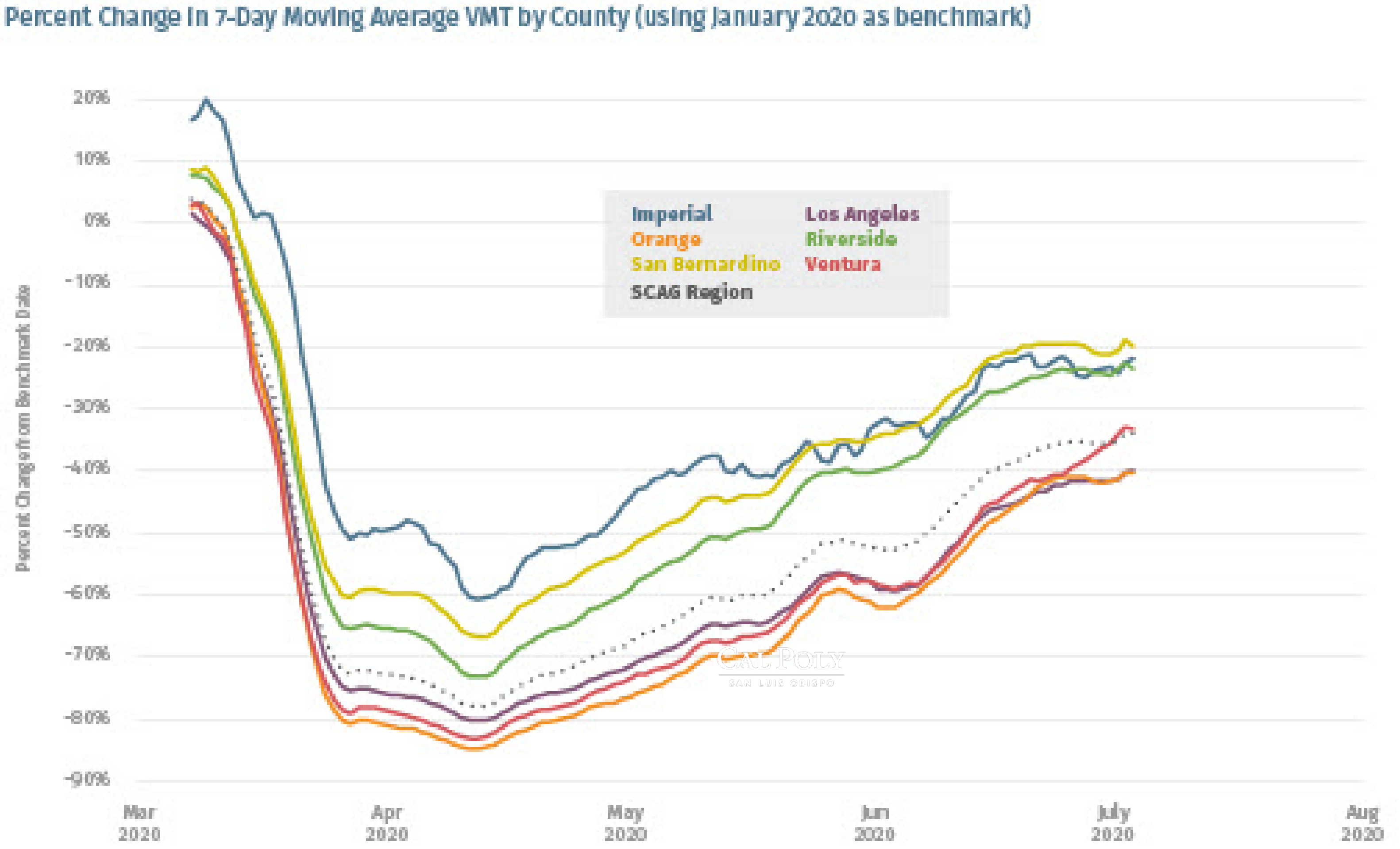
Traffic reductions in South Coast

1. Regional differences
Greater reductions in average VMT were observed in Orange, Ventura, and Los Angeles Counties

2. Trends over time
Peak traffic reductions were observed in mid-April, and are rebounding toward pre-COVID levels

3. Current levels
Current traffic levels have not fully returned to pre-COVID levels

Southern California Association of Governments
Snapshot of COVID-19 Transportation Impacts in the SCAG Region



CELEBRATING 30 YEARS
Marlan and Rosemary Bourns College of Engineering

Motivation (2)

Unhealthy air pollution episodes strike Southern California despite reduced activity

L.A. records worst smog in 26 years

[**Smog,** from A1]
Compton's eight-hour reading was 115 ppb, its highest since monitoring began there in 2008.

Sunday's readings at the downtown L.A. air monitoring station, located on North Main Street in Chinatown, were so far above normal that they triggered a quality control check designed to prevent the release of erroneous data, air quality officials said.

The downtown L.A. readings did not initially appear online and were provided by the South Coast air district in response to questions from The Times about the missing data.

The figures were not reported immediately because the quality control check requires additional, manual validation if pollution readings exceed historic highs, South Coast AQMD spokeswoman Nahal Mogharabi said. If instruments are having problems, they "can show erroneously high levels and the quality control check prevents the automated release of high data that could be incorrect."

But it was no glitch.

"The value for noon on Sunday has been reviewed and is preliminarily valid at 185 ppb," Mogharabi said.

Air quality officials said the high pollution readings were a result of intense heat combined with stagnant

ROBERT GAUTHIER Los Angeles Times

LA Times, September 11, 2020

"The combination of a major wildfire and extreme heat can really send ozone levels through the roof," said Yifang Zhu, a professor of environmental health sciences at UCLA Fielding School of Public Health. "Both are important, and they came together at a very unfortunate time, and that helps explain why we were seeing such extreme levels of ozone last weekend.

BRIAN VAN DER BRUG Los Angeles Times

THICK SMOKE from multiple forest fires Saturday shrouds the iconic El Capitan rock formation and granite walls of the Yosemite Valley at Yosemite National Park.

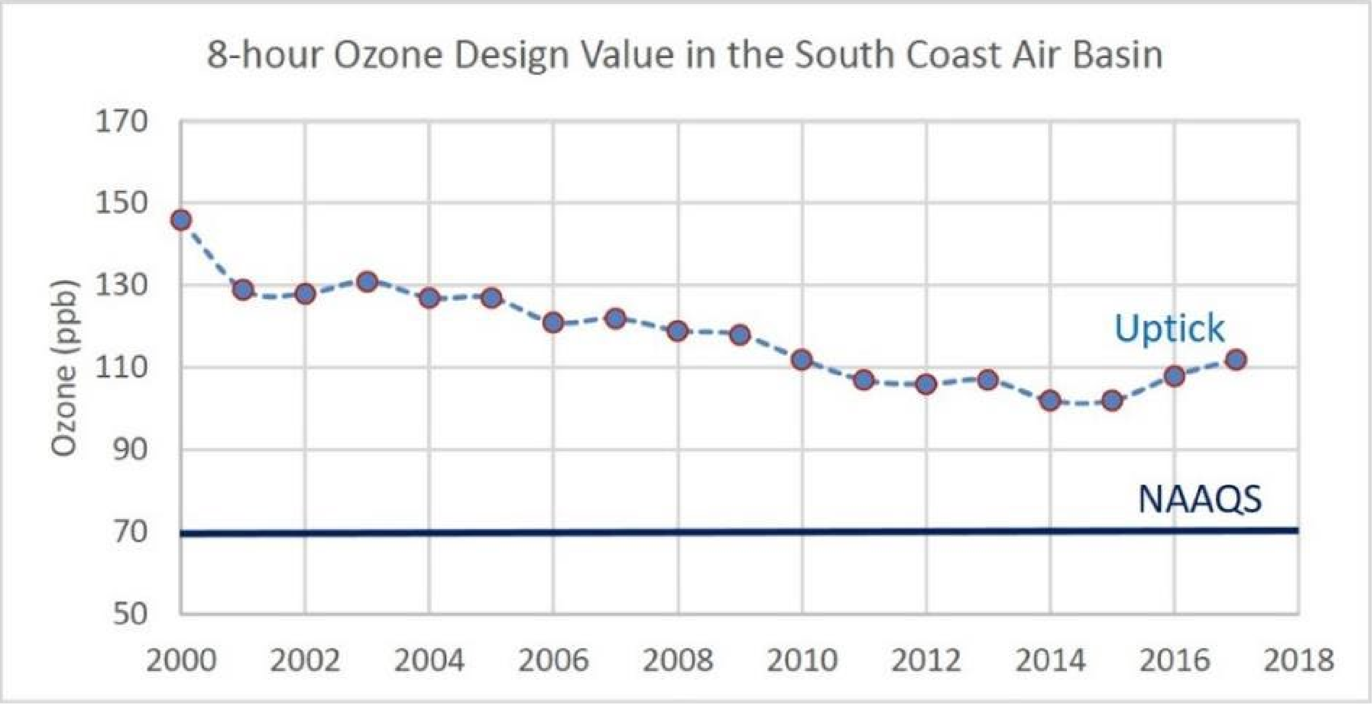
Climate apocalypse has struck California

LA Times, September 13, 2020

Motivation (3)

8-Hour ozone design value reached an inflection point in 2014

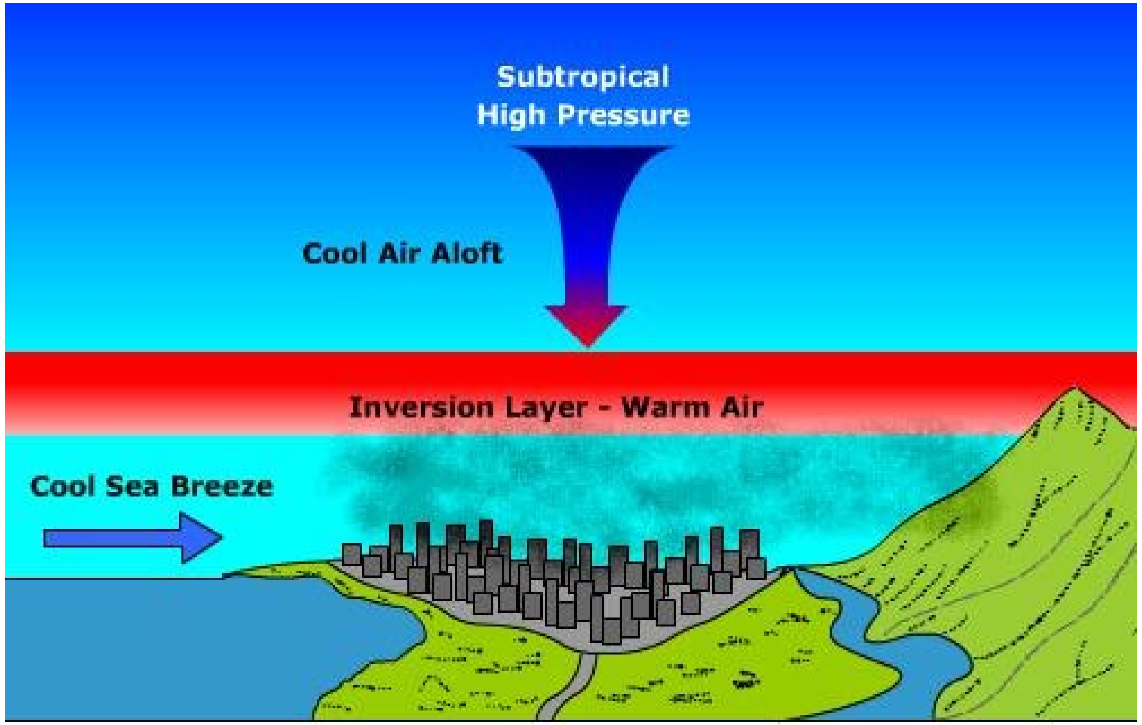
- 2017 = 112 ppb (Crestline)
- 2018 = 111 ppb (Crestline)
- 2019* = 108 ppb (Redlands)
- 2020* = 114 ppb (Redlands)

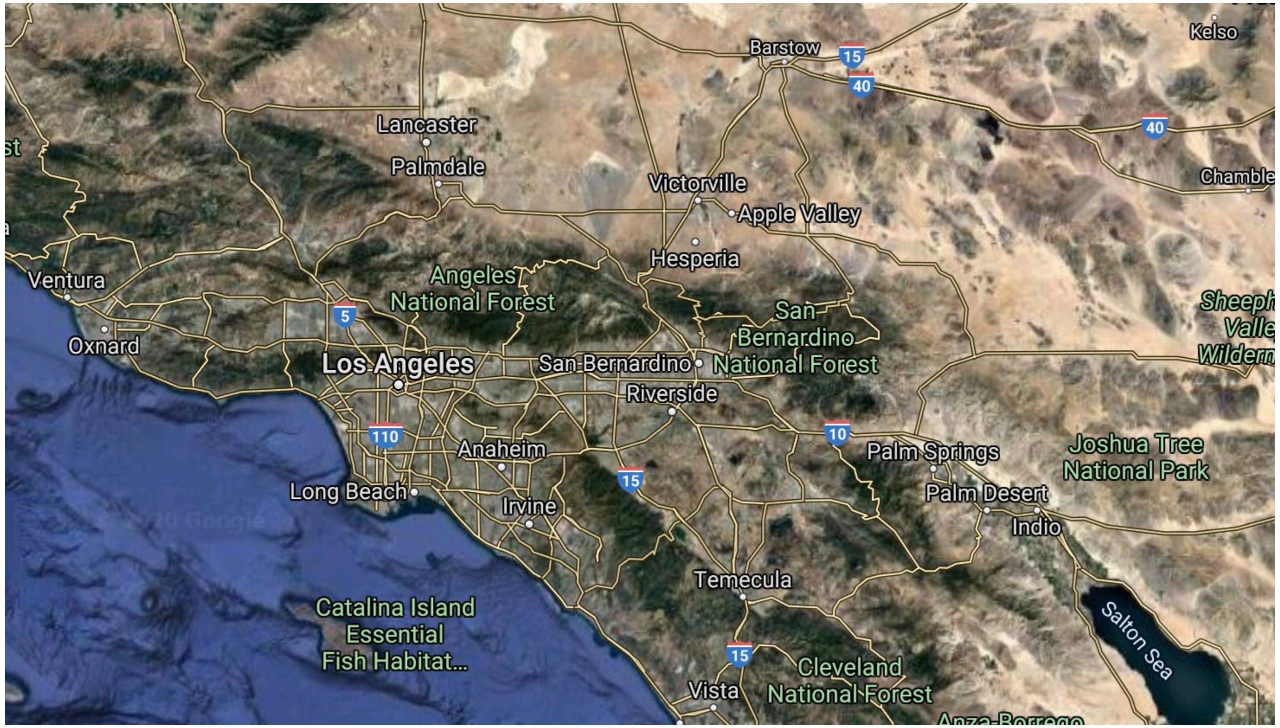


The federal 8-hour design value is based on the "three year average" of the annual 4th high

