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TRB TRANSPORTATION RESEARCH BOARD

TRB Webinar: Telecommuting and Transit Ridership in a Post-Pandemic Future

March 28, 2023

3:00 – 4:30 PM

PDH Certification Information

1.5 Professional Development Hours (PDH) – see follow-up email

You must attend the entire webinar.

Questions? Contact Beth Ewoldsen at TRBwebinar@nas.edu

The Transportation Research Board has met the standards and requirements of the Registered Continuing Education Program. Credit earned on completion of this program will be reported to RCEP at RCEP.net. A certificate of completion will be issued to each participant. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the RCEP.

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Purpose Statement

Understanding the impacts of the COVID-19 pandemic on telecommuting and transit ridership patterns can inform the design and implementation of transit-supportive policies in the post-pandemic era. This webinar will illustrate the impacts of the pandemic on commuting, the trends of telecommuting, and the associated implications for transit ridership in the post-pandemic era. Presenters will show how transit riders‘ demographics and trip purposes have shifted. Presenters will also discuss the challenges and recovery pathways for different types of transit services.

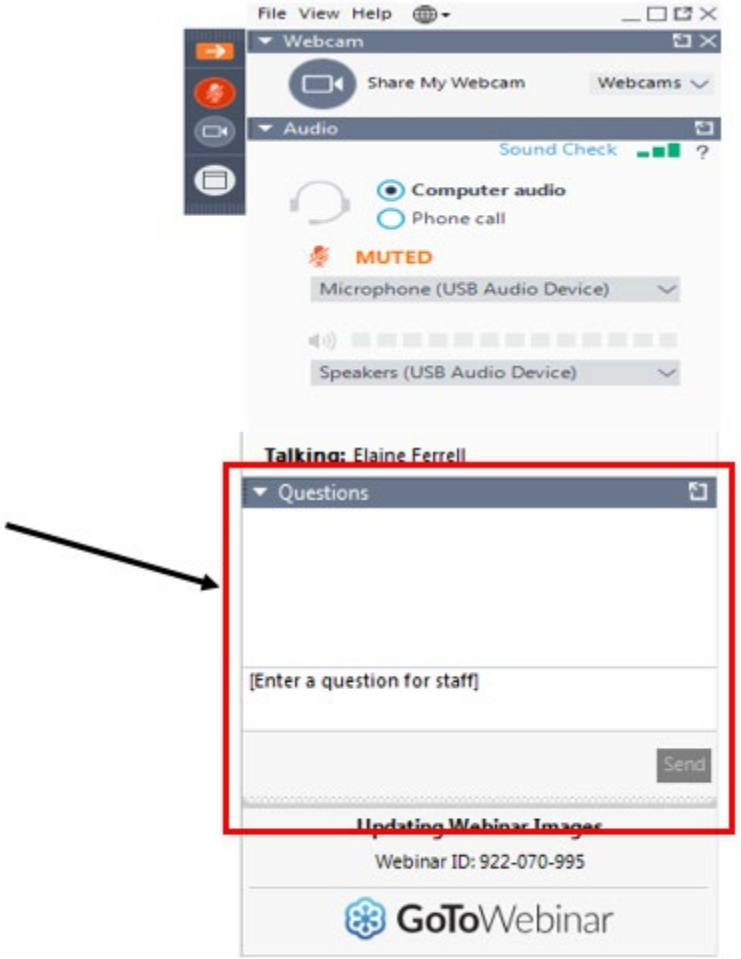
Learning Objectives

At the end of this webinar, you will be able to:

- Determine the scale impact of office commuting and telework on overall transit ridership
- Evaluate the likelihood of success of different transit services in the post-pandemic era

Questions and Answers

- Please type your questions into your webinar control panel
- We will read your questions out loud, and answer as many as time allows



Today's presenters

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The Impacts of COVID-19 on Commuting and Telework, and Associated Equity Issues

Adeel Lari , Frank Douma – Lead Researchers
Maya Sheikh, Kribashini Narayana Moorthy and Mattie Anders – GRAs
Institute for Urban and Regional Infrastructure Finance
Hubert H. Humphrey School of Public Affairs
University of Minnesota

Telecommuting Study Phases

- **E-Workplace Phase (2008-2018)**
  - Encourage telecommuting to reduce congestion and emissions
- **COVID-19**
  - Necessitated telecommuting – from encouraging telecommuting to managing the impacts
- **Post-COVID**
  - Study impact on travel, congestion, emissions and disparate impact on low-income and other disadvantaged communities

From Encouraging Telecommuting to Managing the Impacts

- eWorkplace established research and investments to *encourage* telecommuting among businesses and employees who wanted to telecommute
- COVID-19 *necessitated* telecommuting
- This research aims to understand:
  - Changes in travel behaviors
  - Impacts on core urban centers
  - Employer and employee responses
  - Equity during COVID-19 - who is able to telework?
  - Can we mitigate disparities if telecommuting remains a long-term option?

Encouraging Telecommuting: eWorkplace

- Started in 2008, a state-sponsored initiative to encourage telecommuting to reduce greenhouse gas emissions and travel congestion
- Improvements in productivity, work-life balance, and overall well-being for over 4000 participating employees
- Participants included public agencies, private companies and nonprofits (health care)

COVID-19: The World Went Remote

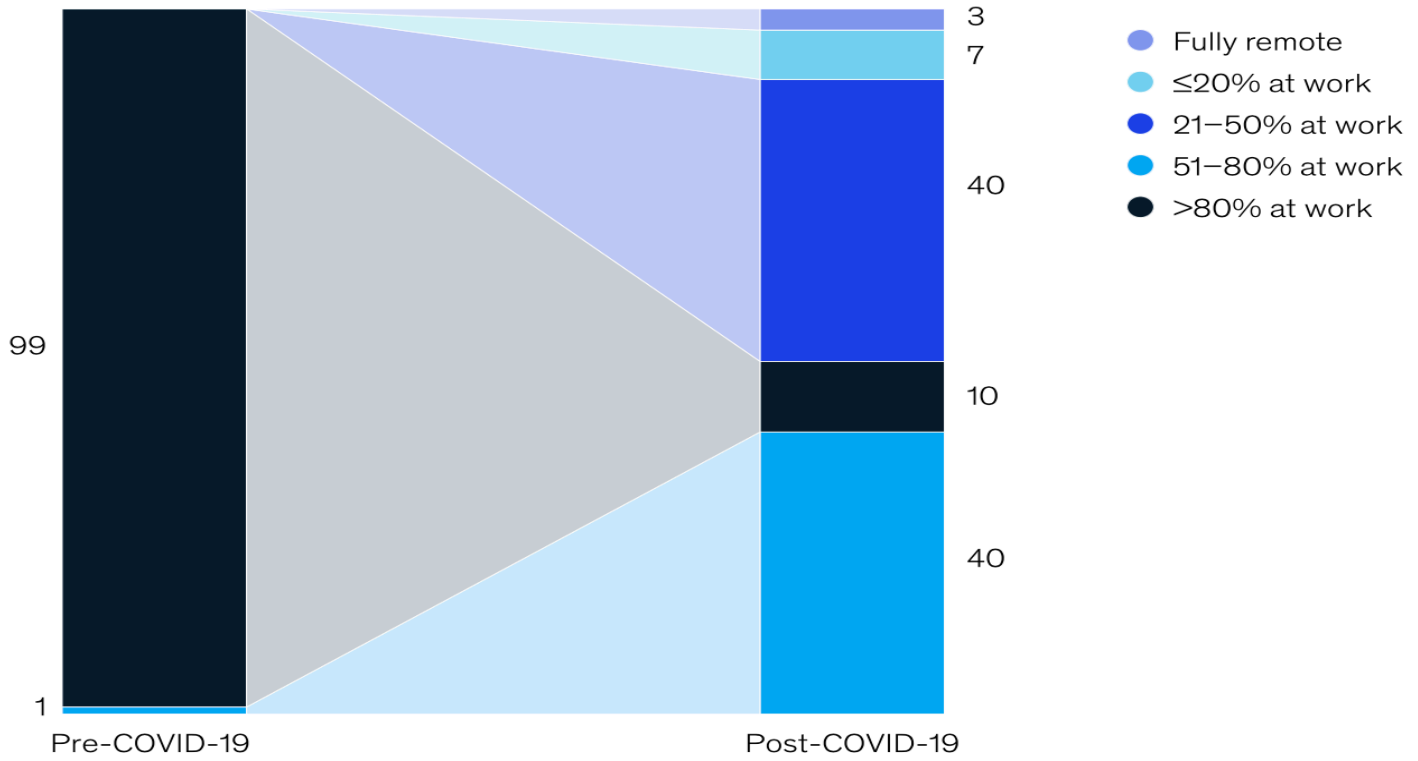
- **71.7% of workers that could work from home effectively did** *(Federal Reserve)*
- **12.2% of workers in Minneapolis Downtown summer of 2020** *(Minneapolis Downtown Council, July 2022)*
  - **30% in May 2021**
  - **Building occupancy 55.5%**
  - **Seated diners 55.8%**
- **Reduction in trips to workplace**
  - **30%** *(Minnesota)*
  - **35%** *(Ramsey County)*
  - **40%** *(Hennepin County)*

  Google Mobility report on July 11, 2022 vs. baseline Jan 2020
- **Not all the 290,000 employees in downtown and Northloop will be coming back**

Post-COVID Work

In the post-COVID-19 future, C-suite executives expect an increase in hybrid work.

Past and future expectations of time spent at work location,[1] % respondents



[1]Question: What level of remote working (for roles typically associated with being office-based) does your organization have?

McKinsey

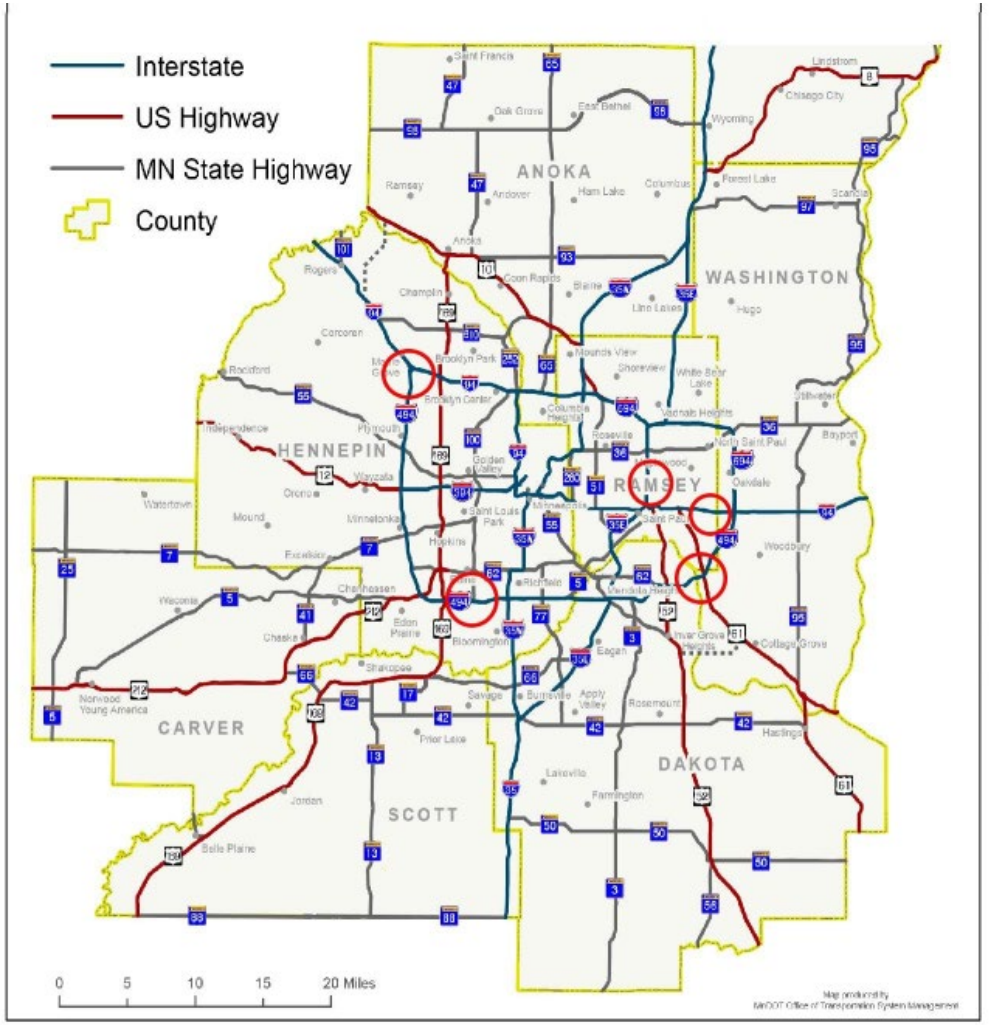
Research Methods

- **Quantitative:**
- Review traffic counts to discern changes in travel patterns pre, during and post-COVID-19
- **Qualitative:**
- Use national and state level data to discern the impact COVID-19 had on transportation and disparate populations
- Interviews to discern:
  - the transportation demands COVID-19 has on transportation,
  - who gets to telework and
  - what actions are being taken to develop a new norm that mitigates discrepancies
- **Why Minnesota?**
- Its where we are
- Among the largest disparities in the nation – useful for comparing to national trends

Telecommuting & COVID-19 (Quantitative)

- **Analyzed weekday travel demand, congestion, and peak travel throughout the Twin Cities metro and suburban areas using MnDOT detectors**
  - 35E north of downtown St. Paul
  - Northwestern corner where 494 and 694 come together
  - 494 crossing Mississippi River
  - East Metro: 1-94 east of Downtown St. Paul
  - West of downtown Minneapolis 100 and 494 highway 394 crossings

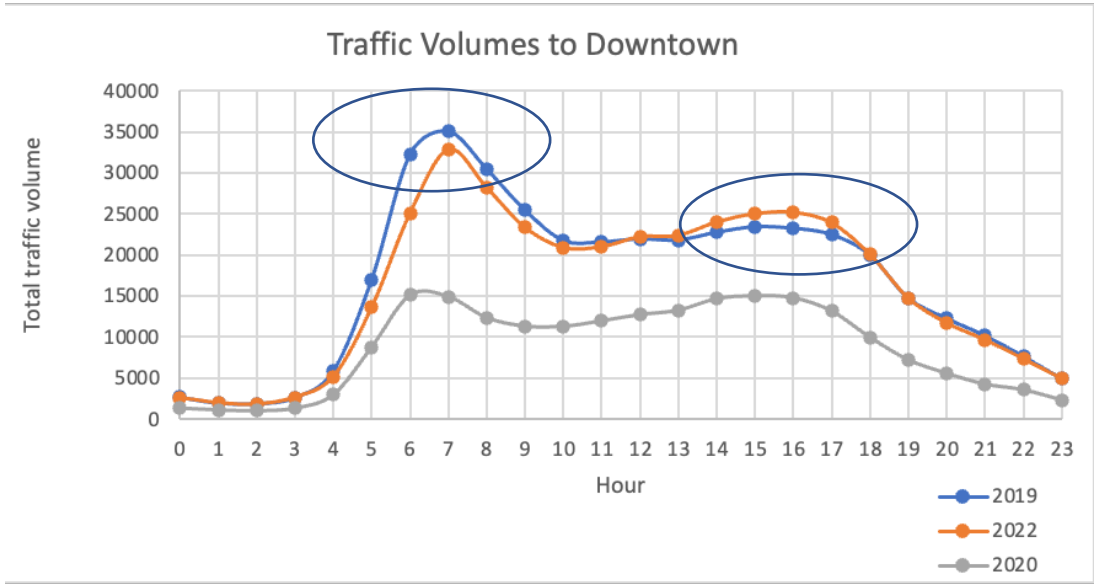
- **These locations were chosen due to their high volume of commuter travel**
- **For the above locations, the hourly traffic volumes were compared for the years 2019 and 2022 for the months of March, April and May**

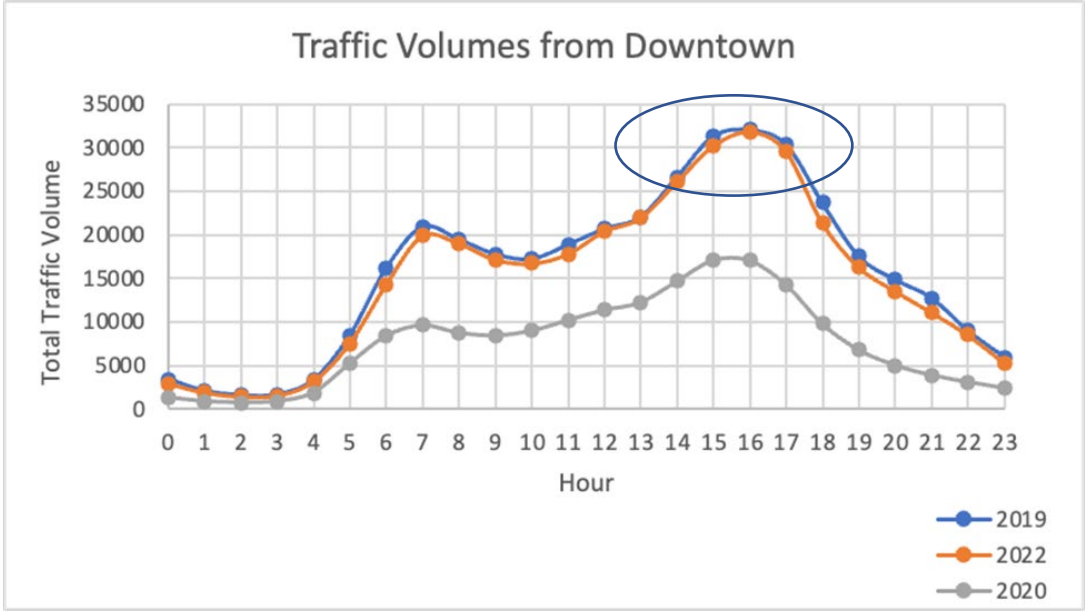


April *(All Sensors)*

By 2022, morning peak volumes remain lower than before COVID-19, and evening volumes have fully recovered

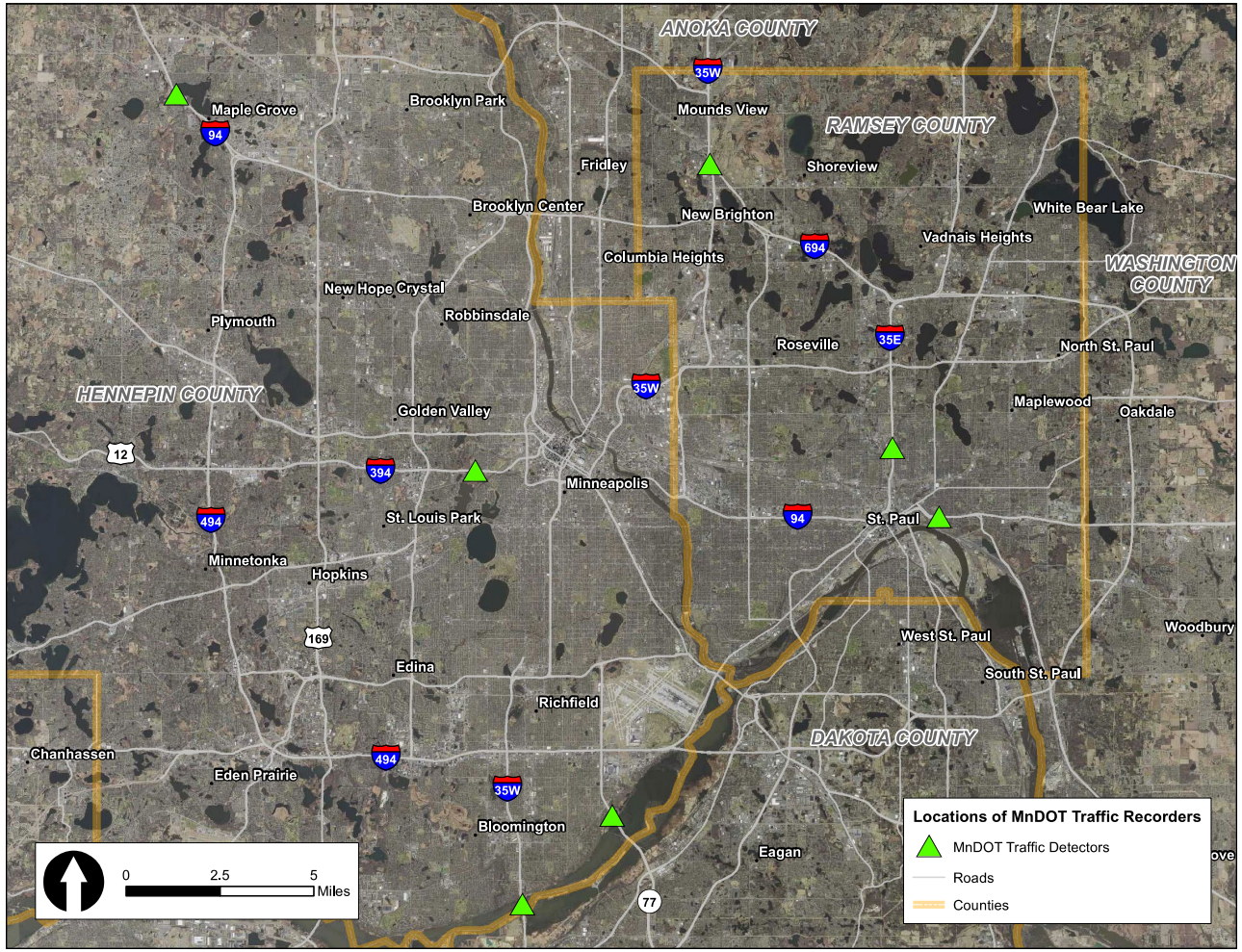
- Does the evening rebound indicate more discretionary trips?
- Commuters have the flexibility to travel to work later in the day



