Prepared for OCTA & SCAG MTF

Dynamic Improvements in Transportation Demand Forecasting (TDF): Mode Swing Modeling

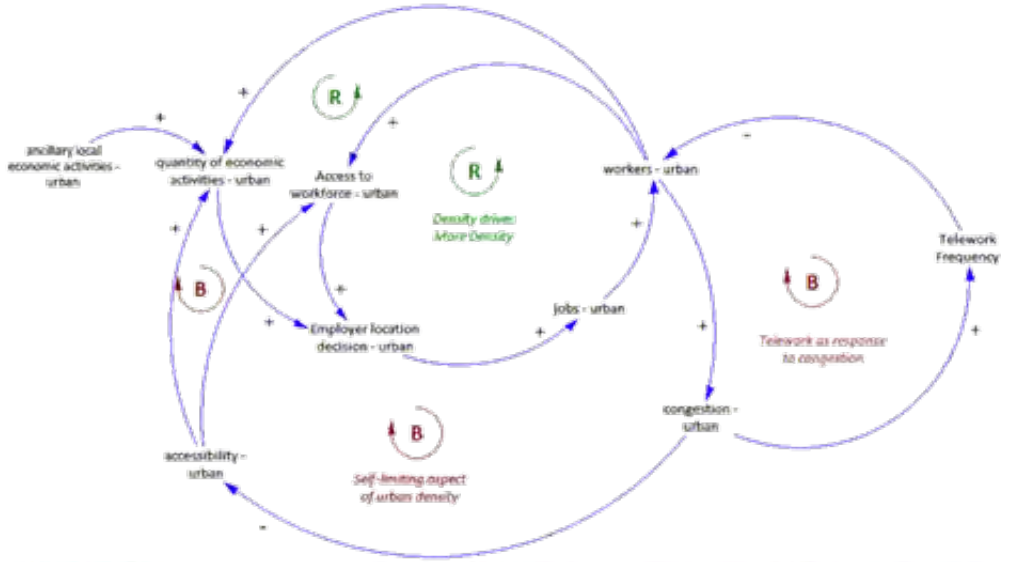
Alan Rao, Ph.D.

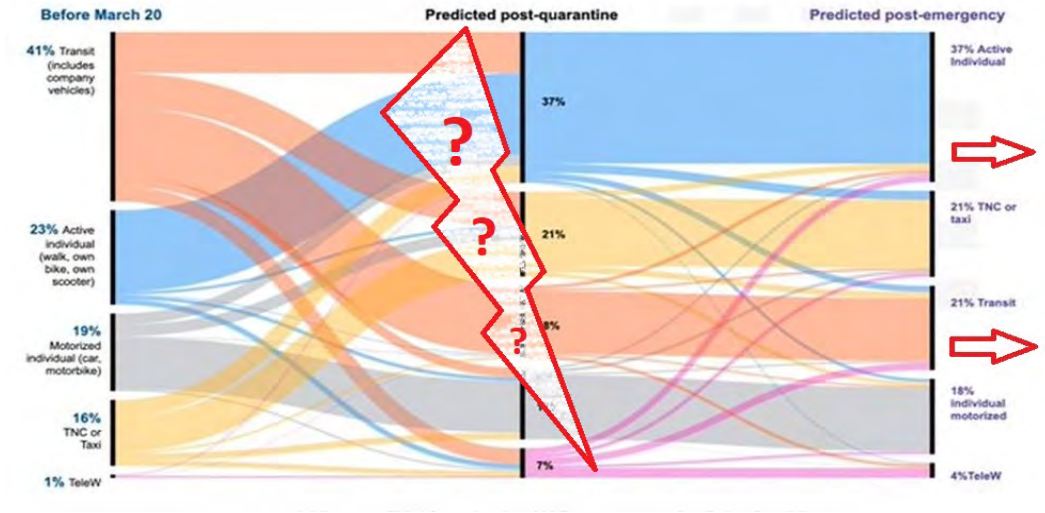
Olivia Gillham, Adrian Hellman, & Scott Lian

September 2021

Presentation Outline

- The Pandemic Challenge
- Volpe Innovation Accelerator (VIA)
- Our Team Proposals
  - Sentiment Analysis (SA-NLP)
  - System Dynamics (SD)
  - Mode Swing Dynamic Forecast (MSDF)
- Data and Case Studies
- Summary and Discussion





U.S. Department of Transportation Volpe Center

COVID-19: Challenges & Opportunities

- Before the Pandemic
  - ITS brought more real time data
  - Flexible schedules & telework
  - Transit-oriented development
  - Ridesharing & TNC services
  - Online shopping & geek economy
- Accelerated changes in IT
  - AI/Machine Learning & Data Sciences
  - Resiliency & Disaster Recovery
- Pandemic Disruptions
  - Shutdown & social distancing
  - Maximum telework (WFH)
  - Unemployment & job losses
  - Online shopping & food delivery
- A Prolonged Recovery
  - Job opportunities
  - Risk perception & vaccines
  - Local policy + social impacts

What We Missed with Travel Demand Forecasting (TDF)

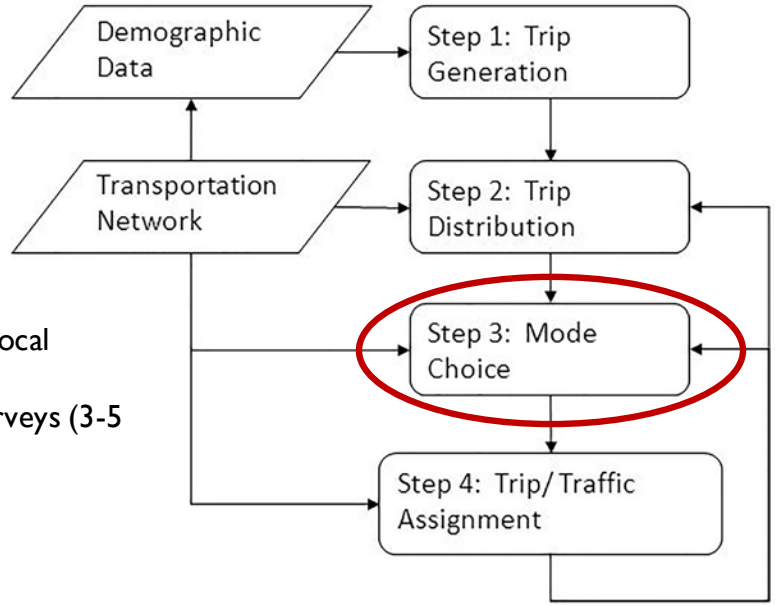
Transportation (Travel) Demand Forecasting (TDF) focus is on car trips and long-term trends, limitations from old static data and a car/transit focus.

- **Mode Choice**: Transit vs. WFH + Carpool vs. TNC + Bike/Walk/ vs. Park'n Ride

Planning organizations have more data than before:

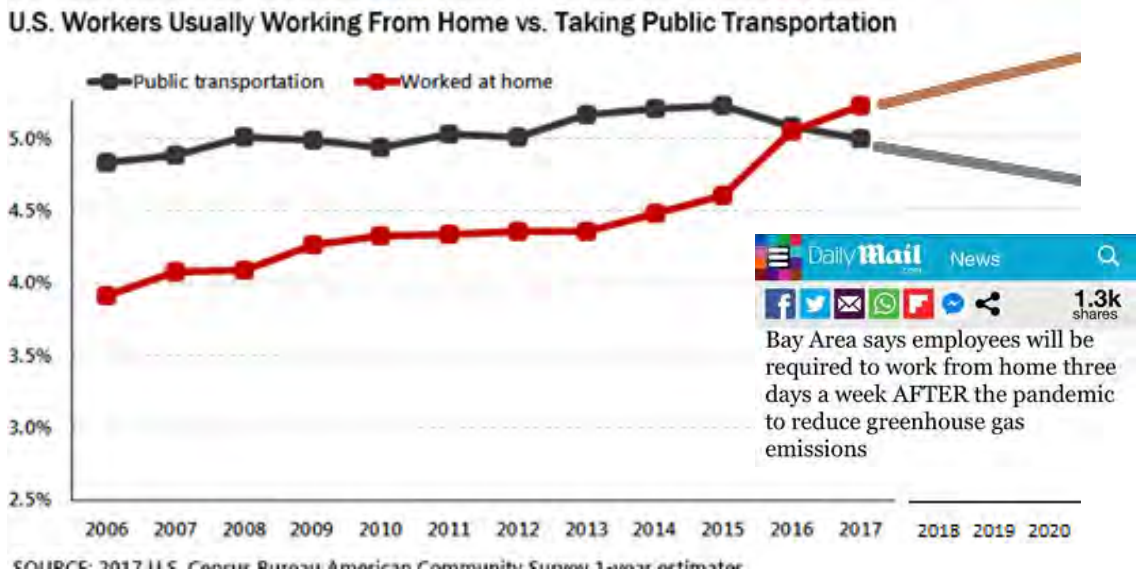
- **Employment, Transit, Environment & Vehicle Flows**