South Coast Air Basin

Unique meteorology, emissions, chemistry, and topography

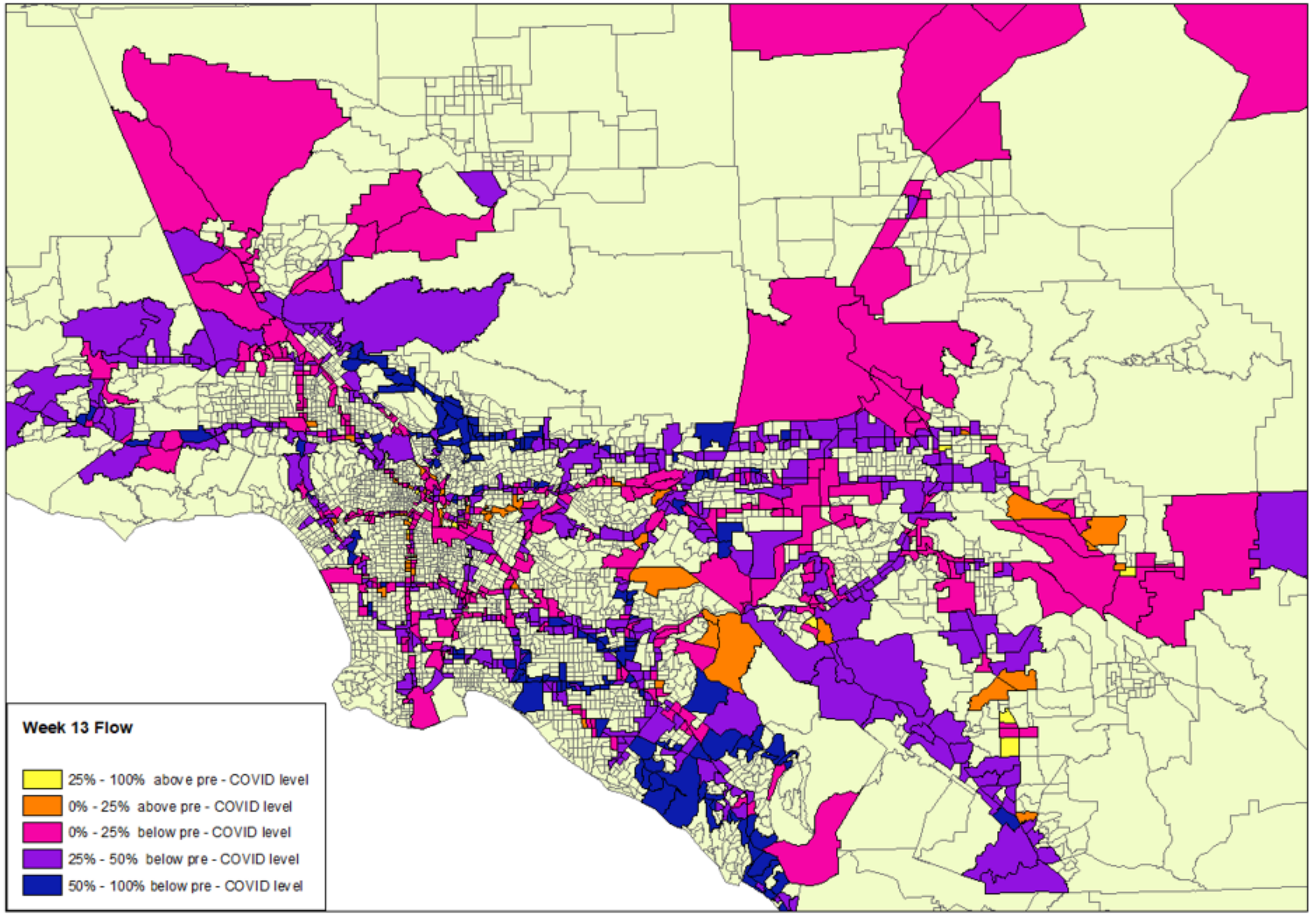




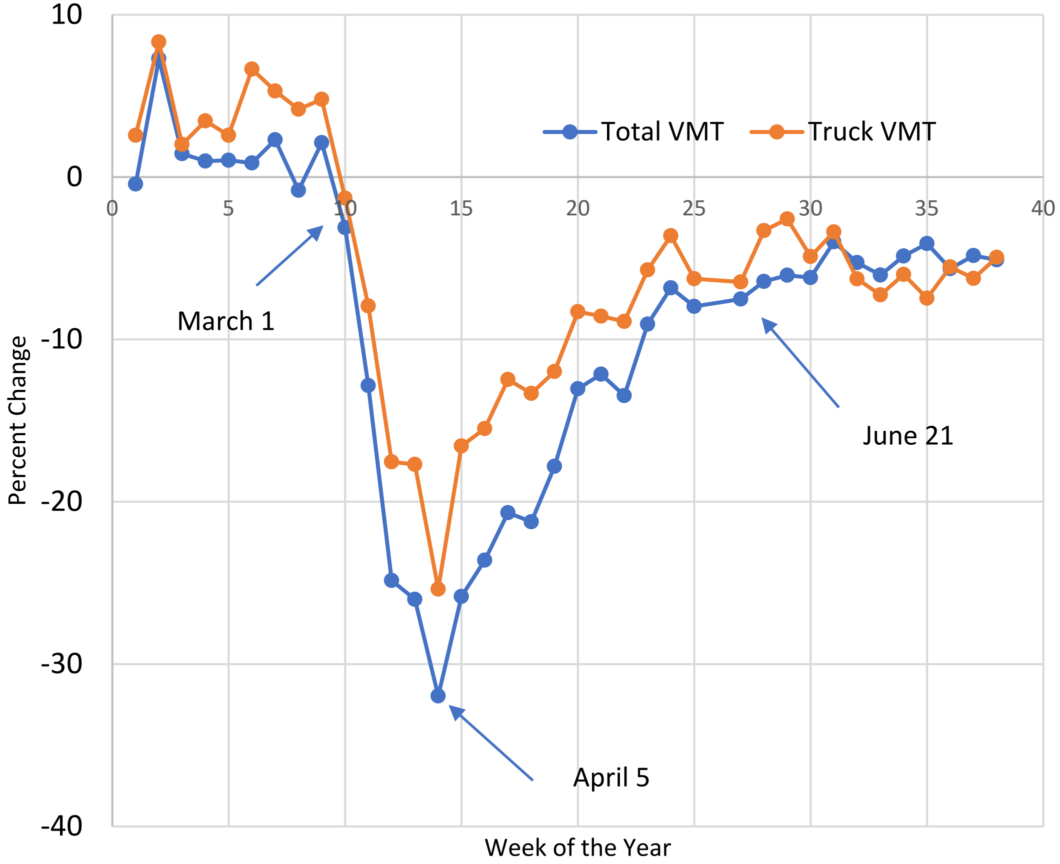
On-shore winds prevail, transporting precursor emissions from west to east in the Basin. High pressure systems induce temperature inversions, with warmer air atop a cooler surface layer.

Traffic Flow Drops In The First Week of Shutdown

March 22 - March 28 Total Flow Change



District 7 – Drop In Vehicle Miles Traveled



Most census tracts being mapped see a drop of 25% to 100%, increasing by the week until May

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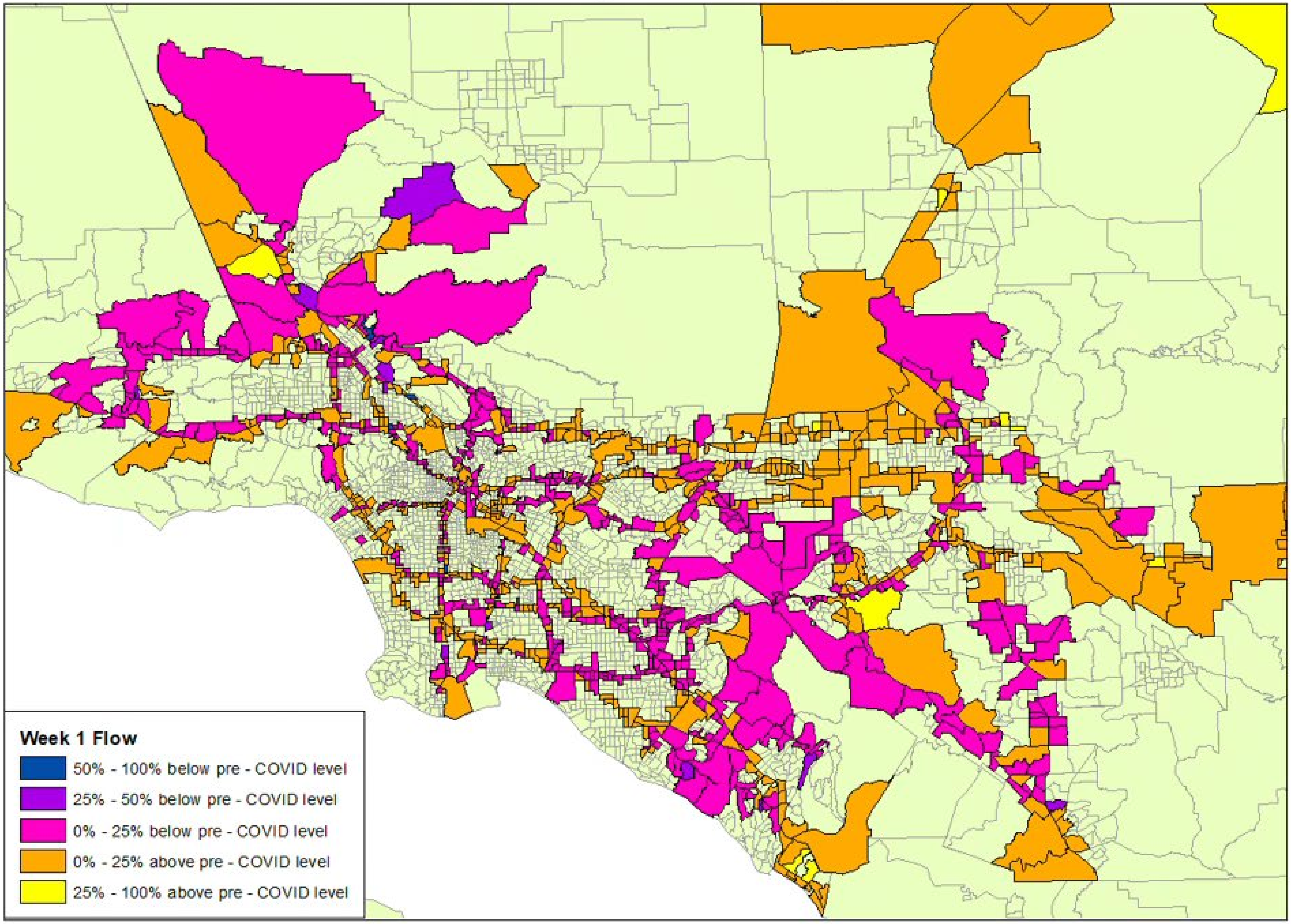
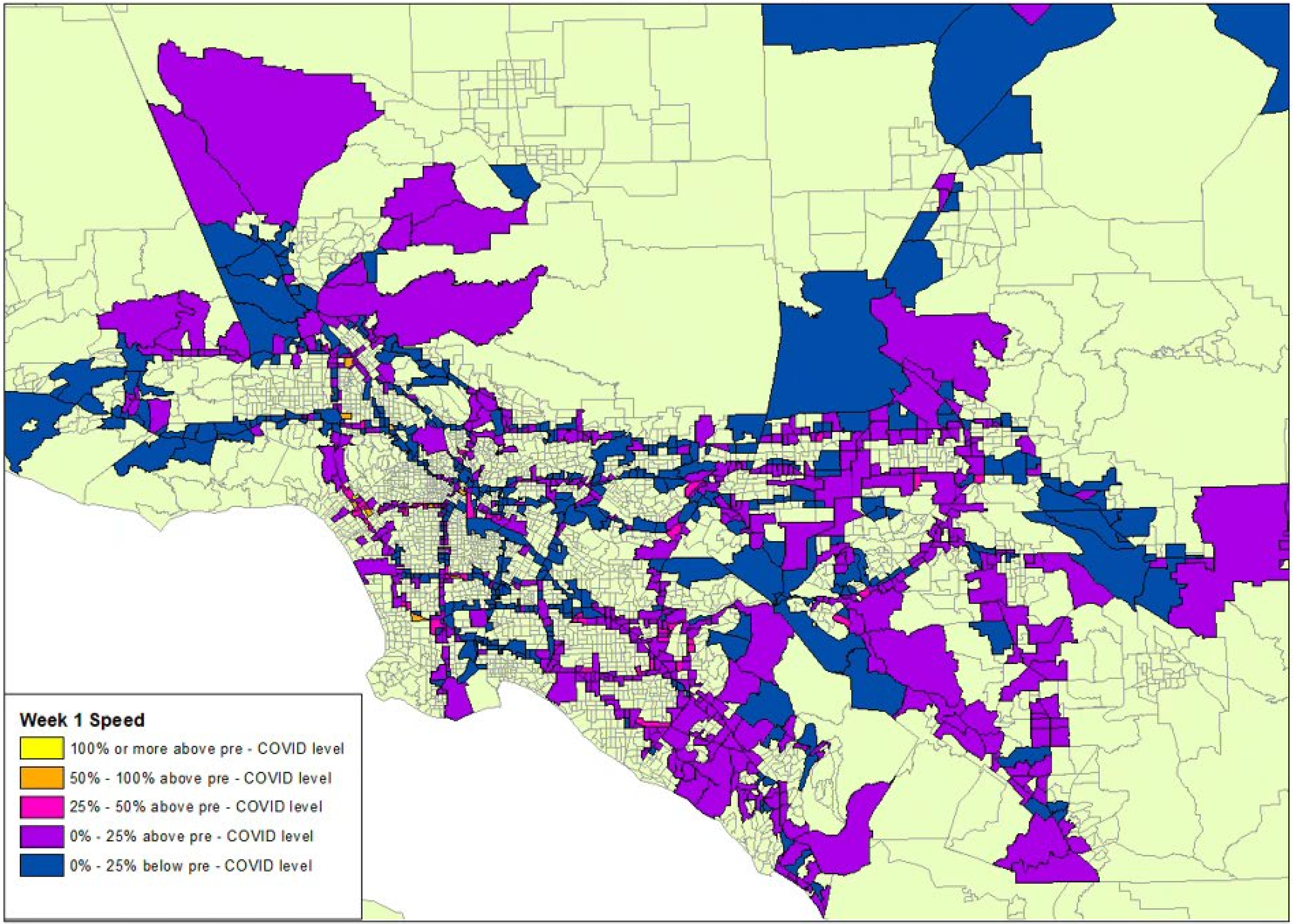
January 1 - January 4 Total Flow Change



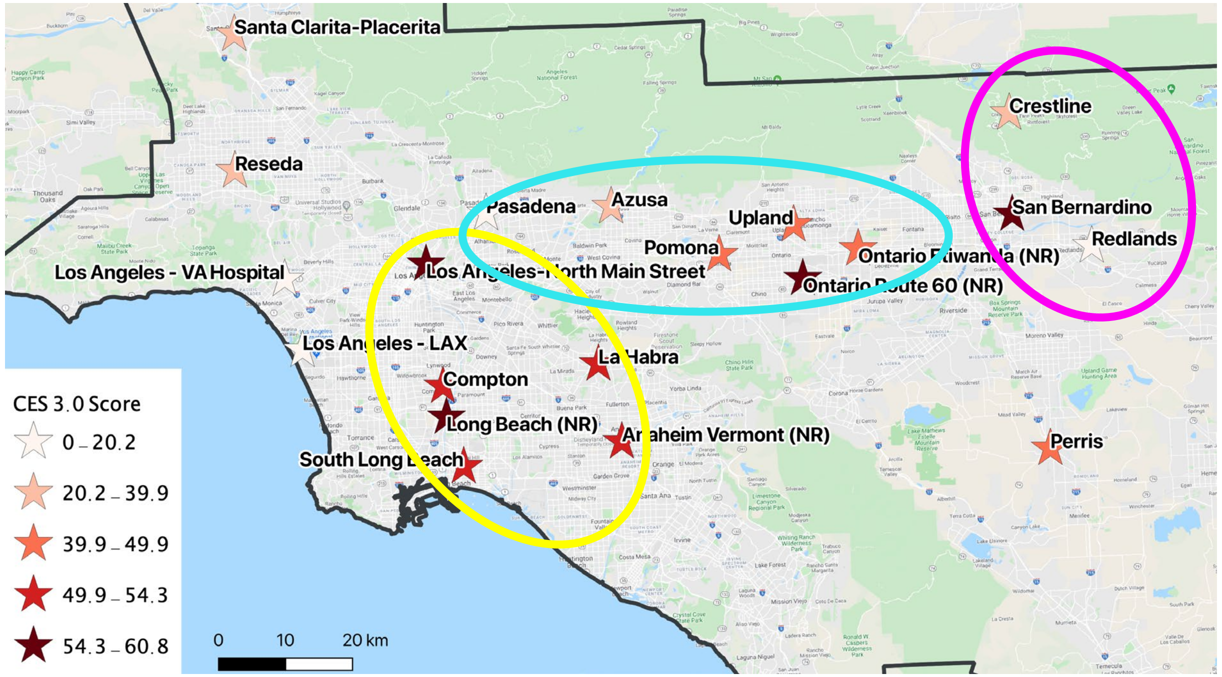
January 1 - January 4 Speed Change



Air Pollution Trends: Hourly, 2020 – Avg (2017-19)