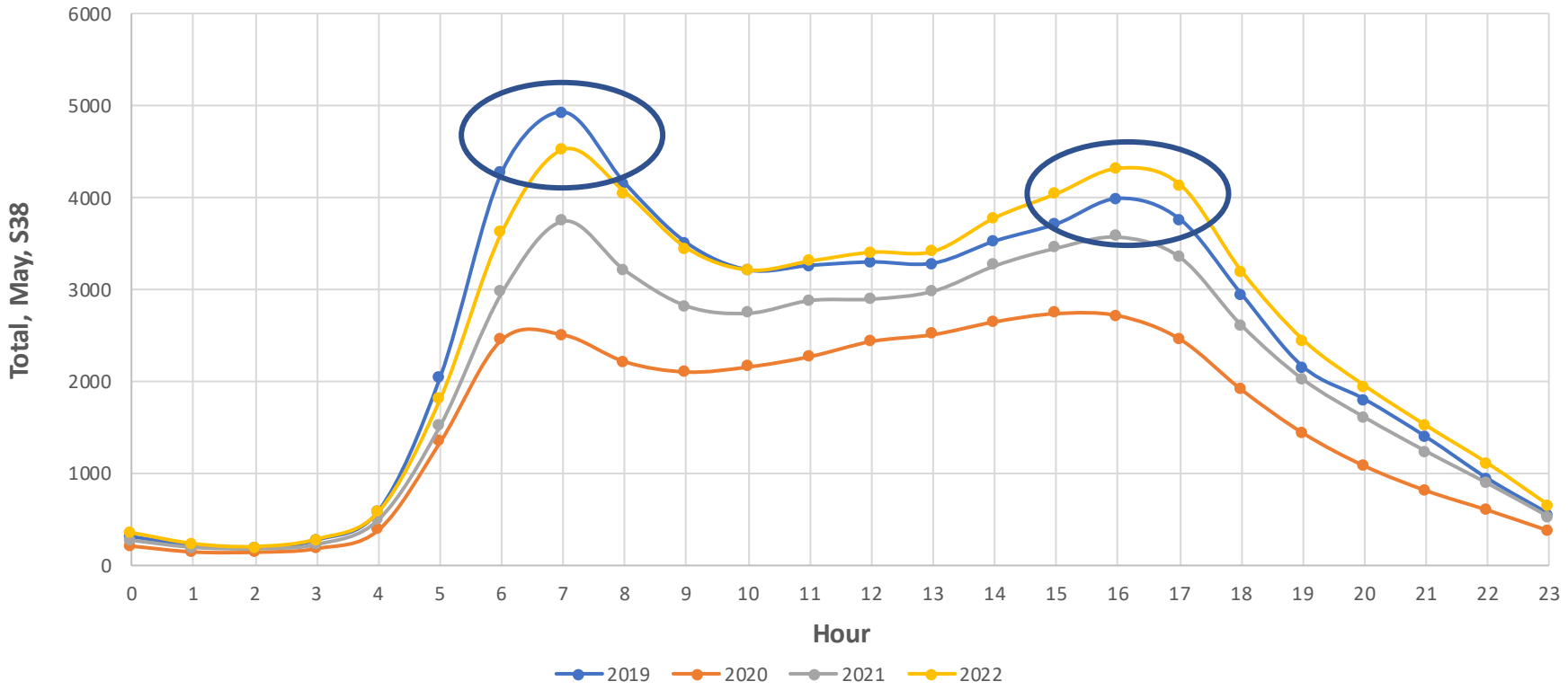


Telecommuting & COVID-19

- Next examined impact of hybrid work on the distribution of commuting trips between workdays.
- Looked at sites that carry significant commuting trips.
  - 35W at 98th street Northbound
  - 35W at TH96 Southbound
  - I94 at Weaver Lake Road Southbound
  - I94 at Century Ave Westbound
  - I394 at Penn Ave Eastbound including EZ Passlane
  - TH 77 at River Crossing Northbound
  - I35E at Larpenteur Ave Southbound
- Compared the sum of May/June 2019 volume distribution with May/June 2022 for morning peak period (i.e from 6am to 9am.)
- Calculated the volumes at these locations for weekdays during morning peak period and then the percentage of traffic for each weekday.

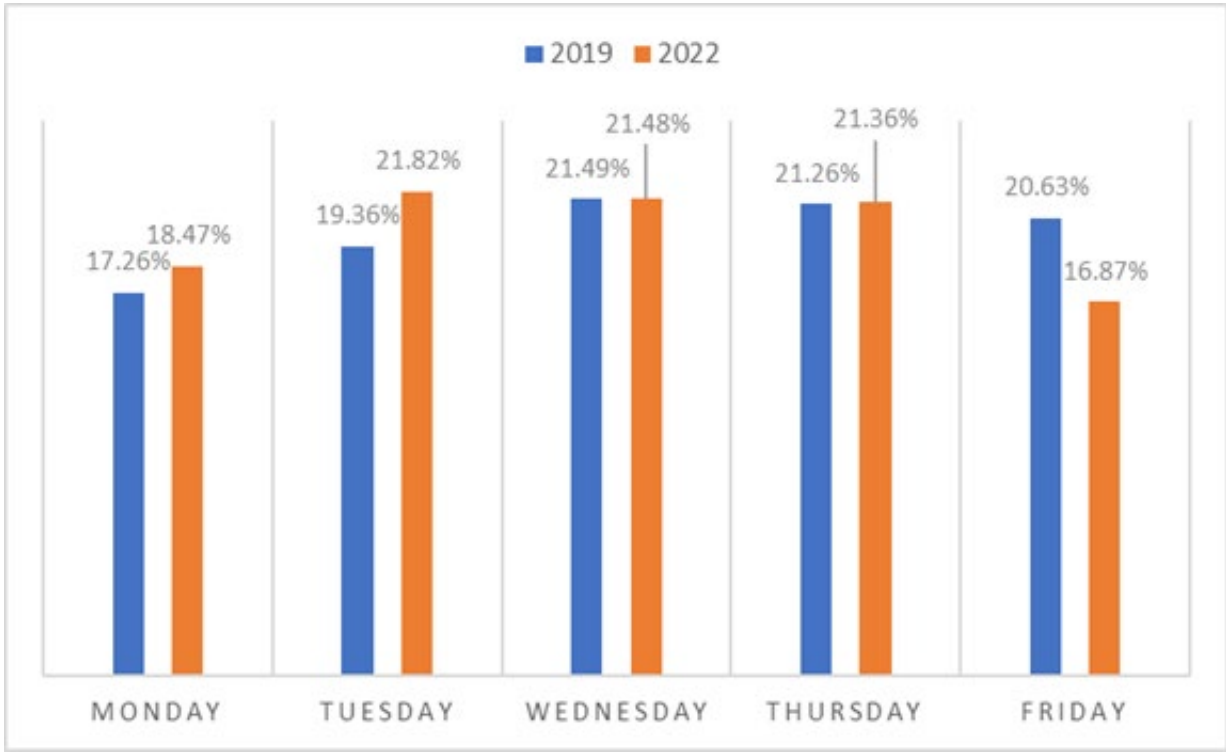


I-35W at 98th Street (Northbound)



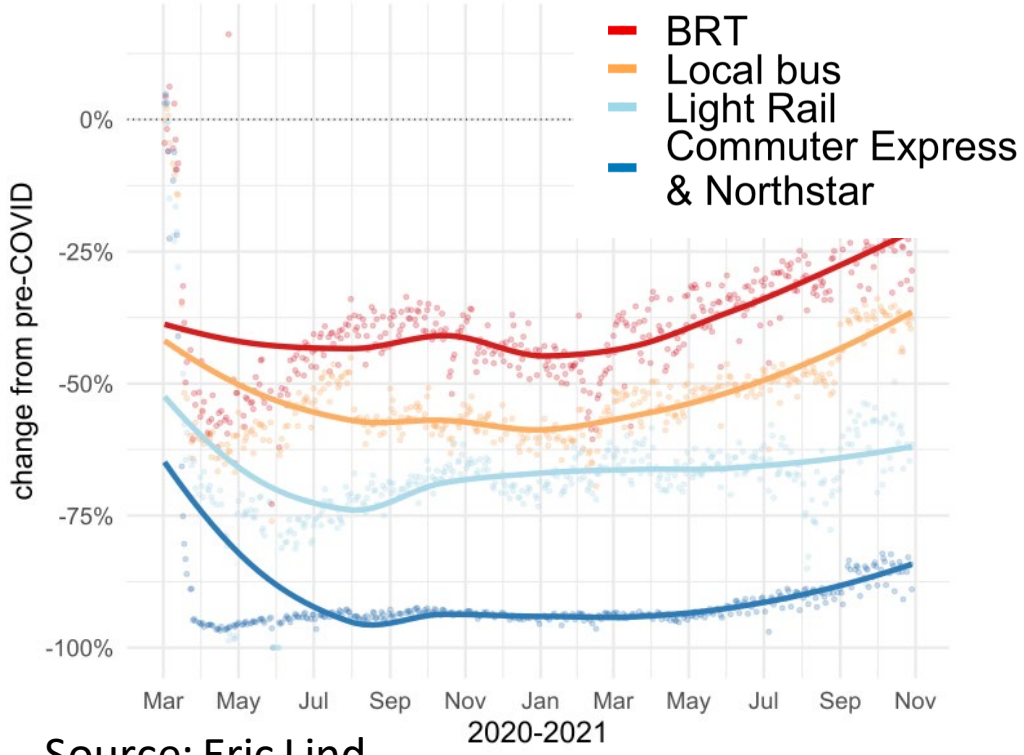
Weekday Trip Distribution

- Aggregate volumes down 20%
- How does the hybrid model influence travel behaviors?
  - The overall trend indicates that we are moving towards a 4-day work week.
  - Distribution of trips is nearly the same
  - Fridays have a lower distribution that previous years, and current weekday volumes for Monday - Thursday



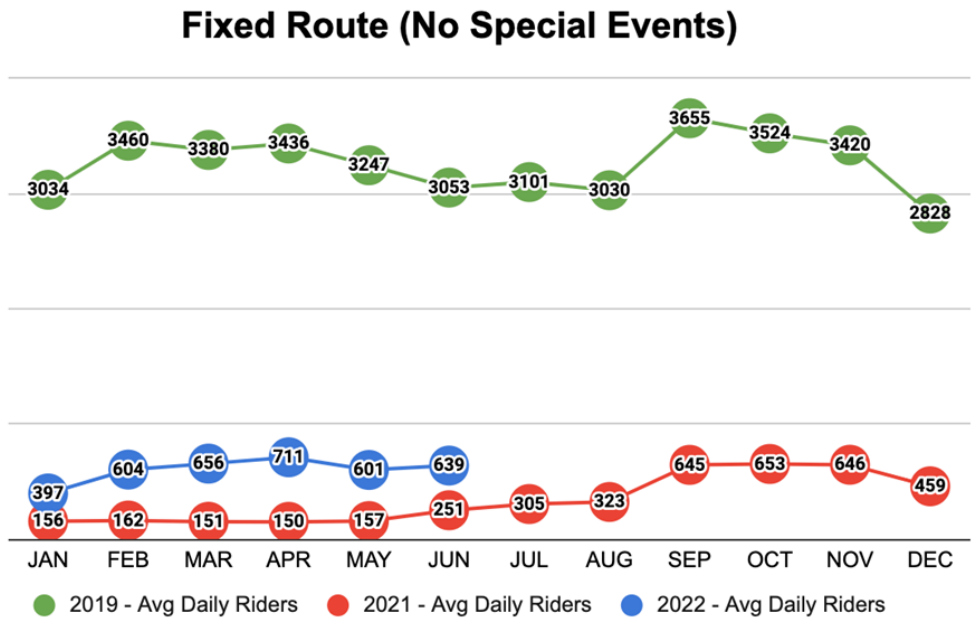
Transit is its own story

Metro Transit



Source: Eric Lind, Metro Transit

SW Transit (Primarily Suburban Express)



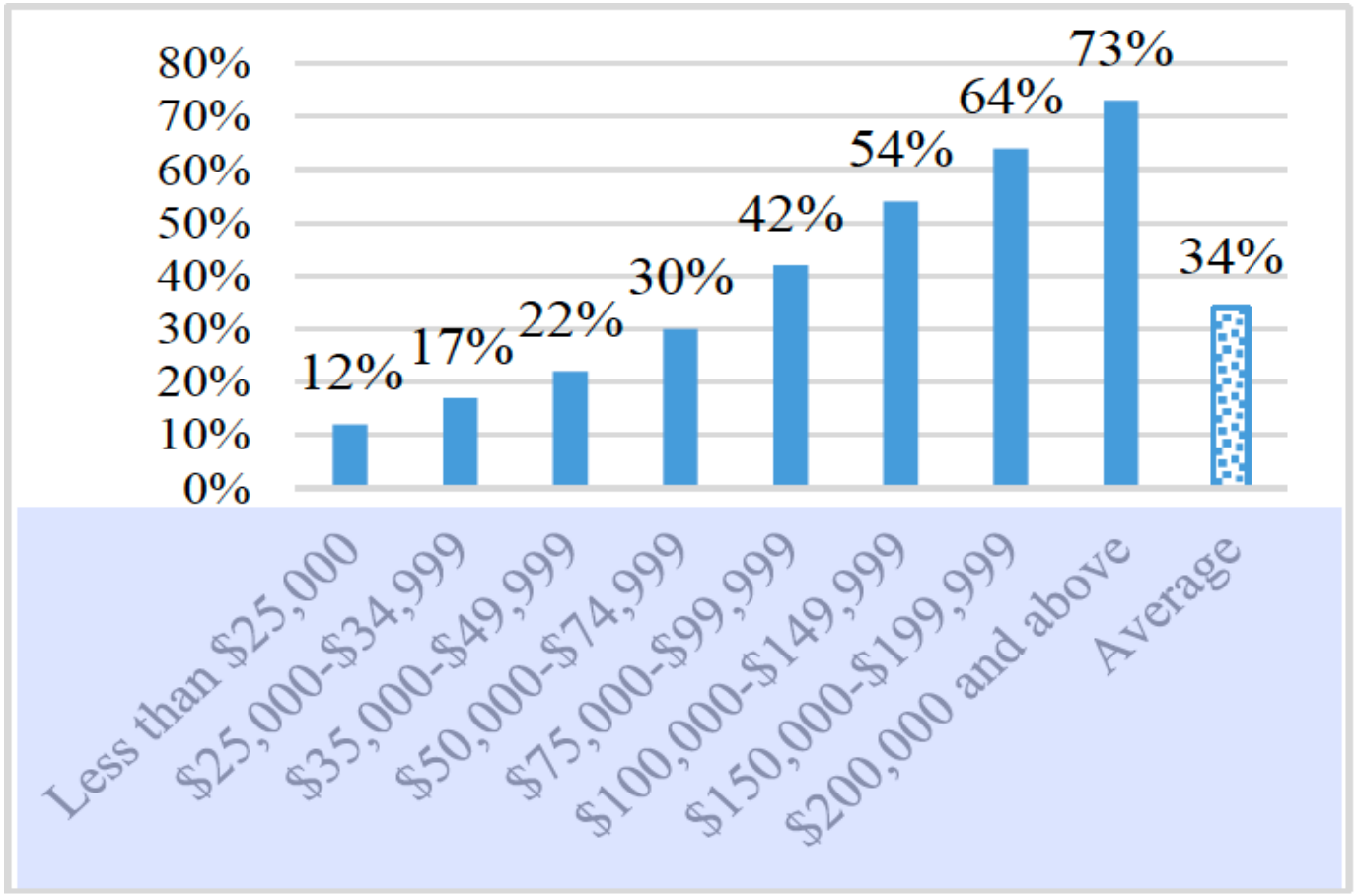
Source: Southwest Transit

Qualitative Methods

- Collected data to determine industry and job-related demographics for the research area.
  - US Labor Statistics
  - American Community Survey (ACS)
  - Census
  - ReferenceUSA
- Conducted interviews with travel management, transit management, and downtown improvement organizations:
  - Move Minnesota (Saint Paul Transit Management Organization)
  - Metro Transit
  - Saint Paul Downtown Alliance
  - 494 Corridor Commission

Income makes the difference

- Telecommuting disparities by income are *stark*
  - By December 2020
  - only 15% with an income of $50,000 telecommuted,
  - 70% with an income higher than $100K did.
  - *(Source: Bureau of Transportation Statistics)*



Source: Census, Pulse Survey, September 2 – 14, 2020

Working from Home - Not for Everyone?

Race	USA '20	USA '21	USA '22	MN '21	MN '22
• White	29.9%	30.71%	32.1%	36.25%	39.3%
• Asian	37.0%	42.84%	46.5%	50.55%	25.7%
• Black	19.7%	23.85%	22.9%	36.72%	19.1%
• Hispanic	16.2%	22.26%	22.6%	22.25%	22.6%
Educational Attainment					
• Less than High School	4.2%	10.55%	10.1%	10.53%	4.7%
• High school graduates	12.6%	14.56%	14.9%	18.19%	19.9%
• Some college or associate degree	24.2%	26.55%	27.6%	34.6%	31.6%
• Bachelor's degree or higher	51.9%	50.63%	51.9%	56.08%	57.6%
Gender					
Male		30%	32.2%		39.0%
Female		28%	28.4%		34.4%

Source: Census Pulse Survey, September 2020, June-July 2021 & June 2022 USA and June-July 2021 & June 2022 Minnesota

Conclusions – and questions

Interviews reinforced preliminary findings and pointed to ongoing concerns.

- Will telecommuting be sustained long term?
- Can telecommuting address existing issues and new unforeseen issues?

- **Environment**
  - Existing: touted benefits of telecommuting (flexibility, reduced congestion, lower emissions) enjoyed most by those in private vehicles
  - Future: transit, future infrastructure investments, account for lower congestion and shifted peaks in future planning

- **Equity**
  - Existing: limited income, language barriers, available employment opportunities made more challenging by limited transit network/service hours
  - Future: cost considerations; inequities from poorer access to transportation

Conclusions – and questions

- **Downtowns**
  - Existing: Concern about perceived safety, adapting to fewer people downtown, reinvented office spaces
  - Future: encouraging people to return to downtowns via events and programming, reconfigured office spaces and leases, reduced travel downtown jeopardizes job security for some, concern about parking investments

- **Reliability and Reliance of transit and transportation system**
  - Existing: the "transportation disadvantaged" do not have reliable access to a car, and are reliant on transit and other modes of transportation that have limitations (network extent, service hours, low ridership, etc.)
  - Future: will telecommuting create a lasting, new normal within the four-day work week? How can we address unmet transportation needs with lower congestion, or need, for new routes or transit lines?

