Lost transit riders in the post-pandemic era: who and where?

Yuanjie (Tukey) Tu, Andisheh Ranjbari, Parastoo Jabbari, Don MacKenzie

Civil and Environmental Engineering, University of Washington

Abstract

We surveyed residents of the Puget Sound, Washington region about their travel habits before the COVID-19 pandemic, during the pandemic, and expectations for post-pandemic. We identified six groups of respondents characterized by their transit use frequency before, during, and after the pandemic. We focus primarily on the group ***lost riders****: those who used transit frequently pre-pandemic but expect to ride less post-pandemic. They account for 28% of transit riders in our sample. Compared with* ***rebounding frequent riders****, who expect to return to heavy transit use post-pandemic, lost transit riders are older and wealthier; no significant attitudinal differences towards taking transit are found between two groups. Though would not return to transit post-pandemic, lost riders would not switch to other travel modes either. Instead, they expect to reduce travel frequency by 3.4 days per week, mainly due to increasing working from home (WFH) frequency by 1.6 days per week, on average.*

Keywords: *COVID-19, lost transit riders, rebounding transit riders, work from home (WFH), ICT use*

Introduction

The prevalence of COVID-19 brought devastating impacts to public transit (Basu and Ferreira 2021; Hu and Chen 2021; Tirachini and Cats 2020). To reduce virus spread, US residents were encouraged to either stay home or enforce physical distancing when traveling. Since the essence of public transit is providing service for large amounts of people, "the physical distancing conflicts with the concept of public transportation" (Musselwhite et al., 2020). As a result, transit ridership fell significantly across the country.

In the Puget Sound region of Washington State, the first month of the pandemic (March, 2020) saw an average drop in transit ridership of 74% compared with the same month in 2019 (WSDOT 2020). The situation is similar in other American cities. Public transit ridership in New York dropped 92% at its peak (Wang et al., 2020), while Chicago saw a 72% ridership drop in 95% of the transit stations (Hu and Chen 2021).

There are concerns that public transit in the US will face greater challenges in the long term (Gillingham et al., 2020; Tirachini and Cats, 2020). Multiple studies argue that there will be "transit inertia," in which some previous riders do not return to taking transit even when the pandemic is over (Basu and Ferreira 2021, 19; Cho and Park 2021; Gillingham et al. 2020; Wang et al., 2020). Many scholars believe transit riders would turn to private cars instead, resulting in more severe traffic congestion and air pollution (Gillingham et al., 2020; Tirachini and Cats, 2020; Wang et al., 2020; Sharifi and Khavarian-Garmsir, 2020). However, the evidence is sparse. Current studies mainly focus on transit riding behavior changes during the pandemic (Brough, Freedman, and Phillips 2020; Hu and Chen 2021; Jung 2020; Shamshiripour et al. 2020; Tirachini and Cats 2020), but very little is known about the expected changes after the pandemic. There is one study concluding that only 64% to 73% of transit ridership would recover after New York City reopens (Wang et al. 2020), but the conclusion is drawn by simulation models with assumptions on different levels of transit use inertia rather than empirical evidence.

This study focuses on a group of transit riders who do not expect to return to their prior levels of transit use post-pandemic, and addresses the following questions about them using a survey of Puget Sound region residents: Who are they? What is their attitude towards taking transit? Where would they go after the pandemic, if they do not expect to return to transit?

Study Area and Data

Study area. This study focuses on the Puget Sound region of Washington State (Figure 1). Anchored by the city of Seattle, the Puget Sound region consists of four counties (King, Snohomish, Kitsap, and Pierce) 82 cities and towns, and a total population of 4.3 million (PSRC 2020a). The Puget Sound region is a national leader in growth of transit service and ridership. The city of Seattle is among the best cities for public transit in the US in terms of transit accessibility (Shafer, 2018; Whitely, 2018) and the state government has been striving to provide “a multimodal transportation system with accessible, fast connections between regional centers and surrounding communities” (WSDOT 2020). By the end of 2018, there were 221 million transit boardings in the central Puget Sound region, an increase of 19% over 2010 (PSRC 2020b).

Data. The data comes from an online survey designed by the University of Washington (UW) researchers that collected data on stated travel behaviors before and during the pandemic, as well as expected travel choices for post-pandemic (Jabbari et al., 2020). Socio demographics, the use of information and communication technologies (ICT), and attitudes towards different transportation modes were also collected. The survey was advertised through the Facebook page of the UW Civil and Environmental Engineering Department and was live for 14 consecutive days in June-July 2020). Ads were run on Facebook, Instagram, Messenger, and other social media platforms owned by Facebook, and were set to be shown only to residents of the Puget Sound region. To promote participation, respondents were entered in a raffle drawing for an Apple iPad or a Microsoft Surface tablet. The ads reached 49,146 people, of whom 1,389 completed the survey (2.8%). There were 1,310 valid responses after data cleaning. Table 1 summarizes the individual characteristics of the sample compared to the Puget Sound Regional Council (PSRC, the region’s Metropolitan Planning Organization) statistics in 2018.

