ANNUAL MERIT REVIEW, JUNE 2021

CHICAGO TRANSIT AUTHORITY (CTA) TRANSIT NETWORK EFFICIENCY AND THE CHANGING MOBILITY LANDSCAPE

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PROJECT OVERVIEW

Timeline	Barriers
• Project start date: October 2019 • Project end date: May 2021 • Percent complete: 100%	• Computational models, design and simulation methodologies • COVID-19 shifted CTA focus • Understand and quantify the impact of user behavior during and after the pandemic • Quantify the impact of CTA response and the resulting user behavior changes
Budget	**Partners**
• FY20 Funding: $300,000 • Additional NVBL funding supported this project ($300,000)	• Argonne (Lead) • Chicago Transit Authority (CTA) • University of Illinois, Chicago (UIC) • Chicago Department of Transportation (CDOT)

RELEVANCE

How to re-shape the future of transit service for improved mobility and energy resiliency after substantial transit ridership loss due to the pandemic?

Conventional, Fixed-Route, Fixed-Schedule Transit

Alternative Mobility Options

Working from Home

Information Technologies

Transit Risk Perception

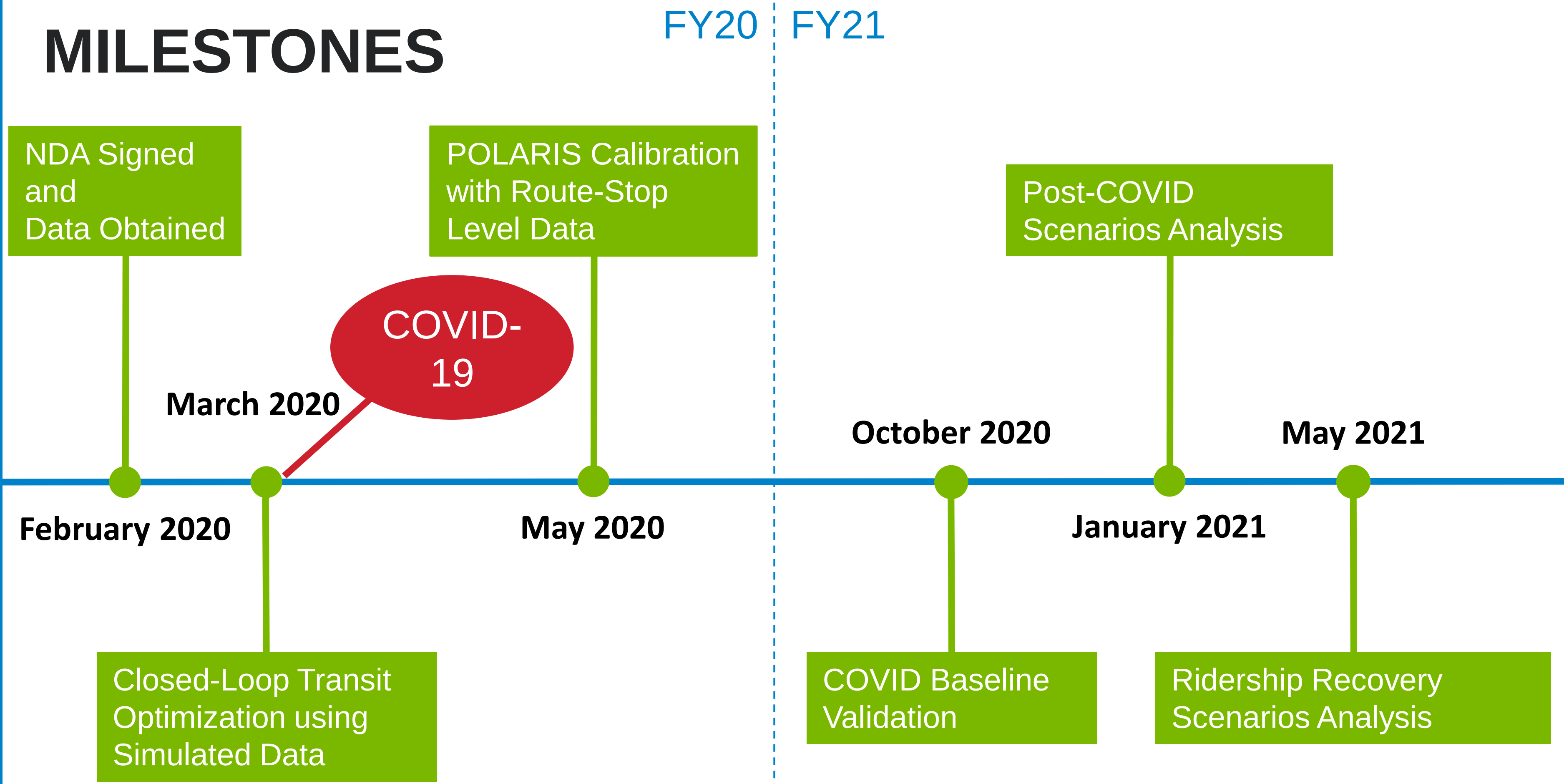
RELEVANCE

- Transit is the **backbone** of an urban transportation system
- It is the **most energy-efficient** mode of transportation on a passenger-mile basis (unless heavily under-utilized)
- Improving transit efficiency and increasing transit ridership **reduces energy consumption and greenhouse gas emissions**.
- Unfortunately, transit agencies are **budget limited,** so allocating resources effectively is critical.

⇒**Optimization algorithms** are critical to evaluate improvement strategies such as new routes, re-allocating frequencies etc.

- To quantify the impact of these proposed strategies, **simulating** the entire transportation system, a **system of systems**, is necessary.
- **High Performance Computing (HPC)** is required to overcome the computational challenges.

MILESTONES



FY20
FY21
NDA Signed and Data Obtained
February 2020
March 2020
COVID-19
Closed-Loop Transit Optimization using Simulated Data
POLARIS Calibration with Route-Stop Level Data
May 2020
October 2020
COVID Baseline Validation
Post-COVID Scenarios Analysis
January 2021
May 2021
Ridership Recovery Scenarios Analysis

APPROACH

High Performance Computing (HPC) enables large number of scenarios

BEBOP High Performance Computing (HPC)

Model Improvement and Validation

- Model the risk perception of shared modes (UIC survey)
- Enhance the telecommuting model (UIC survey)
- Calibrate mode choice, routing, and timing choice parameters (CTA ridership and OD data)
- Validate traffic counts using CDOT roadway data