Traditional 4-step TDF Gravity Model lacks ***sensitivity***



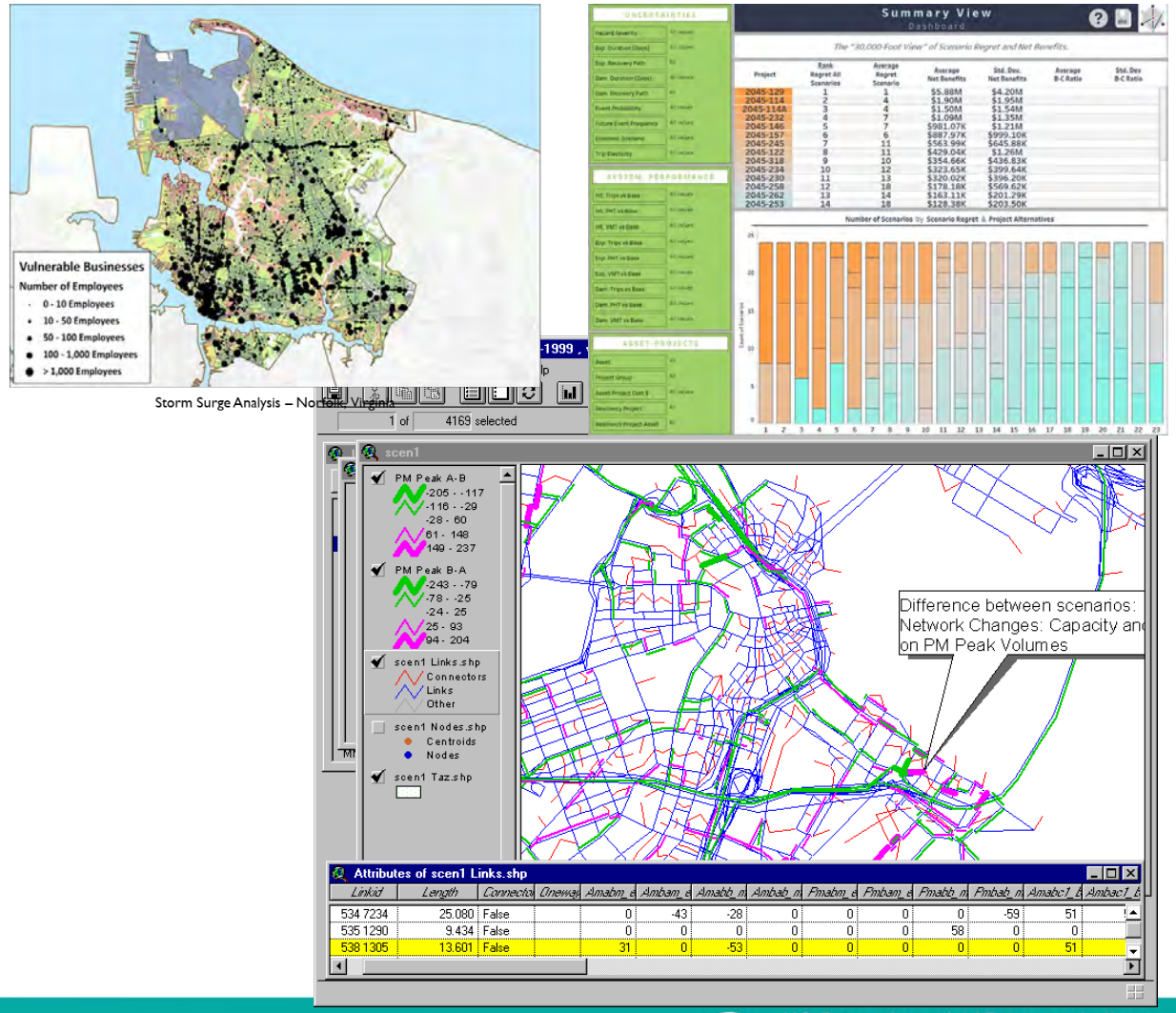
Old Data:

Census (10 years), Local Surveys (5 years)
Commuter O-D Surveys (3-5 years) ACS (annual)



Volpe Center also supports

- Transportation data exchange
  - Data conversion between TDM and GIS: OpenMatrix (OMX) or other formats (Cube, TransCAD, TP+)
- Resiliency & disaster recovery (RDR)
  - Augmented tools for metadata modeling: flood & any road closure
  - Microscopic agent-based simulation: sensitive to technology changes



U.S. Department of Transportation Volpe Center

Volpe Center's Innovation Challenge

(2020 Volpe Innovation Accelerator)

Mode Swing from NLP

- Neural Linguistic Program for Sentiment Analysis from Social Media
- Real time data feeds from road sensors and customer tracking (reporting)

System Dynamics:

- Capture the key components that affect land-use and structural changes in TDMs
- Propose to develop an initial modeling framework to capture the impacts of telework on the interrelationships of transportation and land use

Mode Swing from ML:

- Machine Learning (ML) to get in front of the 4-Step Trip Generation model
- Start the model on Transportation Demand – including non-travelers (work from home)
- Propose the Mode Swing model to include all workforces and their changes between the modes, thus the "mode swings" in %
- Use Dynamic Forecast models like Prophet (Bayesian STAN) sand Dynamic Time Warping (DTW) models to predict the changes in Mode Swings

Our Discussions with SCAG, OCTA & Caltrans

We had many virtual meetings with stakeholders/planners/modelers

Current Practice:

- Using traditional 4-step models under Federal guidelines
- Using assumptions in long term planning
- Trying Activity-Based Model (ABM) for model sensitivity analyses
- Preparing for new surveys before using the 2020 Census data

Urgent Needs:

- Recognizing the Needs to study "Mode Choice"
- Need a better way to model key variables: Telework, Transit, TNC, Policy & Planning scenarios
- More interested in short-term predictions to support trend analysis on changes in both mode choices and traffic patterns

Getting Sentimental: Mode Choice at the Heart of TDF

Zipf Distribution: Empirical Law

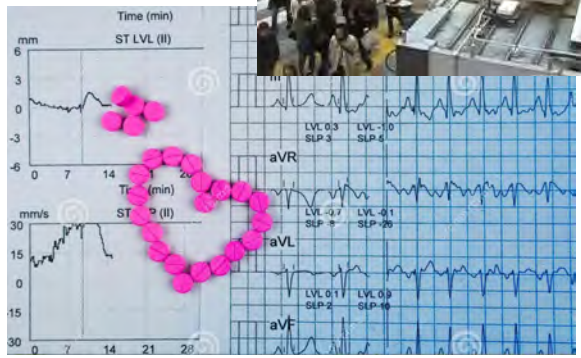
- Not theoretical, 'learns from Data'
  - Can provide insights with large datasets
- Mood Swing similar Index Funds
  - The flow of money in mutual funds – similar to mode choice - when one index fund (mode) under performs (like traffic being too slow), money (travelers) will flow into other funds (or modes) in search of better performance (shorter travel times).

Neuro Linguistic Programming (NLP)

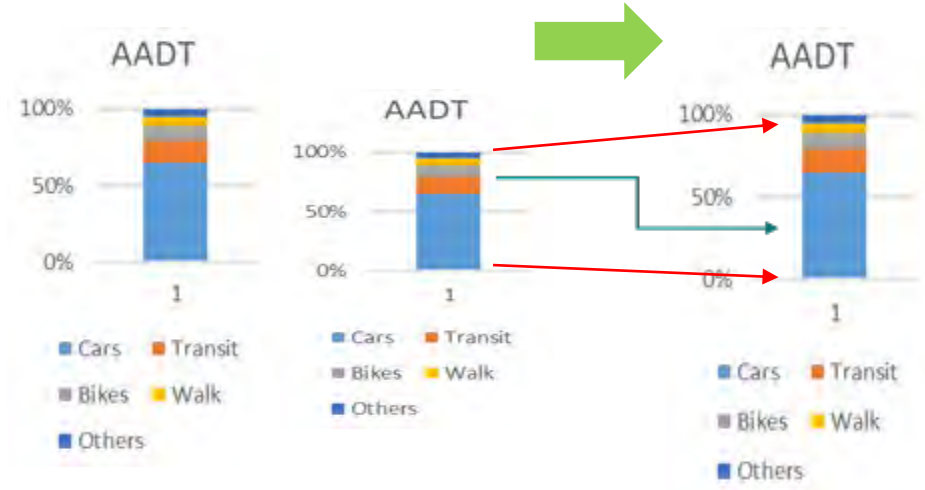
- From Word Association to Variable Association to Mode Swings

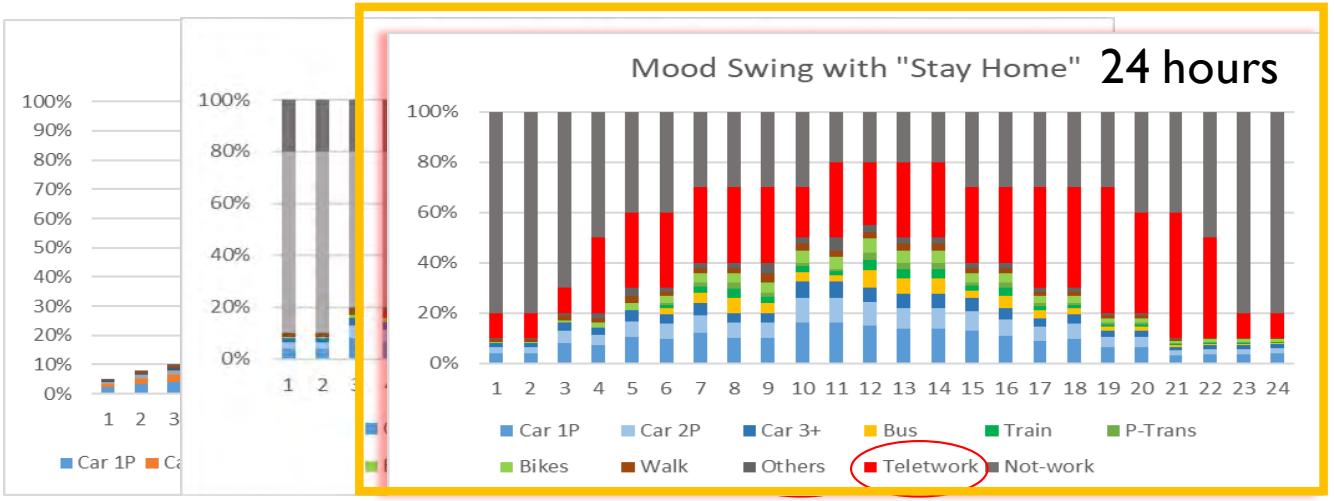
Mode Choice with "Mood Swing" Modeling:

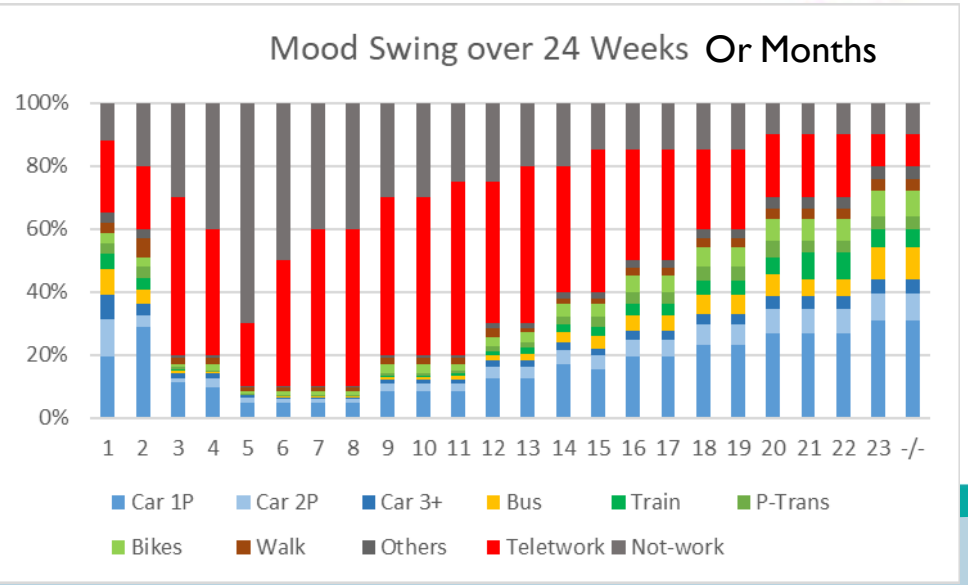
- Machine Learning (ML) examines the dynamic nature of changes by hour, by day, by week by season, by road condition, and eco-social/employment settings



How to Model the Changes between the Modes (Moods)

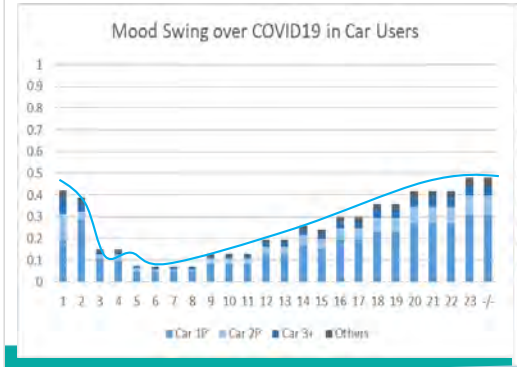


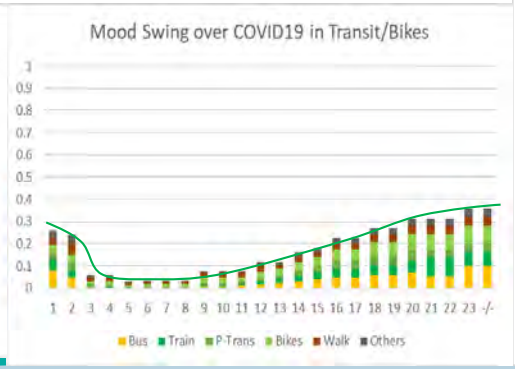


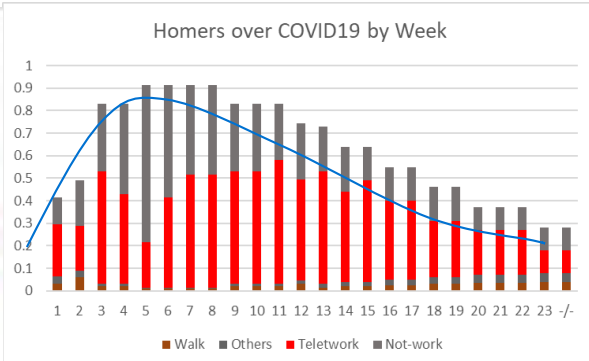


Car Trips vs. Transit Trips: go together, but swing!

Telework is Different!







U.S. Department of Transportation Volpe Center

Samples for Case Study

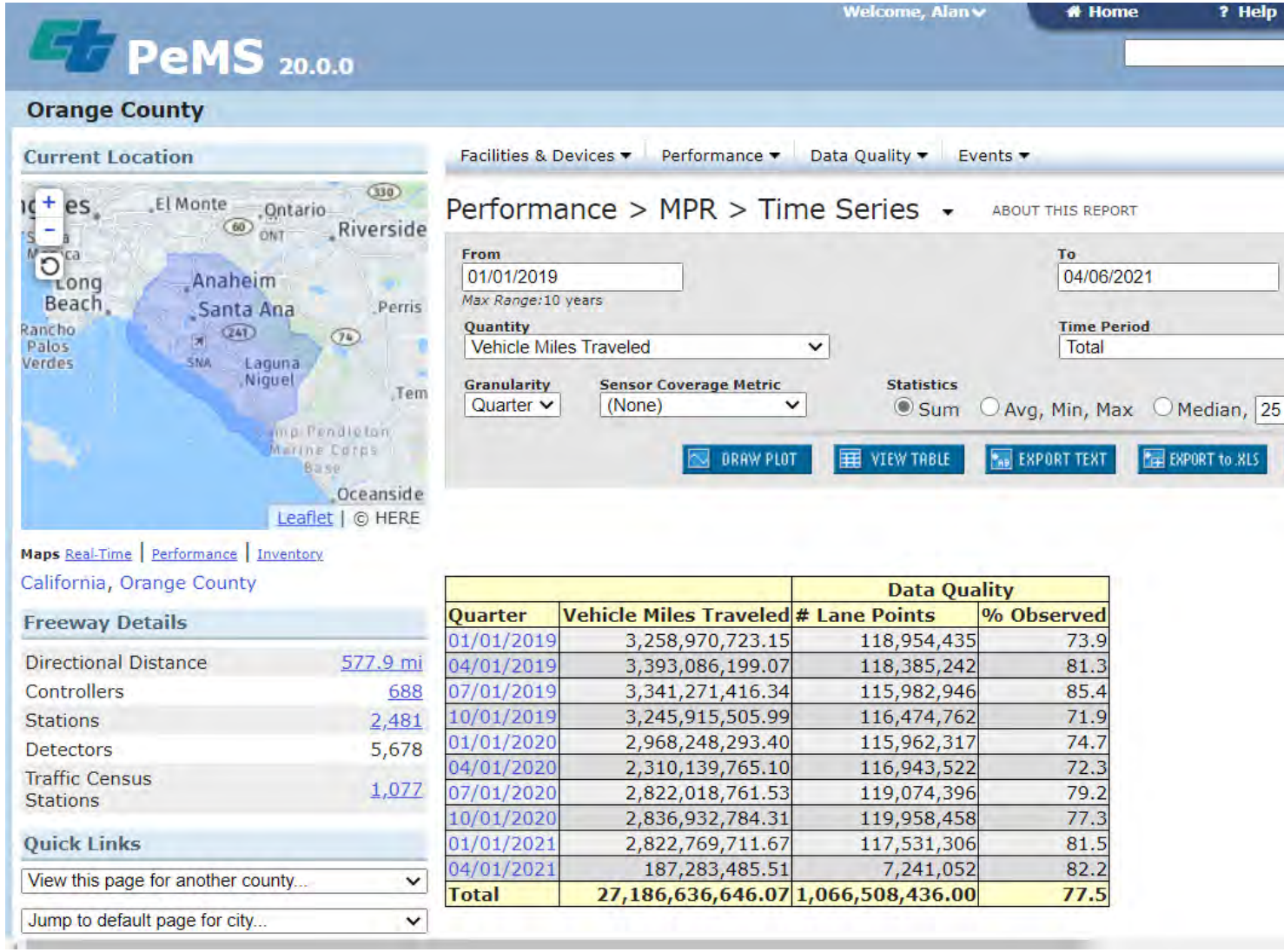
Highway Data:

Caltrans Performance Measurement System (PeMS): from detectors

On Interstate Highways

Estimated for the County

Vehicle Miles Traveled (VMT)



		Data Quality	
Quarter	Vehicle Miles Traveled	# Lane Points	% Observed
01/01/2019	3,258,970,723.15	118,954,435	73.9
04/01/2019	3,393,086,199.07	118,385,242	81.3
07/01/2019	3,341,271,416.34	115,982,946	85.4
10/01/2019	3,245,915,505.99	116,474,762	71.9
01/01/2020	2,968,248,293.40	115,962,317	74.7
04/01/2020	2,310,139,765.10	116,943,522	72.3
07/01/2020	2,822,018,761.53	119,074,396	79.2
10/01/2020	2,836,932,784.31	119,958,458	77.3
01/01/2021	2,822,769,711.67	117,531,306	81.5
04/01/2021	187,283,485.51	7,241,052	82.2
Total	**27,186,636,646.07**	**1,066,508,436.00**	**77.5**