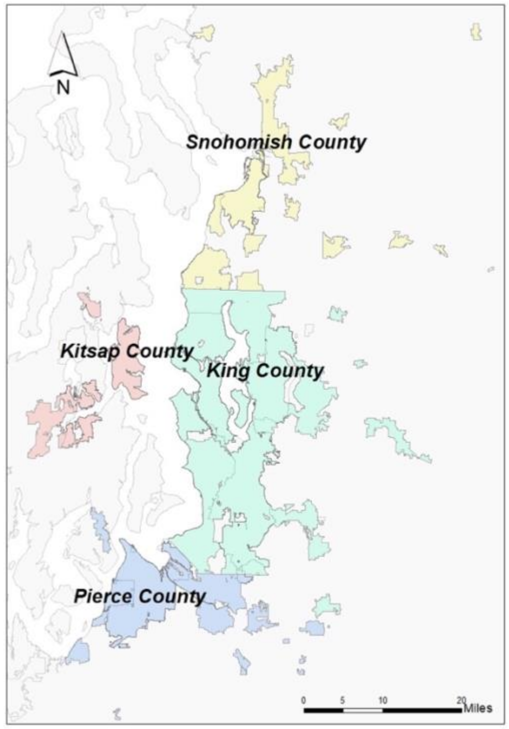

FIGURE 1. Study area (the Puget Sound region in Washington State)

TABLE 1. Data Description (N=1,310)

Characteristic	**This Sample**	**PSRC Population (2018)**
Gender		
Female	50.7%	50.2%
Male	48.5%	49.8%
Others	0.6%	-
Race		
White	78.5%	68.5%
Asian	12.1%	13.5%
African American	1.4%	5.8%
Hispanic or Latino	3.7%	10.1%
Others	4.3%	2.1%
Age		
18-39	39.9%	42.0%
40-64	48.0%	42.0%
65 and above	12.1%	15.9%
County		
King	53.9%	53.0%
Pierce	20.0%	21.1%
Kitsap	5.9%	6.5%
Snohomish	19.7%	19.5%

Transit Rider Groups

To group respondents based on their transit usage, we adopted a bottom-up clustering approach in two steps. In each step, eight clustering methods (K-means, K-medians, complete linkage, single linkage, centroid linkage, average linkage, Ward and Ward2) are applied to detect different transit rider groups based on three variables: days of transit use per week (1) before the pandemic, (2) during the pandemic, and (3) expected frequency of transit use after the pandemic. For ease of interpretation, we converted the ordinal travel frequencies into numerical values1 (we do so throughout the remainder of the paper). For each clustering method, the number of clusters, K, changes from 2 to 10. In total, there were 72 combinations of clustering methods and K. To determine the best combination, 26 clustering quality indices were adapted from Helmus et al. (2020), which are provided in the Appendix. Based on its own criterion, every index votes for the optimal clustering method and number of clusters, K. The combination with the largest number of votes is selected as the optimal option. More details about implementing clustering and quality check can be found in the R package NbCluster (Charrad et al. 2014).

In the first step, using the entire dataset, our clustering approach resulted in the optimal clustering algorithm being K-means and the number of clusters equal to two: non-transit riders (N = 1,106) and transit riders (N = 204). In the second step, the same clustering approach was performed on the 204 transit riders. This time, the single linkage method with K = 5 was selected as the optimal combination. This resulted in a total of six clusters listed below. The days of transit use of each cluster before, during, and after the pandemic are also shown in Figure 2.

Non-transit users. Most respondents (84.4%) are identified as non-transit users. They almost never used transit, and never would.

[1] Everyday: 7, 3-4 days a week: 3.5, 1-2 days a week: 1.5, A few times a month: 0.625, Once a month or less: 0.125, Never: 0

Lost transit riders. This group includes transit riders who are reluctant to ride transit after the pandemic and accounts for 28% of total transit riders in our sample (i.e., excluding the non-transit riders). They rode transit daily before the pandemic and expect to ride it only 2 days per week after the pandemic, on average.

Rebounding frequent riders. Rebounding transit riders are people whose transit use would rebound to the previous level. Rebounding frequent riders are heavy transit riders who reported daily transit use before the pandemic. They depressed their transit use to zero during the pandemic but expect to rebound to daily use. They account for 36% of transit riders.

Rebounding moderate riders. Rebounding moderate riders are transit riders whose transit use frequency were moderate before the pandemic. They used transit 3.5 days per week on average before and expect to do the same after the pandemic, though they were not riding during the pandemic. Rebounding moderate riders accounted for 24% of transit riders.