How COVID changed transit ridership patterns… and what might be next

Eric Lind

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Accessibility Observatory @ Center for Transportation Studies

University of Minnesota

Transit use = supply x demand

Ridership

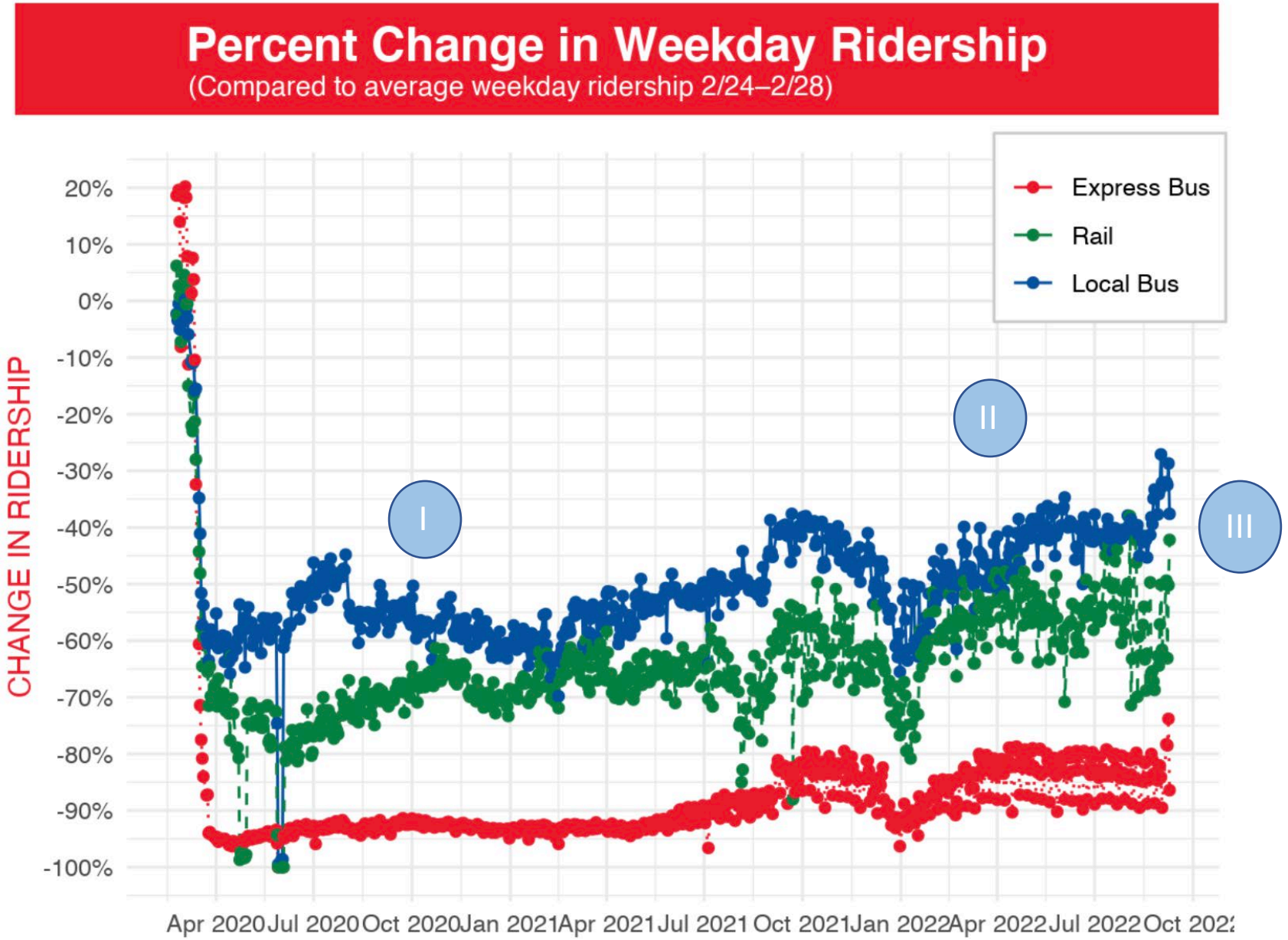
=

decision to travel

x

opportunity provided

Metro Transit flickr

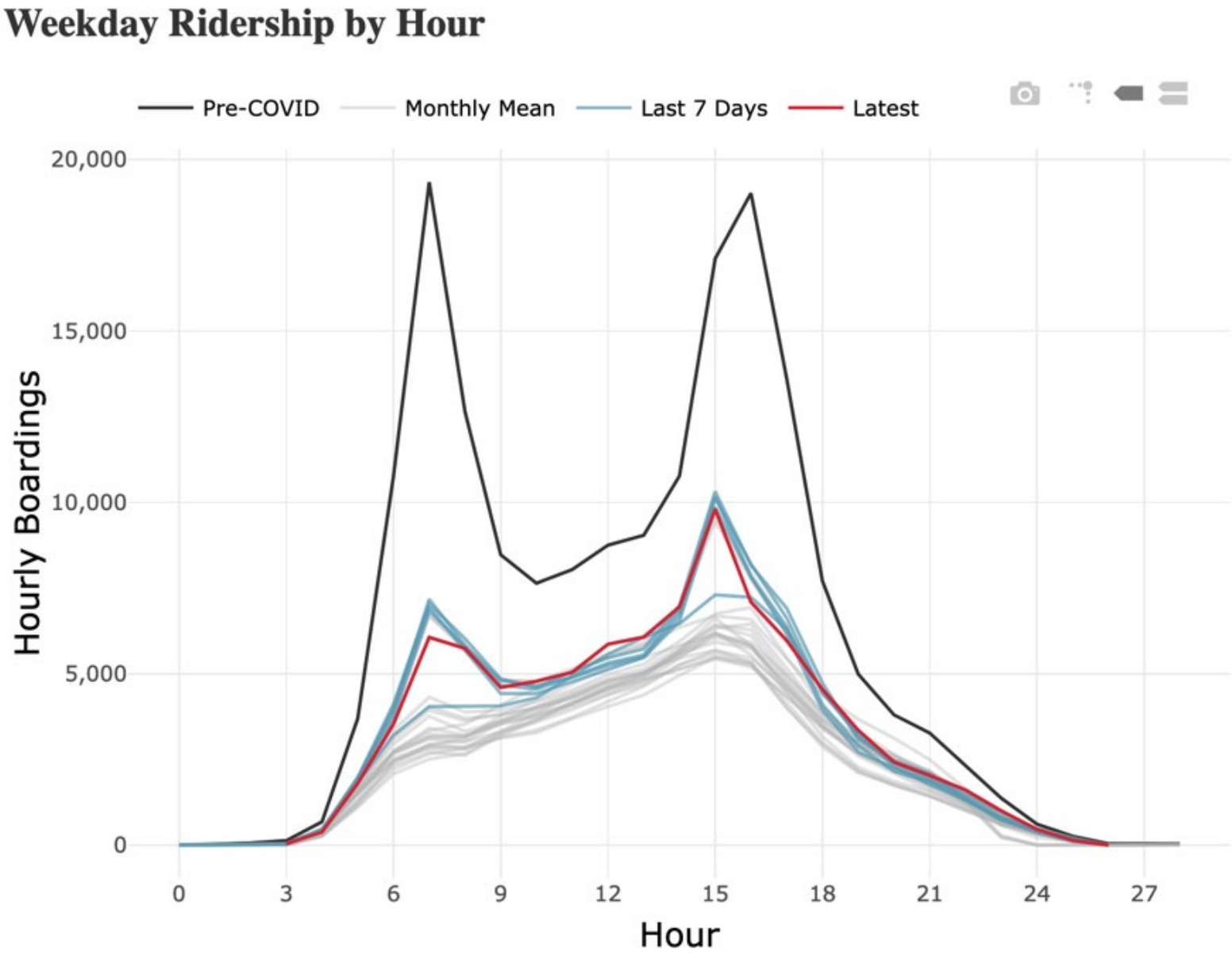


*Preliminary estimates, subject to change

- Period I: COVID demand shock
- Period II: growth under constraint
- Period III: what might be next

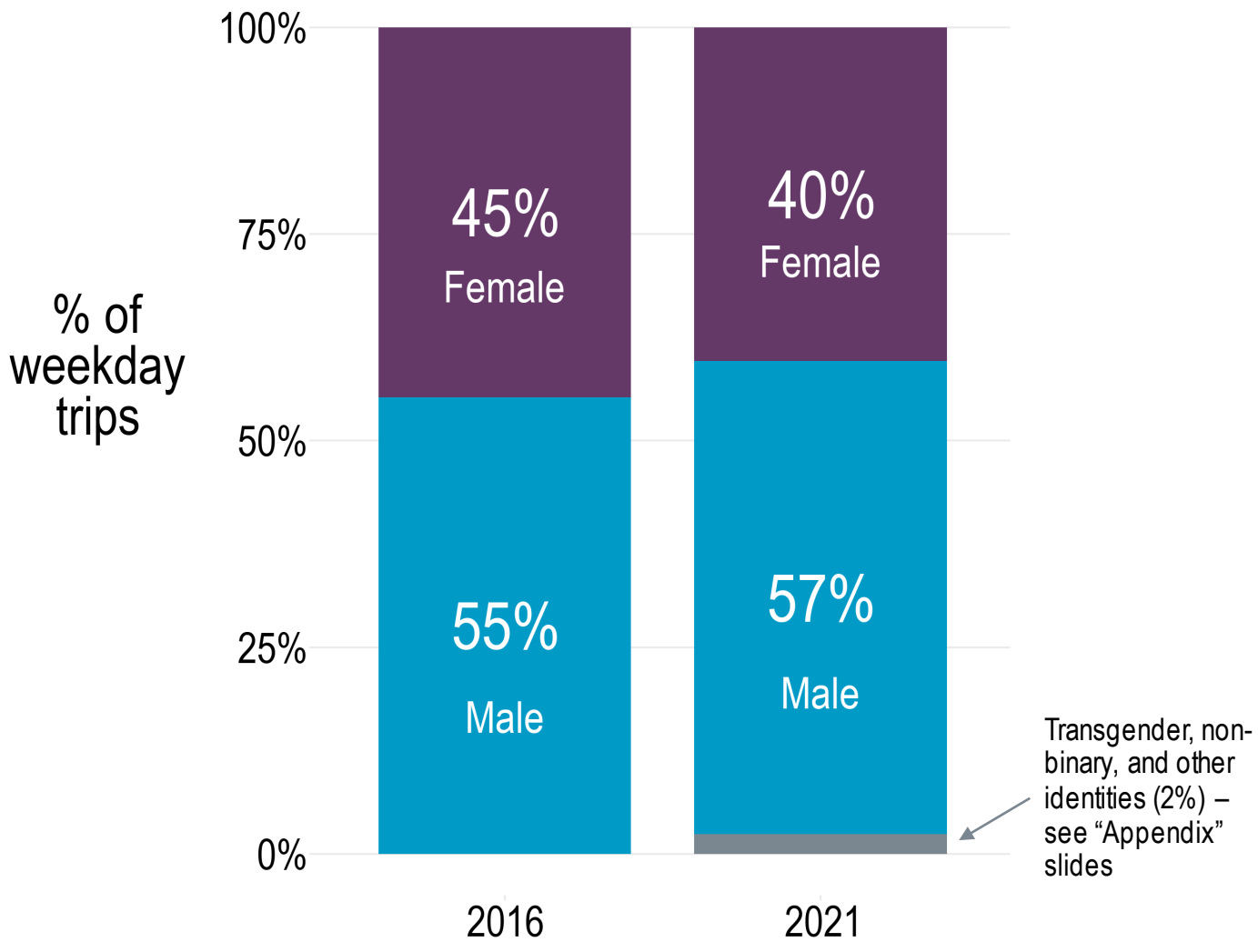
fall 2021: time of day

- peak hours evident
- 3pm peak = school boardings
- PM > AM



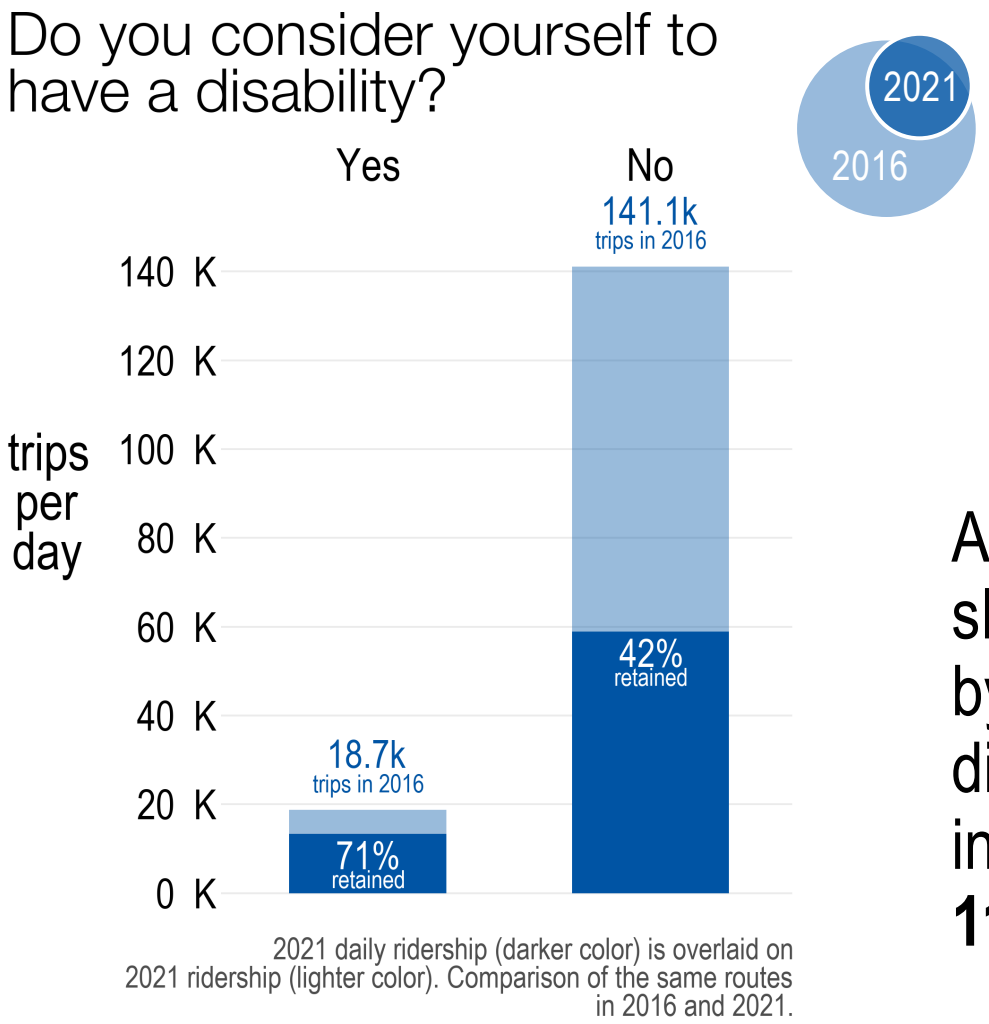
Fall 2021:
Who is on board?

Share of men on-board has increased



Comparison of the same routes in 2016 and 2021.

Retained a greater share of trips by riders with a disability

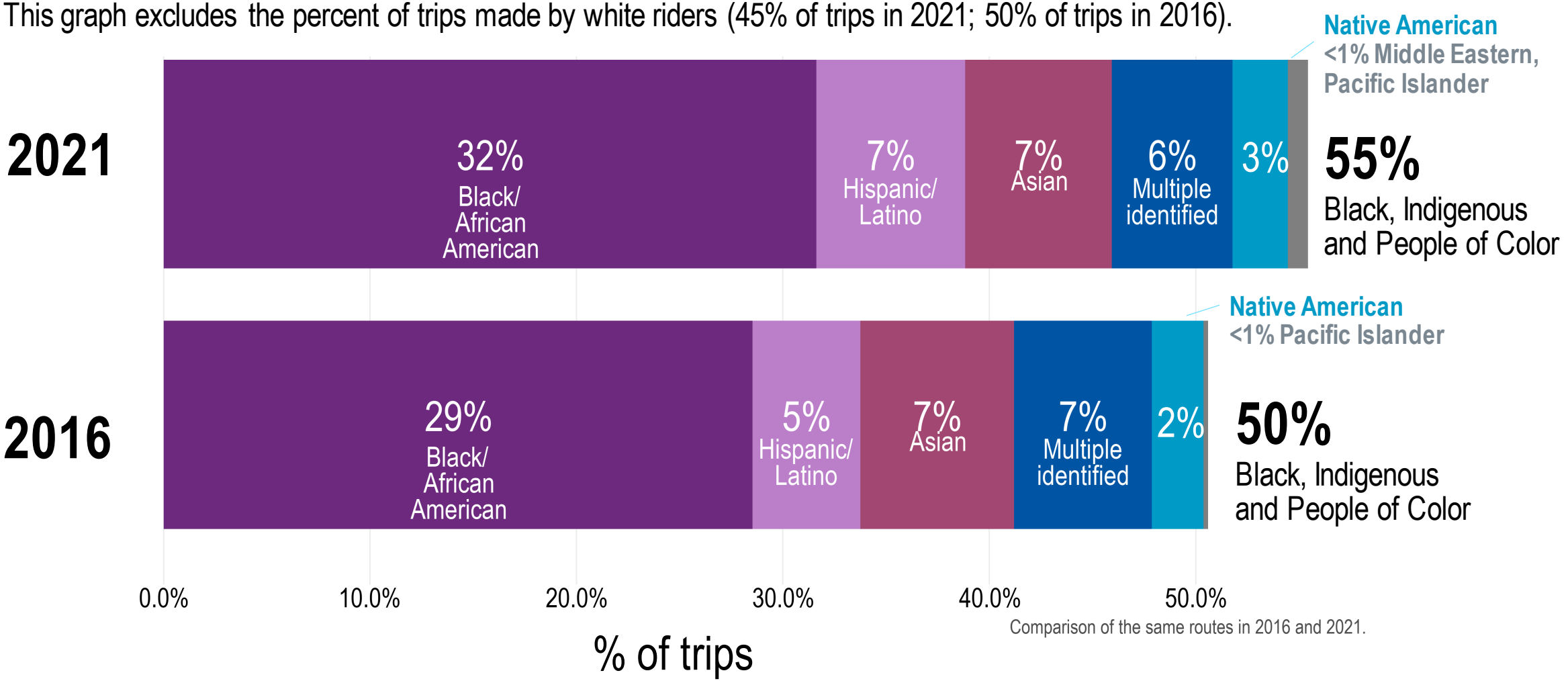


"Prefer not to answer" omitted.

Additionally, the share of trips made by those with a disability has increased from **11%** to **18%**.

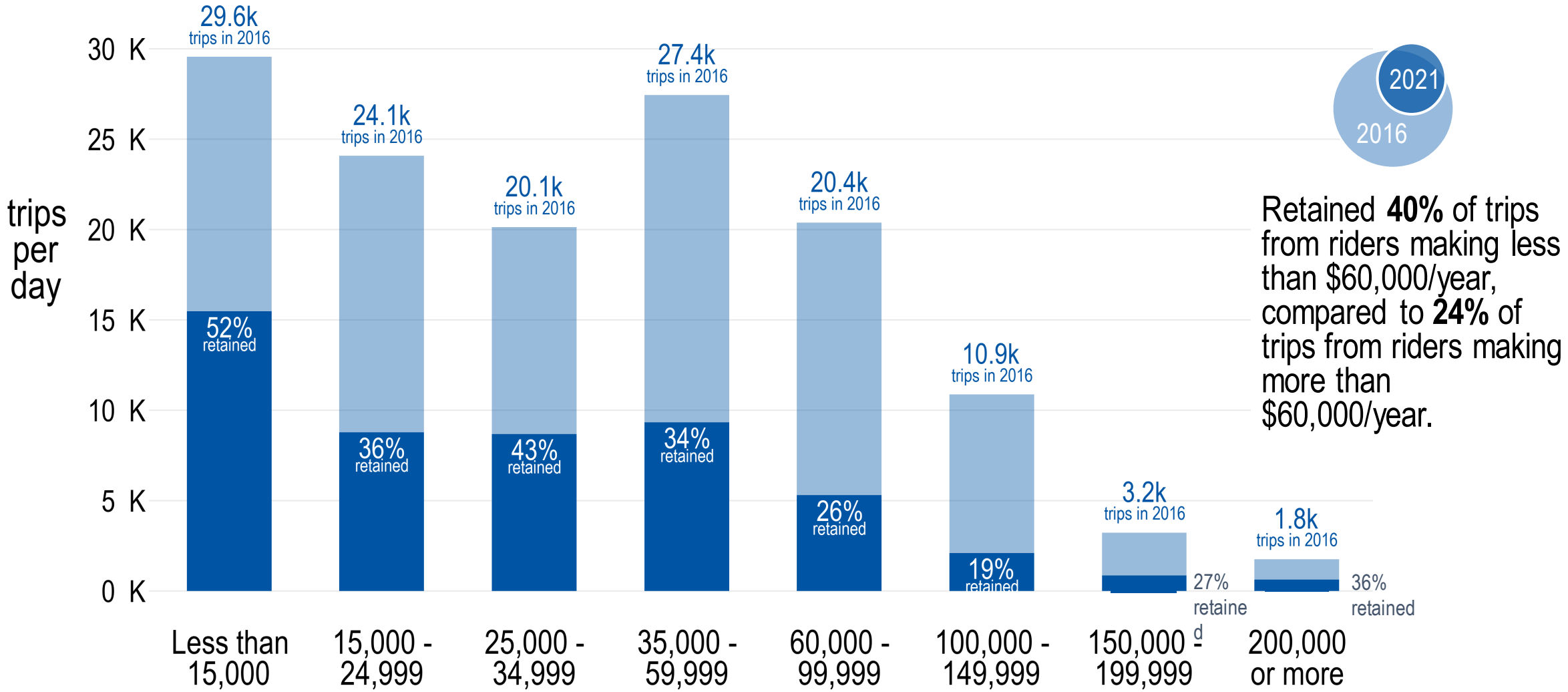
Share of riders who identify as Black or Latino has increased

This graph excludes the percent of trips made by white riders (45% of trips in 2021; 50% of trips in 2016).



Comparison of the same routes in 2016 and 2021.