Predictive Scenario Analysis

- Agency budget reduction
- Telecommuting
- Mode risk perception levels

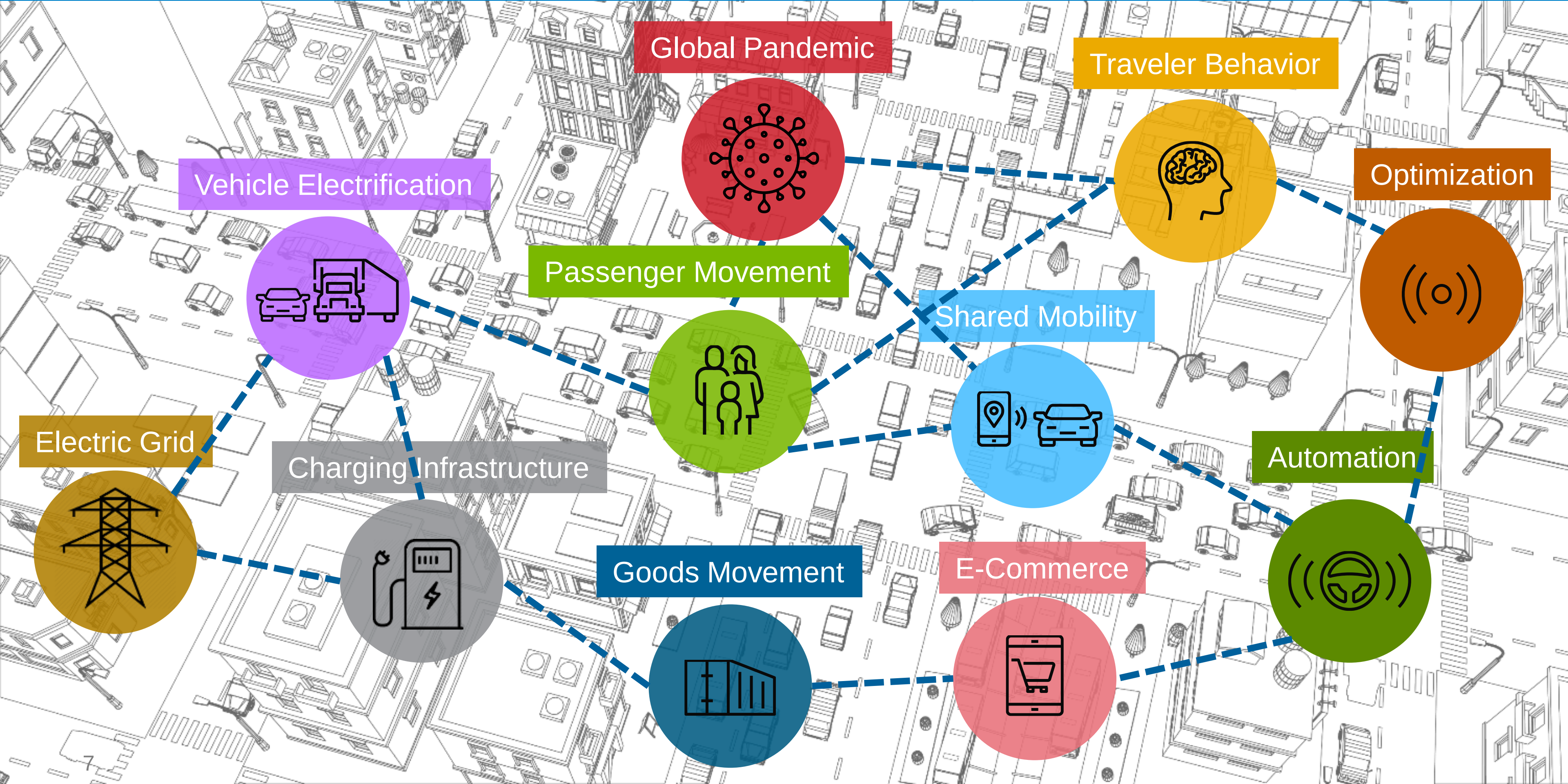
Ridership Recovery Scenario Analysis

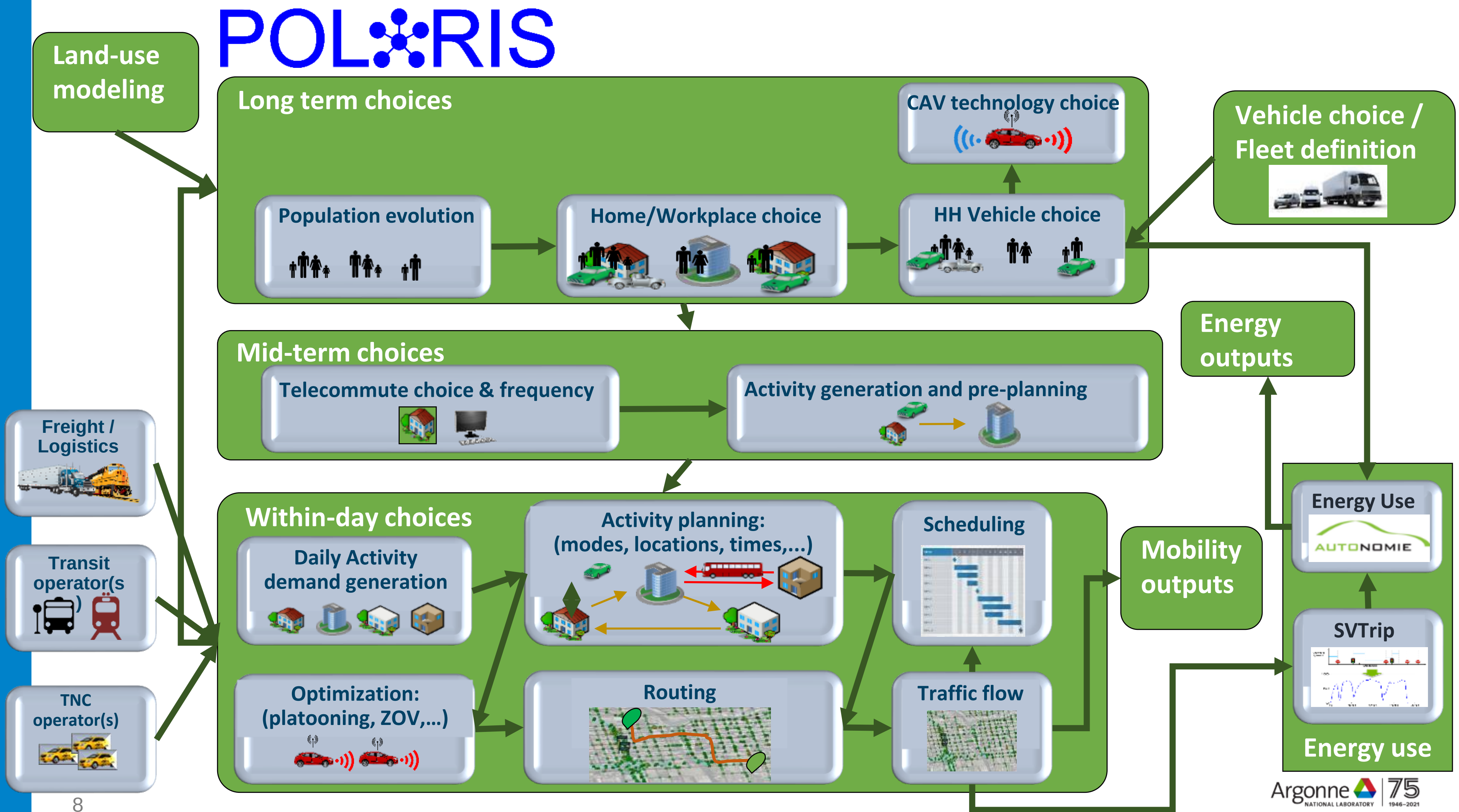
- Optimize frequencies under budget reduction
- Double frequencies
- Add BRT lines

Quantify Impacts

- Ridership
- Congestion
- Economy
- User experience
- Energy
- Emissions
- Equity

Transportation is a Complex System of Systems




POLARIS
Land-use modeling
Long term choices
CAV technology choice
Vehicle choice / Fleet definition
Population evolution
Home/Workplace choice
HH Vehicle choice
Energy outputs
Mid-term choices
Telecommute choice & frequency
Activity generation and pre-planning
Freight / Logistics
Transit operator(s)
TNC operator(s)
Within-day choices
Daily Activity demand generation
Activity planning: (modes, locations, times,...)
Scheduling
Mobility outputs
Energy Use
AUTONOMIE
SVTrip
Optimization: (platooning, ZOV,...)
Routing
Traffic flow
Energy use
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TECHNICAL ACCOMPLISHMENTS

- Predictive Scenario Analysis
- Ridership Recovery Scenario Analysis
  - Optimized Service Cuts
  - Service Improvements

OPTIMIZATION ALGORITHM AND SIMULATION TO IMPROVE TRANSIT SERVICE ENABLED BY HPC

Fleet, Ridership, Cost Data

OPTIMIZATION ALGORITHMS and MANUAL ADDITIONS:

- Transit route design/redesign
- Transit frequency setting and timetabling
  - Non-linear optimization (KNITRO solver)

OUTCOME:

- New routes
- New frequencies and timetables
- Route cuts under predictive scenarios

Multiple iterations

POLARIS Simulation

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PREDICTIVE SCENARIO ANALYSIS

Demand	Service Reductions	Telecommuting and Risk Perception	Names
PRE_COVID	NONE	PRE-COVID (2019 Fall)	No Cut – Base
		LOW	No Cut – Low
		MODERATE	No Cut – Moderate
		HIGH	Half Vaccinated with Load Limits
	20%	PRE-COVID (2019 Fall)	Light Cut – Base
		LOW	Light Cut – Low
		MODERATE	Light Cut – Moderate
	55%	PRE-COVID (2019 Fall)	Heavy Cut – Base
		LOW	Heavy Cut – Low
		MODERATE	Heavy Cut – Moderate