Carbon Monoxide (CO, ppb)	Anaheim Vermont NR	Ontario Etiwanda NR
Pre-COVID March	-34%	-16%
Post-COVID March	-46%	-28%
April	-41%	-13%
May	-36%	9%
June	-37%	-10%

Nitrogen Oxides (NOx, ppb)	Anaheim Vermont NR	Long Beach NR	Ontario Etiwanda NR
Pre-COVID March	-23%	23%	26%
Post-COVID March	-34%	33%	-4%
April	-29%	7%	-23%
May	-26%	41%	4%
June	-24%	54%	10%



Ozone (ppb)	Azusa	Crestline	LA North Main	Pasadena	Redlands	San Bernardino
Pre-COVID March	-2%	4%	28%	28%	17%	17%
Post-COVID March	4%	-3%	29%	38%	20%	19%
April	2%	-7%	6%	19%	16%	12%
May	2%	20%	-10%	22%	30%	14%
June	-2%	-5%	12%	14%	10%	-2%

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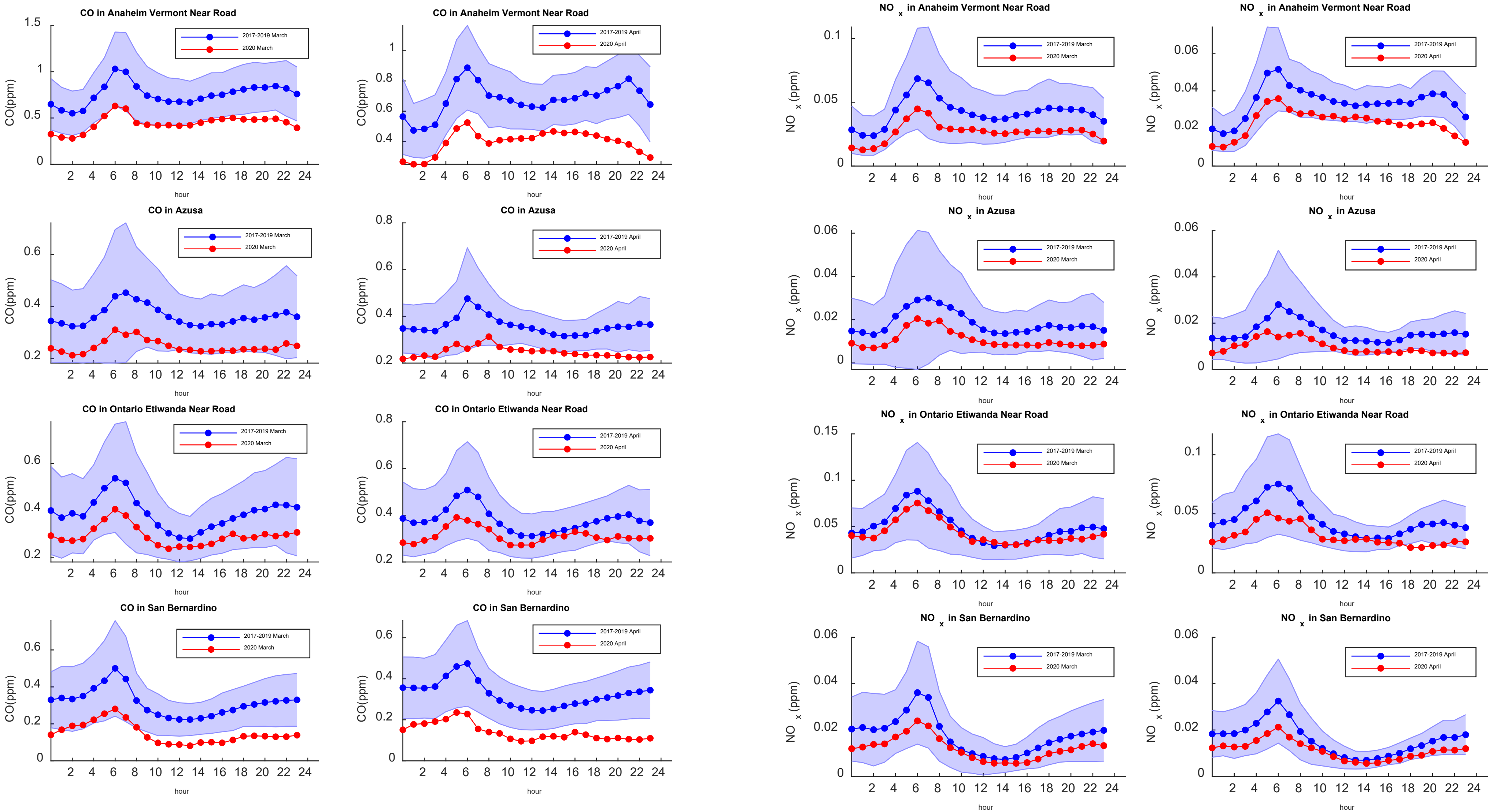
Air Pollution Trends: Diurnal Profile Changes



Air Pollution Trends: Max Daily 8-hr Avg. O_3

COVID-19

- March and April 1990-2019 generalized additive model (GAM) training on MDA8 ozone
- March and April 2020 GAM predictions of MDA8 ozone
- Max temperature, 850 mb WS/RH, ENSO, CARB emissions, etc.

$$MDA8_{Pasadena} = ROG^2 + NOx^2 + (NOx \times ROG) + ns(NOx, 3) + ns(ROG, 3) + ns(T_{max-Bar}, 3) + ns(T_{max-LAX}, 3) + ns(\overline{WS}_{Bar}, 3) + ns(\overline{WS}_{LAX}, 3) + ns(SR_{max}, 3) + bc(WD_{500-Mir}, 4, 360) + bc(WD_{850-Mir}, 4, 360) + WS_{850-Mir} + ns(DewT_{850-Mir}, 3) + ns(RH_{850-Mir}, 3) + ENSO + ns(DOY) + fv(DOW) \qquad (1)$$

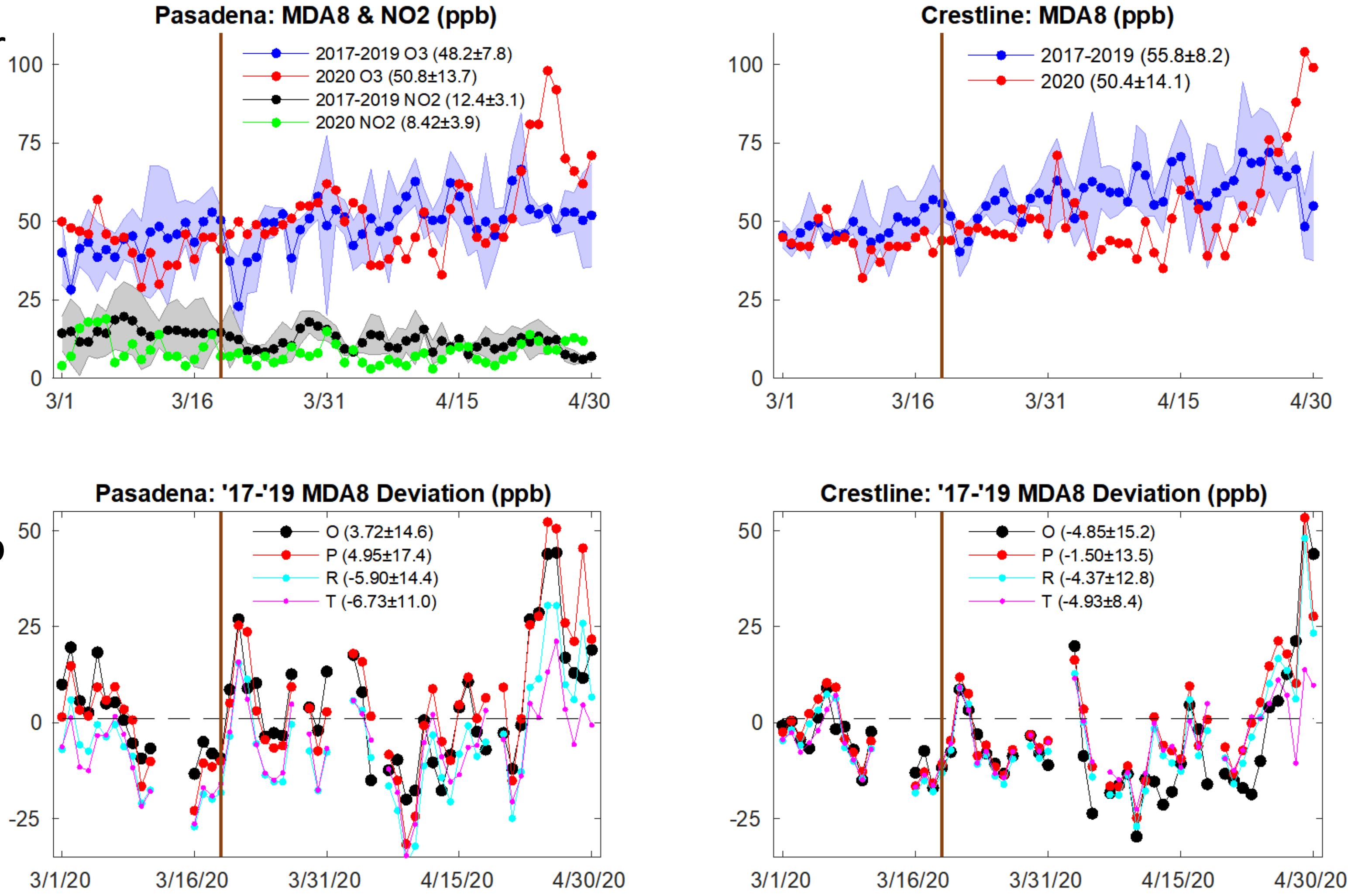
$$MDA8_{Crestline} = ns(NOx, 3) + ns(ROG, 3) + ns(T_{max-Bar}, 3) + ns(T_{max-LAX}, 3) + ns(\overline{WS}_{Bar}, 3) + ns(\overline{WS}_{LAX}, 3) + ns(SR_{max}, 3) + bc(WD_{500-Mir}, 4, 360) + ns(WS_{850-Mir}, 3) + ns(DewT_{850-Mir}, 3) + ns(RH_{850-Mir}, 3) + ns(T_{500-Mir}, 3) + ENSO + ns(DOY) + fv(DOW) \qquad (2)$$

Ivey et al., ***ChemRxiv***, 2020

COVID-19

Air Pollution Trends: Max Daily 8-hr Avg. O_3

- Modeled MDA8 ozone is higher than the 2017-2019 average in Pasadena
- Lower than average in MDA8 ozone Crestline
- Late April high temperatures led to higher than average in both locations
- **Counterfactual MDA8 ozone attributes overall deviations to changes in emissions**



Ivey et al., ***ChemRxiv***, 2020

Potential Policy Implications

Telecommuting

- Access to ‘remote work’ to alleviate on-road exposures in EJ communities
- Additional targeted incentives required for businesses

E-Commerce

- More consumption of online shopping items means more ‘Warehousing’ activity
- Need to manage additional trucking activities in the Inland regions

Conclusions

What have we learned?

1. Traffic shifts are locally variable

From PeMS data, declines in traffic flow (vehicles/hour) were observed over the entire South Coast Air Basin. However, flow recovered at different times and scale for different localized regions.

2. Near-road pollution captures traffic trends

Near-road monitoring locations saw up to 50% reductions in CO and 40% reductions in NOx. Non-near-road locations also saw reductions in CO and NOx.

3. Meteorology plays an important role in air quality

Higher temperatures increased ozone concentrations above expected values during Spring 2020 and subsequent heat waves

4. Future work

We will find the underlying reason for flow reduction – more telecommuting or e-commerce activities?

Exposures to SARS-CoV-2 in small transportation environments

Wen-Whai Li

Department of Civil Engineering, The University of Texas at El Paso, El Paso, TX

Transportation, Air Quality, and Health Symposium, Dec. 3, 2020, College Station, Texas (Webinar)

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Acknowledgements

Some of the information presented in this discussion is adapted from many published articles in the literature without consents of the publishers. The information is designed solely for discussion only and should not be cited or reproduced for any other uses without consulting the author and respective publishers.

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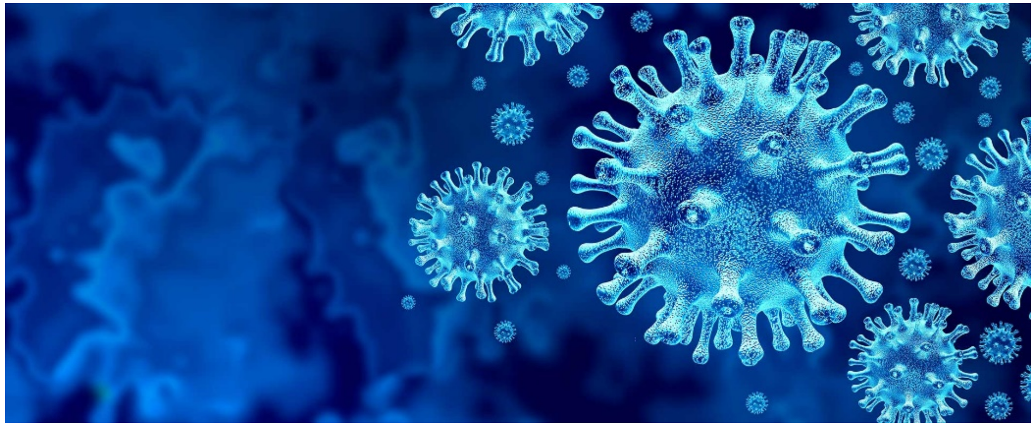
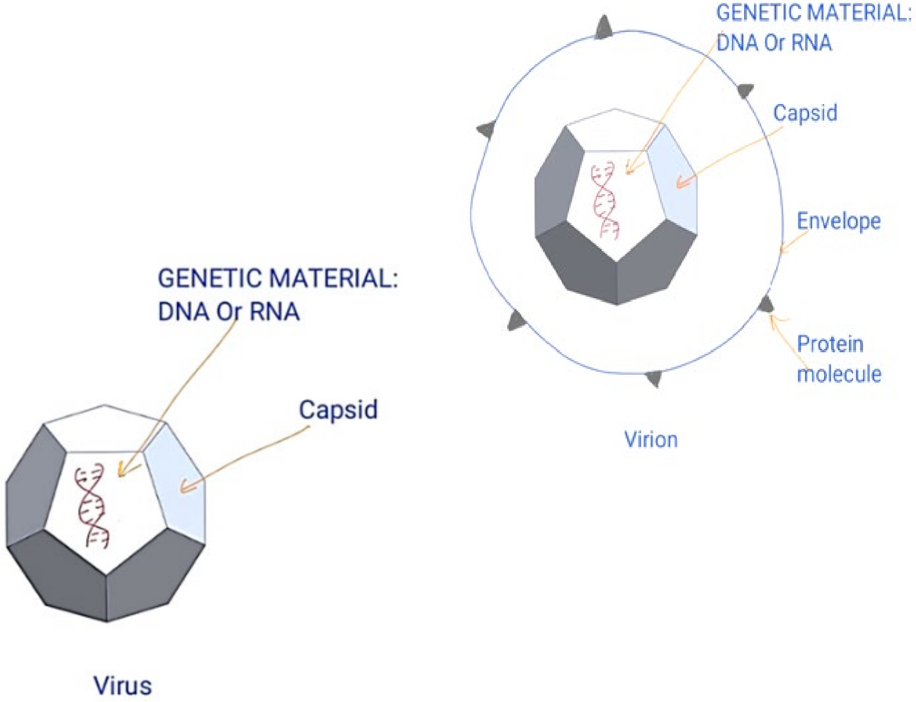
- Characterize aerosol properties of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2)
- Characterize the strength of emissions for SARS-CoV-2 in a small environment
- Conduct rapid assessment of exposures to SARS-CoV-2 in a small environment
- Provide guidelines on exposure reduction of SARS-CoV-2 in small transportation related environments

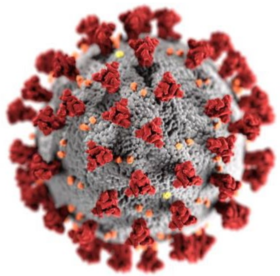
Properties of the Virus



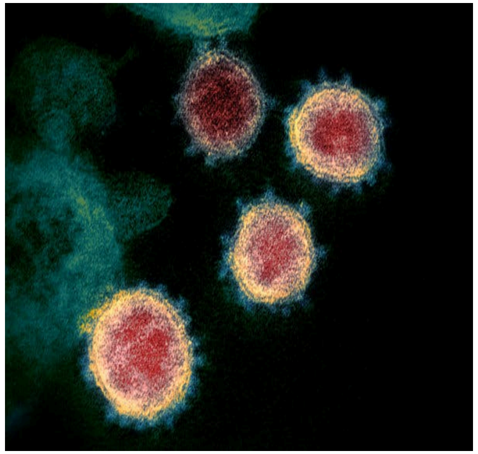
- First reported in Wuhan, China in December 2019[1, 2]
- Spherical with a diameter between 60 - 140 nm[2], or approximately 125 nm by electron tomography and cryo-electron microscopy [4, 5]
- Virus can be found inside a cell while virion (virus particle) which contains a protein coating (capsid) of a virus which can survive outside a cell (Photo[6])
- Virus particles are known to be encapsulated in globs of mucus, saliva, and water, and the fate/behavior of globs in the environment depends on the size of the globs[7]
- The infected cell contains the virus, while the virus particles are 'spores' or reproductive forms [8].