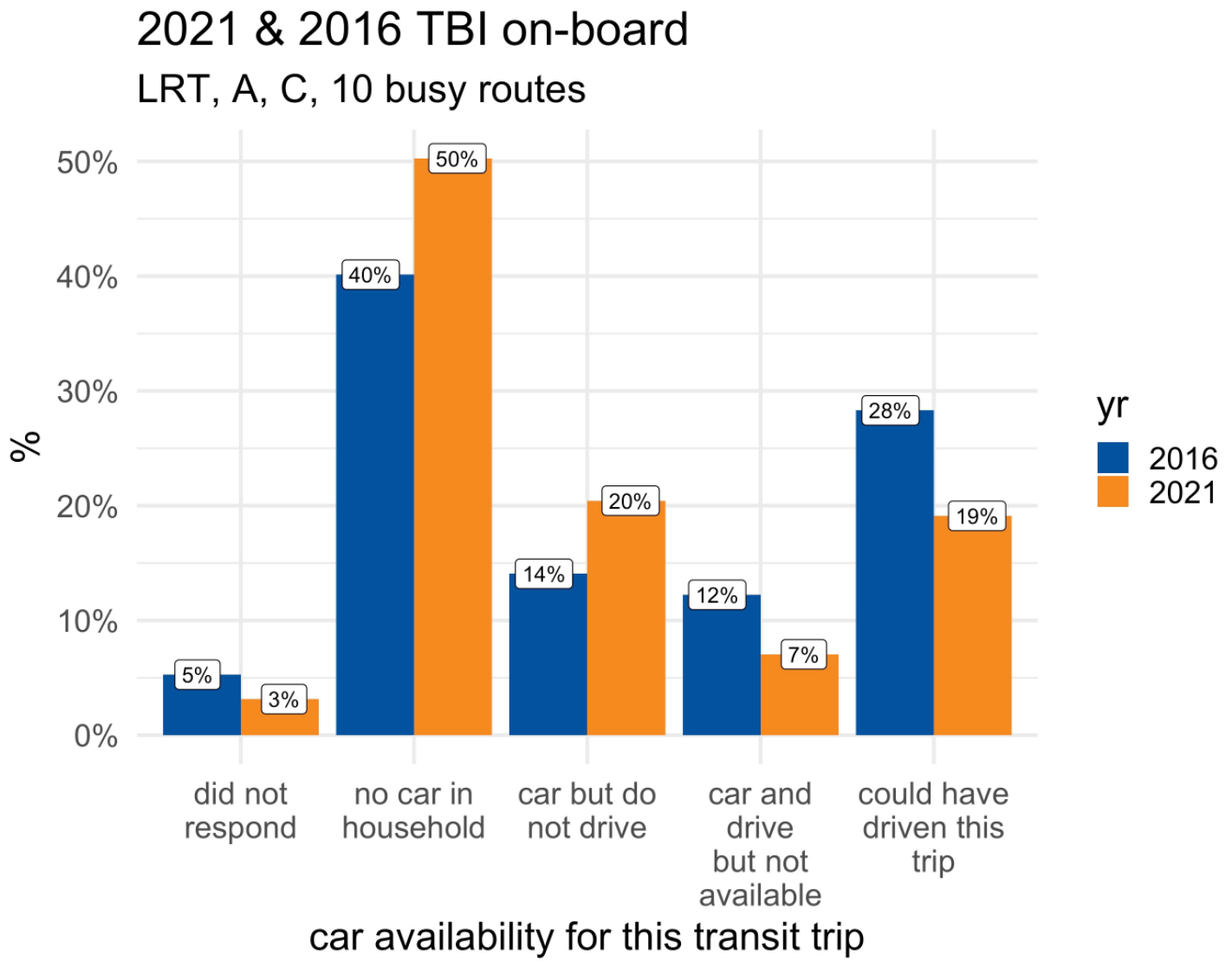
Retained greatest share of trips made by lowest-income riders



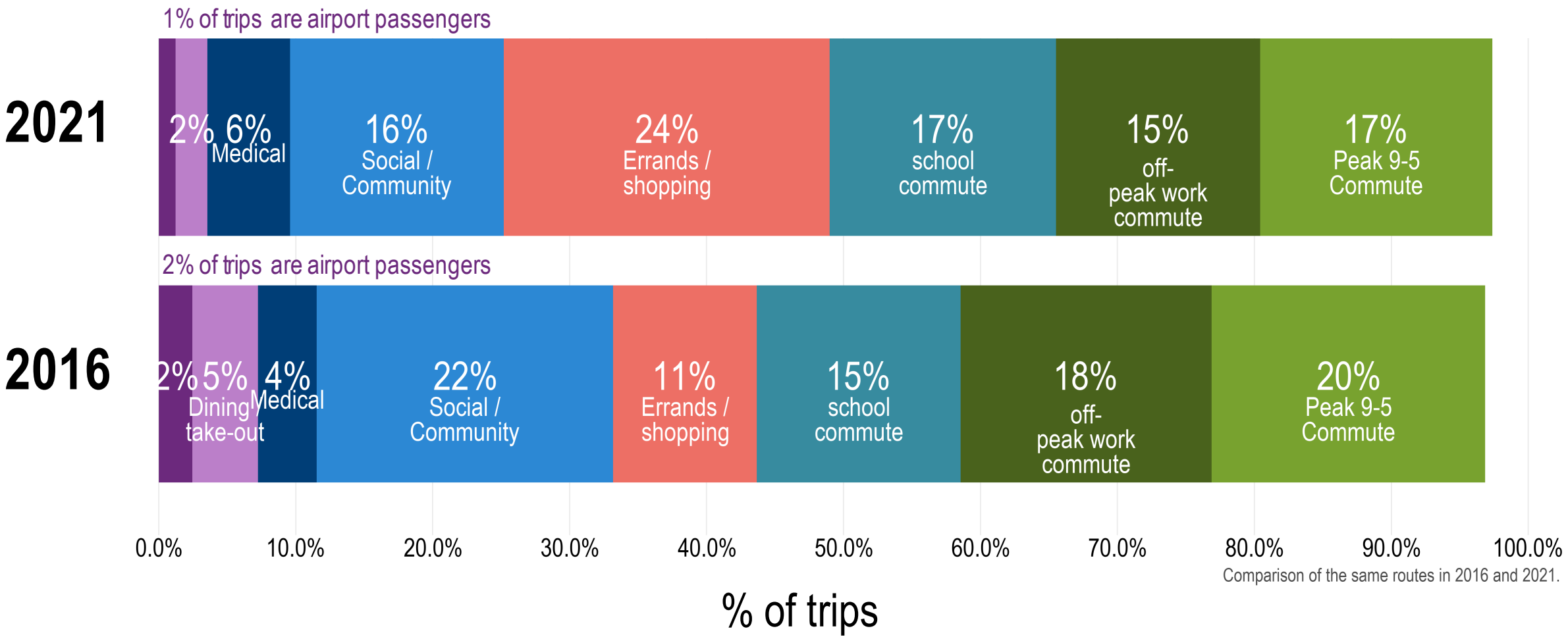
Retained **40%** of trips from riders making less than $60,000/year, compared to **24%** of trips from riders making more than $60,000/year.

2021 daily ridership (darker color) is overlaid on 2021 ridership (lighter color). Comparison of the same routes in 2016 and 2021.

Large majority of transit trips could not have been made by private auto



The share of people traveling for errands has grown



Comparison of the same routes in 2016 and 2021.

who is on board: demand implications

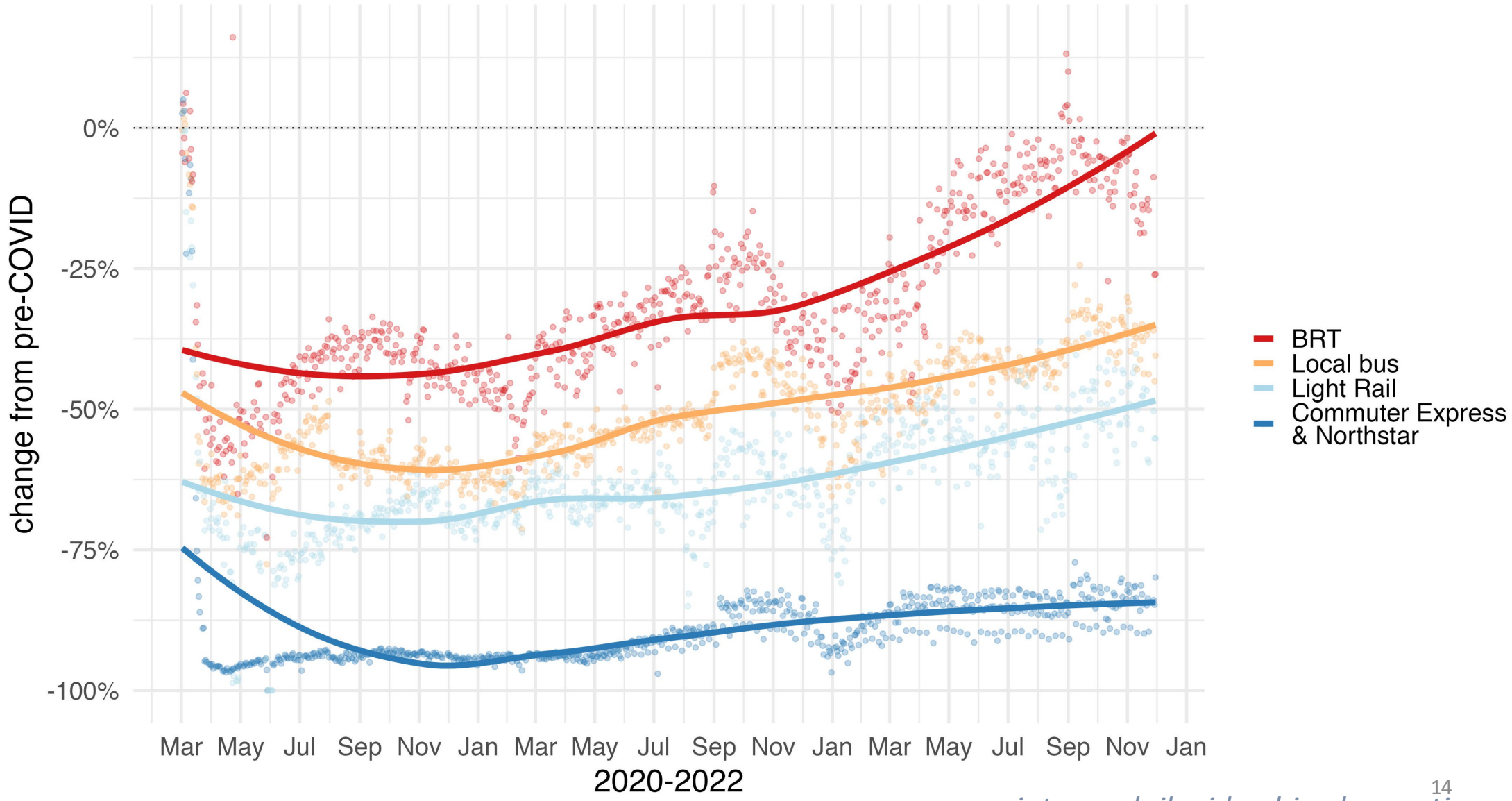
- all-purpose, all-day, all-direction
- multiple destinations
- car-free or car-light living
  - cannot drive
  - cannot afford to drive
  - do not wish to drive


Photo by David Joles, the Star Tribune

what’s next?

the COVID era

BRT has been most resilient; Commuter-express least resilient

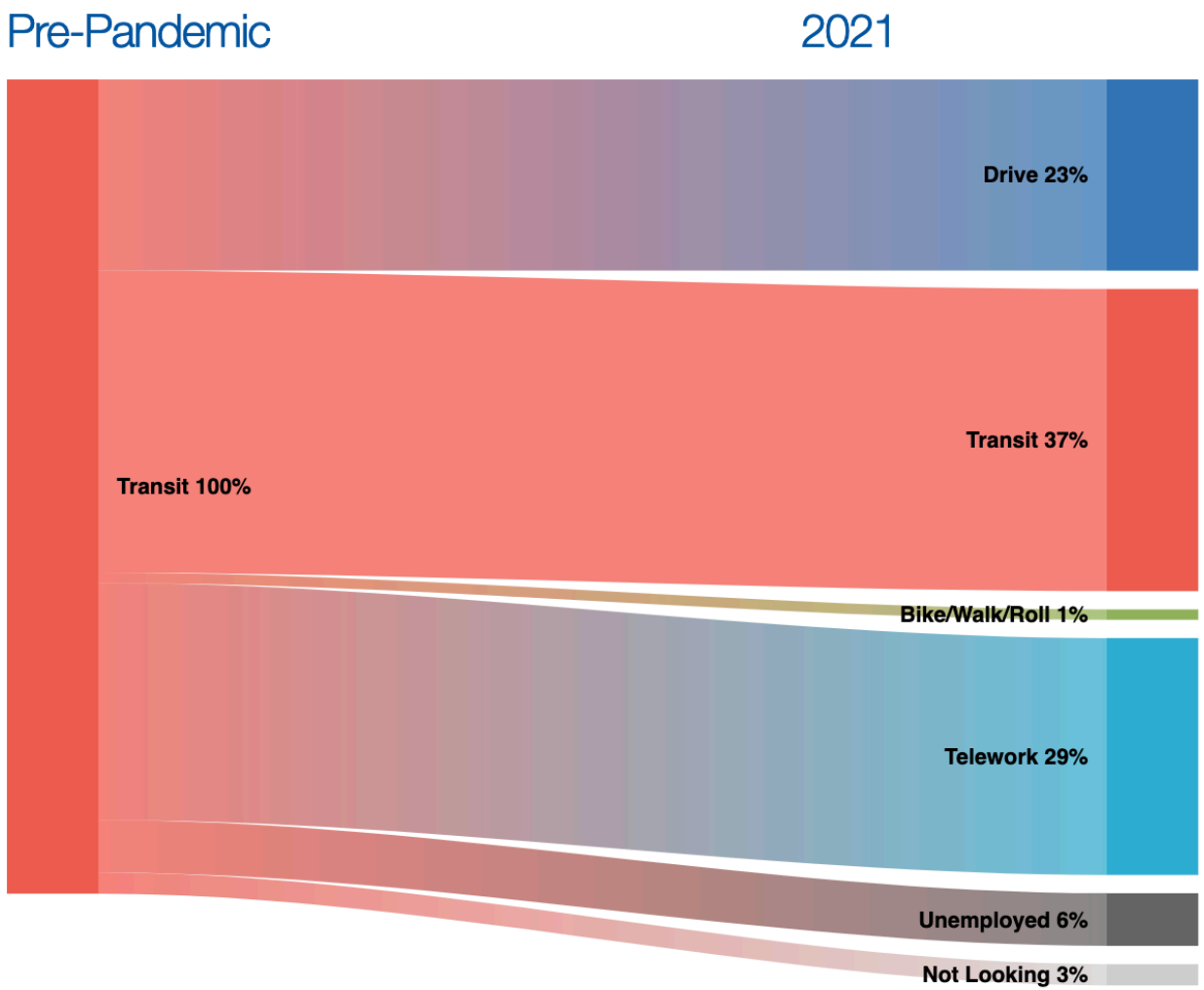


points are daily ridership observations

Commuter (n.)

"one who goes back and forth to work," 1865, American English, originally "**holder of a commutation ticket**," agent noun from *commute* (v.).

https://www.etymonline.com/word/commuter



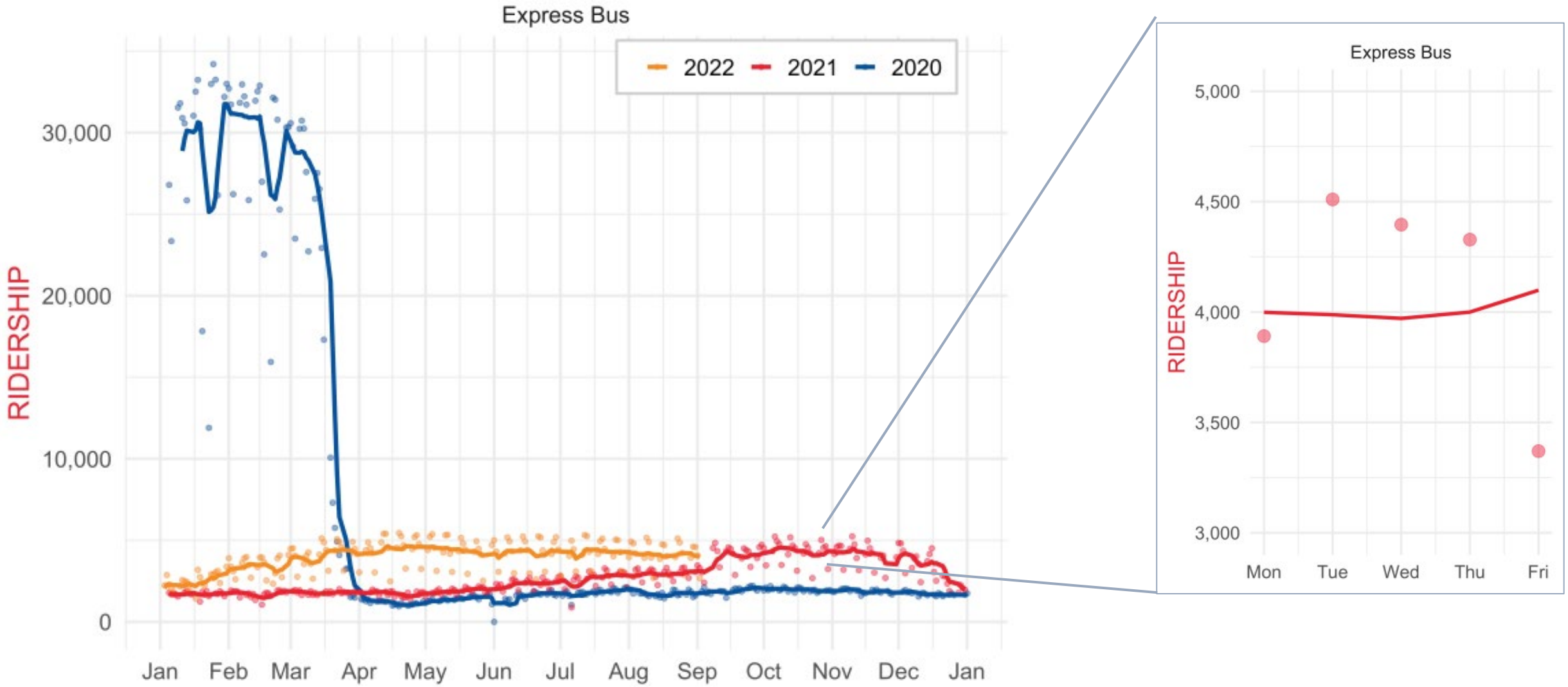
The current graph shows how **adults employed before the pandemic who took transit to work before the pandemic** (left) got to work in 2021 (right). Click on any bar to return to the full graph.

transit commutes have been replaced by telework, driving

try it!

https://metrotransitmn.shinyapps.io/covid_commute/

resuming growth: the challenge of commuter express



Most Important Reason to Return to Metro Transit

Avoiding traffic and parking hassles is the most indicated reason to return to Metro Transit use (44%) among all respondents. Among those with their own or shared access to a vehicle, that reason is even more prevalent (53%). Among those without regular access to a vehicle, 73% indicate that travel without access to a vehicle is most important.

Most Important Reason to Return to Metro Transit Use

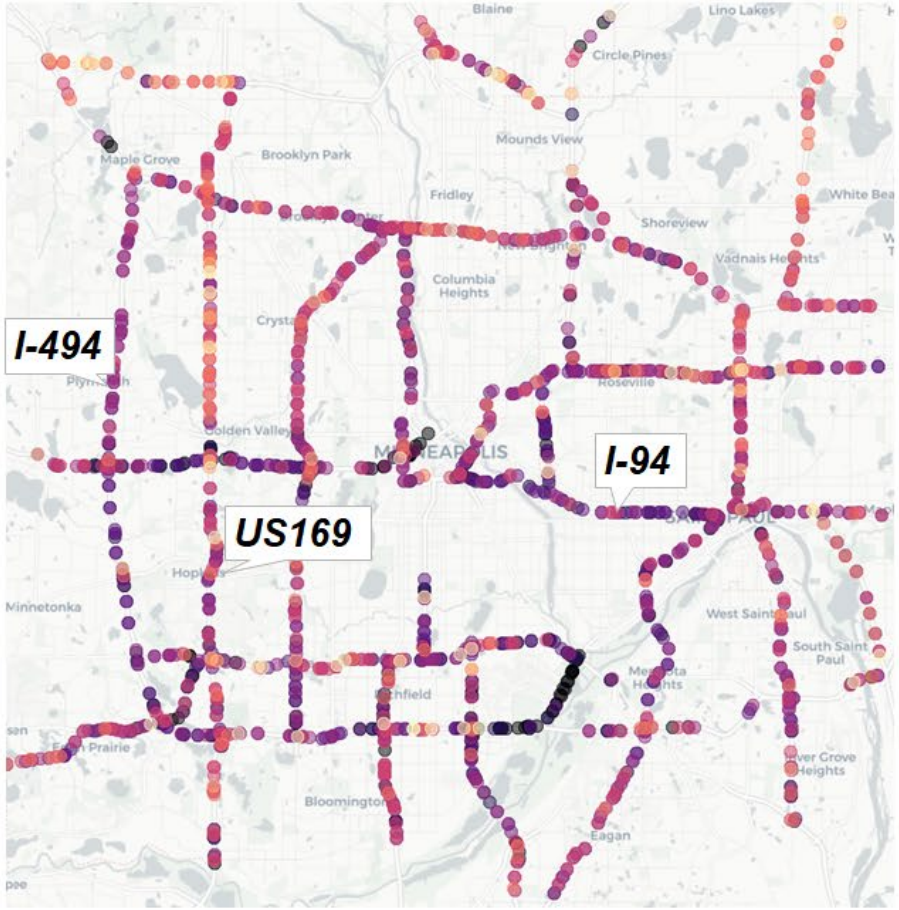
- **44%** AVOIDS TRAFFIC AND PARKING HASSLES
- **22%** ALLOWS TRAVEL WITHOUT OWNING OR HAVING ACCESS TO A VEHICLE
- **17%** SAVES MONEY OVER OTHER OPTIONS
- **11%** IS ENVIRONMENTALLY MORE RESPONSIBLE THAN OTHER OPTIONS
- **6%** GIVES ME TIME TO MYSELF WHILE TRAVELING

n=435

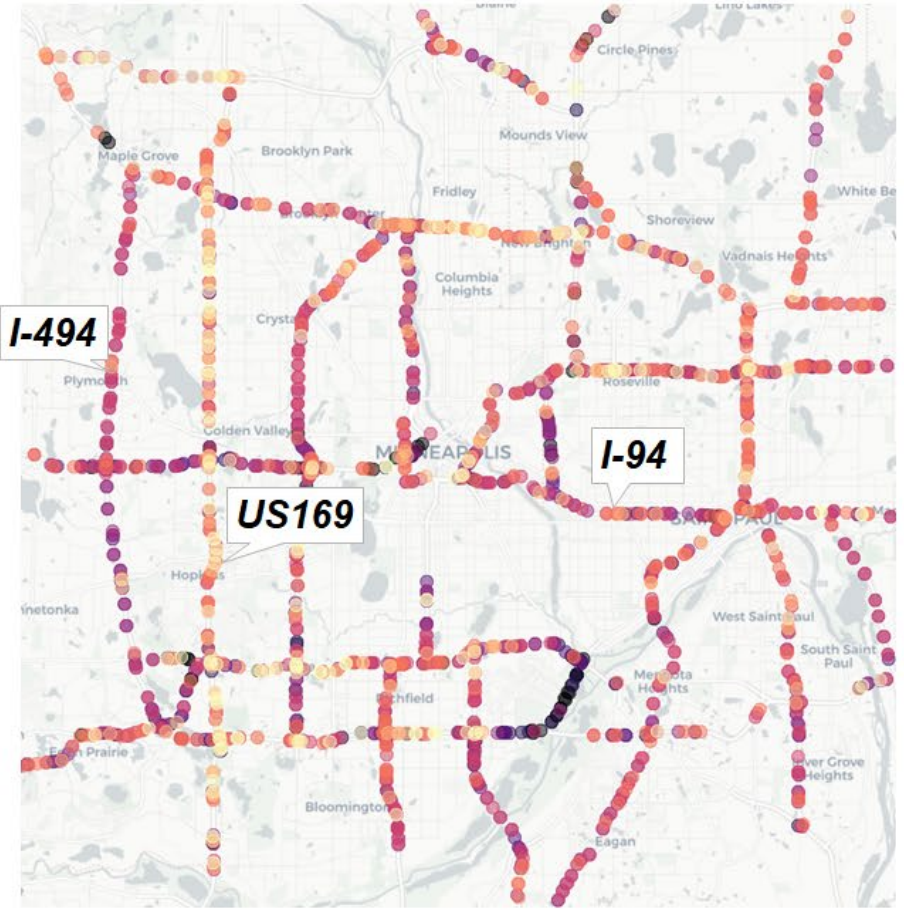
Q9 Which of the following would be the **most** important reason that you would return to using Metro Transit services? Metro Transit:

only PM traffic approaches pre-COVID levels

Weekday Mornings



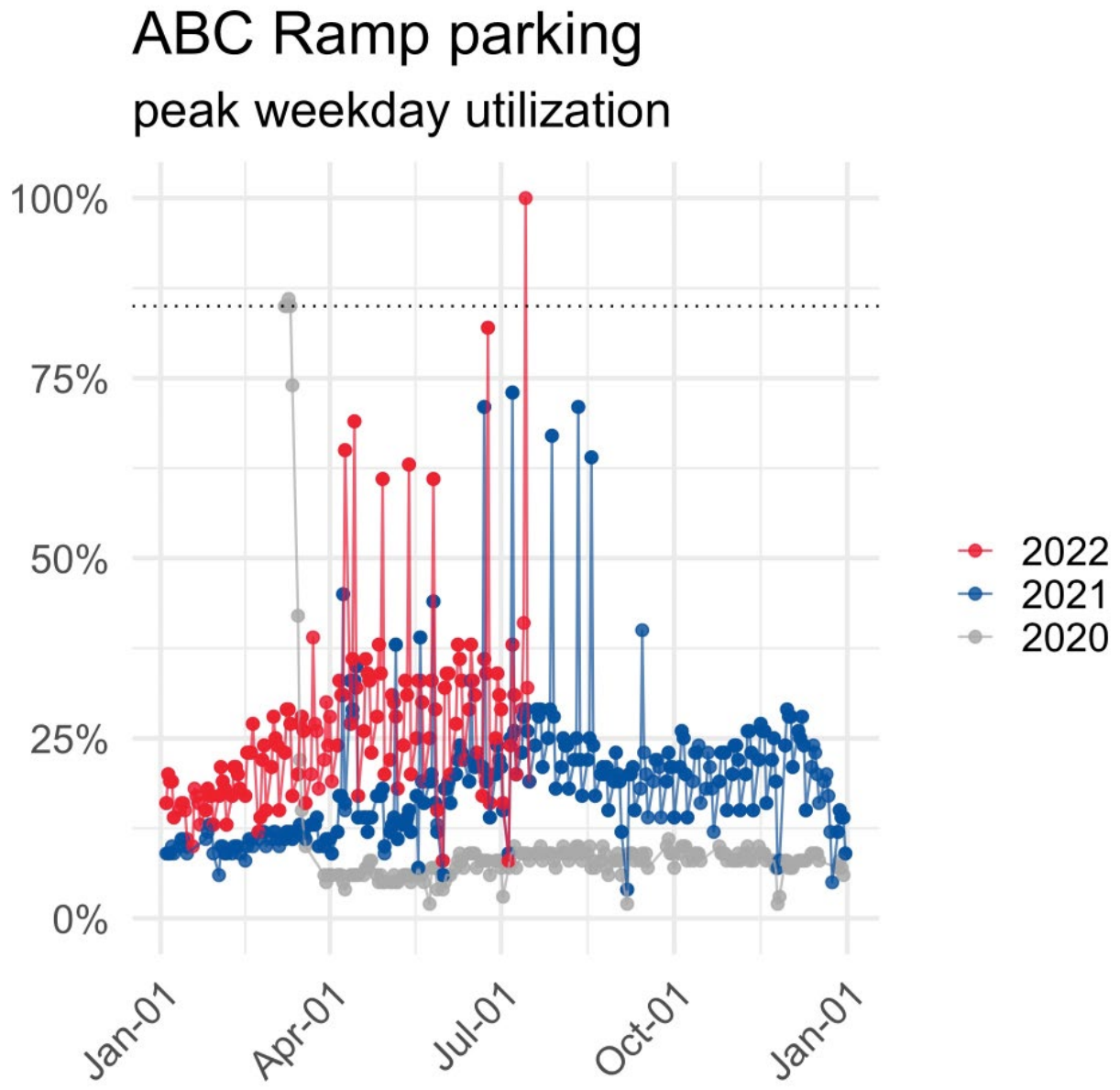
Weekday Evenings



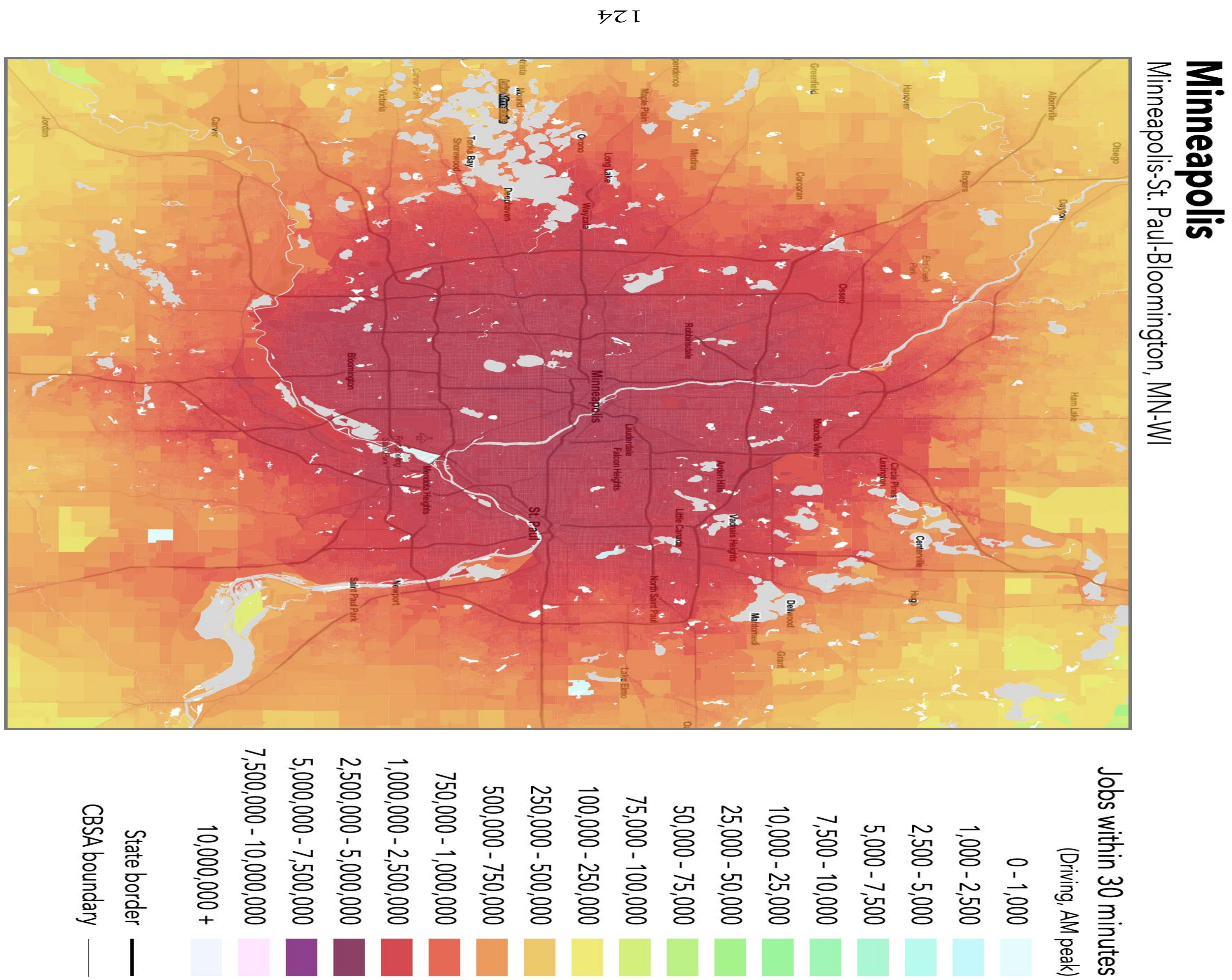
20% higher +
10-20% higher
0 - 10% higher
0 - 10% lower
10-20% lower
20-30% lower
30-40% lower
40% lower +

Maps show traffic declines at metro-area RTMC nodes during the week of 3/1/2021 relative to a 2018-2019 baseline. Mornings = 7-9AM; Evenings = 4-6PM.

Downtown parking demand is 1/3 of pre-COVID



Downtowns are still center of Access



Access Across America, Auto 2020

Transit use = supply x demand

Ridership

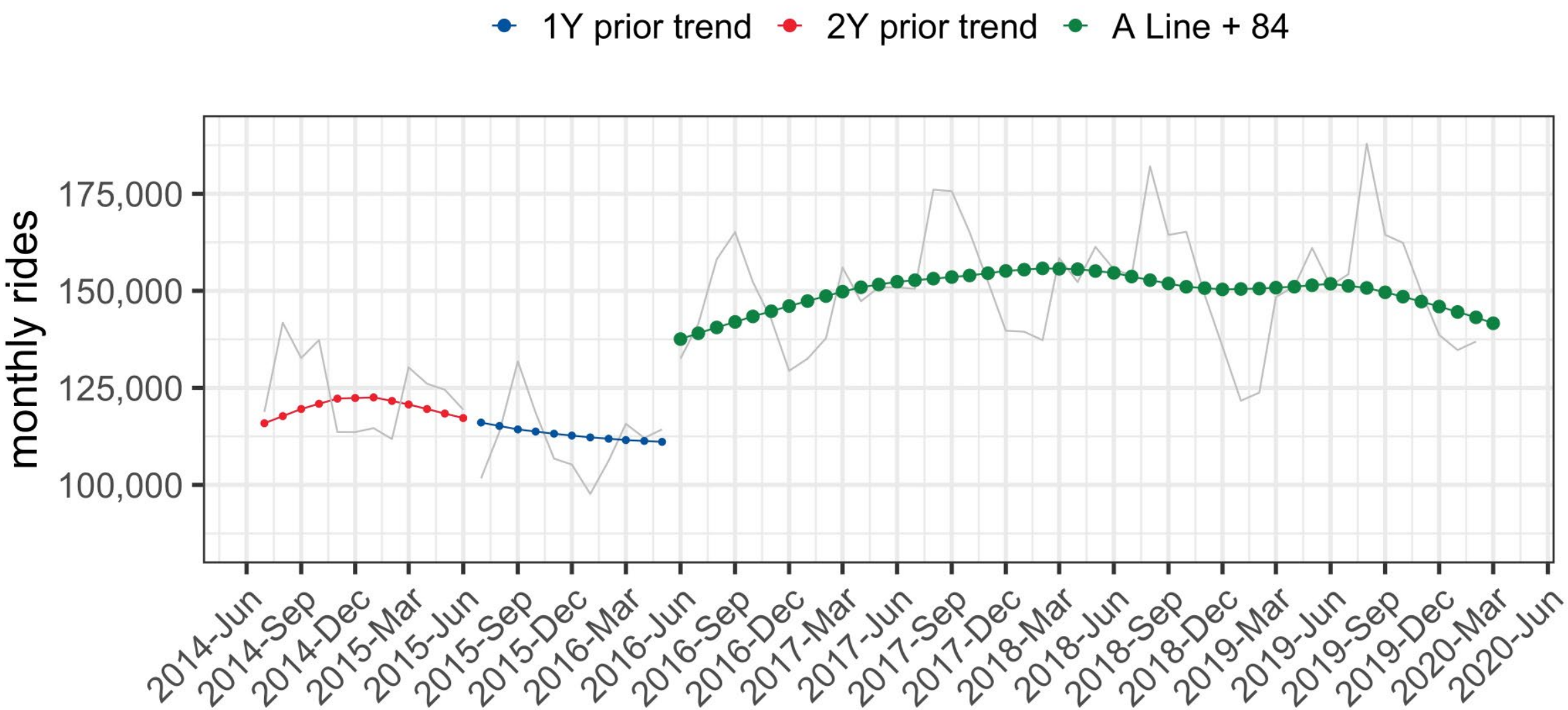
=

decision to travel

x

opportunity provided

Metro Transit flickr


1Y prior trend
2Y prior trend
A Line + 84
monthly rides
175,000
150,000
125,000
100,000
2014-Jun
2014-Sep
2014-Dec
2015-Mar
2015-Jun
2015-Sep
2015-Dec
2016-Mar
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2019-Sep
2019-Dec
2020-Mar
2020-Jun

Metro Transit flickr

elind@umn.edu

COVID-19's Impacts on CTA Transit Ridership: Findings, Expectations, and Recommendations

Yanfeng Ouyang
George Krambles Professor, University of Illinois at Urbana-Champaign
(joint work with Jesus Osorio and Yining Liu)

TRB Webinar: Telecommuting and Transit Ridership in a Post-Pandemic Future
March 28, 2023

Acknowledgments

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- Regional Transportation Authority (RTA)

Technical Review Panel(s):
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- Jessica Hector-Hsu, Co-chair, RTA
- Cemal Ayvalik, Co-chair, RTA
- Jack Cruikshank, IDOT
- Lynnette Ciavarella, Metra Rail Chicago
- Peter Fahrenwald, RTA
- Mary Rose Fissinger, Chicago Transit Authority
- James Garner Jr., Pace Suburban Bus
- Alan Ho, Federal Highway Administration
- David Kralik, Metra Rail Chicago
- Stephanie Levine, CMAP
- Steven Mannella, Metra Rail Chicago
- Dean Mentjes, Federal Highway Administration
- Jason Osborn, Metra Rail Chicago
- Megan Swanson, IDOT
- David Tomzik, Pace Suburban Bus
- Michael Vanderhoof, IDOT
- Scott Wainwright, Chicago Transit Authority
- Cody Wolcott, Metra Rail Chicago

We also thank Kastle Systems for sharing workplace occupancy data.

COVID-19 IMPACTS ON TRANSIT RIDERSHIP

COVID-19 has had far-reaching impacts on public health, the economy and ways of living.

Regulatory strategies, along with people's perceived risk of infection, have altered travel needs and mode choices.

- Remote study/work.
  - March 16, 2020.
- Stay-at-home executive orders
  - March 26, 2020, to June 3, 2020.
  - Nov. 16, 2020, to Jan. 22, 2021.
- Mask mandates indoor
- Social distancing
- Sanitation protocols for public services

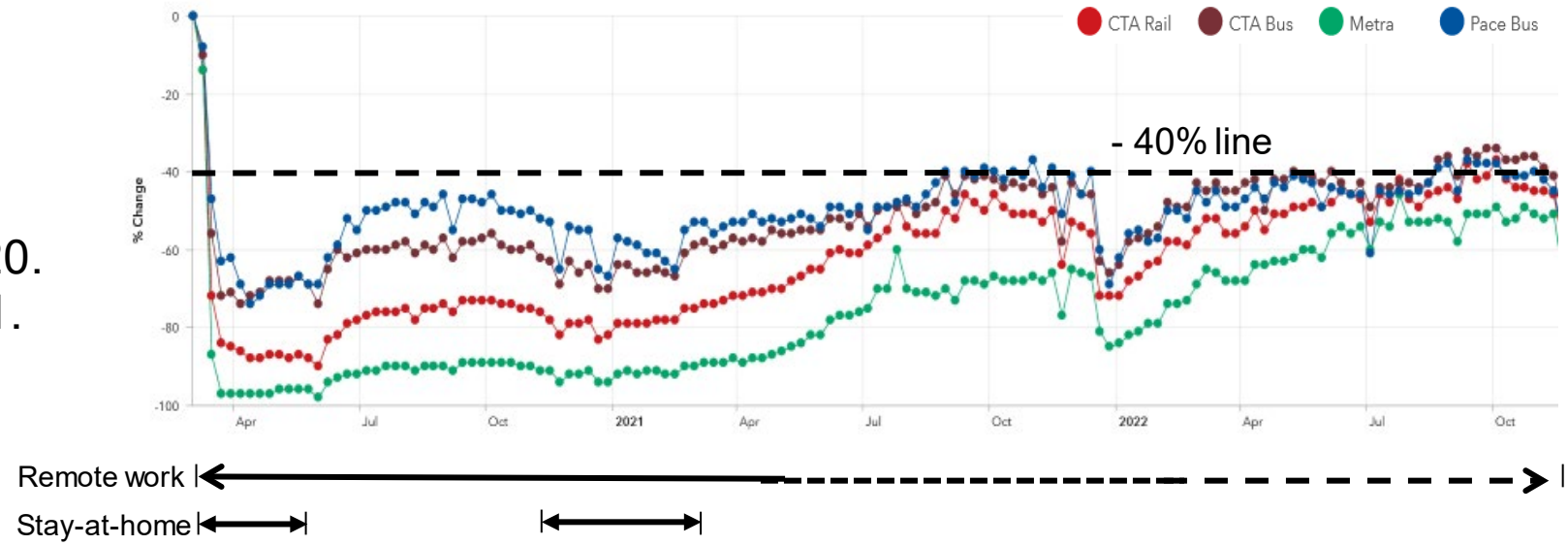


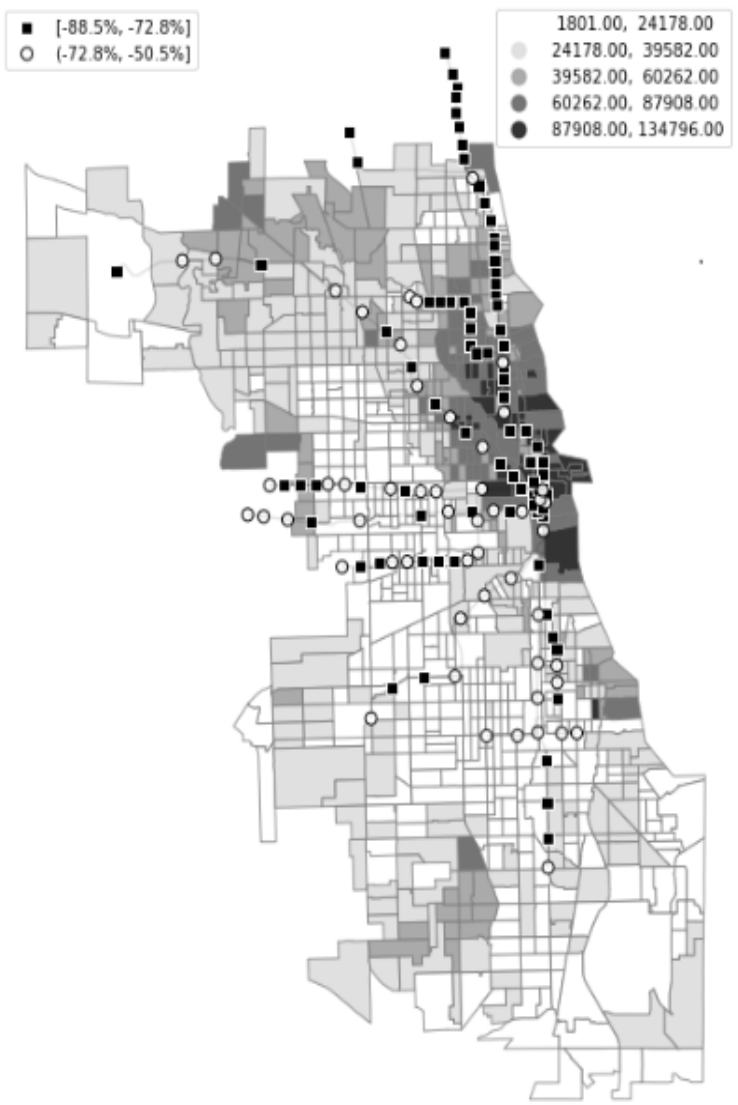
Figure 1. Percent change in transit ridership as compared to pre-COVID-19 numbers in Chicago.

Source: RTA Ridership Dashboard

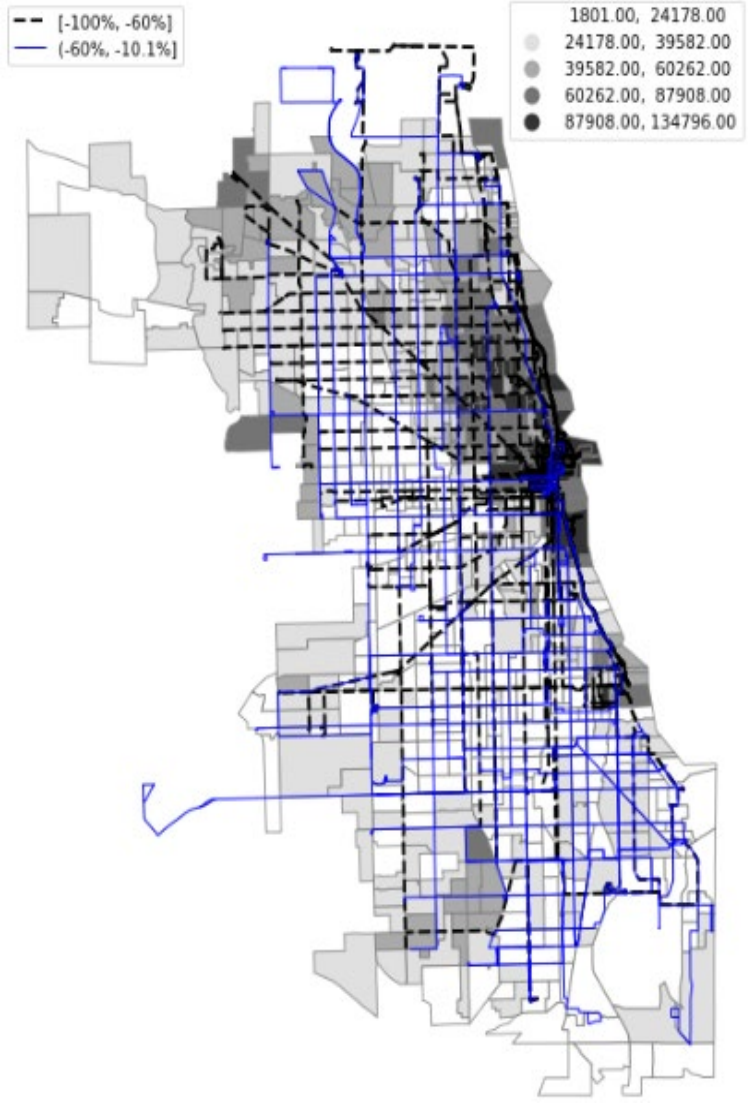
Chicago Analysis: Spatial Patterns (Income)

Figure 3. The yearly per-capita income and the percentage change in total ridership by mode.