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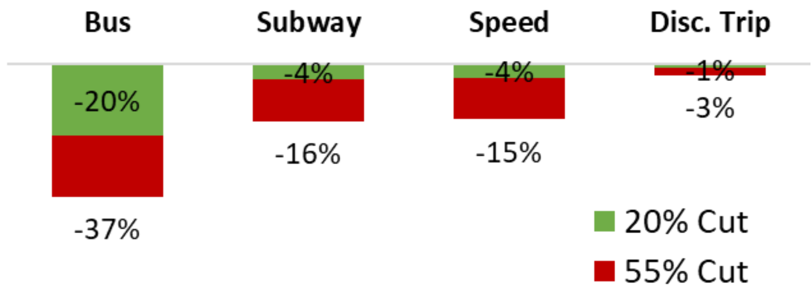
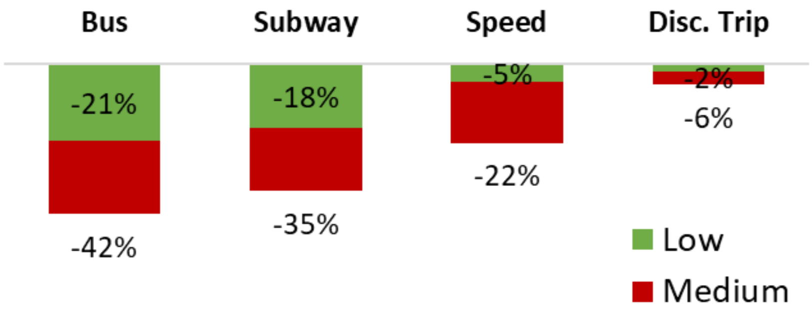
TELECOMMUTING AND RISK PERCEPTION CAN HAVE MORE IMPACT THAN SERVICE CUTS

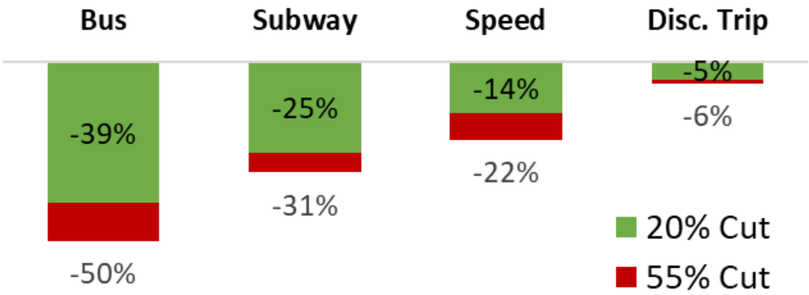
Service Cuts Alone



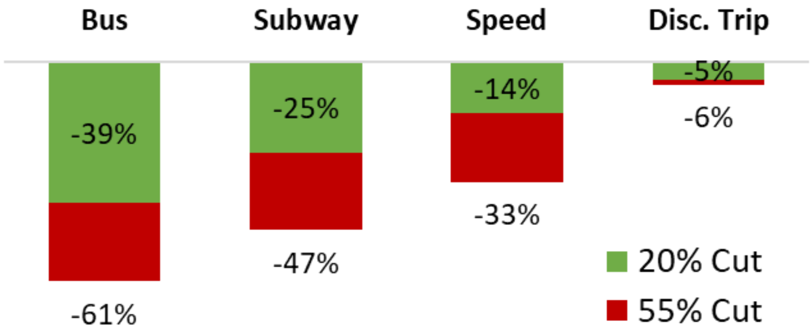
Telecommuting and Risk Perception Alone



Service Cuts + Low Telecommuting + Risk Perception (Best Case)

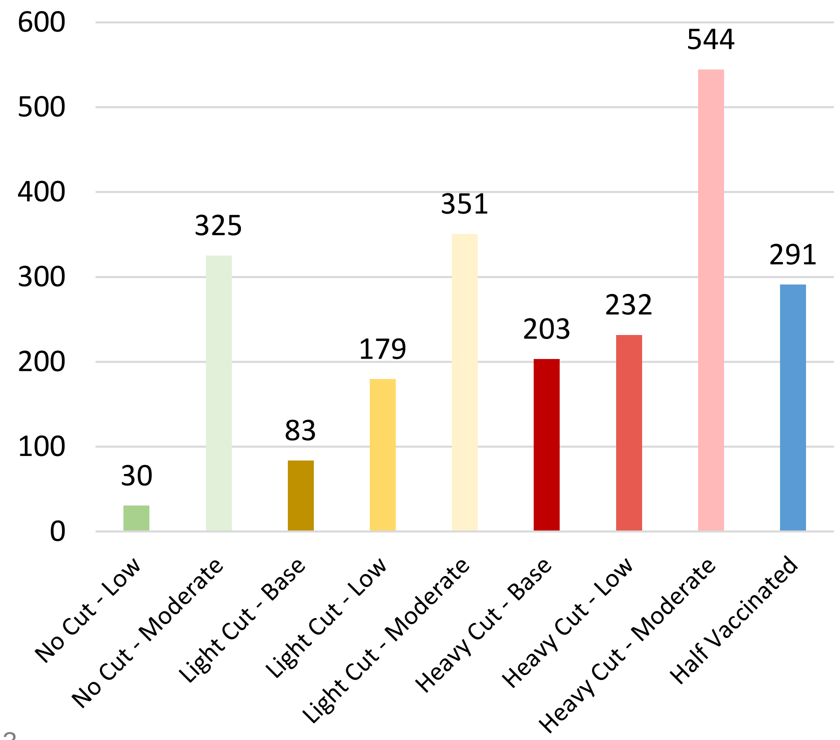


Service Cuts + Medium Telecommuting + Risk Perception (Worst Case)

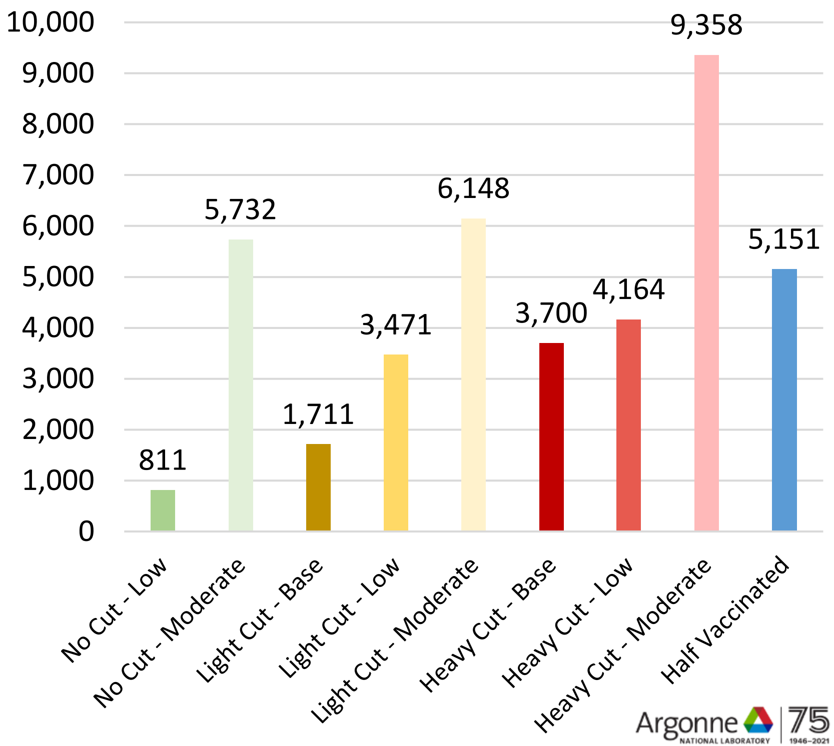


UP TO 544,000 GALLONS OF FUEL AND 9,360 TONS OF GHG INCREASE PER DAY

Δ fuel use (000 gallons)