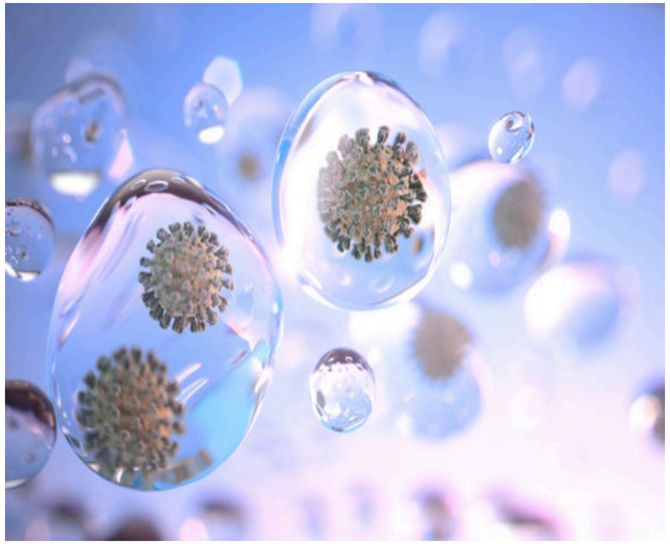
Properties of the Virus



- Quantification by measuring the number of copies of viral RNA in a sample or $TCID_{50}$ (50% tissue-culture infectious dose).
  - The viral loads ranged from 10^3- 10^{11} copies per mL, with 10^5 in throat samples and 10^6 in sputum sample[2]
  - Mean viral load significantly differed between patients who were alive (mean $10^{5.2}$) versus those who had died (mean $10^{6.4}$) [9]



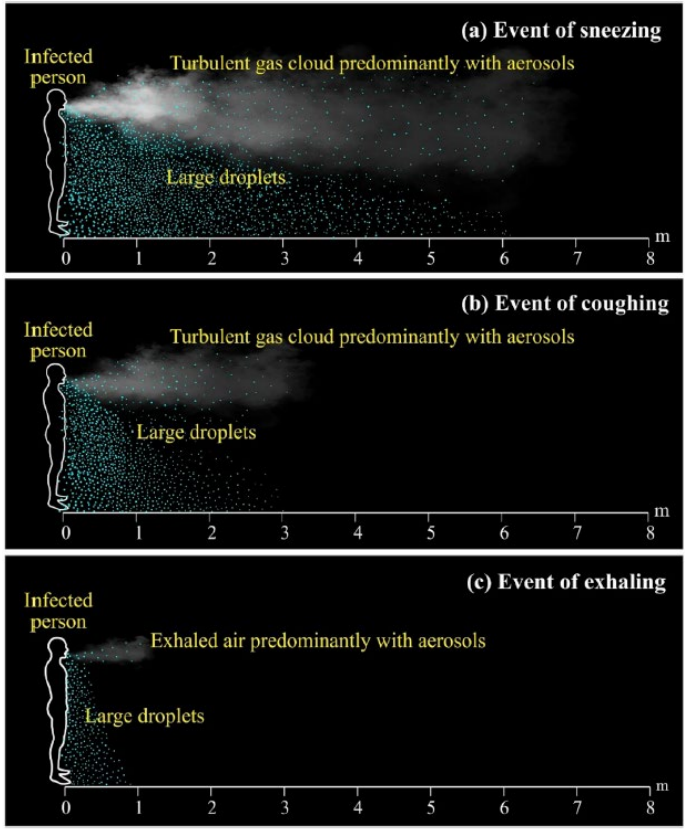
- Concentrations from host[10]
  - Nasopharynx: 10^6-10^9 RNAs/swab
  - Throat: 10^4-10^8 RNAs/swab
  - Stool: 10^4-10^8 RNAs/swab
  - Sputum: 10^6-10^{11} RNAs/swab
- Viruses are self-replicating within the cell. The actual minimum number varies between different viruses
  - The infectious dose of SARS-CoV-2 is still not known, however, studies have shown that just three virus particles are enough to make someone sick for influenza (NEJM)
  - Many researchers speculate that a few hundreds of SARS-CoV-2 viruses would be enough to cause the disease among susceptible hosts[11,12].
  - SARS-CoV-2 virus can remain viable and infectious in aerosols for hours and on surfaces up to days[13]

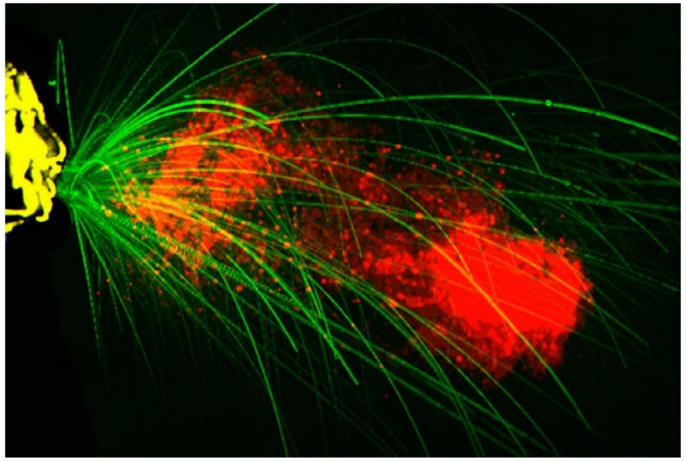


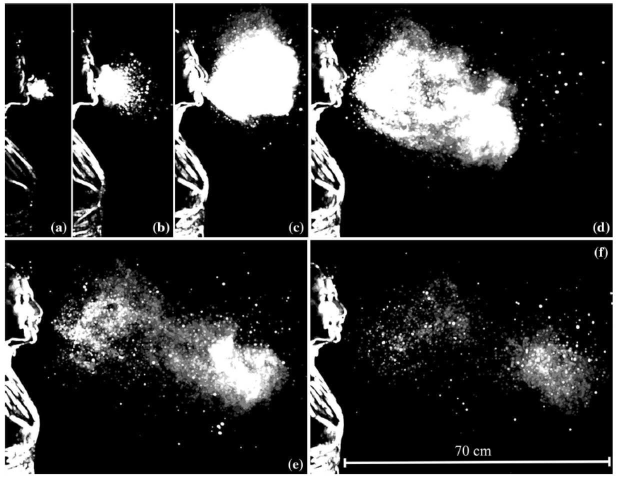
Evidence for SARS-CoV-2 Transmission in Air

- SARS-CoV-2 spreads through both direct (droplet and person-to-person) as well as indirect mechanisms (contaminated objects and airborne transmission) at the University of Nebraska Medical Center[14].
  - In the air samples collected in the hallway outside patient's rooms
  - In ventilation grate, indicating deposition of airborne virion on surfaces
- On surfaces of air exhaust duct screen and air-conditioning filter on a ferryboat and nursing home[18]
- Can be present on PM, thus suggesting a possibility of epidemic recurrence[19]
- SARS-CoV-2 remain viable in aerosol for 3 hours, and more stable on smooth surfaces of up to 84 hours[20, 21]

Aerosol Emissions in Small Environments

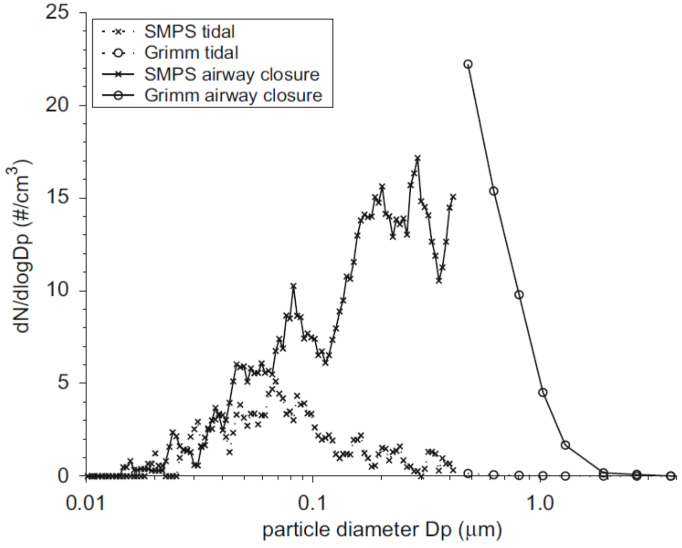


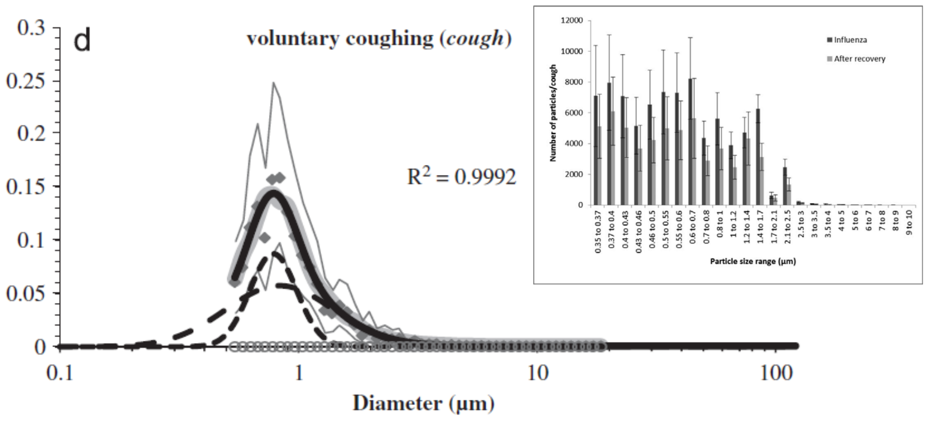


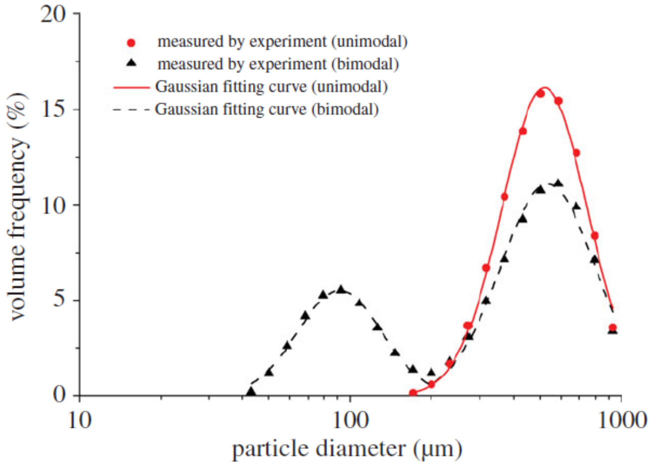


- Breathing, talking, coughing, or sneezing from patients[20, 22, 23, 24]
- Normal speaking causes airborne virus transmission in confined environments[15]
- Loud speech in a closed environment emits droplets larger than 4 µm and can be suspended in air for 8-14 minutes[15]
- Small droplets produced during speech and coughing which can remain viable and infectious in aerosols for 3 h[16]
- Aerosols reduce in size by half in 30 s to 5 min. depending on the ventilation rate in a room[17]

Aerosol Size Distributions in Small Environments







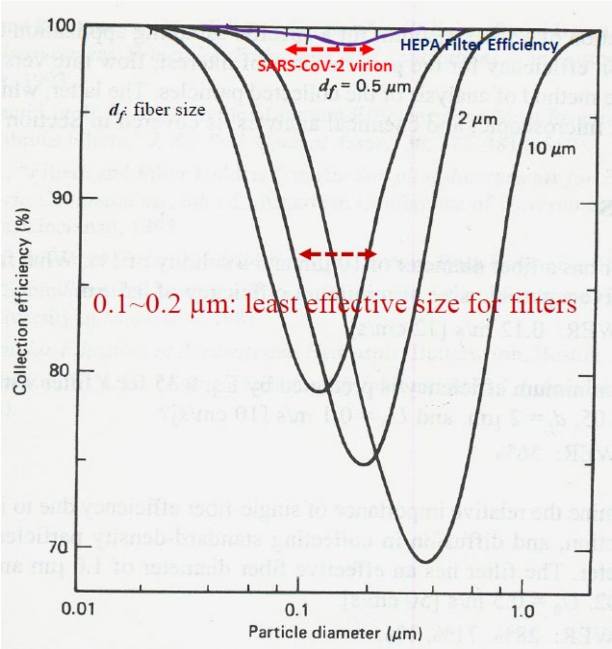
- Breathing[25, 26]
  - 0.01 – 2.0 µm
  - No difference among gender or age
  - Lognormally distributed

- Coughing[27, 28]
  - 0.35 – 10 µm
  - <Initial high expiratory airflow (up to 12 L/s)
  - 900 – 302,000 particles per cough

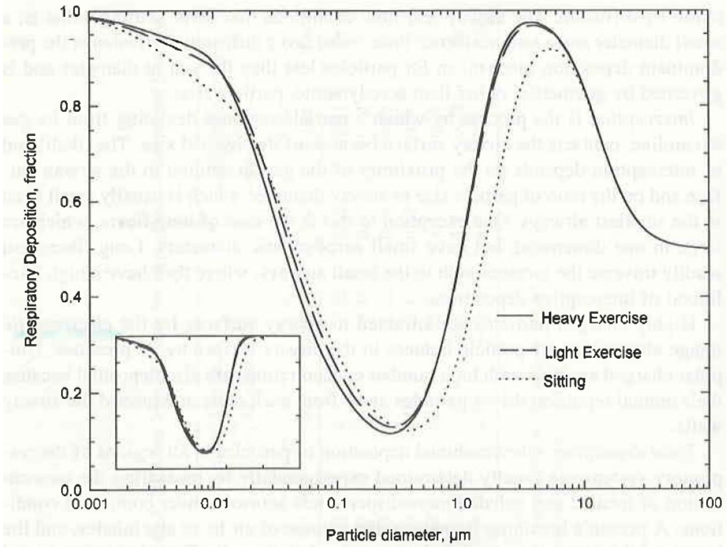
- Sneezing[29,30]
  - 160 – 1,000 µm
  - Bimodal distribution
  - Largest ligament 3 cm
  - Ejection speed: 35 m/s

Properties of involuntary exhaled aerosols

- Highest number counts in submicron range
- Highest mass concentration between 1 – 4 µm
- Rapid stopping in short distance after exhalation
- Rapid evaporation for dry virus in the air
- Longer suspension time in the air
- Less capture efficiency at the size of the virus