Percentage change based on average ridership in 2017-2019 vs. ridership in 2020



Rail Stations

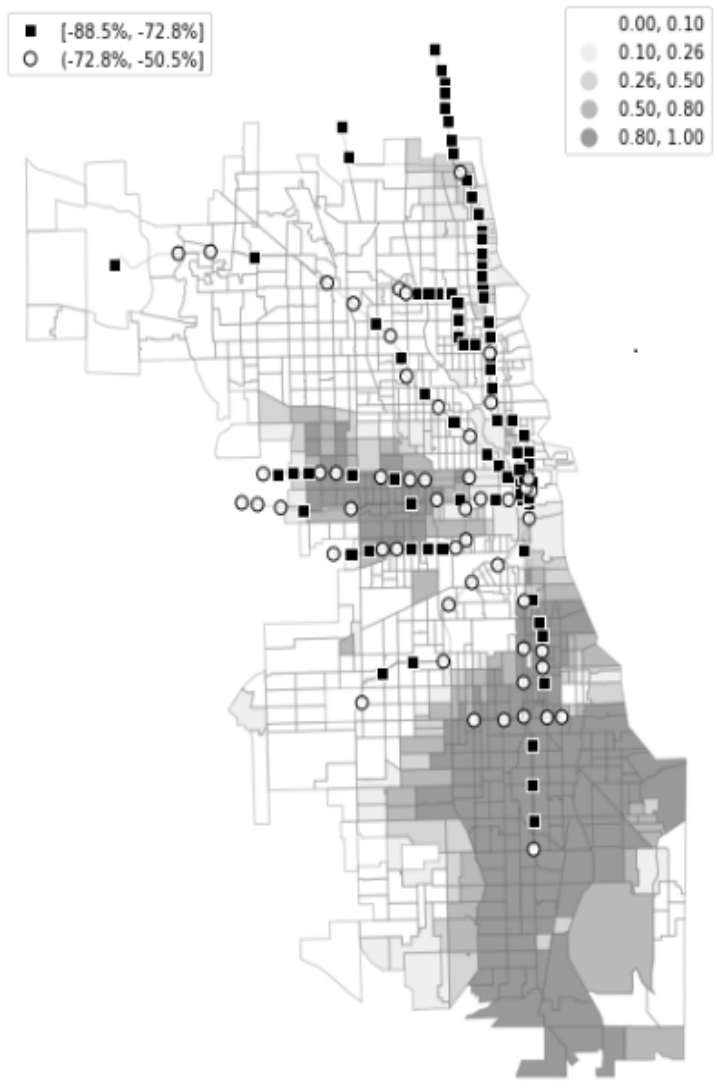


Bus Lines

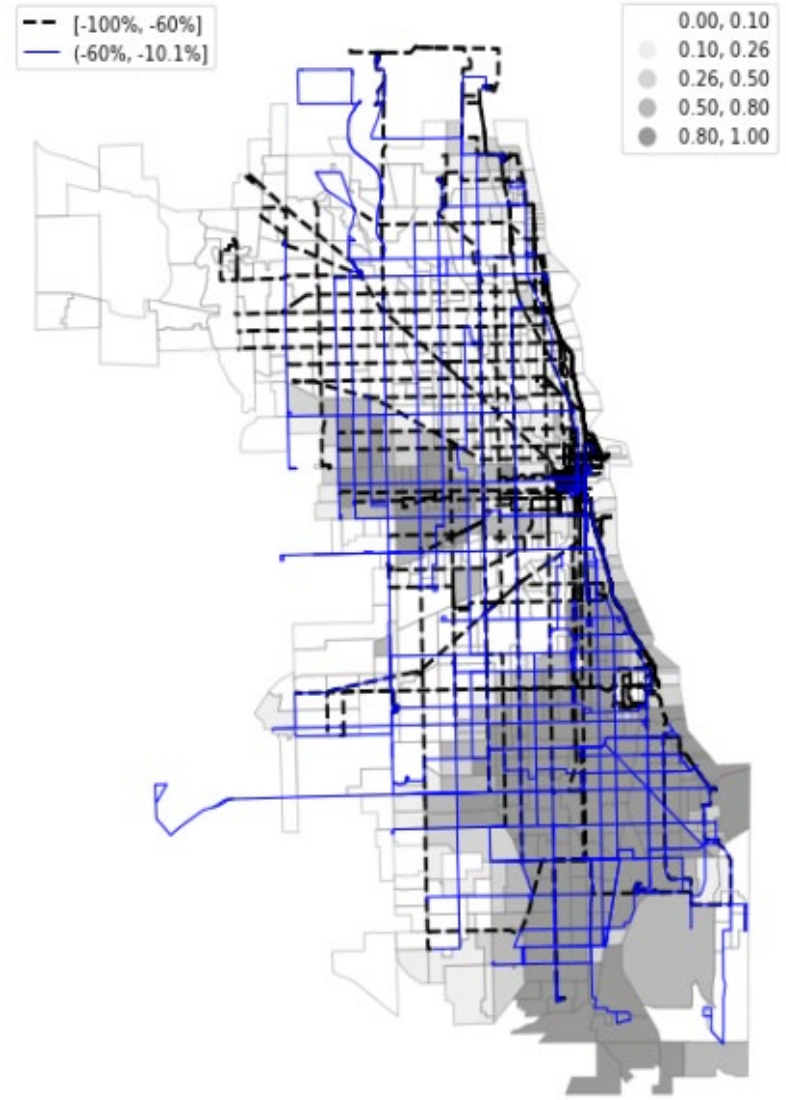
Chicago Analysis: Spatial Patterns (Race)

Figure 4. The proportion of African American residents and the percentage change in total ridership by mode.

Percentage change based on average ridership in 2017-2019 vs. ridership in 2020



Rail Stations



Bus Lines

RESEARCH QUESTIONS

- How did previous prolonged disruptive events (such as epidemics, pandemics and terrorist attacks) in the history affect transit ridership, and how did the ridership recover after those events?
- What are the primary factors that have contributed to the current transit ridership loss under COVID-19?
- How do the effects of these factors vary over time (e.g., development stages of the pandemic), space (e.g., city neighborhoods), and transit modes (e.g., rail vs. bus)?
- How may transit ridership recover, if at all, to pre-COVID-19 levels?
- How can transit agencies learn from the history, and from ongoing ridership variations, to enhance decision making (e.g., to stimulate ridership and to plan service) for the future?

HISTORICAL REVIEW

Recent terrorist attacks

- Sarin Gas Attacks (Tokyo)
- 9/11 Terrorist Attacks (U.S.)
- Bombing Attacks
  - Madrid (interurban trains)
  - London (subway and bus)

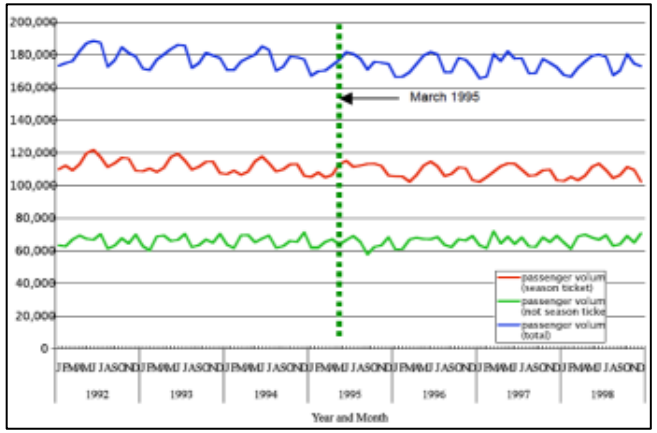


Figure 2a. Tokyo Subway Monthly Ridership 1992-1998 (Attack on 3/20/1995)

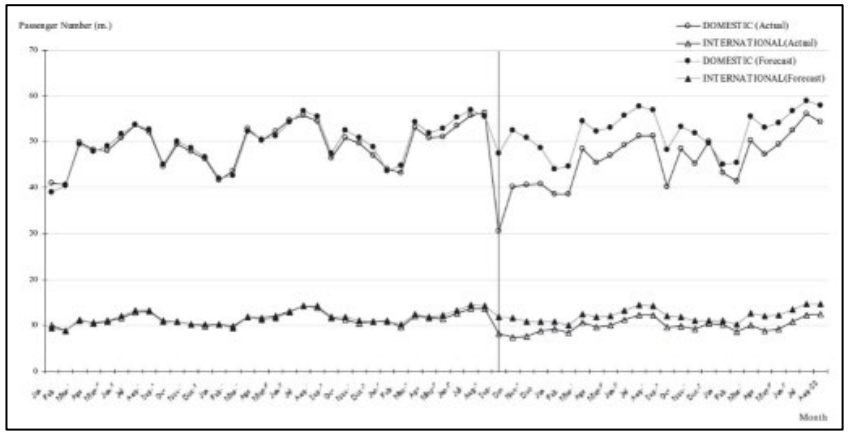


Figure 2b. Predicted and actual U.S. domestic and international air travelers (Attack on 9/11/2001)

Recent pandemics/epidemics

- SARS (Taiwan, Hong Kong, Singapore, Canada, Europe)
- H1N1 (United States)
- MERS (South Korea)
- EBOLA (Sierra Leone, United States)

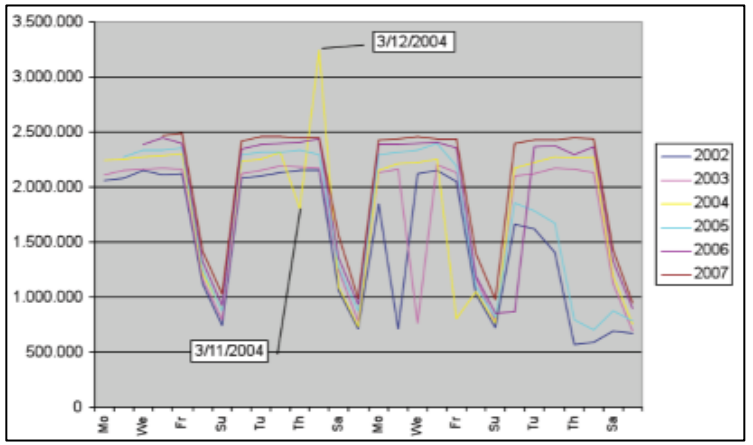


Figure 2c. Madrid metro daily ridership 2002-2007 (Attack on 3/11/2004)

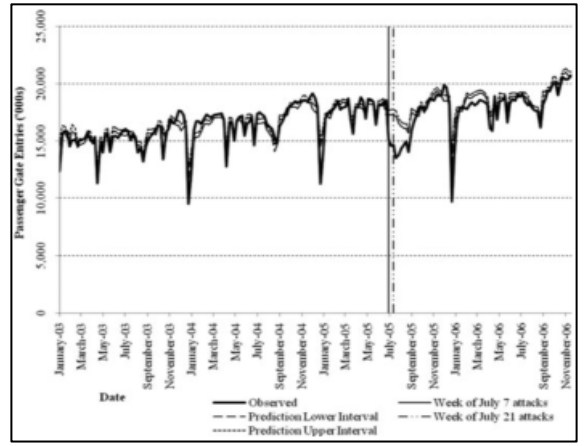


Figure 2d. London metro ridership 2002-2006 (Attack on 7/7/2005)

HISTORICAL REVIEW

Table 1. Summary of previous terrorist attacks' impacts on ridership.

Event	Area	Mode	Impact
Tokyo Sarin Gas Attack (3/20/1995)	Tokyo	Metro	No significant travel behavior changes were observed, possibly due to the relatively smaller scale of the attack, less physical damages to the infrastructure, as well as the transit-oriented commuting culture in Japan.
9/11 Attacks (9/11/2001)	New York City	Air	Air travel dropped 30% in the first month after the event, 8% by the end of 2001, and 4% by the end of the 2002. The revenue passenger miles were still below the pre-event level by the end of 2003.
Madrid Bombing (3/11/2004)	Madrid	Interurban trains	Interurban train ridership declined 4-6% in the first two months after the event. Bus and metro ridership plummeted on the day of the event, but surged on the next day in observation of a political demonstration. No evidence of dread hypothesis was found.
London Bombing (7/7/2005)	London	Metro and Bus	The event induced 8% metro ridership loss over the four months after the event. Mode shift was observed as the usage of bike, motorcycles, and mopeds increased.

Table 2. Summary of previous epidemics and pandemics' impacts on ridership.

Event	Area	Mode	Impact
SARS (2002 - 2003)	Hong Kong	Metro	Ridership plummeted 25%, but quickly bounced back within 6 months after the end of the outbreak.
		Bus	Take Kowloon Motor Bus for example, its ridership reduced by 15.5% at peak and recovered quickly, resulting in only a 2% ridership reduction in the last quarter of 2003.
	Taiwan	Metro	Ridership declined by 50% at the peak, and it only took four months to recover to the pre-pandemic level after the end of the outbreak.
	Toronto	Transit System	It lost 3.5 million riders in 2003, and its ridership was fully recovered in 2004.
	Singapore	Metro	It observed 9.5% ridership reduction at peak, but the 2004 annual ridership already exceeded the pre-pandemic level.
		Bus	The ridership reduced by 4.6% at peak and it remained fluctuating in the following years, possibly due to the competition with metro.
H1N1 (2009 - 2010)	United States	Air	0.34% of missed flight reservations were attributed to people's defensive behaviors induced by the pandemic.
MERS (2015)	Seoul	Metro	The ridership slightly reduced during the outbreak and quickly recovered within one month after the outbreak.
Ebola (2014 - 2016)	Sierra Leone	All modes	Travel demand sharply dropped during the lockdown, but there were no significant post-lockdown impacts on mobility.

A review was also conducted on transit agencies' best practices from previous epidemics to help boost ridership and avoid people's false perception of transit-related risks. These included:

- Cleaning/hygiene protocols
- Effective communication (e.g., advertising and publicity campaigns) to reinstate public confidence in transit
- Discount and promotions
- Collaboration with the private industries
- Maintain essential services (e.g., passengers lack of access to alternative modes, healthcare workers and patients), and reduce only non-essential services (e.g., commuting trips).

DATA COLLECTION AND PROCESSING

- Chicago Transit Authority's (CTA) rail and bus systems' ridership data:
  - Rail ridership (station-level) and bus ridership (route-level)

    -- Daily data, from *01/01/2000* to *05/31/2022*
- COVID-related data
  - Infection cases, deaths, vaccines (city-level)

    -- Daily data, from *03/01/2020* to *11/04/2022*
  - Stay-at-home orders (city-level):

    -- From *03/26/2020* to *06/03/2020*, and

    from *11/16/2020* to *01/22/2021*

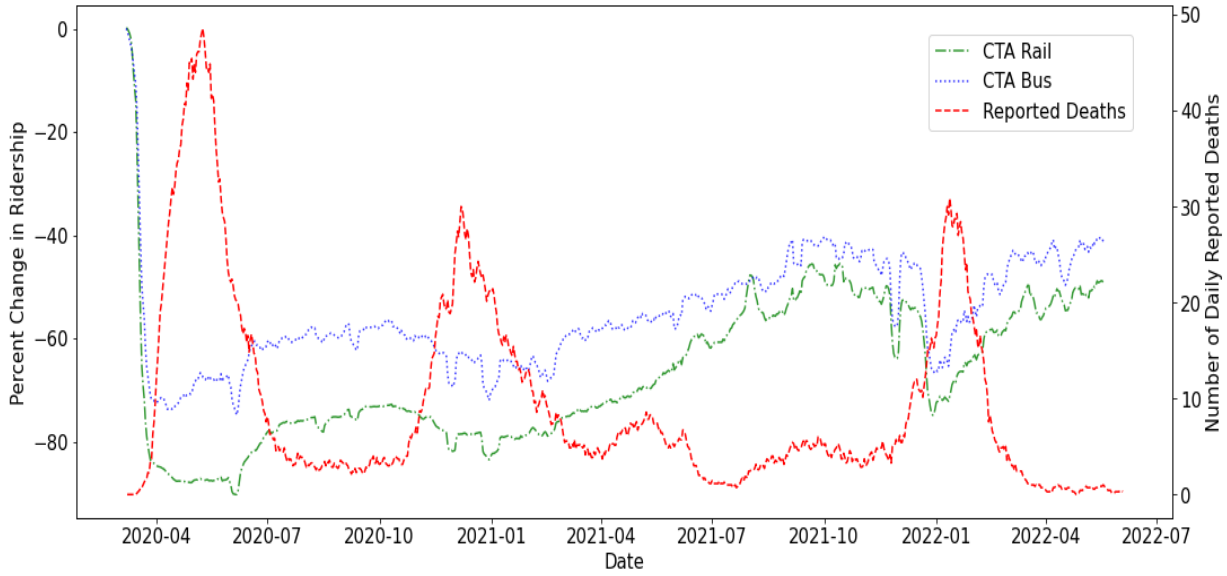


Figure 6. 7-day moving average of CTA bus and rail city-level ridership, and daily reported COVID-19 deaths, from March 1, 2020, to June 1, 2022

DATA COLLECTION AND PROCESSING

- Socio-economic changes – **commuting needs**
  - Unemployment rate (city-level), U.S. Bureau of Labor Statistics
    -- Monthly data, from *January 2001* to *September 2022*
  - Workplace occupancy (city-level), Kastle
    -- Daily data (workday only), from *03/02/2020* to *10/31/2022*
    -- Meaning: observed workplace activities relative to the average activity level from 02/03/2020 to 02/13/2020

→ Capture drop in work-related trips

→ However, miss non-work trips

→ Use workplace occupancy as a proxy of the level of overall travel activities in Chicago

Figure 7. Illustration of monthly unemployment rates in Chicago from January 2020 to April 2022 (left) and workplace occupancy in Chicago from March 2020 to June 2022 (right). (U.S. Bureau of Labor Statistics; Kastle).

OCCUPANCY OVER TIME - MARCH 4, 2020 TO JUNE 1, 2022

DATA COLLECTION AND PROCESSING

- Socio-economic changes – **crimes**
  - Among the reasons cited by riders who reduced or stopped using transit in recent studies:

    "**Concerns about harassment** may be **greater during the pandemic** in areas where reduce ridership means that transit vehicles are less crowded, leading to greater feelings of isolation and vulnerability for those remaining… **Hispanic or Latinx riders, female riders, and nonbinary gender queer riders** are more likely to cite concerns about harassment" (He et al., 2022)

    "56% of Hispanic or Latinx and 48.3% of female and other gender identities reported harassment concerns as the **reason for reducing** their transit use " (He et al., 2022)
  - Crime records (coordinate-level)

    -- Police record of each incident, from *01/01/2000* to *10/31/2022*

    -- Focus on the crime types that may affect people's usage of transit service, such as:

    Arson, assault, battery, homicide, stalking, theft, intimidation, and criminal sexual assault

DATA COLLECTION AND PROCESSING

- Socio-economic changes – **prices**
  - Gas price (city-level), U.S. Energy Information Administration

    -- Weekly data, from *06/05/2000* to *10/31/2022*

  - Promotions on transit fare (city-level)

    -- Discounts on three types of unlimited-ride passes:

    One-day pass: $5 (down from $10)

    Three-day pass: $15 (down from $20)

    Seven-day pass: $20 (down from $28)

    -- Effective since *05/28/2021*

Figure 8. Weekly regular reformulated retail gasoline prices in Chicago (U.S. Energy Information Administration).

DATA COLLECTION AND PROCESSING

- Socio-demographic and Land use data

Table 6. Socio-demographic and Land use data considered in the study

Variable	Description	Spatial Unit	Source
prop_male	% of male population	Census Tracts	US Census Bureau
prop_age_0_24	% of population between 0 and 24 years old		
prop_age_25_39	% of population between 25 and 39 years old		
prop_age_40_64	% of population between 40 and 64 years old		
prop_white	% of white population		
prop_black	% of black population		
prop_asian	% of Asian population		
prop_edu	% of population with at least a high school degree		
prop_employ	% of population employed		
prop_poverty	% of population under the poverty line		
prop_W_manuf	% of workers with jobs in the manufacturing industry		
prop_W_trade	% of workers with jobs in the wholesale or retail trade industry		
prop_W_edu	% of workers with jobs in the educational service industry		
prop_W_health	% of workers with jobs in the health industry		
prop_LU_residential	% of residential land	Parcel	CMAP
prop_LU_commercial	% of commercial land		
prop_LU_industrial	% of industrial land		
prop_LU_education	% of educational institutional land		
prop_LU_medical	% of medical institutional land		
prop_LU_openspace	% of open space land		

DATA COLLECTION AND PROCESSING

- Data Processing
  - Spatial level: aggregate crime counts to each rail station/bus route neighborhood
  - Temporal level:

    -- Approx. daily unemployment rate and daily gas price using their monthly and weekly average values, respectively

    -- Linearly interpolate workplace occupancy data to estimate occupancy levels on weekends and holidays
  - For visualization, all data below are normalized to a value between 0 and 1, $x_{\text{plotted}} = \frac{x - x_{\min}}{x_{\max} - x_{\min}}$.