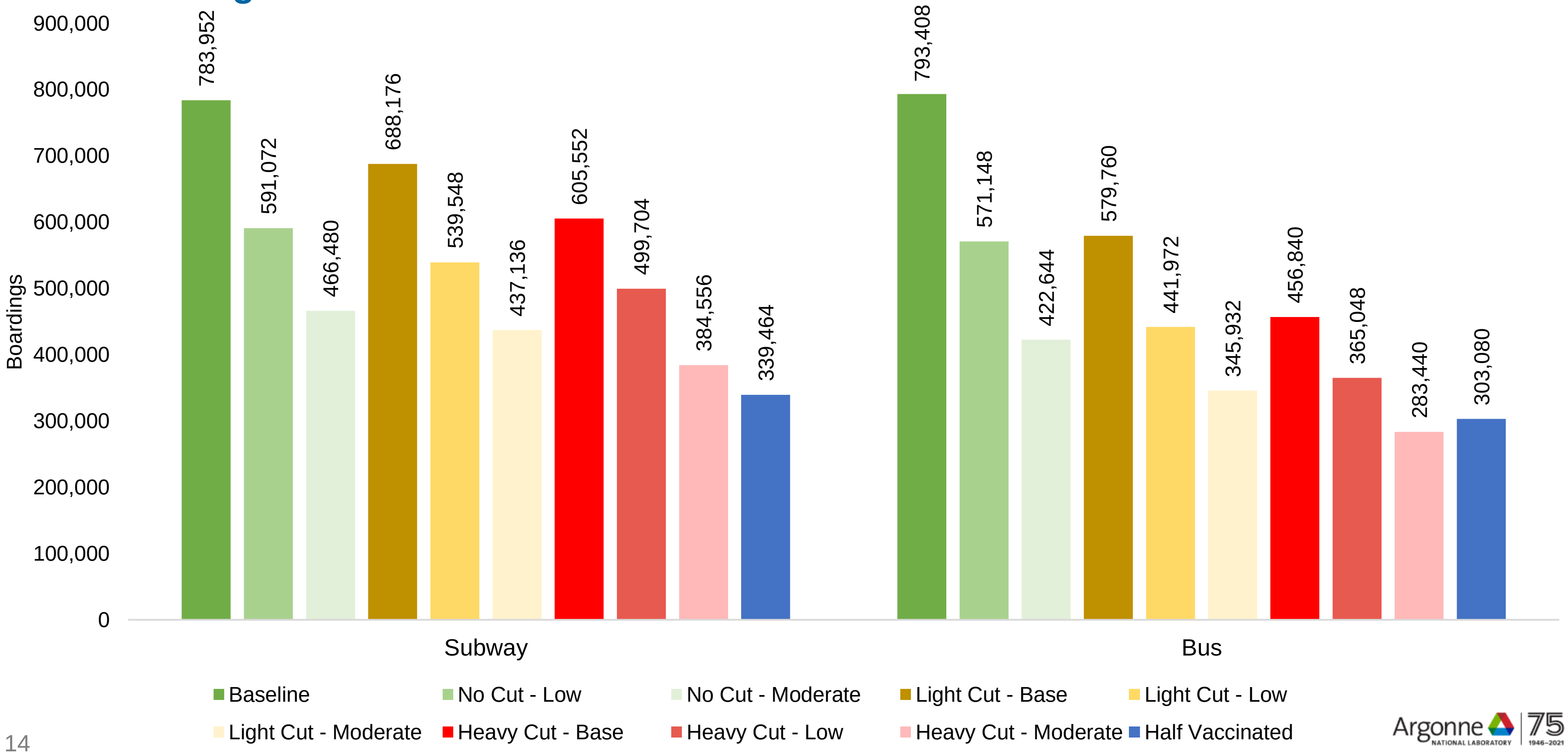


Δ GHG emissions (tons)



CONTINUED COVID RISK PERCEPTION HAS THE POTENTIAL TO DISRUPT BOARDINGS MORE THAN DEEP SERVICE CUTS OR TELECOMMUTING

CTA Boardings – Predictive Scenarios



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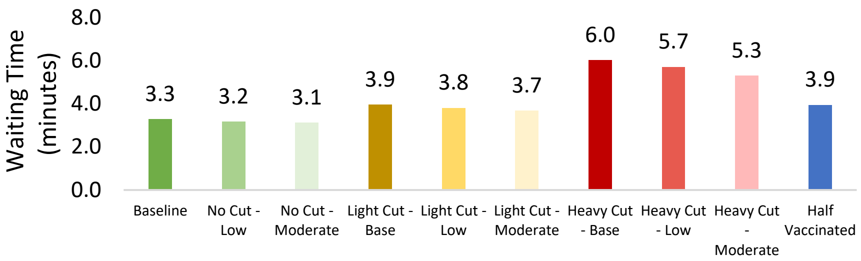
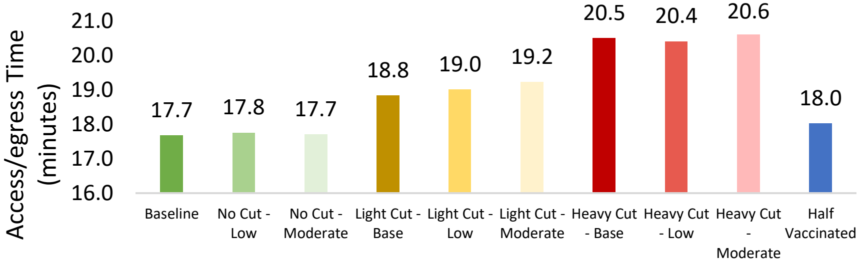
TRANSIT USER EXPERIENCE DEGRADES AS SERVICE IS CUT, BUT LOWER DEMAND SLIGHTLY IMPROVES IT

User Experience – Predictive Scenarios

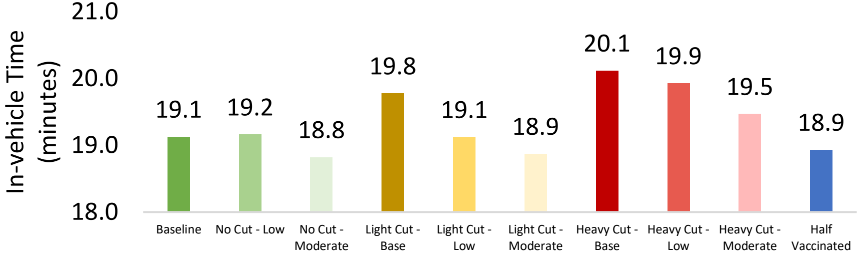
Waiting time increases with transit cuts



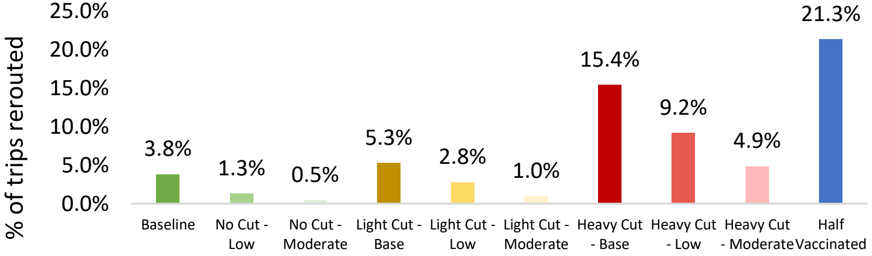
Access/egress time increases with transit cuts