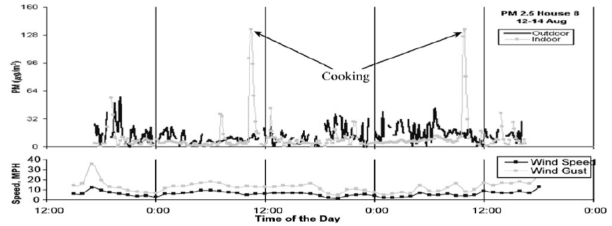
Size range µm	µm	#	Avg. size µm	Fraction #	Mass	Terminal Velocity m/sec	Stopping Distance m	Residence time Sec.	Evap. Time sec
0	0.1	0	0.05	0.00E+00	0.00E+00	3.78E-07	3.85E-06	3.89E+05	4.37E-06
0.1	0.37	6500	0.235	8.51E-02	6.67E-04	2.89E-06	1.50E-05	1.00E+05	9.66E-05
0.37	0.43	14000	0.4	1.83E-01	7.08E-03	6.85E-06	4.15E-05	3.62E+04	2.80E-04
0.43	0.5	10500	0.465	1.38E-01	8.34E-03	8.86E-06	5.52E-05	2.72E+04	3.78E-04
0.5	0.6	13000	0.55	1.70E-01	1.71E-02	1.19E-05	7.57E-05	1.98E+04	5.29E-04
0.6	0.7	7500	0.65	9.82E-02	1.63E-02	1.60E-05	1.04E-04	1.45E+04	7.39E-04
0.7	0.8	4000	0.75	5.24E-02	1.33E-02	2.07E-05	1.35E-04	1.11E+04	9.83E-04
0.8	1	5000	0.9	6.55E-02	2.88E-02	2.89E-05	1.90E-04	7.91E+03	1.42E-03
1	1.4	7500	1.2	9.82E-02	1.02E-01	4.94E-05	3.22E-04	4.67E+03	2.52E-03
1.4	2.5	7800	1.95	1.02E-01	4.57E-01	1.24E-04	7.73E-04	1.94E+03	6.65E-03
2.5	3	300	2.75	3.93E-03	4.93E-02	2.42E-04	1.42E-03	1.06E+03	1.32E-02
3	4	150	3.5	1.96E-03	5.08E-02	3.87E-04	2.17E-03	6.92E+02	2.14E-02
4	5	40	4.5	5.24E-04	2.88E-02	6.33E-04	3.34E-03	4.49E+02	3.54E-02
5	10	66	7.5	8.64E-04	2.20E-01	1.73E-03	7.93E-03	1.89E+02	9.83E-02
10	35	0	22.5	0.00E+00	0.00E+00	1.54E-02	4.71E-02	3.18E+01	8.85E-01
35	100	0	67.5	0.00E+00	0.00E+00	1.38E-01	2.56E-01	5.85E+00	7.97E+00



1. Based on Vo = 100 m/sec; 2. Based on a breathing height of 1.5 m3. Based on pure water droplets; * Calculated from AEROCALC[31, 32]

Dispersion in Small Environments

- Small environments associated with transportation facilities are: truck cabin, bus, passenger vehicles, cruise ship cabin, aircraft fuselage
- Air exchange with outside air
- Rapid initial mixing[34]

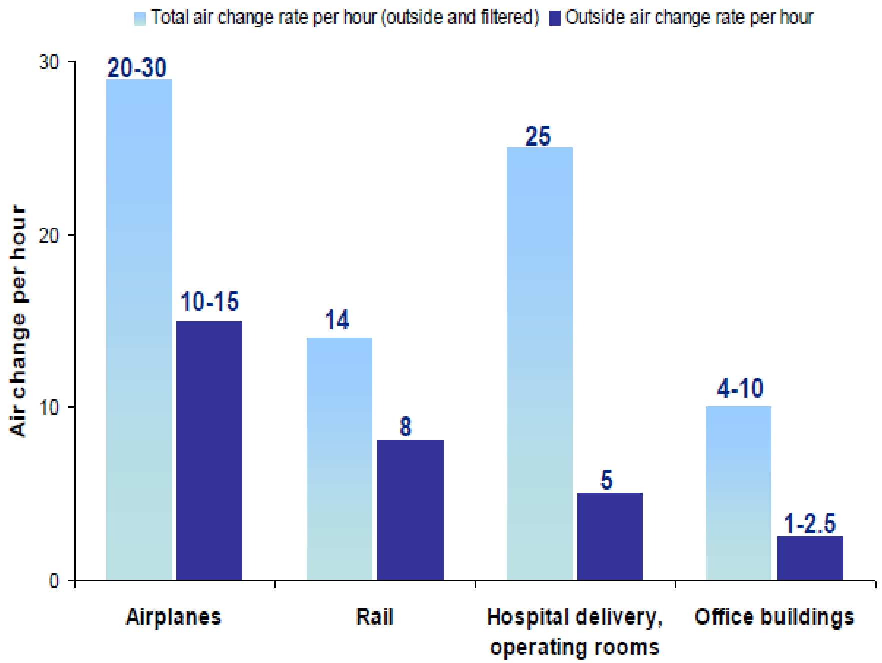


- Virus can spread over a long range and long time
- Ventilation helps spread the virus but also dilute the concentration
- Indoor environments pose higher risks than outdoors

Interior space and air change rate for various transportation vessels

Vehicle		**Interior Space**	**Air Change, #/hr**	
		m^3	Fan off	Ventilation
Passenger	Subcompact	<2.4	1-6.6	8-50
	Compact	3	1-6.6	8-50
	Mid-size	3.2	1-6.6	8-50
Wagen	Small	>3.4	1-6.6	8-50
	Mid-size	3.7	1-6.6	8-50
	Large	4.5	1-6.6	8-50
School Bus				
	Small	30	-	Varies
	Mid-size	45	-	Varies
	Large	56	2.6-4.6 (a)	Varies
Airplane		Multiple Chamber	20-30	

Air change rate for aircraft (Boeing 787) and other facilities[33]



Ratio of Indoor Air Concentration to Initial Air Concentration, $C_{in}(t)/C_s$

t(min)/n (ac)	1	2	3	4	5	7.5	10	12.5	15	17.5	20	25	30	35	40	45	50	60
0	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
1	9.83E-01	9.67E-01	9.51E-01	9.36E-01	9.20E-01	8.82E-01	8.46E-01	8.12E-01	7.79E-01	7.47E-01	7.17E-01	6.59E-01	6.07E-01	5.58E-01	5.13E-01	4.72E-01	4.35E-01	3.68E-01
2	9.67E-01	9.36E-01	9.05E-01	8.75E-01	8.46E-01	7.79E-01	7.17E-01	6.59E-01	6.07E-01	5.58E-01	5.13E-01	4.35E-01	3.68E-01	3.11E-01	2.64E-01	2.23E-01	1.89E-01	1.35E-01
3	9.51E-01	9.05E-01	8.61E-01	8.19E-01	7.79E-01	6.87E-01	6.07E-01	5.35E-01	4.72E-01	4.17E-01	3.68E-01	2.87E-01	2.23E-01	1.74E-01	1.35E-01	1.05E-01	8.21E-02	4.98E-02
4	9.36E-01	8.75E-01	8.19E-01	7.66E-01	7.17E-01	6.07E-01	5.13E-01	4.35E-01	3.68E-01	3.11E-01	2.64E-01	1.89E-01	1.35E-01	9.70E-02	6.95E-02	4.98E-02	3.57E-02	1.83E-02
5	9.20E-01	8.46E-01	7.79E-01	7.17E-01	6.59E-01	5.35E-01	4.35E-01	3.53E-01	2.87E-01	2.33E-01	1.89E-01	1.25E-01	8.21E-02	5.41E-02	3.57E-02	2.35E-02	1.55E-02	6.74E-03
6	9.05E-01	8.19E-01	7.41E-01	6.70E-01	6.07E-01	4.72E-01	3.68E-01	2.87E-01	2.23E-01	1.74E-01	1.35E-01	8.21E-02	4.98E-02	3.02E-02	1.83E-02	1.11E-02	6.74E-03	2.48E-03
7	8.90E-01	7.92E-01	7.05E-01	6.27E-01	5.58E-01	4.17E-01	3.11E-01	2.33E-01	1.74E-01	1.30E-01	9.70E-02	5.41E-02	3.02E-02	1.69E-02	9.40E-03	5.25E-03	2.93E-03	9.12E-04
8	8.75E-01	7.66E-01	6.70E-01	5.87E-01	5.13E-01	3.68E-01	2.64E-01	1.89E-01	1.35E-01	9.70E-02	6.95E-02	3.57E-02	1.83E-02	9.40E-03	4.83E-03	2.48E-03	1.27E-03	3.35E-04
9	8.61E-01	7.41E-01	6.38E-01	5.49E-01	4.72E-01	3.25E-01	2.23E-01	1.53E-01	1.05E-01	7.24E-02	4.98E-02	2.35E-02	1.11E-02	5.25E-03	2.48E-03	1.17E-03	5.53E-04	1.23E-04
10	8.46E-01	7.17E-01	6.07E-01	5.13E-01	4.35E-01	2.87E-01	1.89E-01	1.25E-01	8.21E-02	5.41E-02	3.57E-02	1.55E-02	6.74E-03	2.93E-03	1.27E-03	5.53E-04	2.40E-04	4.54E-05
12	8.19E-01	6.70E-01	5.49E-01	4.49E-01	3.68E-01	2.23E-01	1.35E-01	8.21E-02	4.98E-02	3.02E-02	1.83E-02	6.74E-03	2.48E-03	9.12E-04	3.35E-04	1.23E-04	4.54E-05	6.14E-06
14	7.92E-01	6.27E-01	4.97E-01	3.93E-01	3.11E-01	1.74E-01	9.70E-02	5.41E-02	3.02E-02	1.69E-02	9.40E-03	2.93E-03	9.12E-04	2.84E-04	8.84E-05	2.75E-05	8.57E-06	8.32E-07
16	7.66E-01	5.87E-01	4.49E-01	3.44E-01	2.64E-01	1.35E-01	6.95E-02	3.57E-02	1.83E-02	9.40E-03	4.83E-03	1.27E-03	3.35E-04	8.84E-05	2.33E-05	6.14E-06	1.62E-06	1.13E-07
18	7.41E-01	5.49E-01	4.07E-01	3.01E-01	2.23E-01	1.05E-01	4.98E-02	2.35E-02	1.11E-02	5.25E-03	2.48E-03	5.53E-04	1.23E-04	2.75E-05	6.14E-06	1.37E-06	3.06E-07	1.52E-08
20	7.17E-01	5.13E-01	3.68E-01	2.64E-01	1.89E-01	8.21E-02	3.57E-02	1.55E-02	6.74E-03	2.93E-03	1.27E-03	2.40E-04	4.54E-05	8.57E-06	1.62E-06	3.06E-07	5.78E-08	2.06E-09
22	6.93E-01	4.80E-01	3.33E-01	2.31E-01	1.60E-01	6.39E-02	2.56E-02	1.02E-02	4.09E-03	1.63E-03	6.53E-04	1.04E-04	1.67E-05	2.67E-06	4.27E-07	6.83E-08	1.09E-08	2.79E-10
24	6.70E-01	4.49E-01	3.01E-01	2.02E-01	1.35E-01	4.98E-02	1.83E-02	6.74E-03	2.48E-03	9.12E-04	3.35E-04	4.54E-05	6.14E-06	8.32E-07	1.13E-07	1.52E-08	2.06E-09	3.78E-11
26	6.48E-01	4.20E-01	2.73E-01	1.77E-01	1.15E-01	3.88E-02	1.31E-02	4.44E-03	1.50E-03	5.09E-04	1.72E-04	1.97E-05	2.26E-06	2.59E-07	2.97E-08	3.40E-09	3.89E-10	5.11E-12
28	6.27E-01	3.93E-01	2.47E-01	1.55E-01	9.70E-02	3.02E-02	9.40E-03	2.93E-03	9.12E-04	2.84E-04	8.84E-05	8.57E-06	8.32E-07	8.06E-08	7.82E-09	7.58E-10	7.35E-11	6.91E-13
30	6.07E-01	3.68E-01	2.23E-01	1.35E-01	8.21E-02	2.35E-02	6.74E-03	1.93E-03	5.53E-04	1.58E-04	4.54E-05	3.73E-06	3.06E-07	2.51E-08	2.06E-09	1.69E-10	1.39E-11	9.36E-14
35	5.58E-01	3.11E-01	1.74E-01	9.70E-02	5.41E-02	1.26E-02	2.93E-03	6.81E-04	1.58E-04	3.69E-05	8.57E-06	4.64E-07	2.51E-08	1.36E-09	7.35E-11	3.98E-12	2.15E-13	6.31E-16
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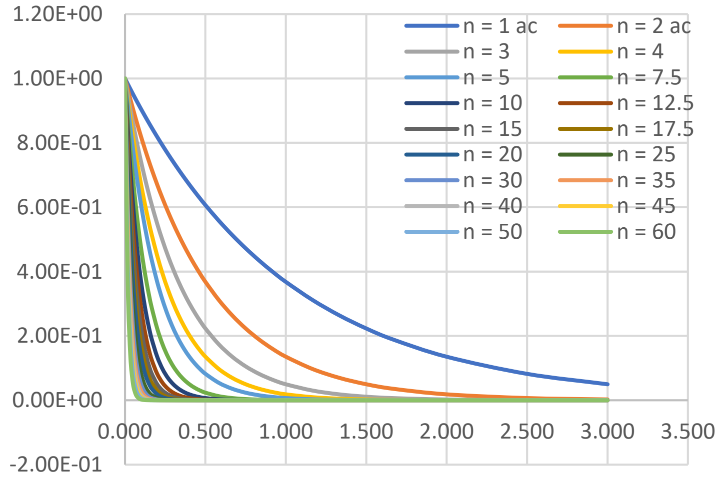
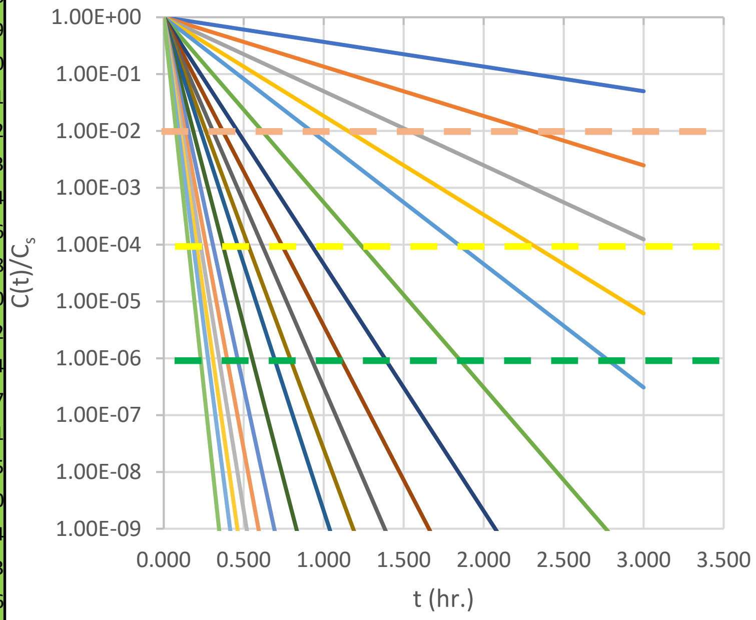
45	4.72E-01	2.23E-01	1.05E-01	4.98E-02	2.35E-02	3.61E-03	5.53E-04	8.48E-05	1.30E-05	1.99E-06	3.06E-07	7.19E-09	1.69E-10	3.98E-12	9.36E-14	2.20E-15	5.18E-17	2.86E-20
50	4.35E-01	1.89E-01	8.21E-02	3.57E-02	1.55E-02	1.93E-03	2.40E-04	2.99E-05	3.73E-06	4.64E-07	5.78E-08	8.96E-10	1.39E-11	2.15E-13	3.34E-15	5.18E-17	8.02E-19	1.93E-22
55	4.00E-01	1.60E-01	6.39E-02	2.56E-02	1.02E-02	1.03E-03	1.04E-04	1.06E-05	1.07E-06	1.08E-07	1.09E-08	1.12E-10	1.14E-12	1.17E-14	1.19E-16	1.22E-18	1.24E-20	1.30E-24
60	3.68E-01	1.35E-01	4.98E-02	1.83E-02	6.74E-03	5.53E-04	4.54E-05	3.73E-06	3.06E-07	2.51E-08	2.06E-09	1.39E-11	9.36E-14	6.31E-16	4.25E-18	2.86E-20	1.93E-22	8.76E-27
70	3.11E-01	9.70E-02	3.02E-02	9.40E-03	2.93E-03	1.58E-04	8.57E-06	4.64E-07	2.51E-08	1.36E-09	7.35E-11	2.15E-13	6.31E-16	1.85E-18	5.41E-21	1.58E-23	4.64E-26	3.98E-31
80	2.64E-01	6.95E-02	1.83E-02	4.83E-03	1.27E-03	4.54E-05	1.62E-06	5.78E-08	2.06E-09	7.35E-11	2.62E-12	3.34E-15	4.25E-18	5.41E-21	6.88E-24	8.76E-27	1.11E-29	1.80E-35
90	2.23E-01	4.98E-02	1.11E-02	2.48E-03	5.53E-04	1.30E-05	3.06E-07	7.19E-09	1.69E-10	3.98E-12	9.36E-14	5.18E-17	2.86E-20	1.58E-23	8.76E-27	4.84E-30	2.68E-33	8.19E-40
100	1.89E-01	3.57E-02	6.74E-03	1.27E-03	2.40E-04	3.73E-06	5.78E-08	8.96E-10	1.39E-11	2.15E-13	3.34E-15	8.02E-19	1.93E-22	4.64E-26	1.11E-29	2.68E-33	6.44E-37	3.72E-44
120	1.35E-01	1.83E-02	2.48E-03	3.35E-04	4.54E-05	3.06E-07	2.06E-09	1.39E-11	9.36E-14	6.31E-16	4.25E-18	1.93E-22	8.76E-27	3.98E-31	1.80E-35	8.19E-40	3.72E-44	7.67E-53
150	8.21E-02	6.74E-03	5.53E-04	4.54E-05	3.73E-06	7.19E-09	1.39E-11	2.68E-14	5.18E-17	9.99E-20	1.93E-22	7.19E-28	2.68E-33	9.98E-39	3.72E-44	1.39E-49	5.17E-55	7.18E-66
180	4.98E-02	2.48E-03	1.23E-04	6.14E-06	3.06E-07	1.69E-10	9.36E-14	5.18E-17	2.86E-20	1.58E-23	8.76E-27	2.68E-33	8.19E-40	2.51E-46	7.67E-53	2.35E-59	7.18E-66	6.71E-79