Data from Orange County, CA: Traffic

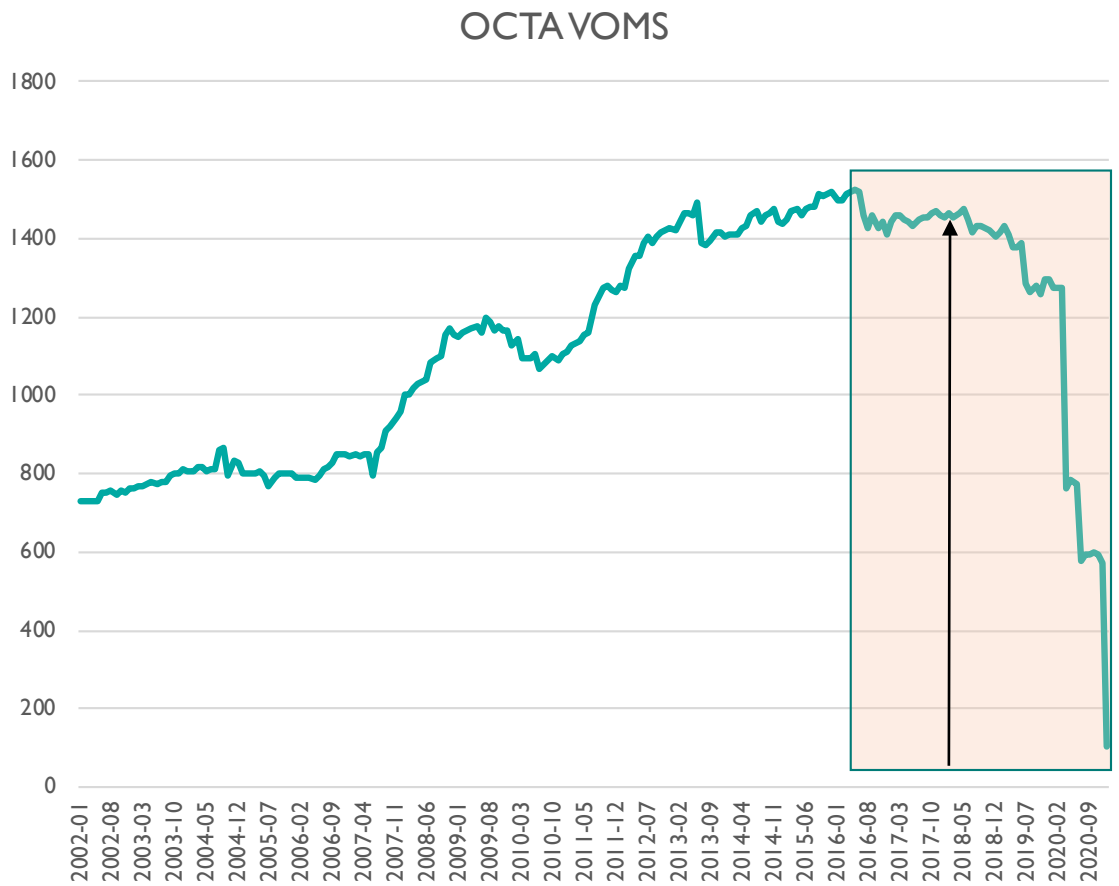
- Highway has seen the VMT decline since Q1 2018
- The transportation demand is an indicator of economic activity or employment – with time lag
- Two years after transit decline, the highway VMT also declined – has telework played a role?

Source: Caltrans PeMS: 2011-2021

Data for Orange County, CA: Transit

- OCTA began to reduce service (as measured by Vehicles Operated in Maximum Service (VOMS)) in 2017
- What changed in policy, service, or fare (cost or quality)?

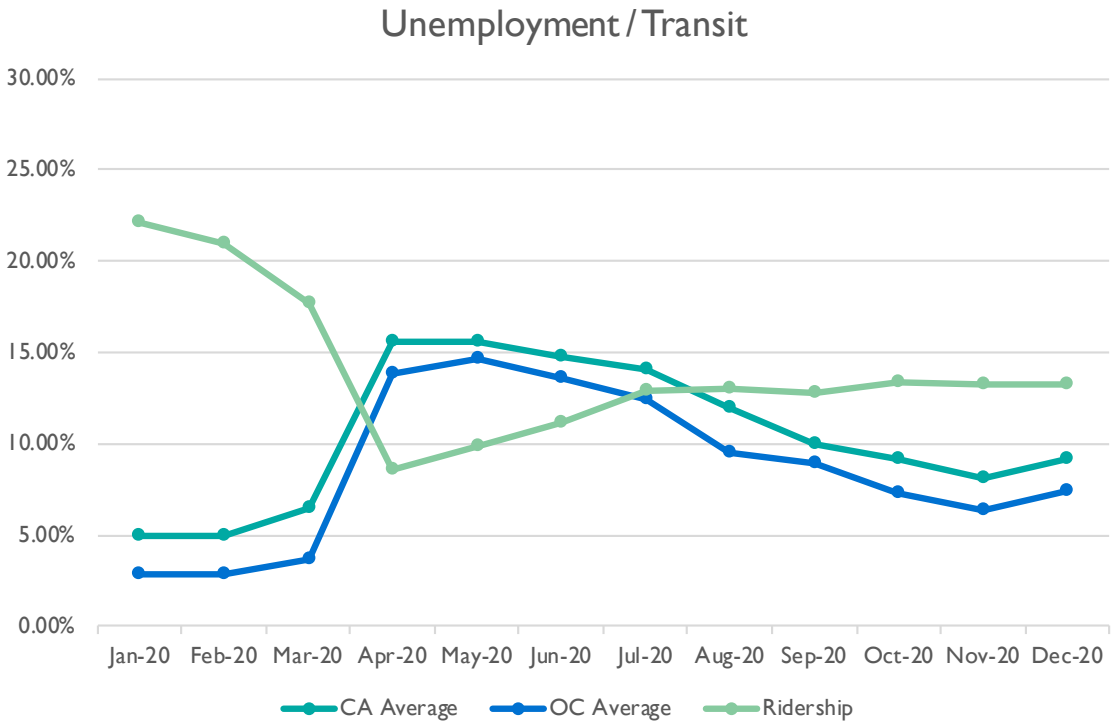
Source: FTA/OCTA 2002-2021



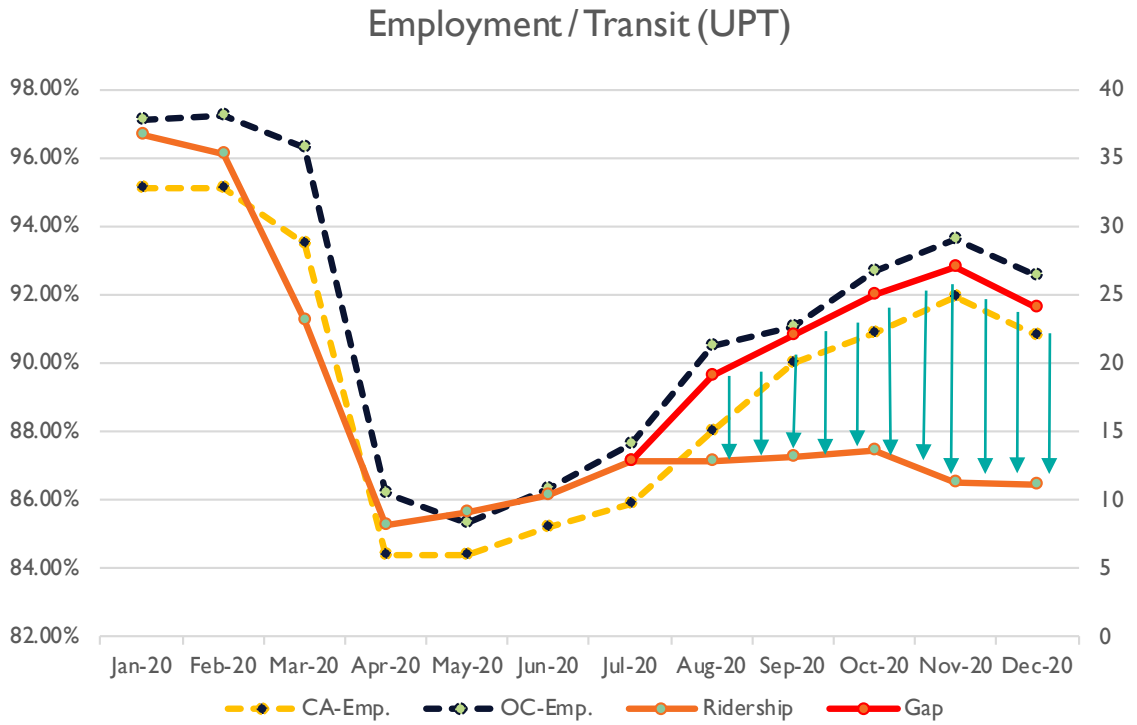
OC: Main Factors: Employment/Telework/Risk Perception

The Gap (between Red & Brown Lines) is Transit Loss due to "Risk Perception" after Employment Rise 8/2020