In-vehicle time increases as travelers are forced to more indirect routes



Re-routing decreases with demand, but increases as service is cut



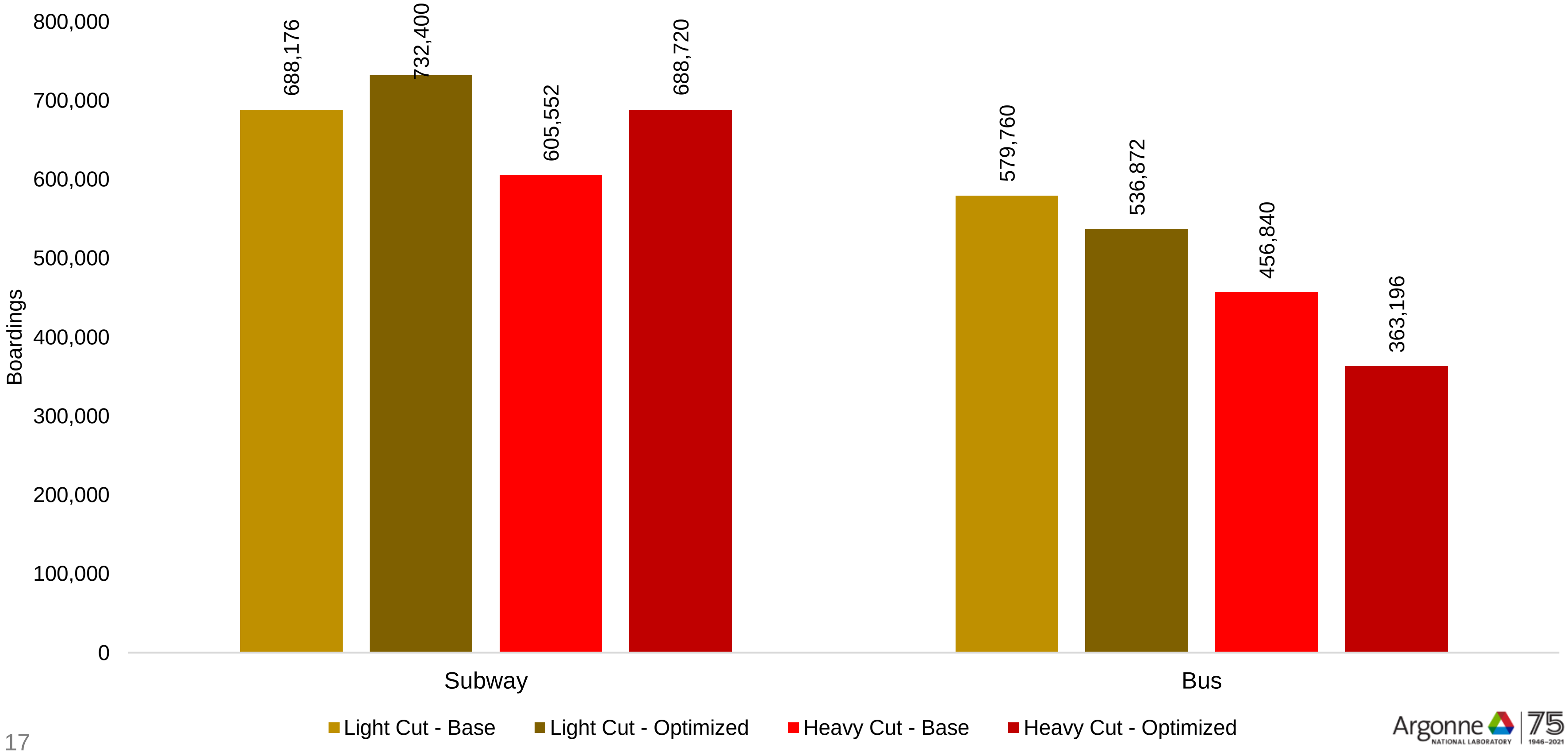
RIDERSHIP RECOVERY SCENARIO ANALYSIS

- Optimized Service Cuts
  - Instead of reducing frequencies homogenously across the board, we optimized the frequencies under equivalent budget of 20% cut and 55% cut
  - We adhered to the bus route elimination of the 20% cut and 55% cut scenarios

- Service Improvements
  - Provide 200% of existing frequencies
  - Add 2 Bus Rapid Transit (BRT) lines
  - Provide 200% of existing frequencies and add 2 Bus Rapid Transit (BRT) lines

OPTIMIZING FREQUENCIES SHIFTS SERVICE AND RIDERSHIP FROM BUS TO RAIL WITHOUT IMPACTING TOTAL RIDERSHIP

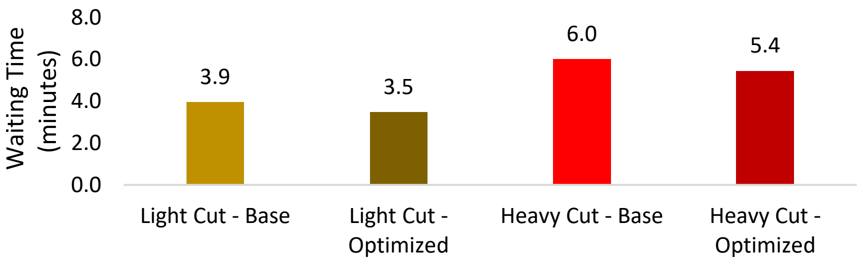
CTA Boardings – Optimized Service Cut Scenarios



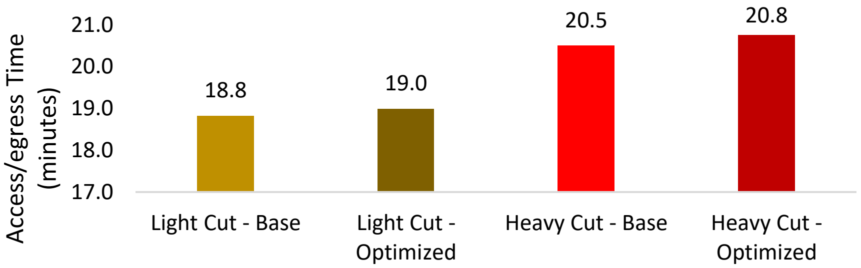
OPTIMIZING FREQUENCIES UNDER CUTS IMPROVES OVERALL USER EXPERIENCE

User Experience – Optimized Service Cut Scenarios

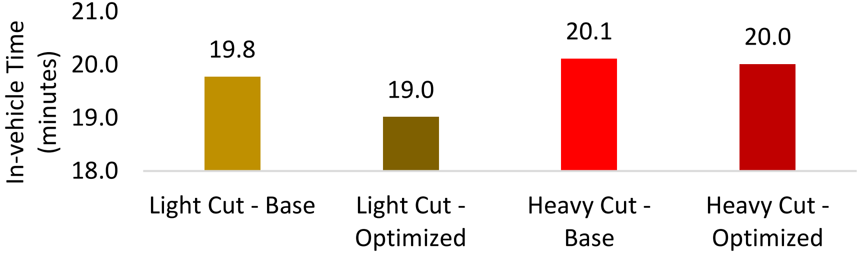
Waiting times decrease due to increased rail frequencies



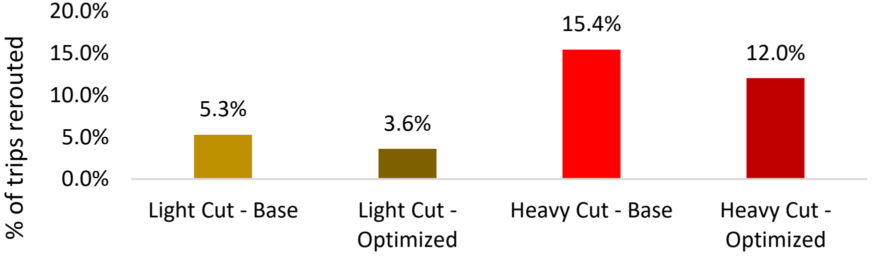
Access/egress time increases slightly because service is shifted to rail