Exposure Reduction

Source Emission — Eliminate Emission

- Isolate the spreader
- Apply negative pressure and HEPA filter
- Increase ventilation
- Apply disinfectants
- Mask the spreader

Transport of Pollutant — Enhance Dispersion

- Increase ventilation/air flow
- Upwind or higher location
- Avoid adverse meteorology when outdoor
- Keep sufficient distance

Exposure at Receptor — Reduce dose

- Stop breathing at the source for the 1st minute
- Increase ventilation
- Apply sanitizer
- Seek upwind and higher locations
- Keep sufficient distance
- Wear mask/Use air filter
- Vaccination

Summary

- Transport of virus in the air is well studied with a good level of confidence
- Uncertainties remain in the quantification of emissions, survival rate or half life of the virus, threshold of infection.
- Ventilation enhances dispersion and reduces the exposure concentration of virus.
- In a small environment, exposure of >1 % of the virus emitted from a spreader continues for at least 10 minutes
- If the virus exists with the same toxicity in the air, any social distance will not be safe
- Virus continues to stay in a small environment at a level of $>10^{-4}$ strength for up to 3 hours depending on the air change rate
- Air pollution prevention and reduction measures are applicable to the prevention of SARS-CoV-2
- Masking appears to be the most direct and effective preventive measure at this juncture besides vaccination.

Thank you for your attention!

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THE UNIVERSITY OF TEXAS AT EL PASO
COLLEGE OF ENGINEERING

MOVING TOWARDS A MORE SUSTAINABLE "NEW NORMAL" - A CASE STUDY OF EL PASO, TEXAS

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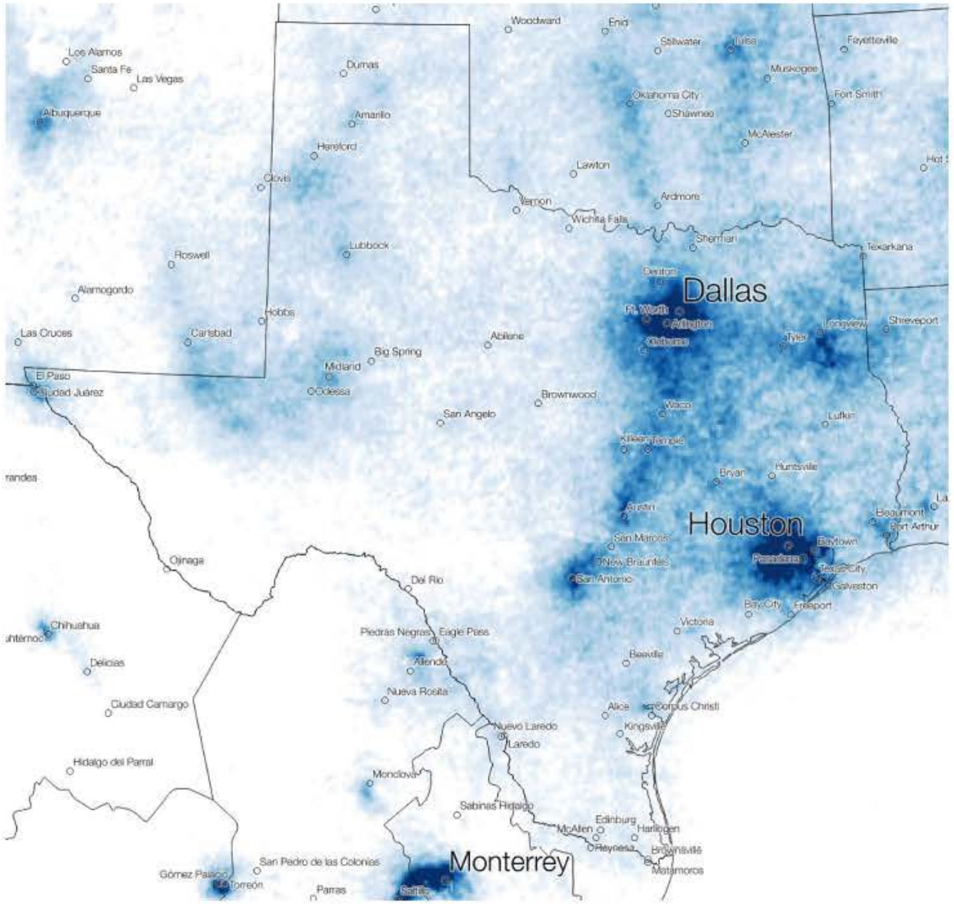
Center for Advancing Research In Transportation Emissions, Energy, and Health (CARTEEH)
Texas A&M Transportation Institute

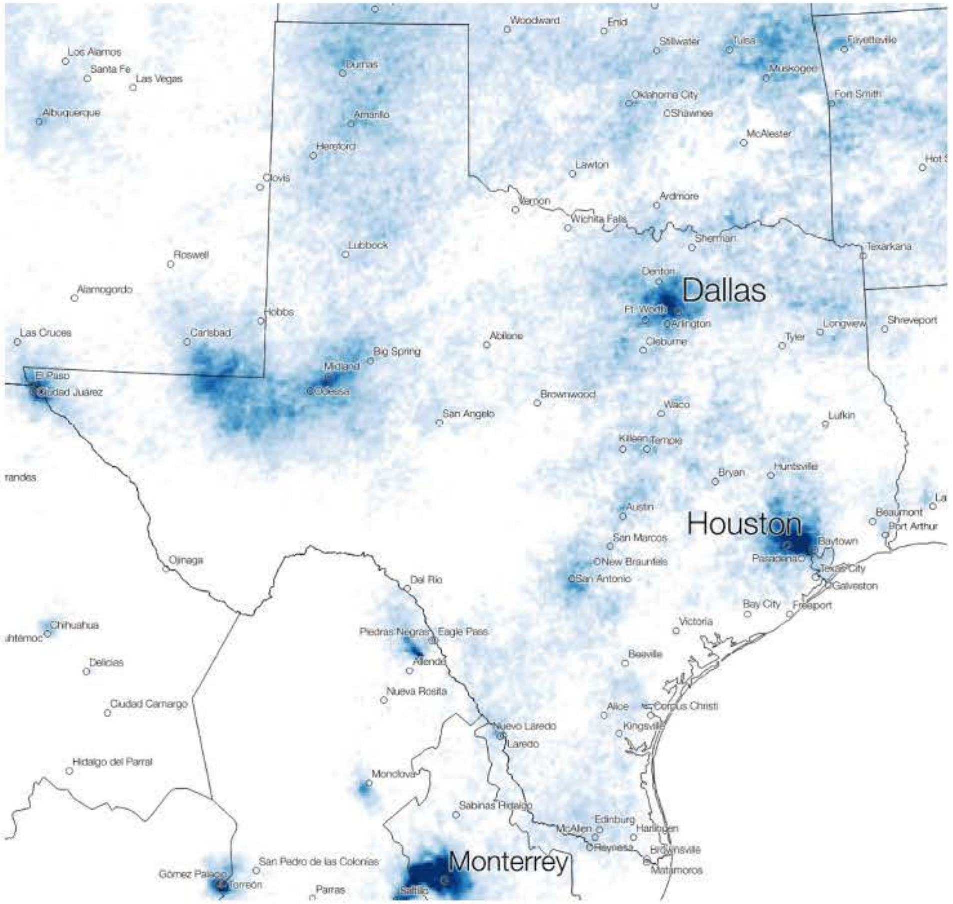
Background

Texas Nitrogen Dioxide (NO_2) Level

Feb, 2020



Week of March 29, 2020



Source:
(Descartes Labs Inc, 2020)

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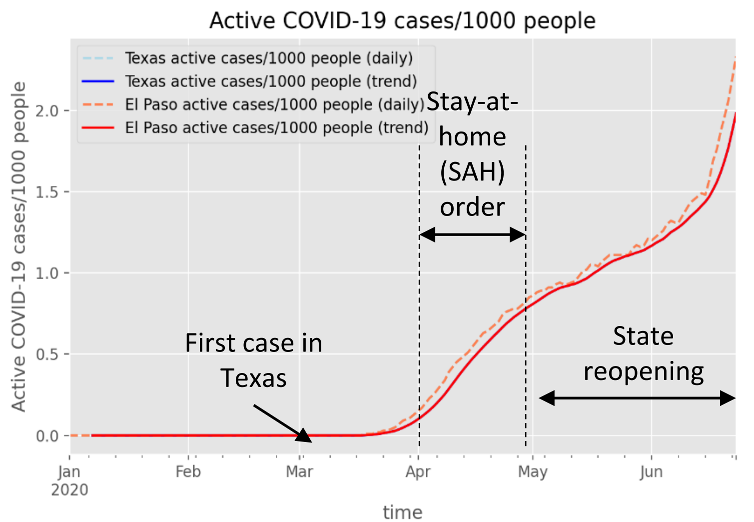
Passenger Travel Trends in Texas during COVID-19

Data Source:

- University of Maryland (UMD) COVID-19 Impact Analysis Platform (https://data.covid.umd.edu/)

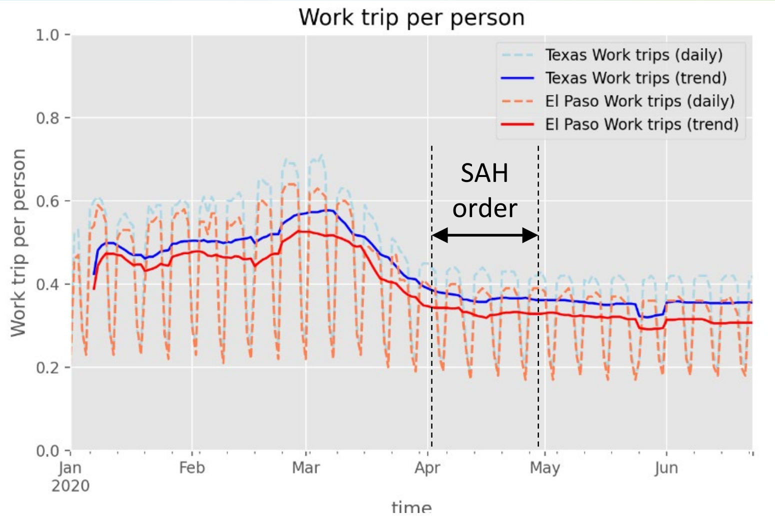
Active cases /1000 people

(Derived from JHU COVID-19 data)



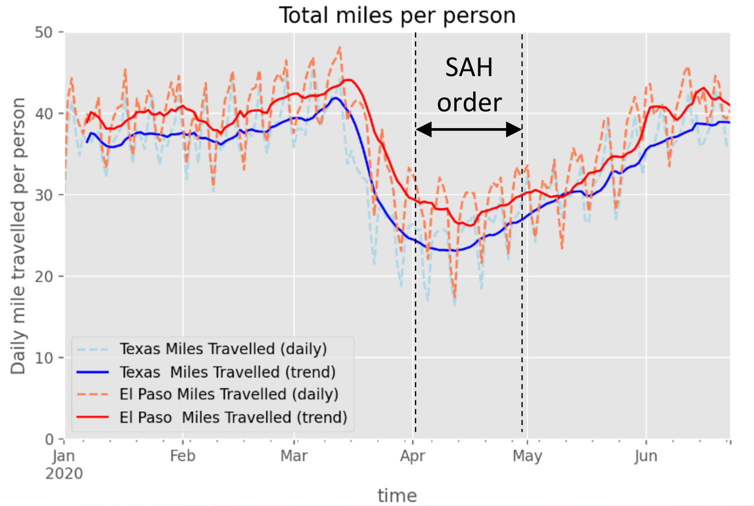
Work trips /person

(mobile device data, trip purpose tagged using geo location)



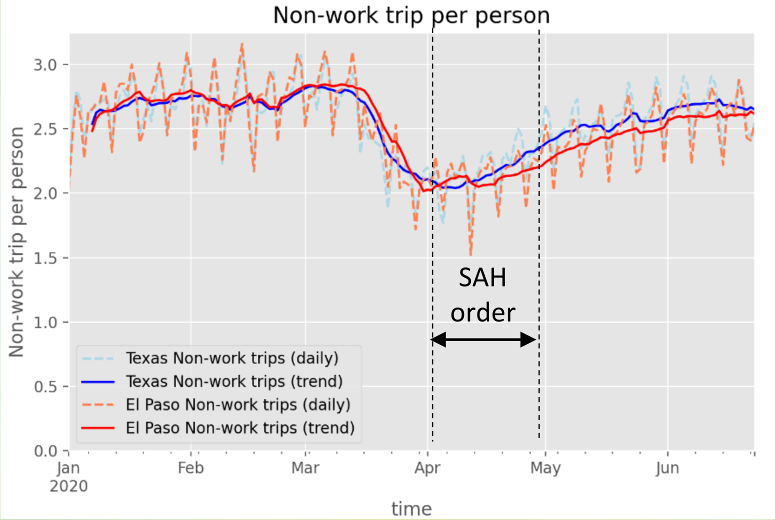
Total miles /person

(movement data collected from mobile devices)



Non-work trips /person

(mobile device data, trip purpose tagged using geo location)



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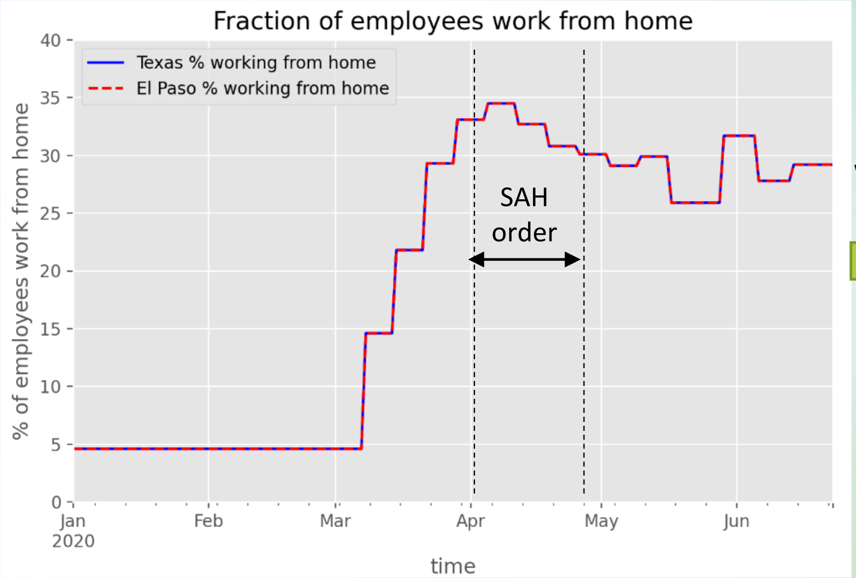
Work Trip Trends in Texas