Unemployment/Transit Ridership



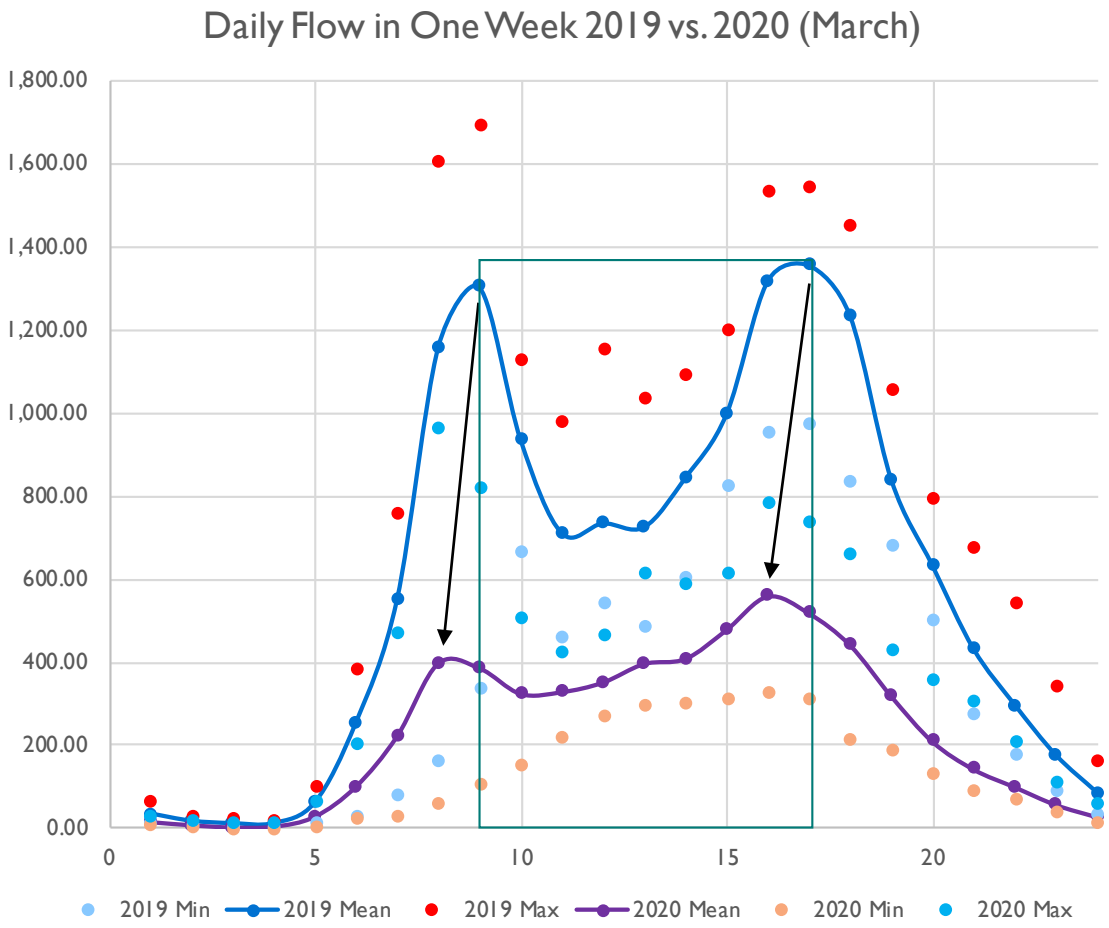
• Employment/Transit Gap: Emp. R



OC: The Pandemic Impacts on Traffic Flows

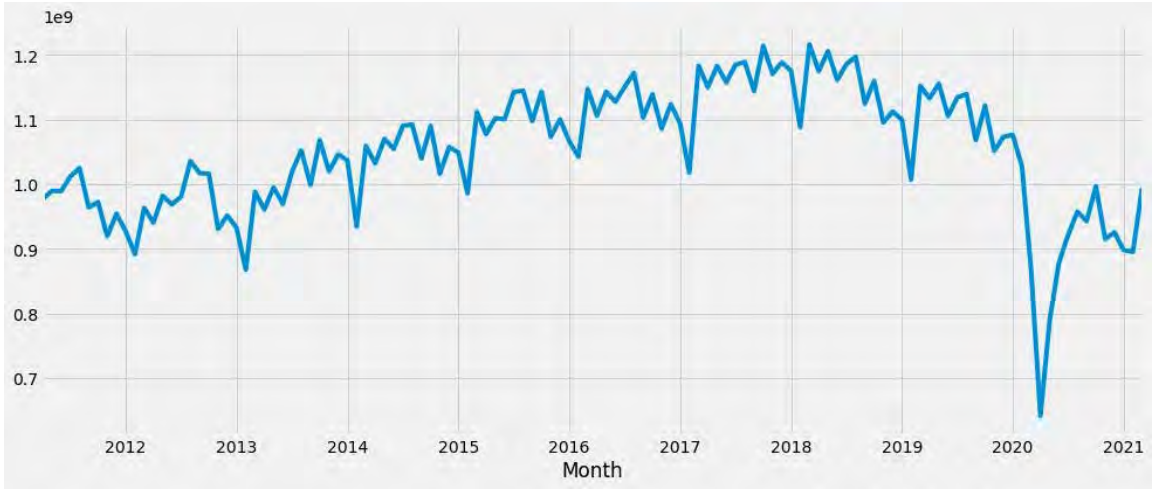
Data from Caltrans PeMS (detector at i405/Jeffrey 1):

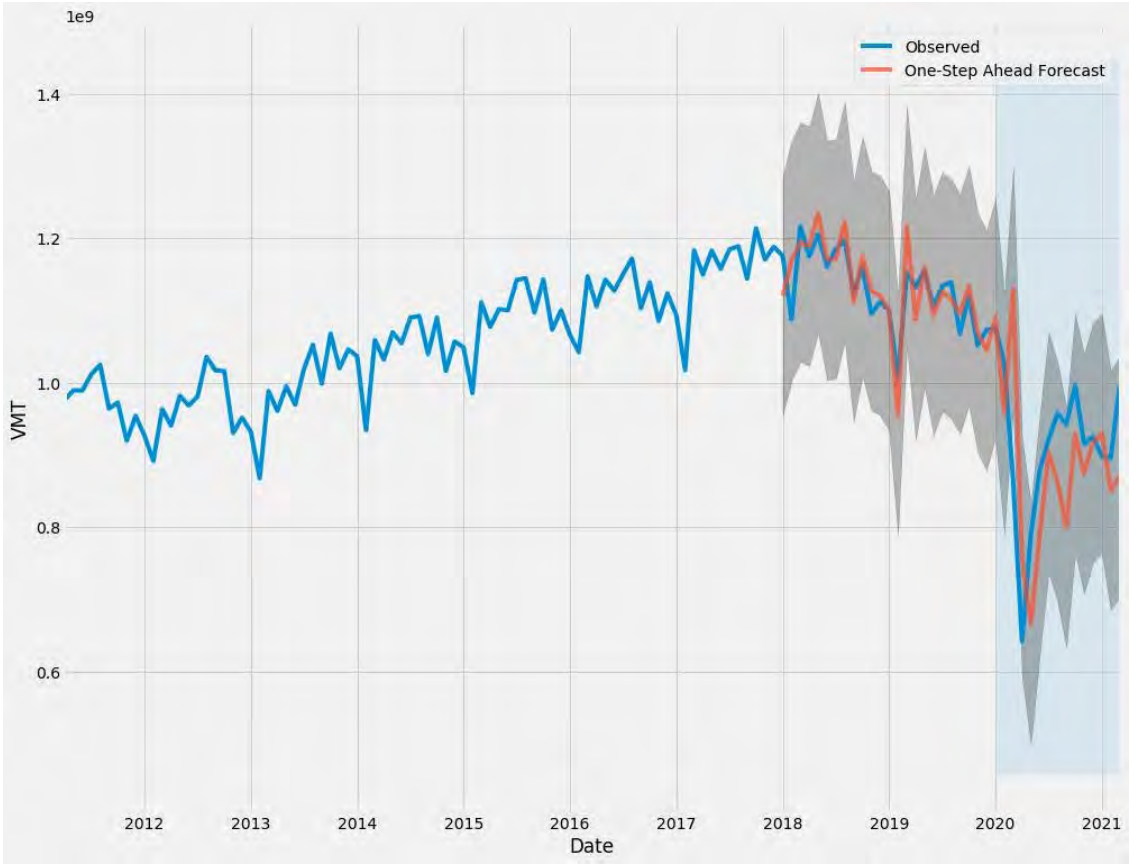
- Traffic Flow (vehicles/hour) reduced by ~ 55% at PM peak hour
- Time of the peak also moved earlier



OC: VMT Changes 2011-2021 in Pandemic

- Using Moving Average – Pattern Recognition, the model can see a short-term trend

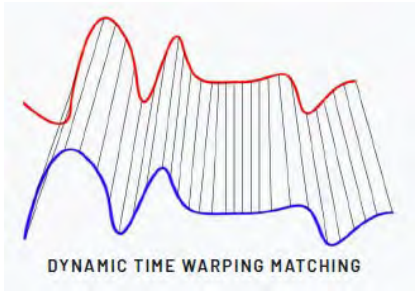




Mode Swing Dynamic Forecast (MSDF)

-- A New Way to Look at Transportation Demand

- To handle the lagging effect between any time series data, we applied the Dynamic Time Warping (DTW) technique to improve the Euclidean Match



$f(x_i)$ *maps to* $f(x_j)$ *when* $i <= j$

$f(x_i)$ *maps to* $f(x_j)$ *only when* $(j - i)$ *is within fixed range*

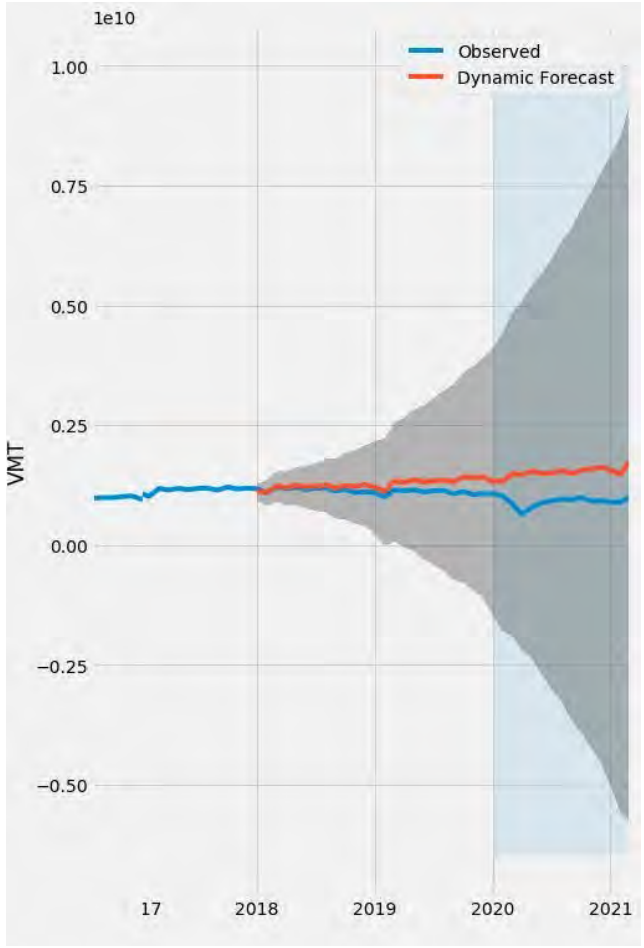
- For Fine-Grained Time Series Forecasting at Scale, we used the Facebook's Prophet (automatic forecasting procedure) and adopted Greg Rafferty's Python application for machine learning