In-vehicle time improves because rail is faster

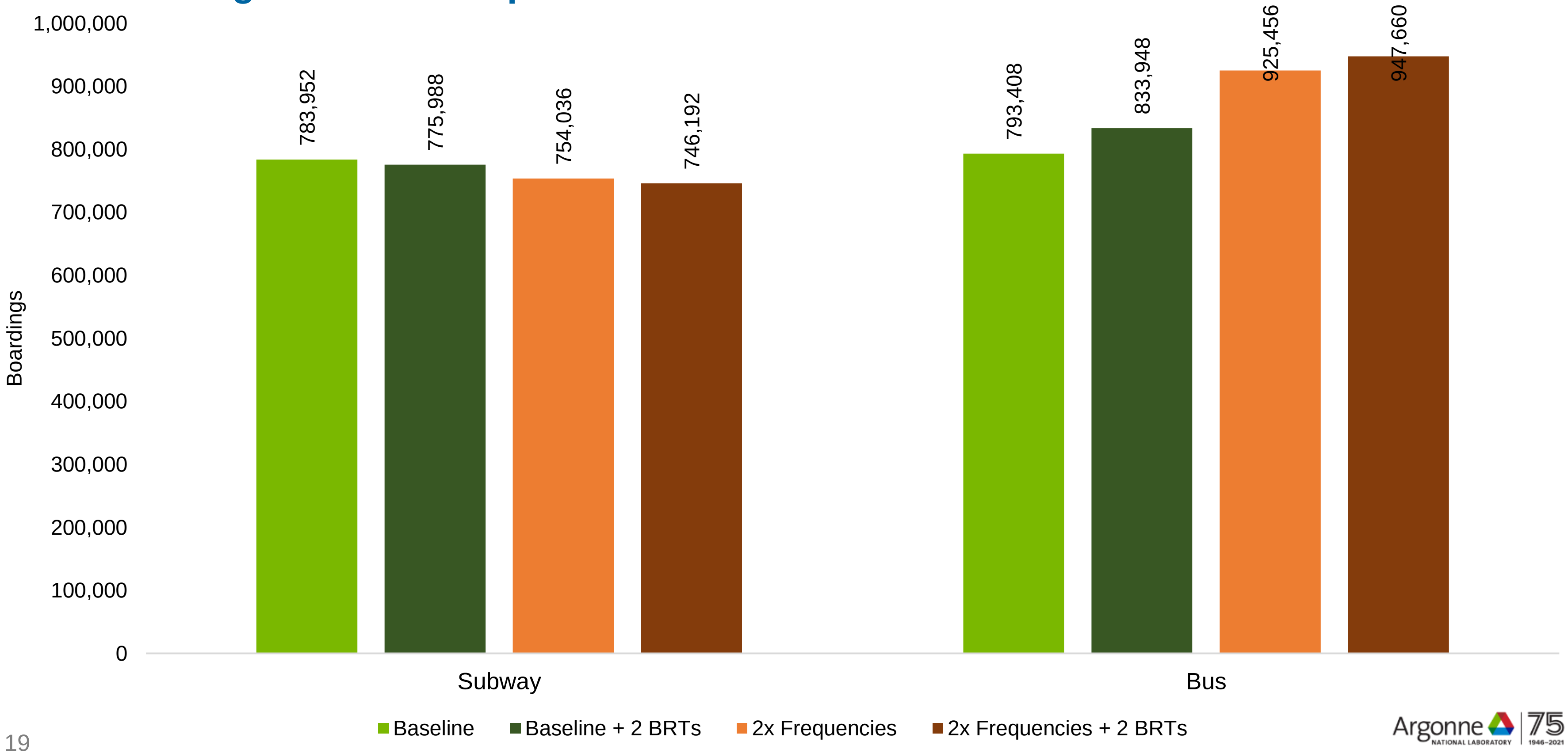


Re-routing decreases because there is more capacity on rail



INCREASING FREQUENCIES OR ADDING BRT LINES INDUCES TRANSIT RIDERSHIP AND SHIFTS TRAVELERS FROM RAIL TO BUS

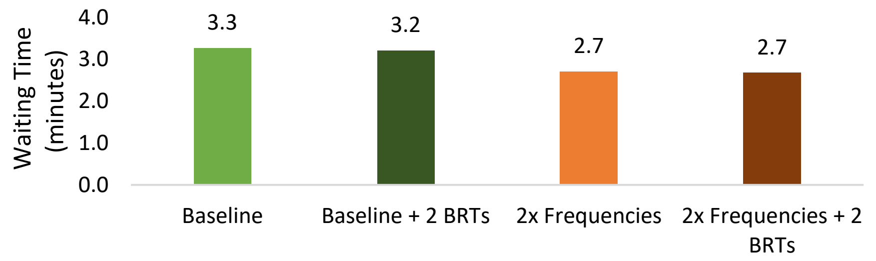
CTA Boardings – Service Improvement Scenarios



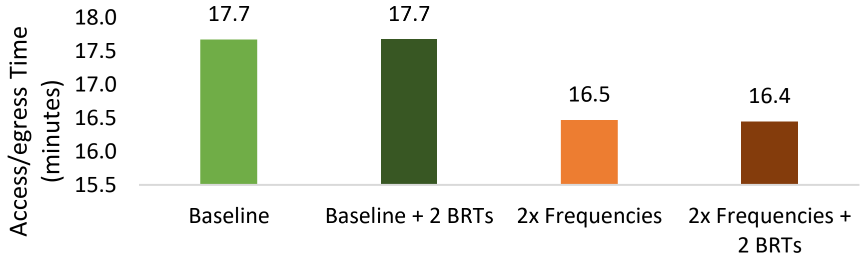
TRANSIT USER EXPERIENCE GENERALLY IMPROVES AS SERVICE IS ADDED IN THE SHAPE OF FREQUENCIES OR BRT

User Experience – Service Improvement Scenarios

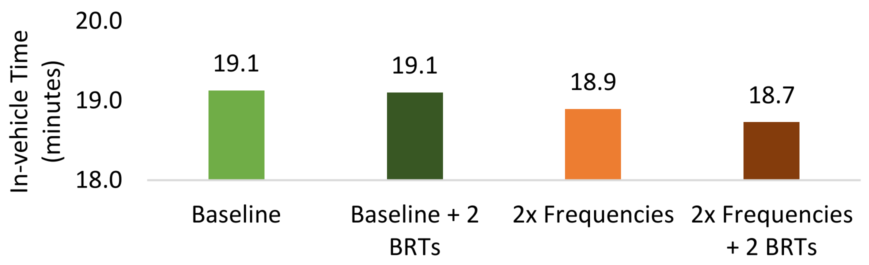
Waiting time decreases as more service is added



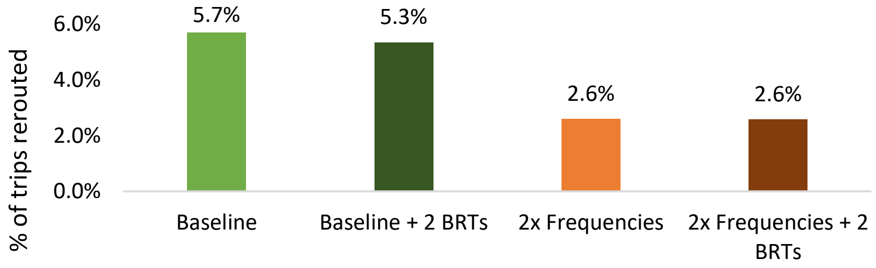
Access/egress time decreases because closer lines are more frequent



In-vehicle time slightly decreases because faster lines are more frequent



Re-routing decreases due to increased capacity



RESPONSE TO PREVIOUS YEAR REVIEWERS' COMMENTS

Reviewer Comment	Answer
The research question of how to reshape the future of transit seems much broader than the research, which investigates optimization of scheduling and routing.	We agree with the reviewer that transit is a wide research area. Pending future funding, we are looking to investigate and analyze additional strategies.
Slide 6 indicates that an early step was analysis of factors impacting CTA ridership, including TNC level of service and price, but it is not clear how this analysis informed the research design.	The analysis did not inform the study due to delay in signing the NDA. Due to the new agency's focus on COVID and recovering from it, we shifted our attention to mode risk perception and telecommuting.
Energy impacts are not shown as a direct output of the work. Presumably, the increase in boardings would save energy, but an explicit energy finding would be desirable in this multi-modal urban setting.	We have included energy and emissions analysis in our predictive scenario runs.