% work from home

(Estimated by UMD based on other work –related attributes)

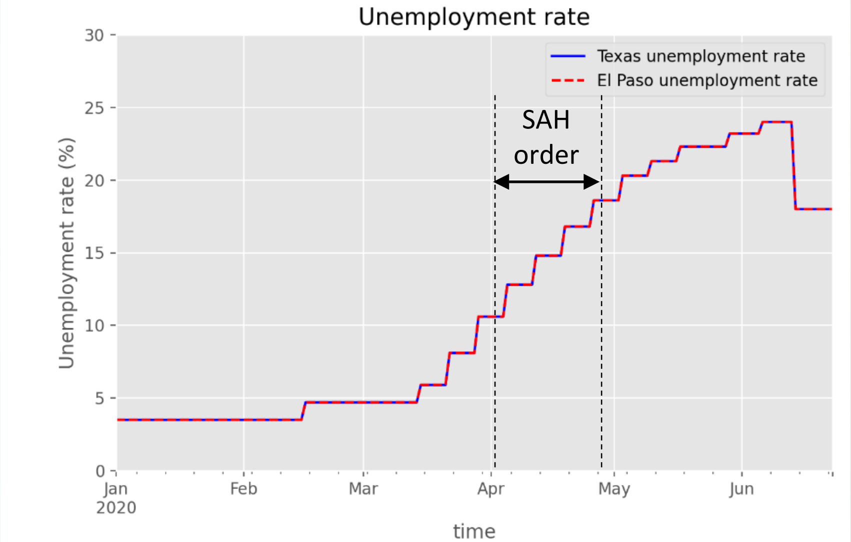


Work from home

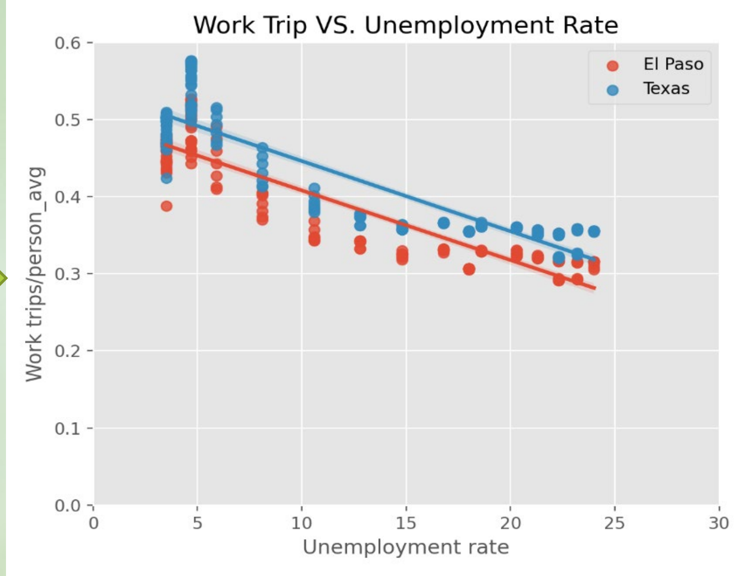
Work trip/person VS. % work from home

Unemployment rate

(Calculated using data from department of labor)



Unemployment



Work trip/person VS. Unemployment rate

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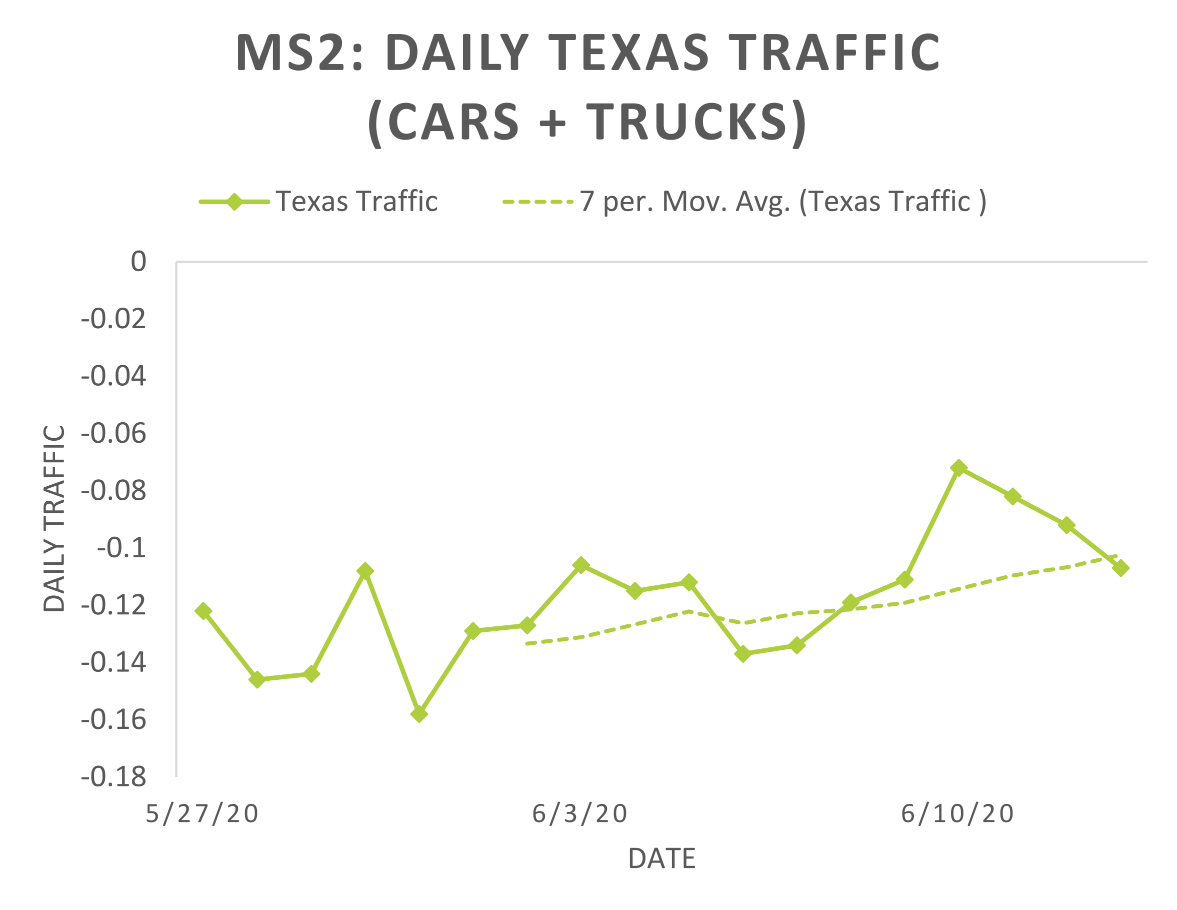
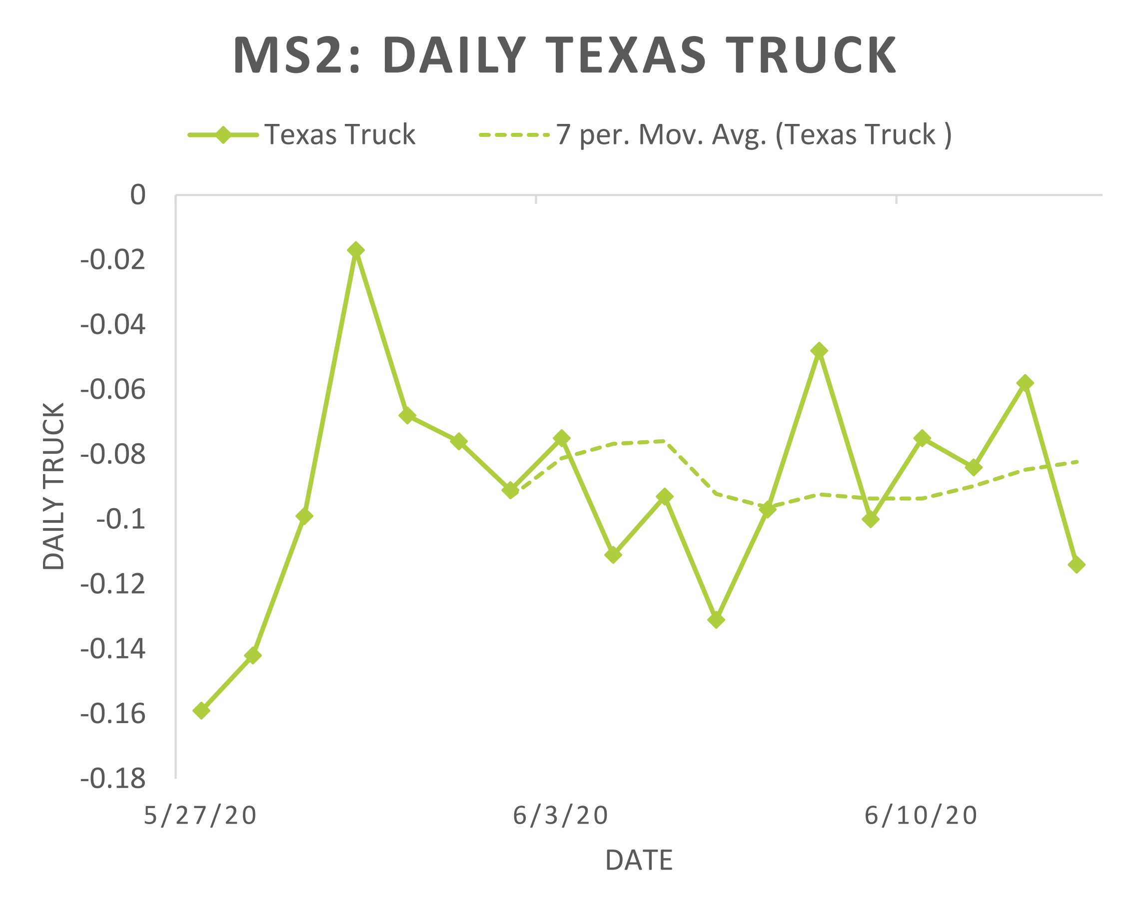
Truck Traffic Trends in Texas during COVID-19

Traffic Reduction Compared to the Traffic from the Same Time Previous Year





MS2 Software. Traffic Dashboard. https://www.ms2soft.com/traffic-dashboard.

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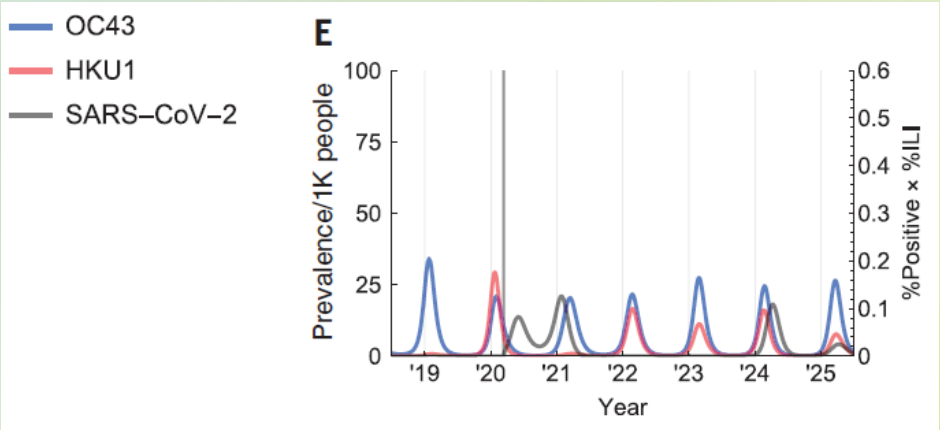
Plausible Post-COVID Scenarios

Could work from home become the ‘new normal’?

- 37% of U.S. jobs can be done completely at home (Dingel and Neiman, 2020)
- The immunity of COVID-19 may not be permanent and we may face seasonal outbreak (Kissler, et al. 2020)
  - Social distance may be needed in the long-term
- After adaption to remote working culture, some companies allow their employees to work from home in the long term
  - Amazon, Facebook, Twitter, etc. have announced long-term plan to support remote working



Forecasted seasonal resurgence of COVID-19

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An Envisioned Texas Sustainable ‘New Normal’

Assumption Overview

- Work-from-home is supported at the maximum level
  - In Texas, up to **30%** of employees continue to work from home
  - Non-work trips return to pre-pandemic levels
- Economic recovered to pre-pandemic-level
  - Unemployment = **3.5%**
  - Freight movement going back to normal
  - EV sales unaffected, and will reach **6%** penetration by 2030
- Other transportation mode returned to pre-pandemic level
  - Transit, bike, walk, etc.

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An Envisioned Texas Sustainable ‘New Normal’-cont.

Methodology Overview

- Performed a case study of El Paso, TX
- Full-chain analysis using TEMPO

https://tempo-dashboard.io/home

- Baseline traffic represent business-as-usual case with pre-pandemic traffic
- Full results: http://54.159.31.130:3838/

Percent reduction compared to baseline	**Post-COVID:** 18% work trip reduction	**Post-COVID + EV:** 18% work trip reduction + 6% EVs among LDVs
VMT	3.5%	3.5%
Delay	10%	10%
CO_2	3.5%	7.3%
NO_X	1.8%	2.7%
$PM_{2.5}$	1.8%	2.5%

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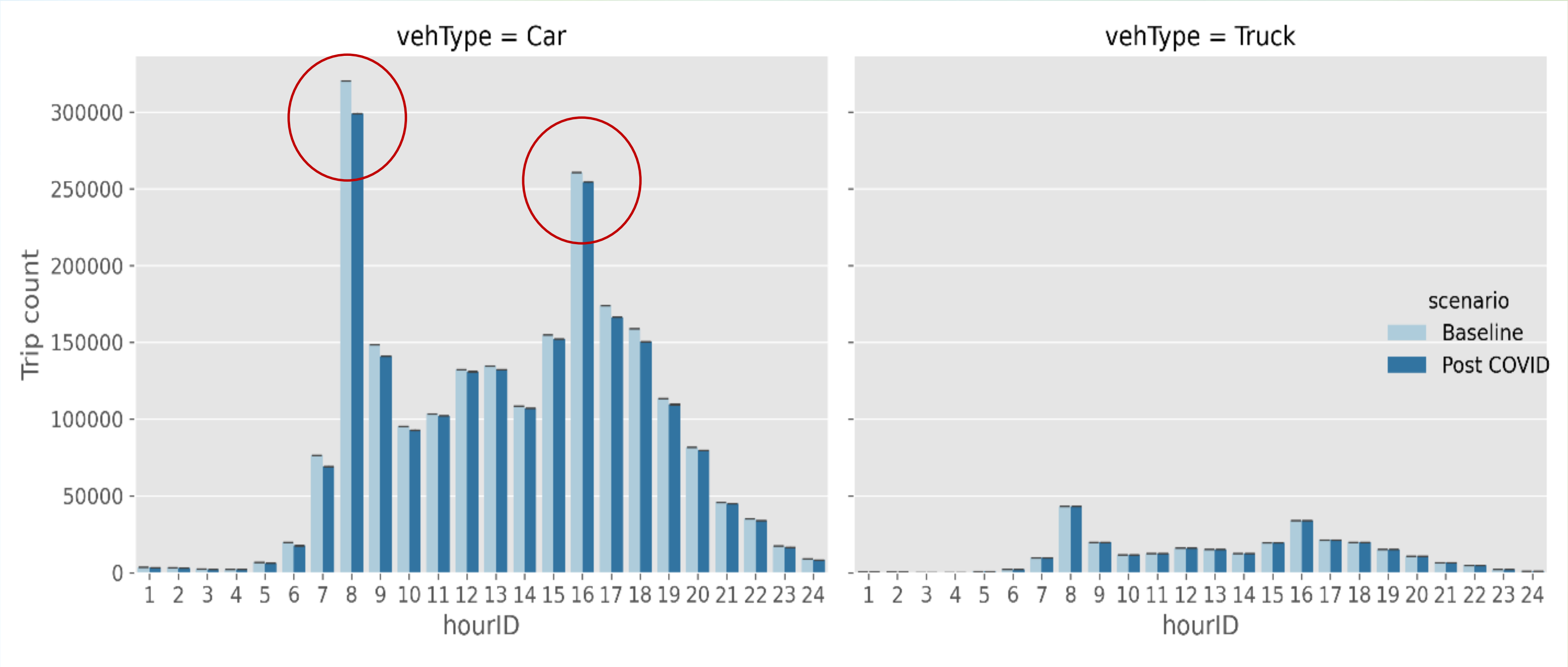
Post-pandemic Travel Demand