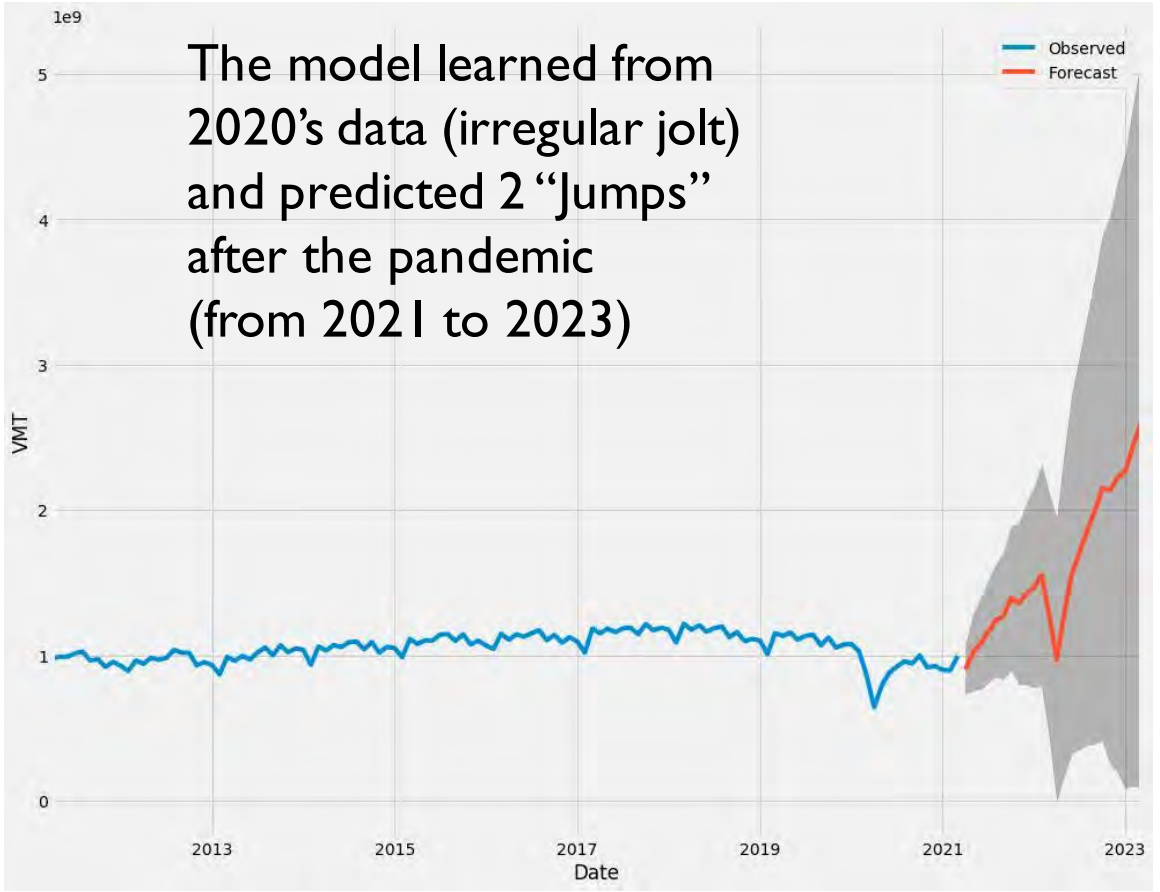
PROPHET

* Both techniques are widely used in Finance and Social Media forecasting

OC Highway: Prediction of VMT after Pandemic

- Dynamic Forecast throughout 2021

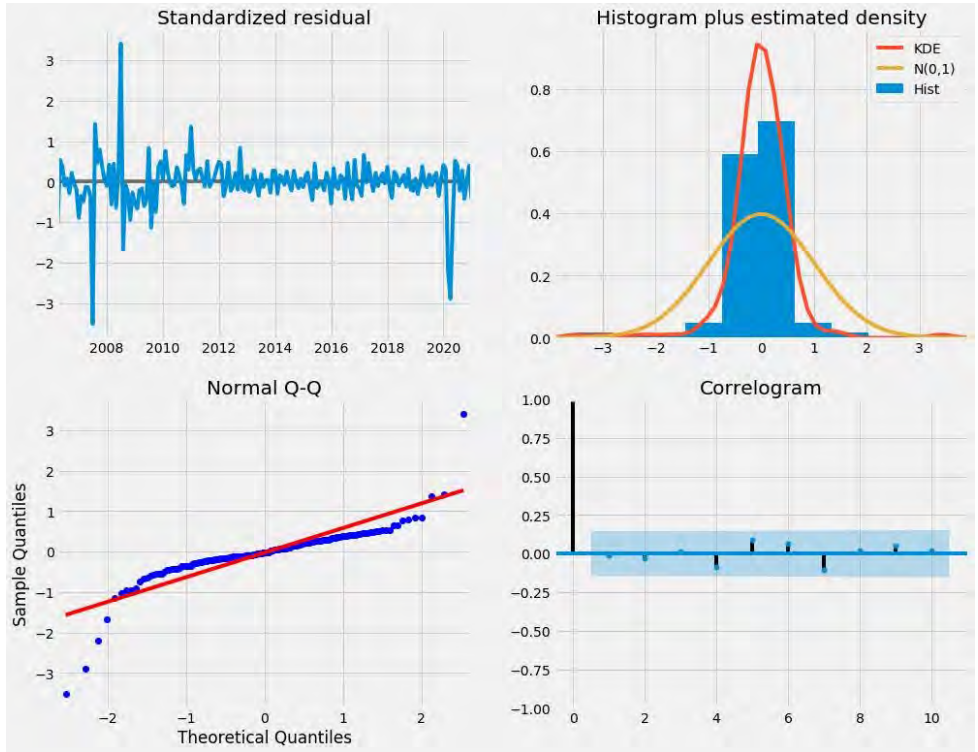




The model learned from 2020's data (irregular jolt) and predicted 2 "Jumps" after the pandemic (from 2021 to 2023)

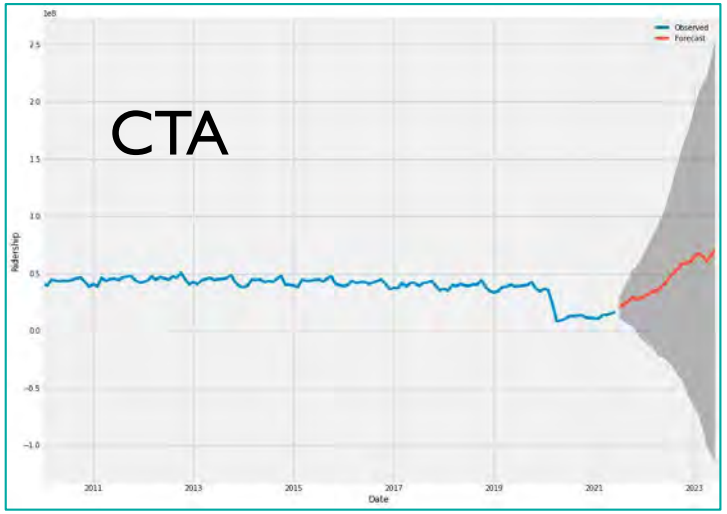
OC: Transit Ridership (include Pandemic data)

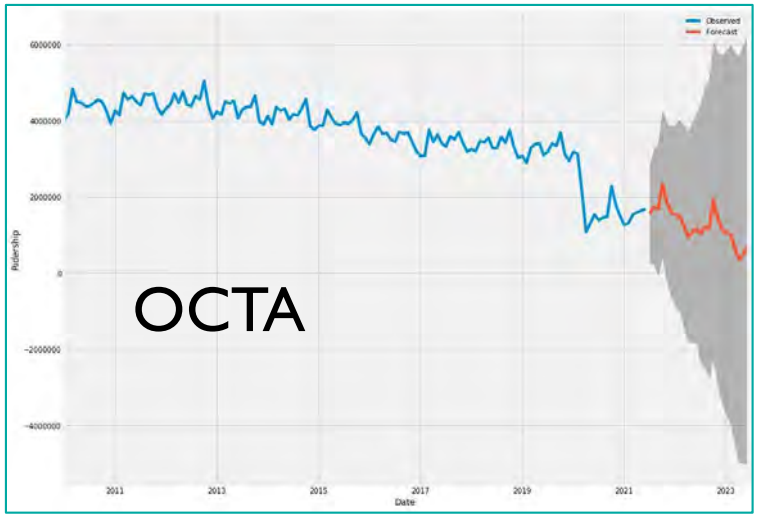
- Dynamic Model predict a decline for 2021