PARTNERSHIPS AND COLLABORATIONS

- Chicago Transit Authority (CTA)
  - Ridership, OD, and fleet data
  - Scenario definitions
  - Results analysis

- CDOT
  - Roadway data
  - Scenario definitions

- UIC
  - COVID behavior modeling

REMAINING CHALLENGES AND BARRIERS

- Risk perception model needs to be continuously updated with new survey data.
- Frequency optimization by itself is not sufficient to recover or increase ridership
  - Rail frequency is already very high -> marginal ridership improvement
  - Reducing bus frequency has equity implications
- Optimizing route design and frequencies jointly necessary to dramatically increase ridership
  - Frequency optimization
    - Direct effect on waiting times only, indirect effect on other metrics
  - Route optimization
    - Expands service coverage
    - Improves access times
    - Provides more direct service
    - Improves overall travel time
  - Very complex problem on top of a very complex problem

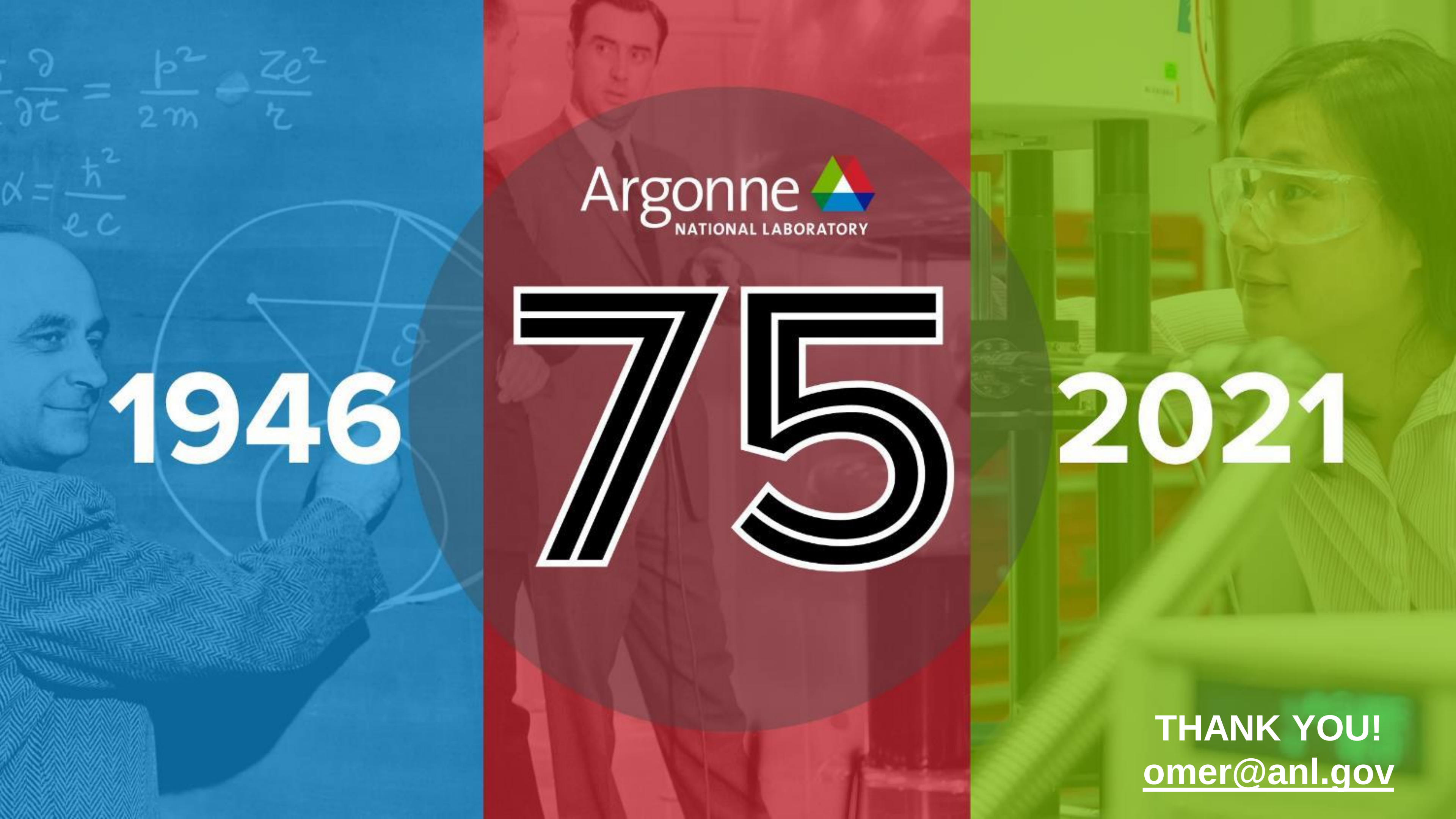
PROPOSED FUTURE RESEARCH

- Joint optimization of route design and frequency setting
- Transit signal priority
- Timed transfers
- Transit bus electrification
- Integration with first-mile/last-mile (FMLM) services

Any proposed future work is subject to change based on funding levels

SUMMARY

- Transit is the backbone of transportation.
  - Decrease in ridership negatively impacts the rest of the city: congestion, energy use, emissions, economy, and equity
- Continued COVID risk perception on transit has the potential to disrupt boardings more than deep service cuts or telecommuting.
- Optimizing frequencies under possible budget cuts is not sufficient to recover ridership but it improves traveler experience.
- Increasing frequencies by 100% induces transit ridership but also shifts some ridership from rail to bus, while it also improves traveler experience.
- The addition of 2 new BRT lines induces transit ridership but also shifts some ridership from rail to bus, while it also improves traveler experience.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THANK YOU!
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TECHNICAL BACKUP SLIDES

POLARIS CHICAGO MODEL

Transit network

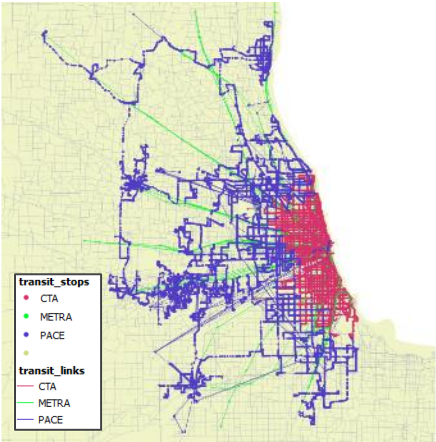
- 35,077 nodes (CTA, PACE, METRA)
- 160,642 links
- 344 transit routes with 2,098 transit patterns
- 28,138 transit vehicle trips
- Intermodal and walking connections

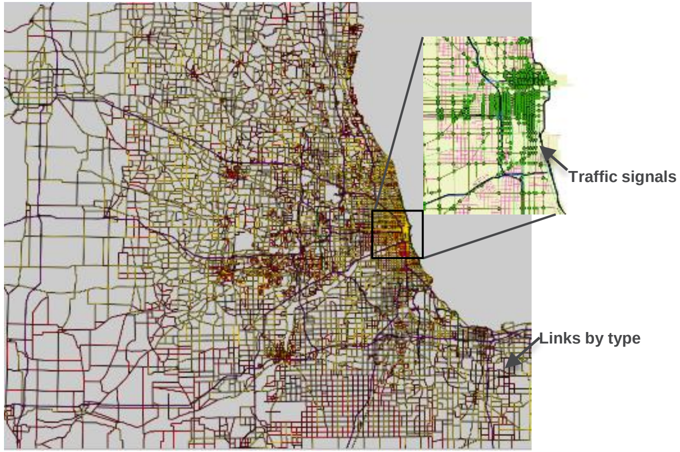
Street network

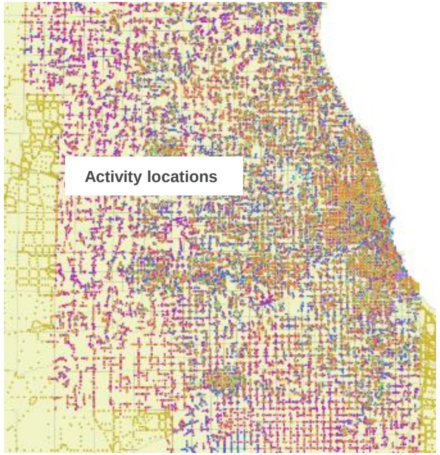
- 18,951 nodes
- 56,477 links with
- 7,900 traffic signals
- 12,500 stop signs
- 38 million trips

Demand

- 500,000 individual activity locations
  - Associated with activity types
  - Form start/end point for trips
- 1,961 Traffic analysis zones
- 10.2MM persons in 3.8MM HH