- Work trip reduction come from % work from home and unemployment rate
- Developed a linear regression model using UMD data
- 18% of work trips can be reduced if % work from home increase from 5% (pre-COVID) to 30% (post-COVID), without reduction from unemployment rate



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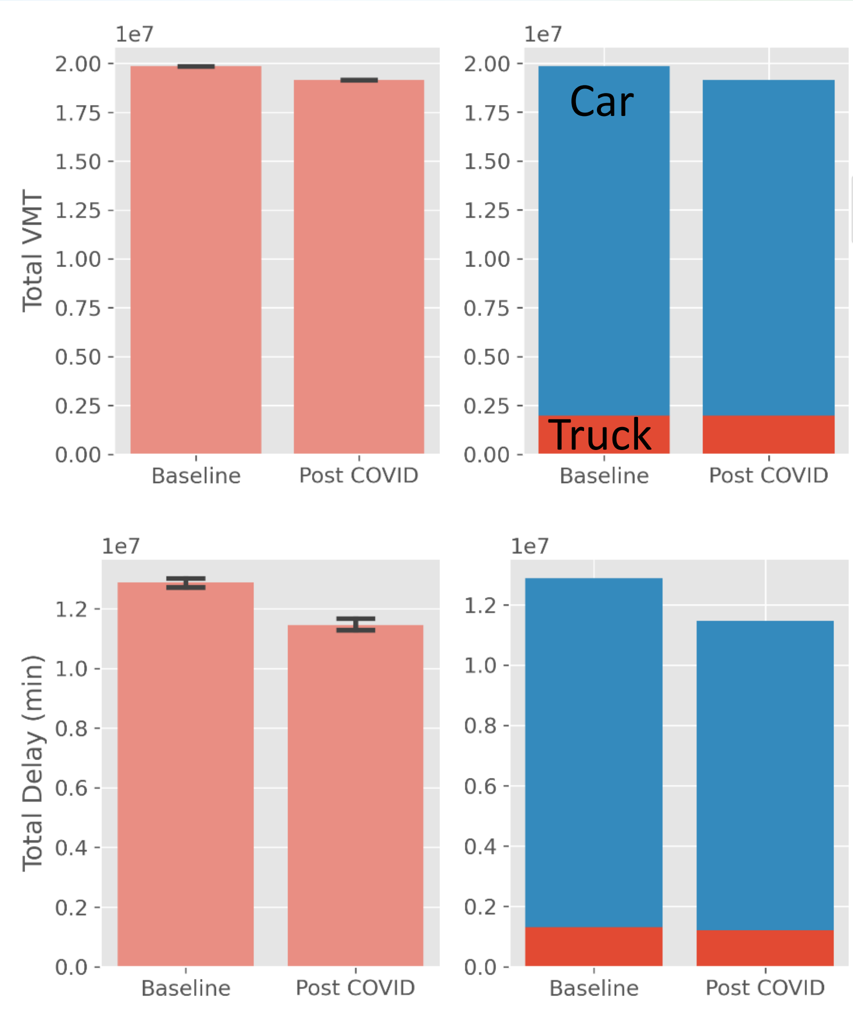
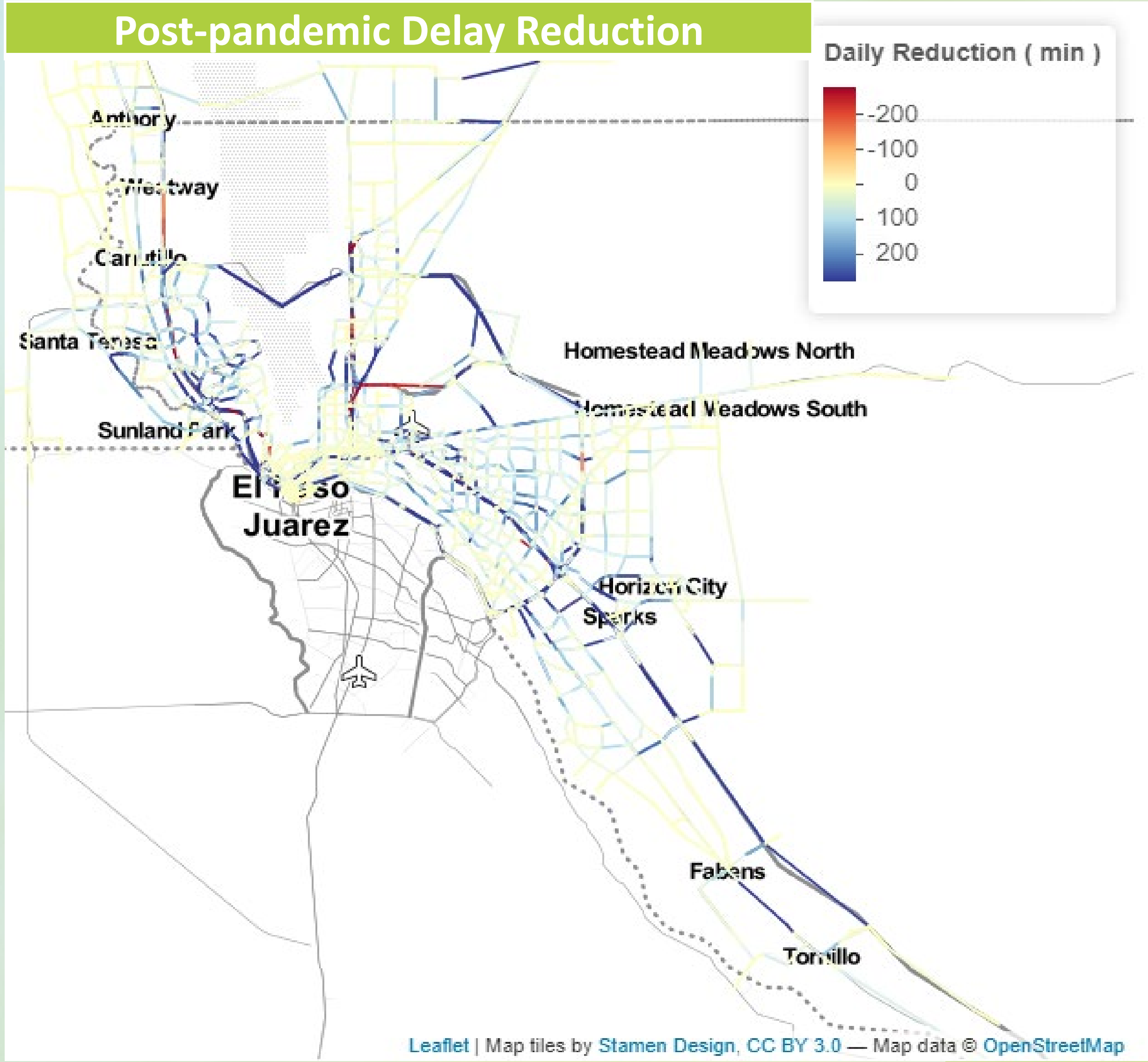
Post-pandemic Congestion Impact

- With 18% work trips removed

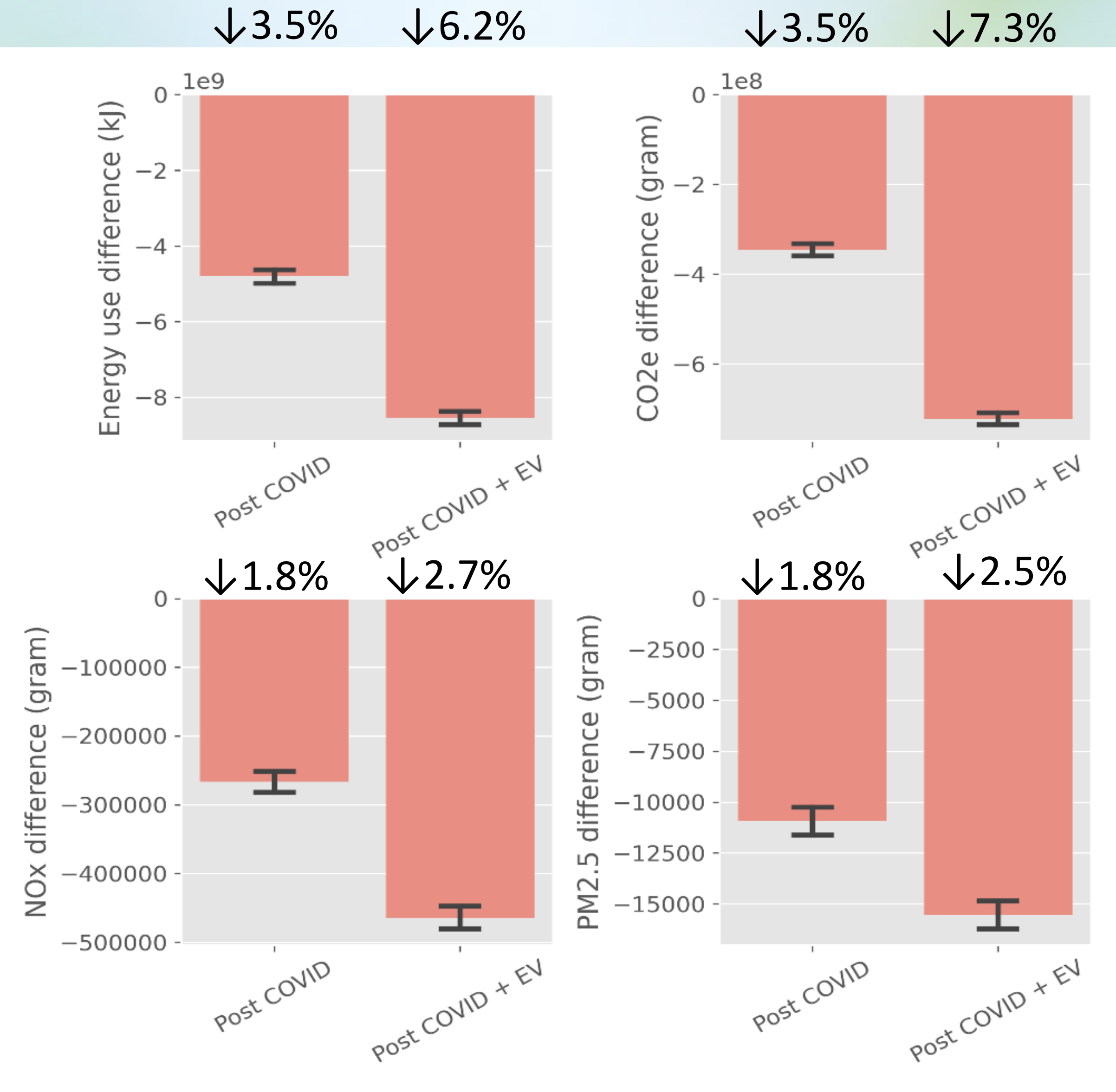
Daily VMT ↓ 3.5%

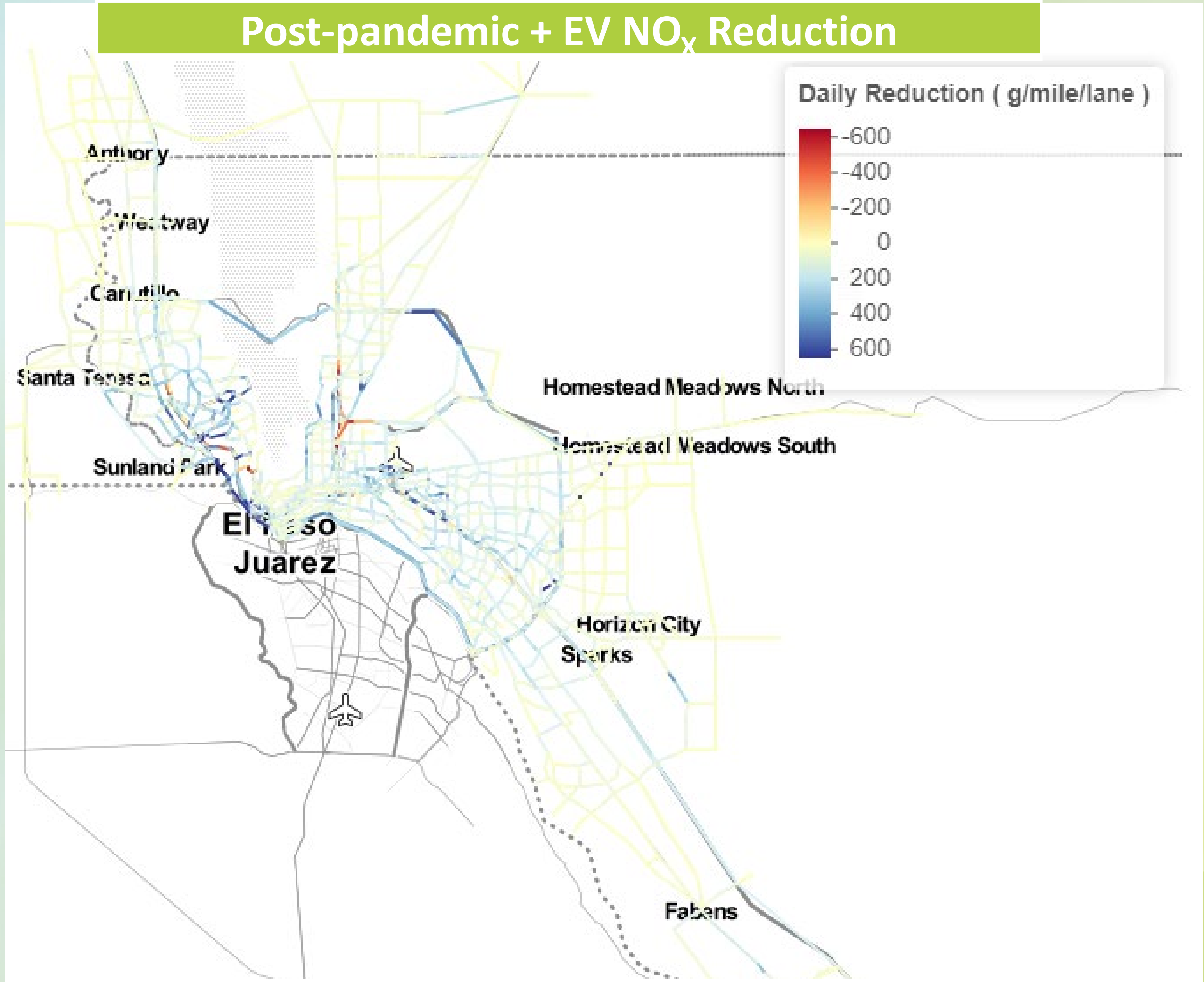


Total Delay ↓ 10%



Post-pandemic Emission Reduction





Assumes 6% EVs among LDVs (https://www.iea.org/commentaries/as-the-covid-19-crisis-hammers-the-auto-industry-electric-cars-remain-a-bright-spot)

Leaflet | Map tiles by Stamen Design, CC BY 3.0 — Map data © OpenStreetMap

Findings

- In Texas, work trips dropped during COVID-19 pandemic, with no immediate trends going back to normal
- The work trip reduction can be attributed to more employees work from home and growing unemployment rate
- If the work culture shift and EV sales trends can last after the pandemic, we can expect:
  - Less travel demand and less congestion
  - Some emission reductions
- To move towards a more sustainable ‘new normal’:
  - Work from home is an effective pathway to reduce congestion and emissions
  - We need additional strategies for meaningful air quality benefits

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On-going TTI Projects (tentative)

- Post-pandemic scenario planning
  - Disease outbreak and economic impact (UMD data from January to November, 2020)
  - Demographic pattern changes (Census data, expected March 2021)
  - Travel trends for all transportation modes (TxDOT traffic count, expected mid 2021 after FHWA review)
- Emission analysis for major metropolitan areas
  - Houston
  - Dallas
  - El Paso

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Questions, Answers, and Discussion