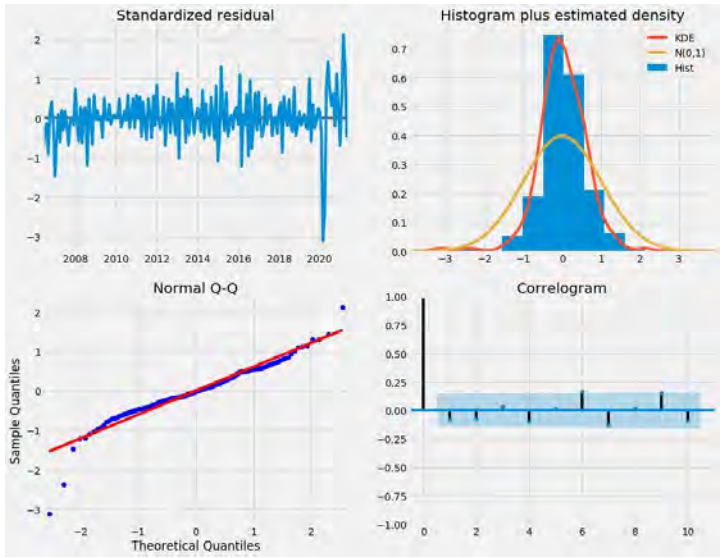


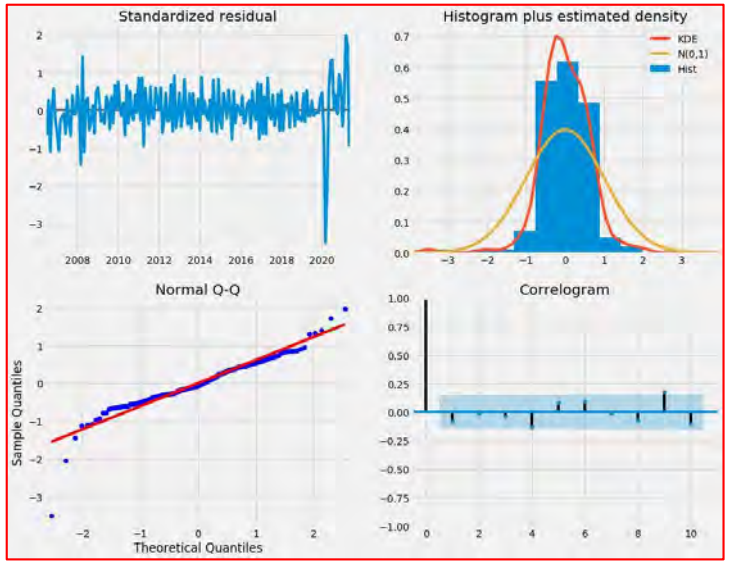
U.S. Department of Transportation Volpe Center

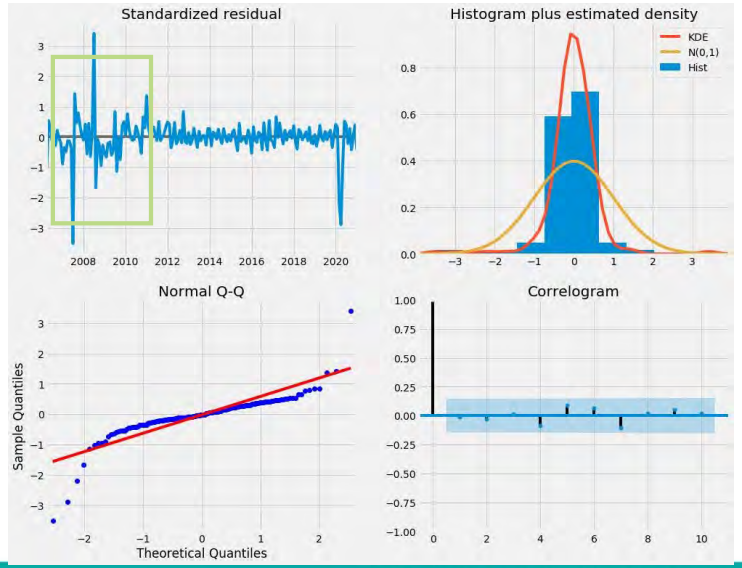
Predict Transit Ridership: MBTA, CTA, OCTA





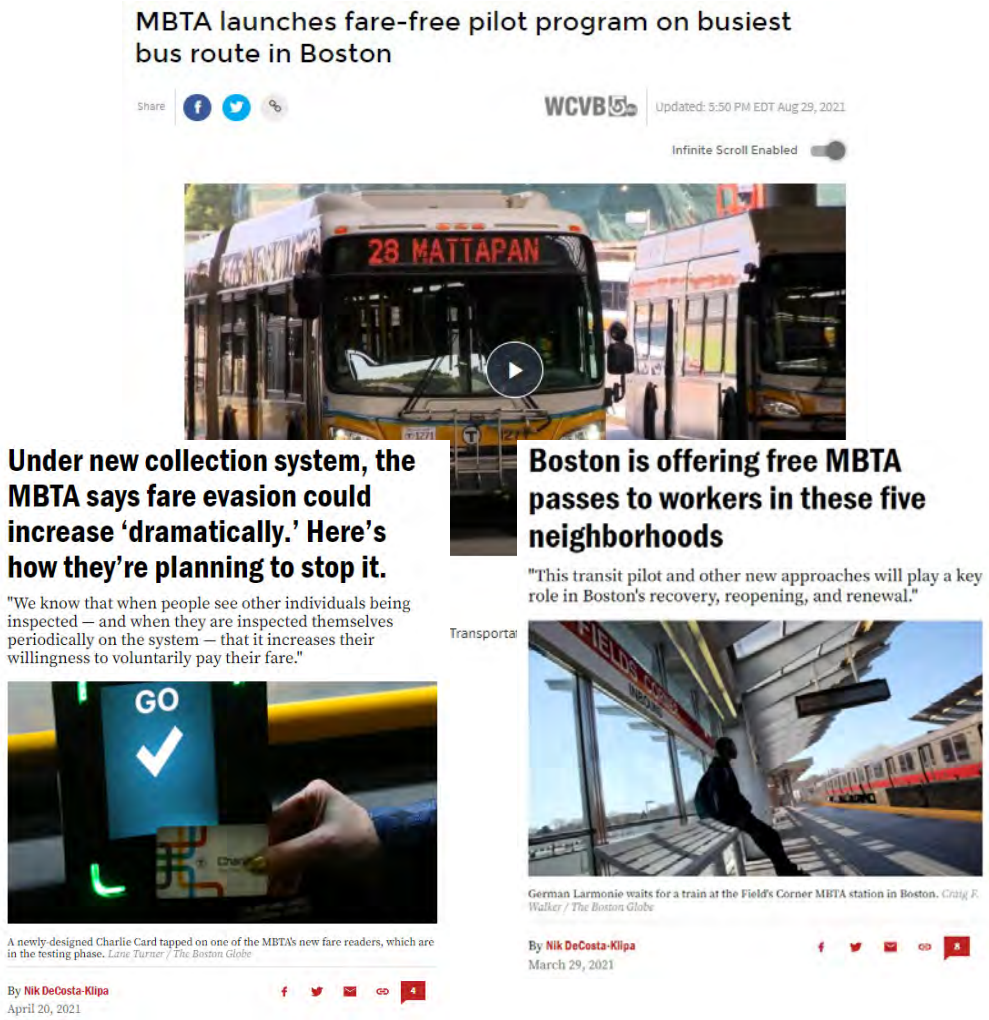




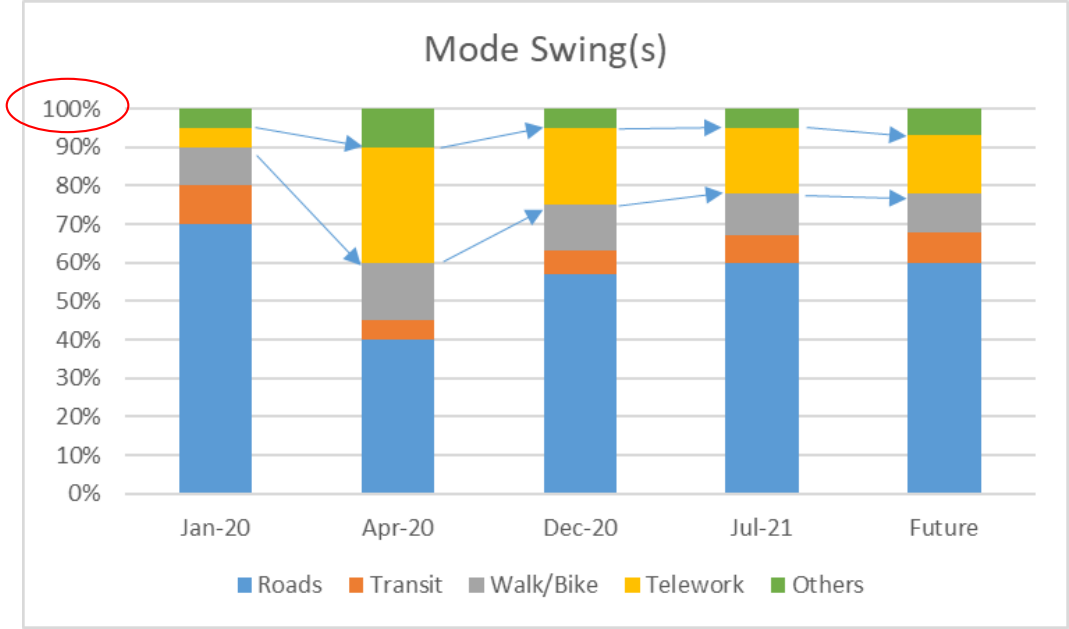


MSDF is "Result Driven" – Measure Policy Impacts

- Transit on Demand - Policy Changes
  - Lower the Price: Keep Subsidies
  - Free T-passes to workers in certain areas
  - Add frequency (more vehicles) to popular routes (reduce frequency on other rutes)
  - Promote key routes for free rides – marketing on social media
  - Build more bus (only) lanes to speed up the buses (with windows open)
  - Lower penalty on gate-jumpers (no arrest)