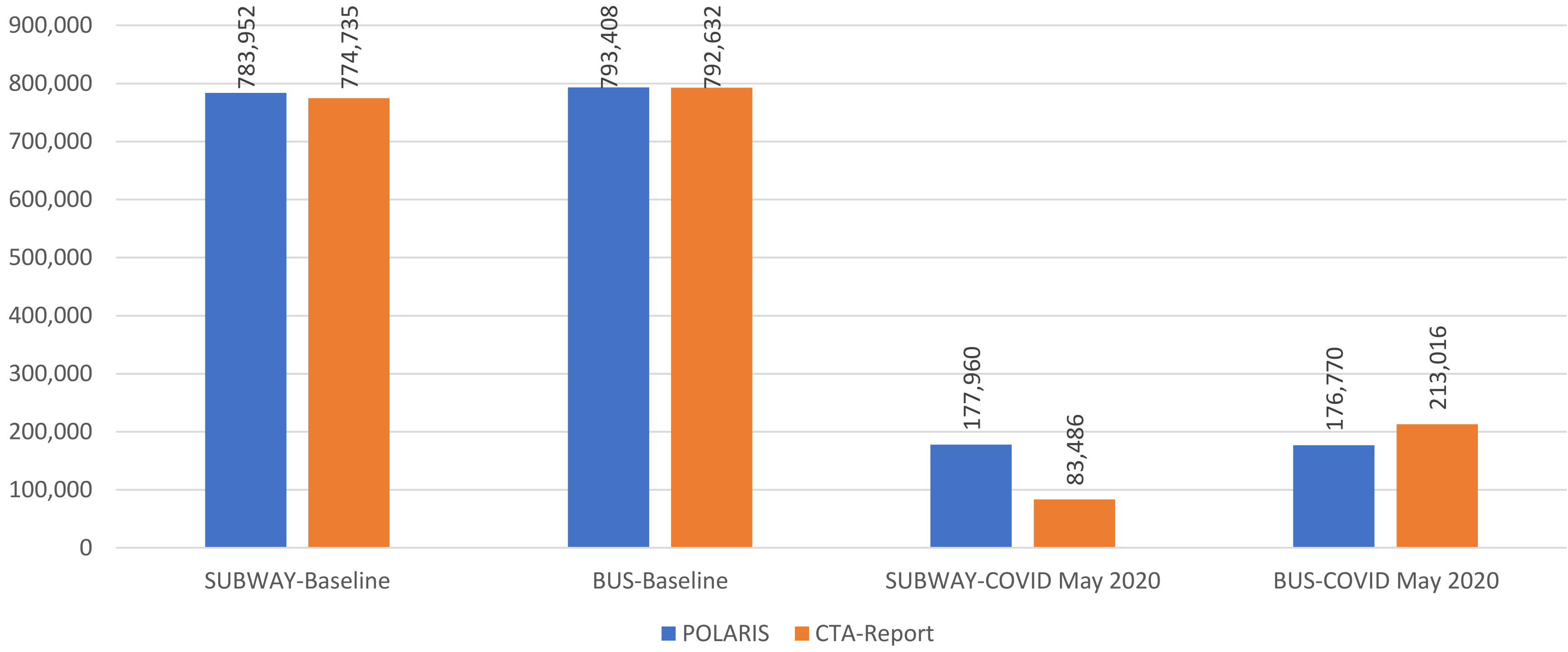




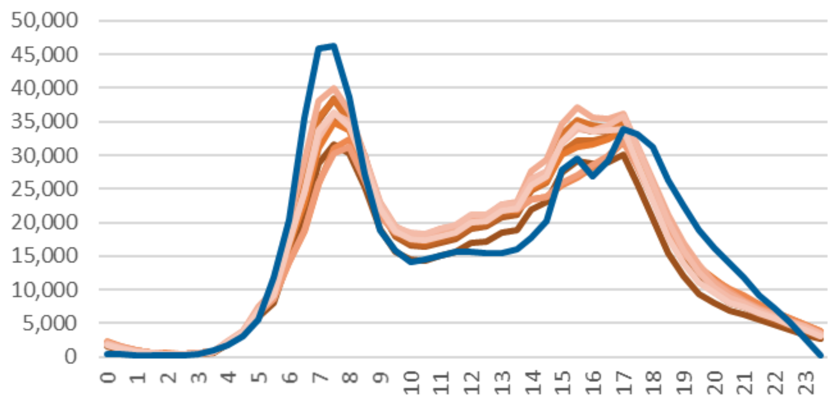
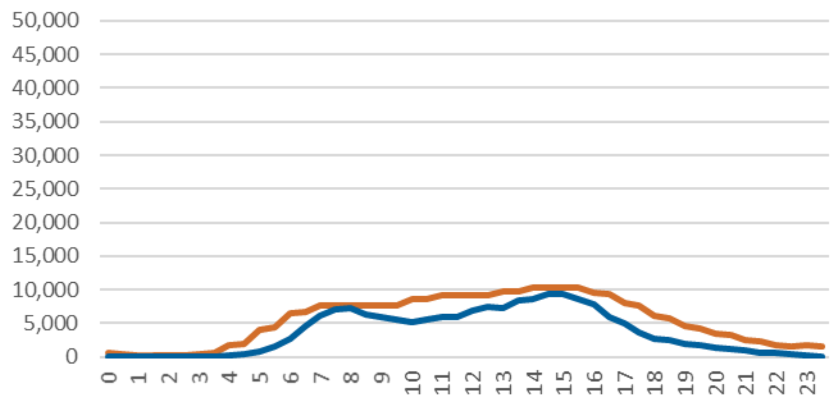
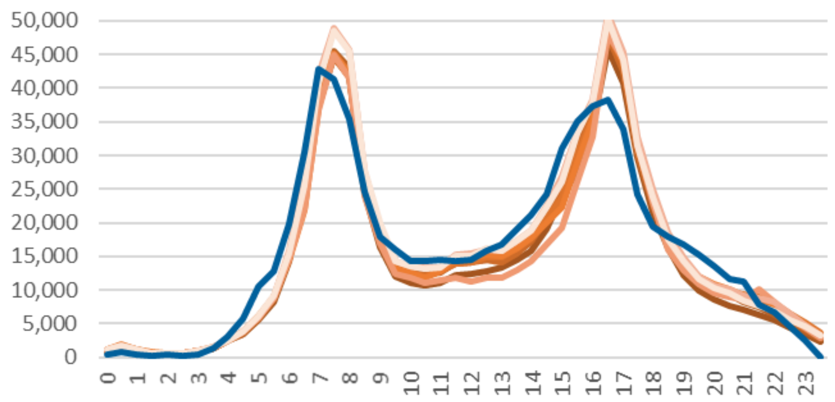
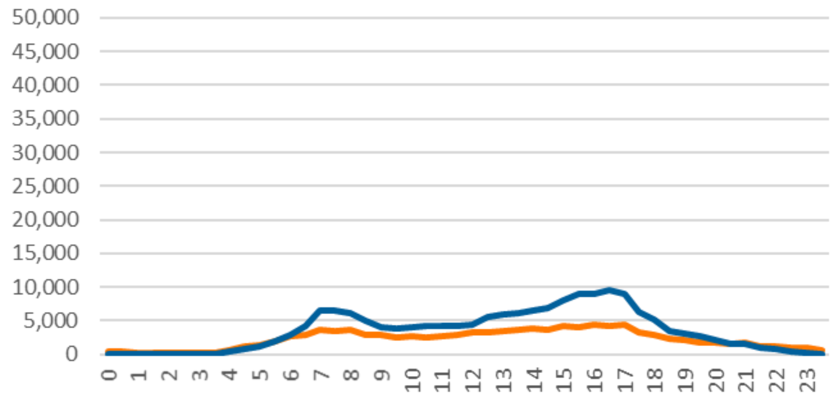


VALIDATION OF CTA BOARDINGS

Weekday Totals



VALIDATION OF HOURLY CTA BOARDINGS

	OCTOBER 2019 (Pre-COVID) VALIDATION	MAY 2020 (COVID) VALIDATION
BUS		
RAIL		

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