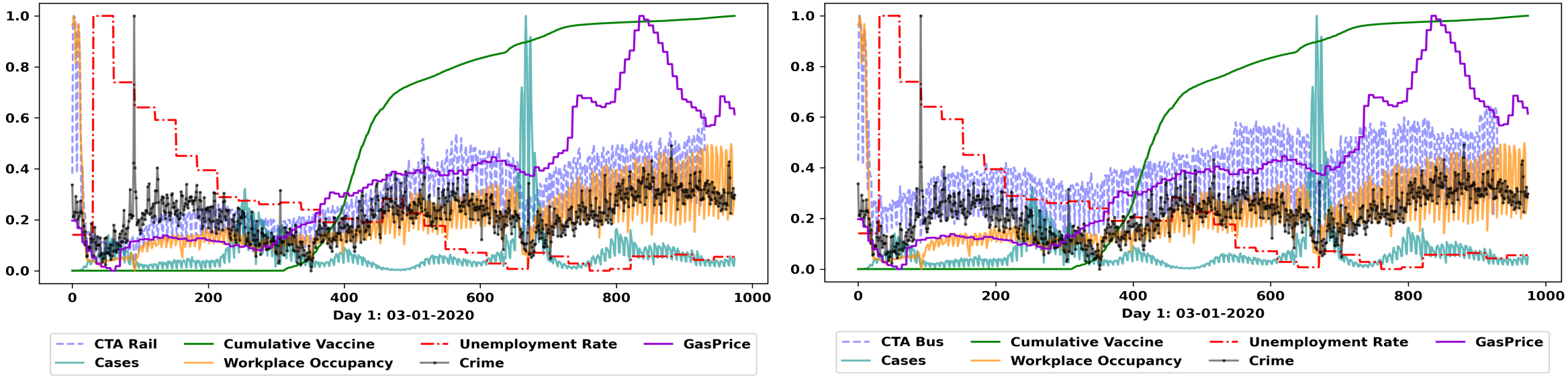


Figure 9. Normalized time-series plot of pandemic-related factors, socioeconomic factors, and CTA rail ridership (left) and bus ridership (right)

Statistical Modeling Framework

Historical daily ridership 2001 - 2019

Temporal factors; e.g.,
- COVID-19 deaths
- Executive orders
- Work-remote
- Vaccination

Spatial factors; e.g.,
- Socio-demographic
- Land use

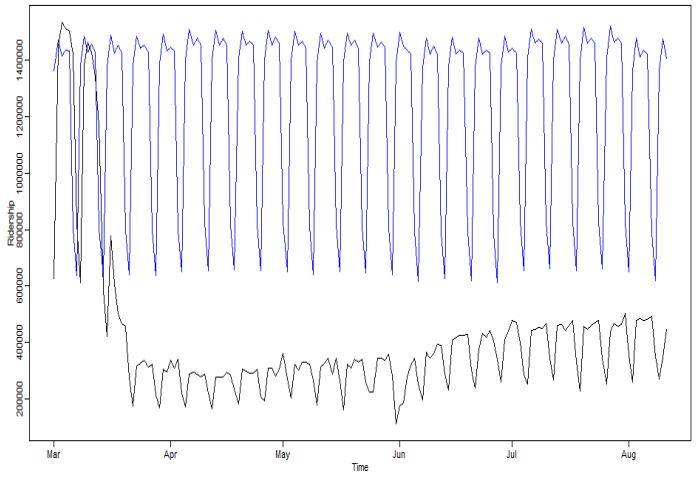
Bayesian Structural Time Series (BSTS) Model

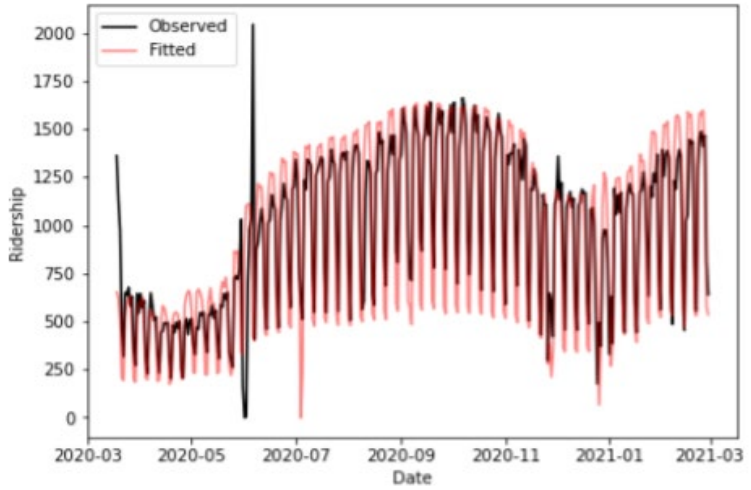
Predicted Counterfactual Ridership after 2020

Dynamics Model for Daily Ridership Variations

Quantification of Pandemic's Effects

Ordinary Least Squares (OLS) Regressions





Variable	L_d		L_q		L_c		L_s	
	Estimate	p-value	Estimate	p-value	Estimate	p-value	Estimate	p-value
(Intercept)	4.34E-01	1.22E-02	1.06E-04	6.26E-01	-1.74E+00	9.61E-02	-8.09E-04	8.92E-01
prop_age_0_24	-	-	-	-	-	-	4.23E-02	2.42E-03
prop_age_0_24_2	-5.34E-01	5.13E-02	-	-	-	-	-	-
prop_age_25_39	-1.12E+00	1.85E-03	-	-	-	-	-	-
prop_age_25_39_2	1.13E+00	8.33E-03	-	-	-	-	8.95E-02	1.66E-07
prop_age_40_64	-7.02E-01	2.30E-02	-	-	-	-	-	-
prop_white	-	-	1.40E-03	1.30E-07	-	-	-	-
prop_black	-	-	-	-	-1.80E-01	5.34E-06	-	-
prop_asian	4.54E-01	2.40E-03	-4.94E-03	1.00E-03	-	-	-	-
prop_asian_2	-7.07E-01	2.44E-02	1.24E-02	5.70E-05	-	-	5.67E-02	3.56E-03
prop_employ	-	-	-	-	7.01E+00	5.75E-03	-	-
prop_employ_2	-	-	-	-	-4.24E+00	4.91E-03	-	-
prop_poverty	-1.73E-01	6.65E-02	-	-	-1.09E+00	3.0.E-05	-1.30E-01	2.44E-04
prop_poverty_2	-	-	-	-	1.89E+00	1.18E-03	2.45E-01	1.66E-03
prop_R_manuf	-	-	-7.78E-03	8.55E-05	-	-	-	-
prop_R_trade	-	-	-	-	-1.96E+00	9.63E-08	-	-
prop_R_edu	-3.32E-01	6.21E-02	-	-	-	-	-	-
prop_R_edu_2	-	-	-	-	-	-	3.82E-01	7.92E-05
prop_R_health_2	2.97E+00	4.96E-03	-	-	-	-	-	-
prop_W_manuf	-	-	-	-	2.79E-01	2.15E-02	-	-
prop_W_edu	-	-	-	-	-4.36E-01	1.45E-03	-	-
prop_W_edu_2	-	-	-	-	6.96E-01	1.70E-03	-5.35E-02	1.36E-03
prop_LU_residential	-	-	-	-	-5.56E-01	1.12E-02	-	-
prop_LU_residential_2	-	-	-	-	7.85E-01	2.54E-02	-	-
prop_LU_commercial	-	-	7.62E-03	4.52E-05	-	-	-2.54E-02	1.92E-02
prop_LU_commercial_2	-	-	-1.16E-02	1.12E-03	-	-	-	-
prop_LU_industrial	8.23E-01	1.06E-03	-	-	-	-	-	-
prop_LU_industrial_2	-2.55E+00	5.86E-03	-	-	-1.83E+00	2.30E-04	-	-
prop_LU_education	-	-	2.95E-03	6.22E-03	2.97E-01	1.42E-02	-	-
prop_LU_transportation	-5.01E-01	1.34E-02	-	-	-	-	-	-
Adjusted R^2	0.158		0.456		0.751		0.347	

NUMERICAL RESULTS - Temporal

- Temporal analysis results – Fitted ridership

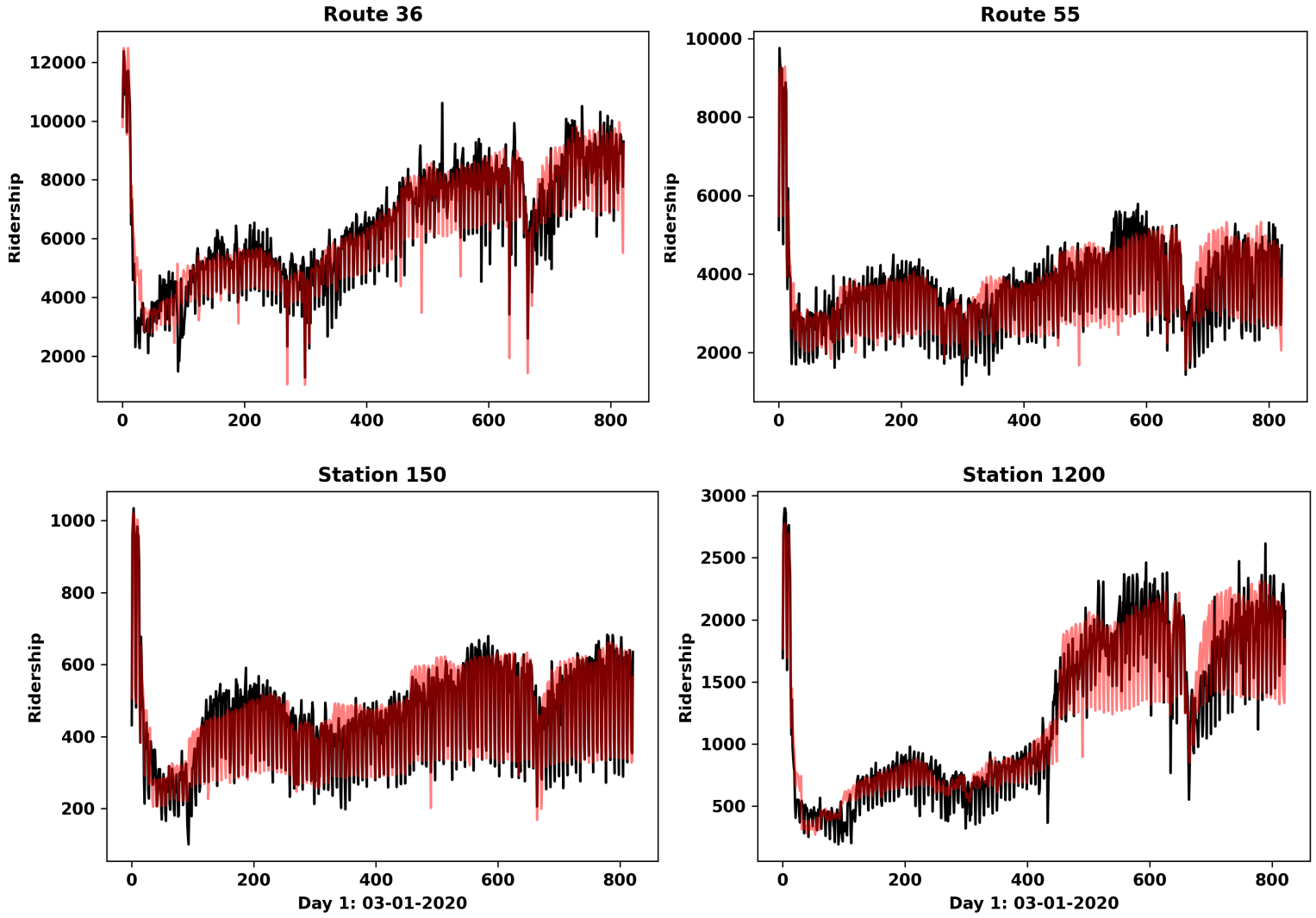


Figure 11. Examples of temporal regression model fits for CTA bus routes (upper) and CTA rail stations (lower).

NUMERICAL RESULTS - Temporal

- Temporal analysis results – predicted ridership (Up to October 31, 2022)

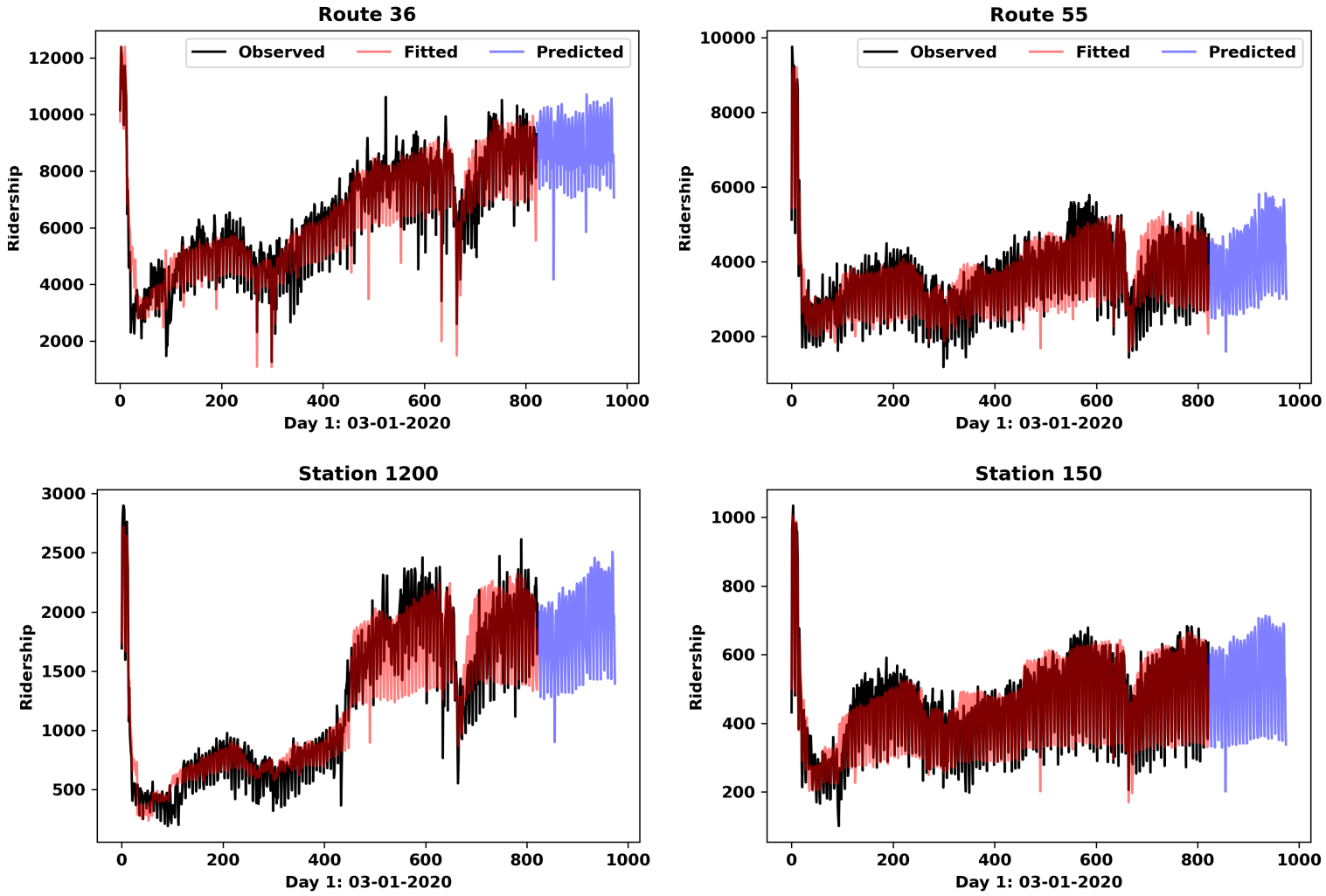


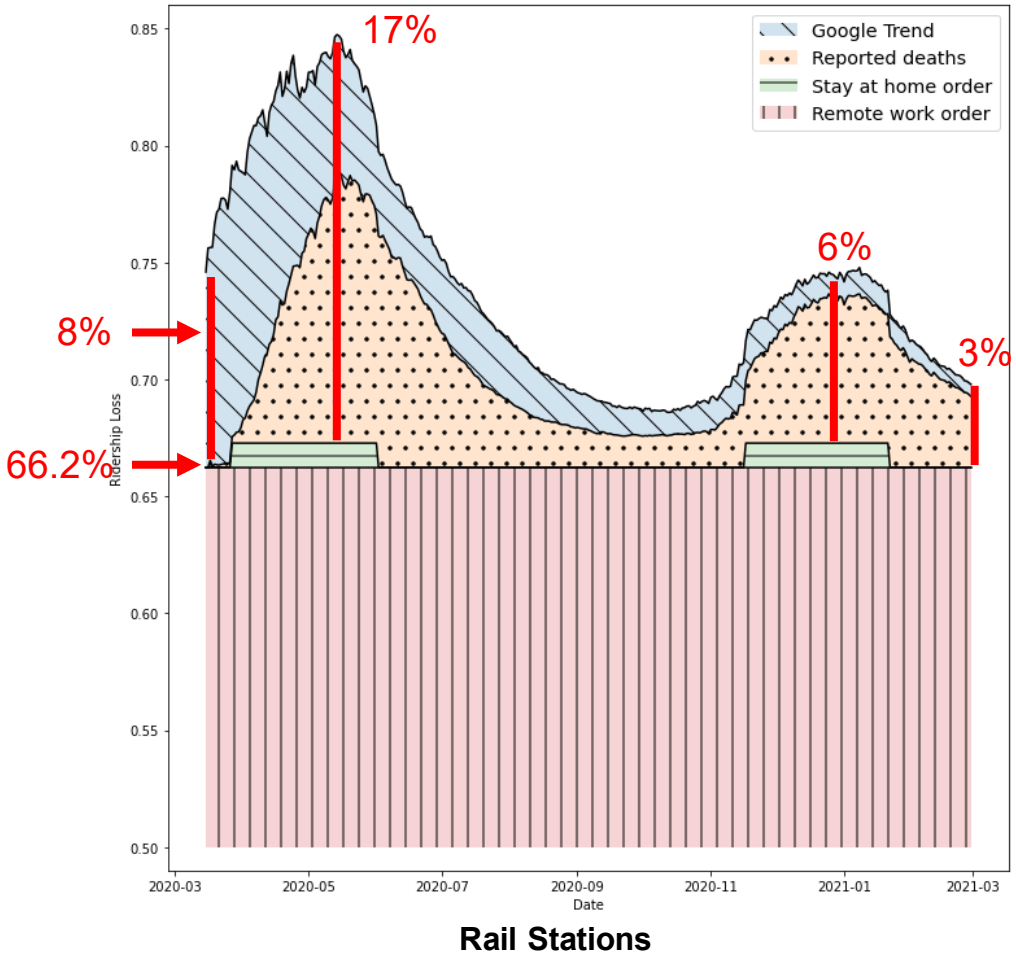
Figure 13. Examples of predicted ridership for CTA bus routes (upper) and CTA rail stations (lower).