A New Method to Collect Data: Mode Swing Home Origin (MSHO)



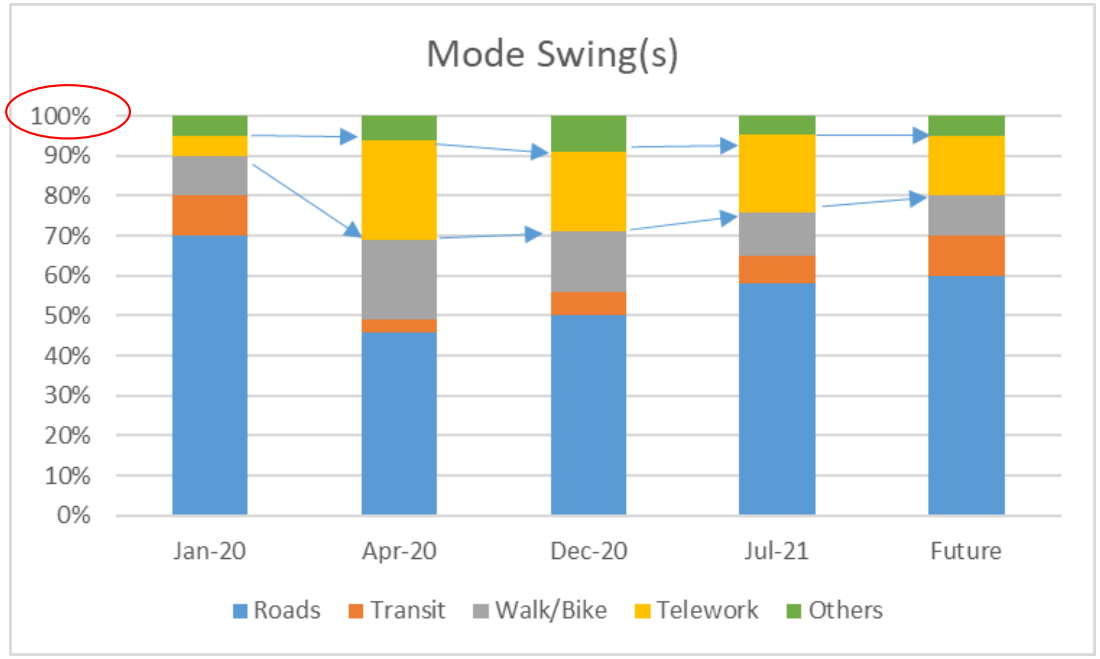
TD Home Origin – Trip Generation

- How to "Go to Work"
- ACS/CPS on Local Population
- Civilian Labor Workforce
- Consider Trip Ratio (TR) or Local Factors

New Survey Questions (BLS):

- What's your Ability to telework?
- If yes, is it monthly, weekly, or daily?
- If travel, do you have any ability to change your schedule or set a flexible working hours?

A New Method to Collect Data: Mode Swing Work Destination (MSWD)



Ask MPO and planning agency to Re-design Business Surveys on TW

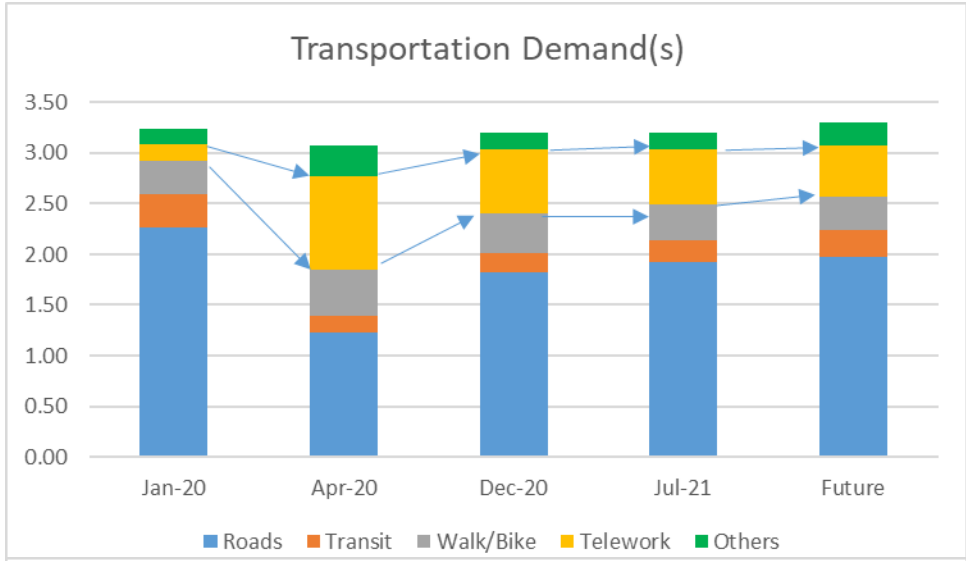
TD Work Destination – for Job Sites - Trip Attractions – Trip Generation for Return Home

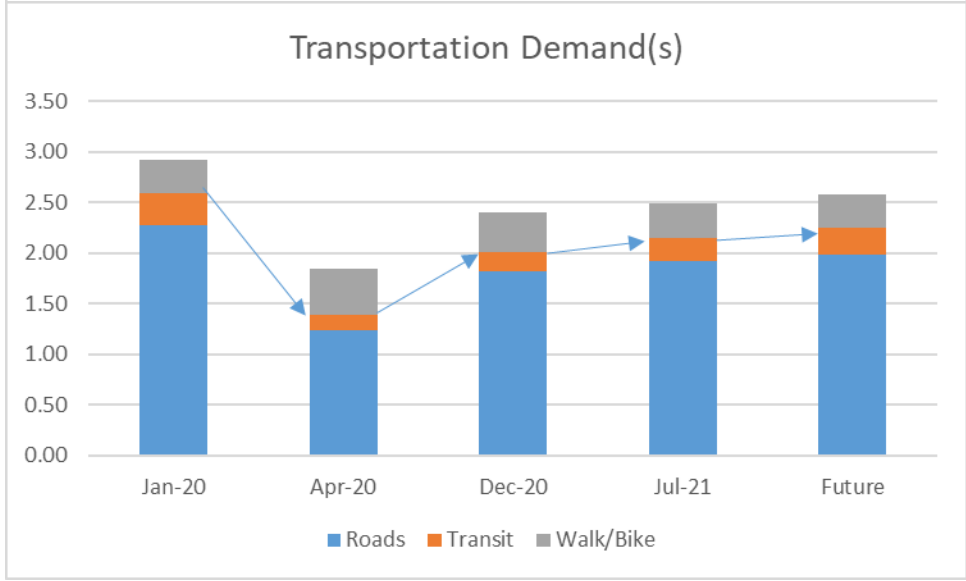
- Do you have employees working elsewhere?
- What's your Policy on telework?
  - If yes, is it monthly, weekly, or daily?
- If travel, do you have any ability to change your schedule or set a flexible working hours?
- Does the company offer Parking, Shuttle, or Transit Benefit?
- Does the company use contract workers?
  - In transportation and logistic services?

Interpolate Mode Swing to Travel Demand (TD): one way

	Jan-20	Apr-20	Dec-20	Jul-21	Future
Roads	70%	40%	57%	60%	60%
Transit	10%	5%	6%	7%	8%
Walk/Bike	10%	15%	12%	11%	10%
Telework	5%	30%	20%	17%	15%
Others	5%	10%	5%	5%	7%
	100%	100%	100%	100%	100%

Roads	2.27	1.23	1.82	1.92	1.98
Transit	0.32	0.15	0.19	0.22	0.26
Walk/Bike	0.32	0.46	0.38	0.35	0.33
Telework	0.16	0.92	0.64	0.54	0.50
Others	0.16	0.31	0.16	0.16	0.23
	3.24	3.08	3.20	3.20	3.30
WF	1.62	1.54	1.60	1.60	1.65
Trips	3.24	3.08	3.20	3.20	3.30





Turn the Mode Swing % to TD: VMT or Trips or Riders

- Turn off Telework to get Road Users (bottom chart)

Summary

- This MSDF model captured the patterns of Transportation Demands (TDs) before and during the pandemic
- Both highways and transit systems are on the decline in performance
- Transit is slow to recover – lagging behind highways when more jobs are added
- Transit may be the first and the last choice for low income (new/young) workers for long distance commute
- Telework & Bike/Walk are the preferred choices when the work permits
- [COVID-19 cases and restrictive policies]
- Risk Perception and Telework Policy will have a long-lasting impact on TDs and Mode Swings (MS)
- Flexible Schedule and Job Arrangement are becoming more common (for many job sites) and they're changing the peak hour time of workdays
- This System Dynamics and Dynamic Forecasting can be used to examine other factors from Amazon, TNC, Policy and Economic Incentives
- More data available for short-term forecasting, then improve long-term prediction

Team & Acknowledgement

- Co-leads
  - Alan Rao
  - Jingsi Shaw
- Team members
  - Adrian Hellan
  - Olivia Gillham
  - Scott Lian
  - Kendall Mahavier
  - Hannah Rakoff
  - Scott Smith
  - Joseph Stanford
- Advisors
  - Matt Cuddy
  - Alex Linthicum
  - Cynthia Maloney
  - Luisa Paiewonsky
  - Gregg Flemming