NUMERICAL RESULTS - Temporal

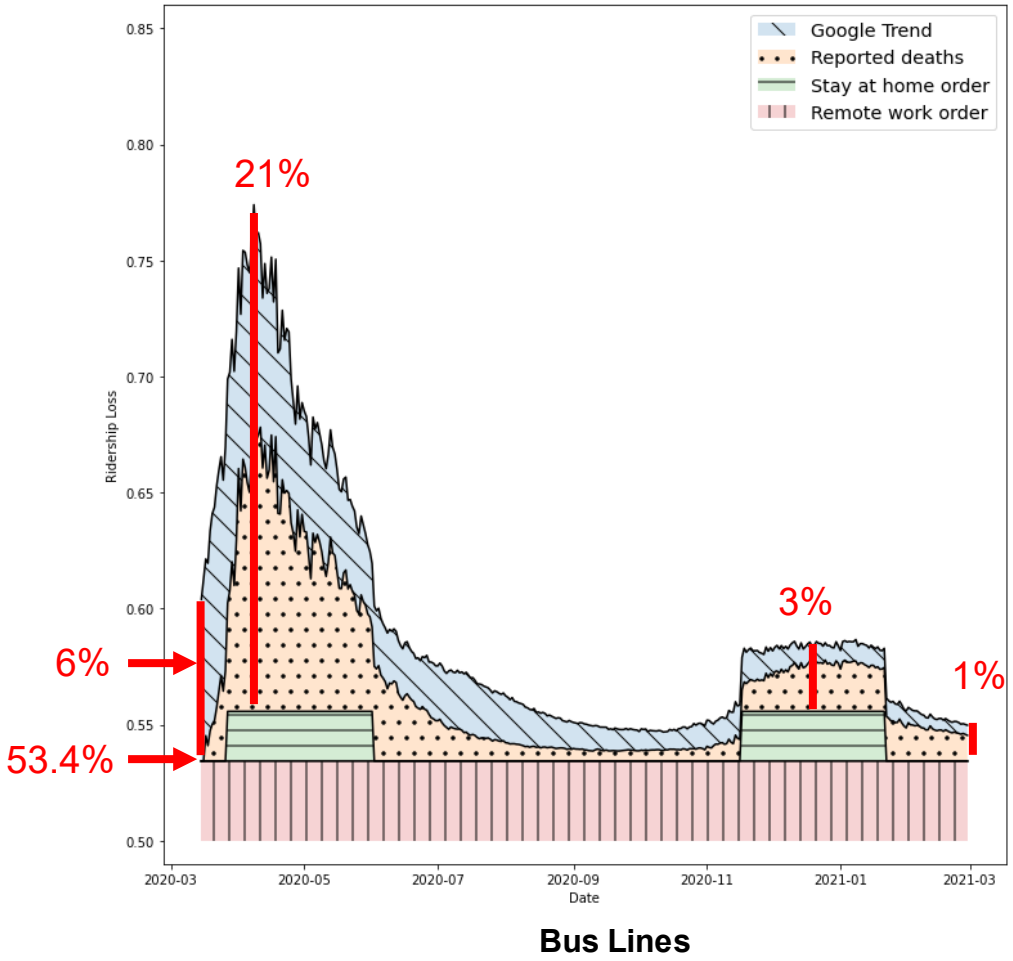
Table 7. Summary statistics of all temporal model estimates

Params	CTA Rail				CTA Bus			
	Max	Min	Mean	%Significant	Max	Min	Mean	%Significant
Constant	4.89E+02	-3.13E+03	-4.89E+02	99.2	-9.11E+01	-2.65E+03	-8.56E+02	98.4
Cases	4.15E-05	3.68E-06	1.19E-05	89.2	1.66E-05	4.36E-06	1.04E-05	93.5
Cumu. Vaccine	8.41E-08	-1.56E-07	-4.76E-08	76.9	4.66E-08	-1.15E-07	-4.31E-08	71.0
Workplace Occupancy Reduction	1.17E+00	5.34E-01	8.11E-01	100	9.14E-01	5.46E-01	7.28E-01	100
Stay-at-home	8.86E-02	-1.49E-02	3.72E-02	63.1	9.78E-02	1.51E-02	4.02E-02	88.7
Crime	3.70E-11	-1.60E-01	-2.73E-02	53.8	-1.05E-02	-1.41E-01	-5.15E-02	83.9
Gas Price	1.22E-01	1.55E-02	5.43E-02	98.5	7.21E-02	-1.81E-02	3.14E-02	87.1
Unemployment	1.96E-02	1.95E-03	7.81E-03	96.9	1.64E-02	-7.85E-03	5.96E-03	74.2
Discount	-2.08E-02	-2.49E-01	-7.46E-02	86.9	4.37E-02	-1.07E-01	-5.24E-02	53.2

NUMERICAL RESULTS - Temporal



Rail Stations

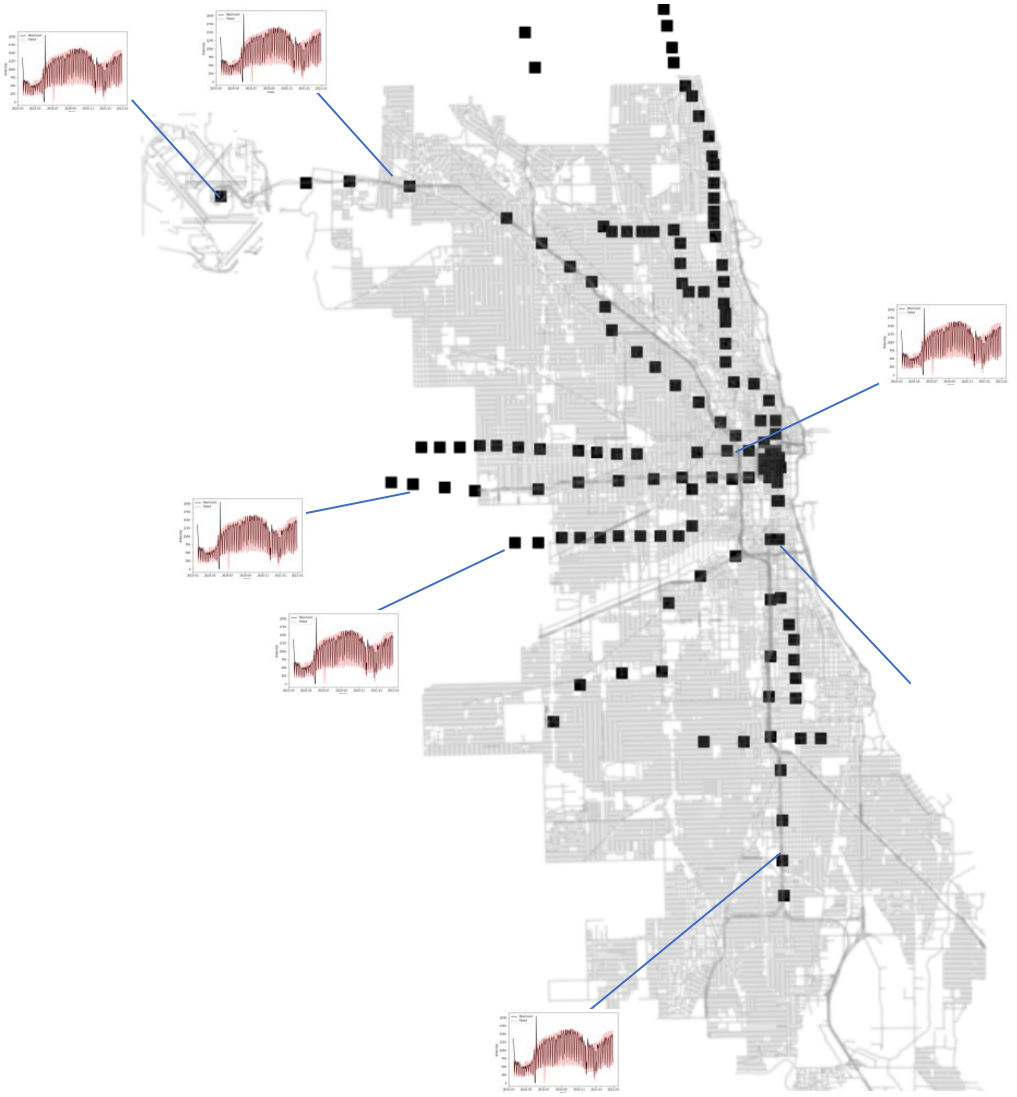


Bus Lines

Figure 7. Effects of various contributing factors on average ridership loss per day across all rail stations and bus lines.

NUMERICAL RESULTS - Spatial

- From the temporal regression, we obtain the time-varying behavior of ridership at each station during the first year of the pandemic.
- However, the ridership loss curves are different for each stations.
- We want to also explore the spatial relationships between the ridership loss due to fear or executive order and the socio-economic characteristics around each of the stations.



NUMERICAL RESULTS - Spatial

CTA Rail

- We assume that people would access rail stations according to proximity.
- The catchment areas are determined via Voronoi tessellation.
- We obtain the intersection between the geographic area of each socio demographic spatial unit and the station catchment area.
- The population of the intersected regions are used as weights to aggregate demographic data.

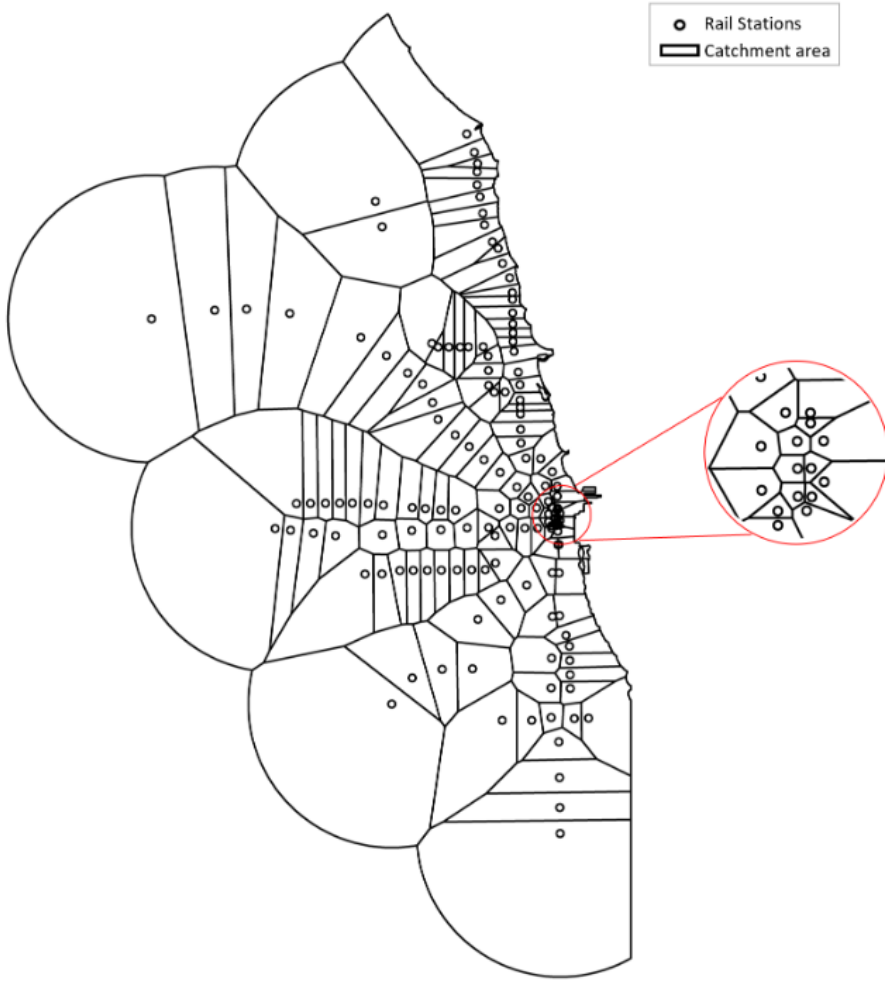
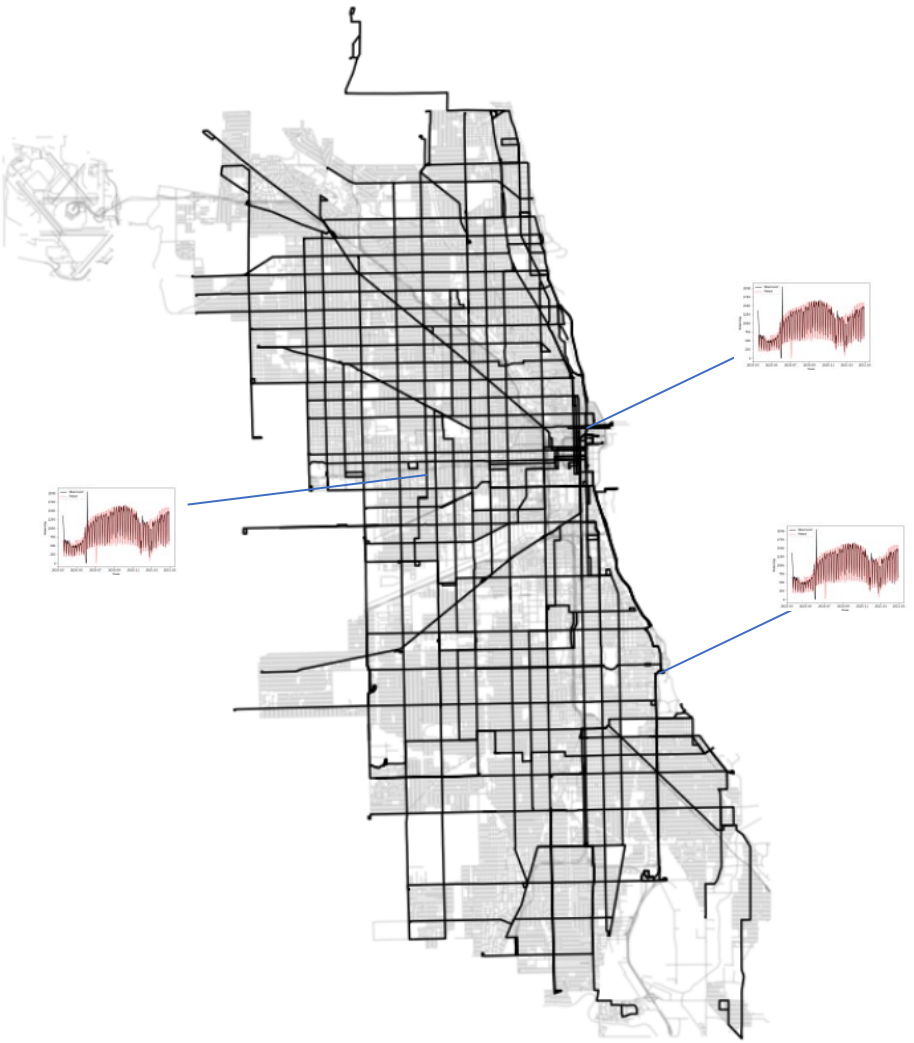


Figure 11. Catchment area of each rail station in Chicago based on proximity.

CTA Bus

- The line-level data makes it challenging to produce realistic catchment areas.
- For bus system, each bus line may intersect with several census tracts, so we aggregate all socio-demographic information at the census tract level and use the number of bus stops within each census tract as the weight.
- This weighted average is used as the socio-demographic characteristics along this entire bus line



NUMERICAL RESULTS - Spatial

- Correlations with ridership loss
- "+" means significantly and positively correlated with ridership loss in that mode, and vice versa.

Table 8. Summary of correlations for spatial analysis of CTA rail and CTA bus systems.

Variables	COVID Cases, α_c		Vaccine, α_v		Workplace Occup. Reduction, α_o		Unemployment Rate, α_u		Crime, α_e		Discount, α_d		Gas Price, α_g	
	Bus	Rail	Bus	Rail	Bus	Rail	Bus	Rail	Bus	Rail	Bus	Rail	Bus	Rail
prop_male							+	+					−	
prop_age_0_24		−				+				−		+	+	
prop_age_25_39		−				+		−			+	+		
prop_age_40_64								−					−	
prop_white			−		+					−				
prop_black	+	−		+	+	+		−				+		
prop_asian						+		−			−	−		−
prop_poverty		+		−		−		+				−		+
prop_edu		+					+			+			−	
prop_employ											−		+	+
prop_W_Manuf	−													
prop_W_Trade	−				−						−			
prop_W_Edu														
prop_W_Health			+		−						−			
prop_LU_residential				−	−	+							−	+
prop_LU_commercial							−				+			
prop_LU_industrial	+				−						−		−	
prop_LU_education			−		+				+		+			+
prop_LU_medical		−		+							+	+		
prop_LU_openspace	+			−		+	+			−	+	−	−	
LUM					−					−				

NUMERICAL RESULTS - Spatial

Table 4. Impacts related to **executive orders**.

Rail System				
Variable (Proportion of)	Black population	Residents working in the wholesale or retail industry	Educational land use	Industrial land use
Significant Correlation with Ridership Reduction	Negative	Negative	Positive	Negative

Bus System					
Variable (Proportion of)	White population	Educational land use	Workers in health industry	Open space land use	Industrial land use
Significant Correlation with Ridership Reduction	Positive	Positive	Negative	Negative	Negative

NUMERICAL RESULTS - Spatial

Table 5. Impacts related to **public fear**.

Rail System			
Variable (Proportion of)	White Population	Residents working in the manufacturing industry	Educational land use
Significant Correlation with Ridership Reduction	Positive	Negative	Positive

Bus System					
Variable (Proportion of)	Black population	Educational land use	Transportation land use	Workers in the manufacturing industry	Workers in the wholesale or retail industry
Significant Correlation with Ridership Reduction	Negative	Positive	Positive	Positive	Negative

SUMMARY OF FINDINGS

Historical review and statistical analysis of Chicago CTA rail and bus systems during the COVID-19 pandemic (up to May 2022) show that:

- For both bus and rail systems, the **remote work/learning** is responsible for the majority of transit ridership loss, i.e., flexibility to work remotely will be a key factor on determining future ridership recovery.
- For the first part of the pandemic, the "**fear**" accounted for about **17-21%** of the ridership loss, which is reduced to only **1-3%** by the end of the first year as a result of "caution fatigue."
- Discount programs found effective in affecting those who continued riding during the pandemic (esp. minority and essential workers).
- There are vast differences of socioeconomic factors' impacts on different types of ridership loss, and between different transit modes, indicating the necessity to develop different ridership recovery strategies for different areas and different mode, targeting specific socioeconomic and demographic groups.
- Transit agencies may need to leverage their ridership recovery efforts through proactive policy instruments and incentive programs that can stimulate demand among those who have changed their commuting needs.
- Recovery programs have seen success in Toronto and Hong Kong during previous pandemics such as SARS. These strategies may include partnerships with the private sector, launching discount programs and promotional activities, improve service quality during the peak hours, or advertisement campaigns.

Thank you!

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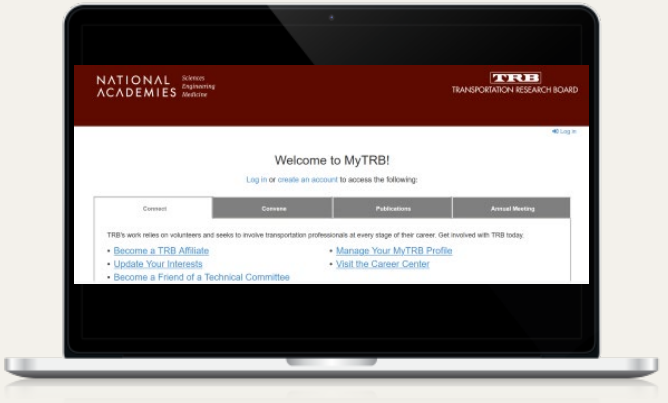

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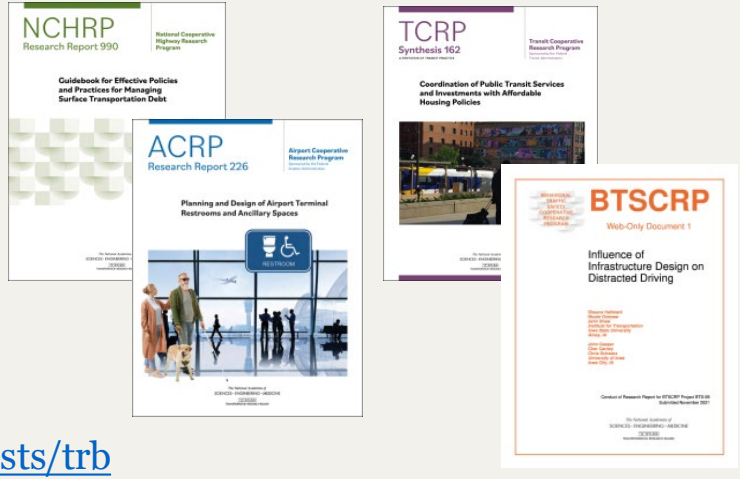

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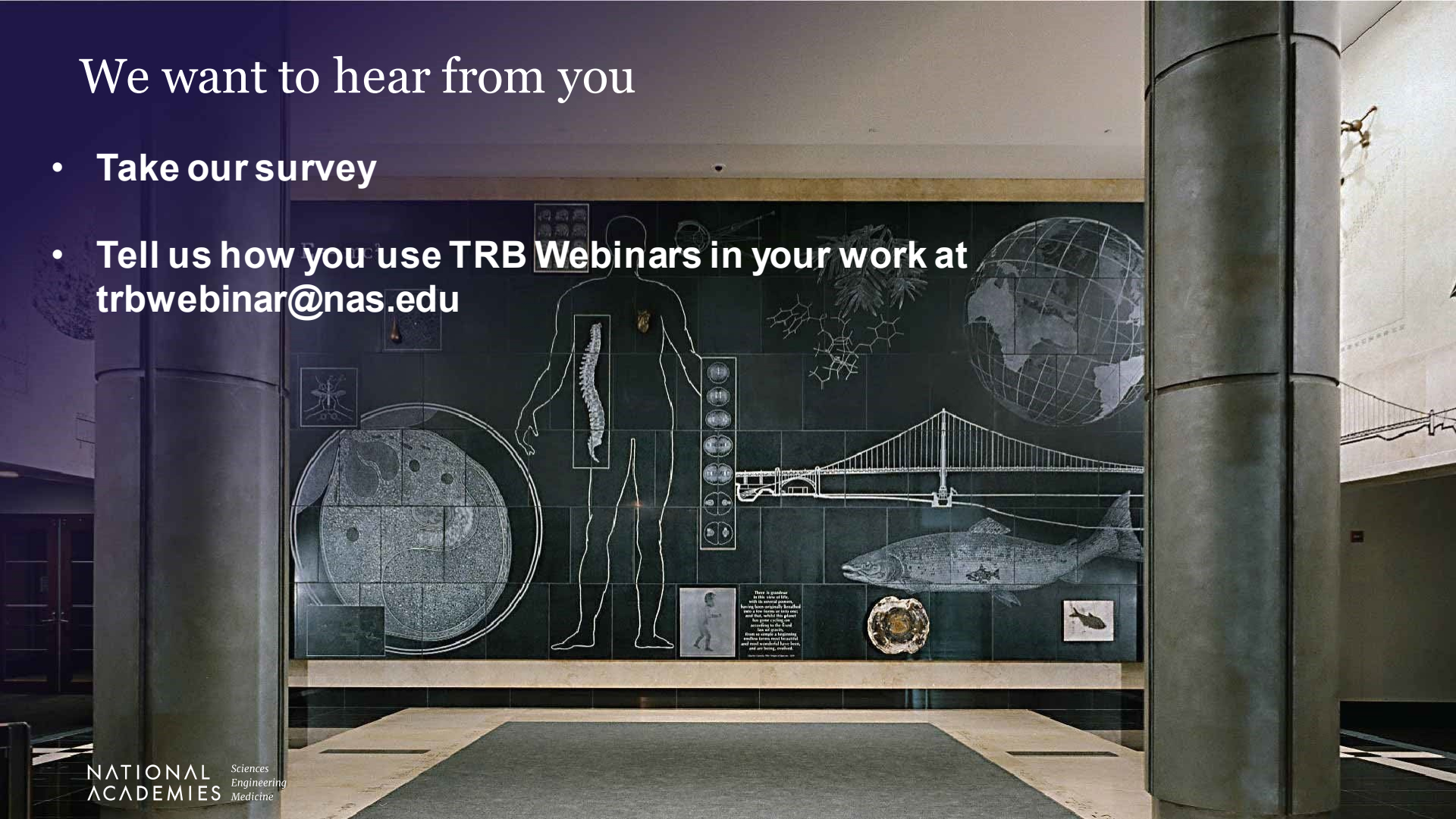

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