Rebounding higher riders. Rebounding higher riders depressed their transit use during the pandemic, but they expect an increased transit riding frequency when it ends. They account for 10% of the transit users.

Loyal transit riders. Loyal transit riders have high transit riding frequency, even during the pandemic, and expect to keep it at that level after it ends. However, only 3 respondents, or less than 2% of our sample, fell into this category.

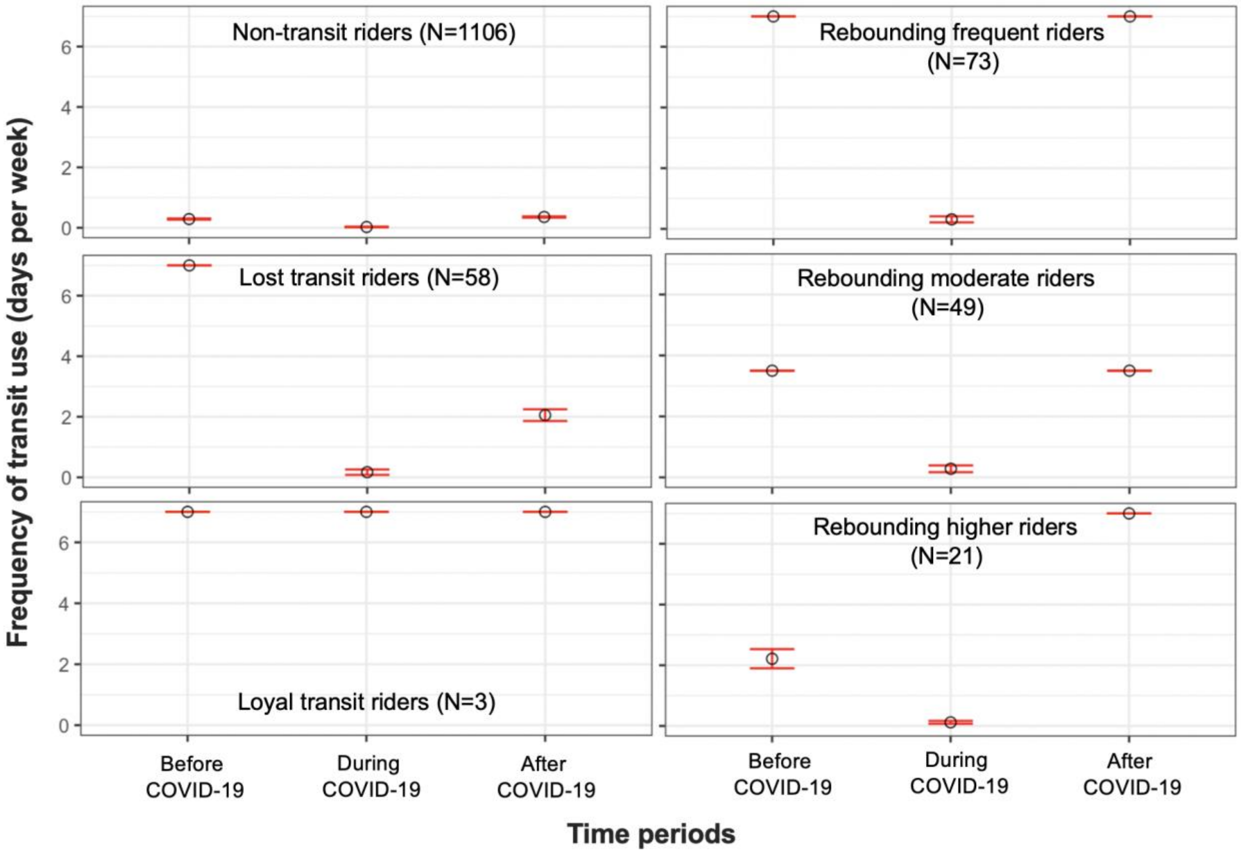

FIGURE 2. Transit rider groups derived by the clustering approach and their corresponding transit riding frequency.

Note: Black circles are average values, and red lines are error bars representing 95% confidence intervals (CI) for the means

Who Are They?

Lost riders and rebounding frequent riders were both heavy transit riders that reduced their transit use to near zero but expect to part ways after the pandemic. Why would lost riders not return to transit as rebounding frequent riders do? To unravel this puzzle, we present the socio-demographics of both groups. We used the Fisher's exact test to assess the distribution differences between the two groups. The Fisher's exact test is especially useful for data with small sample sizes (an expected frequency less than 5).

The age and income differences between the two groups are found significant. Both groups are relatively young, with 60% of lost riders and 80% of rebounding frequent riders between the age of 18 to 39. Although both groups skew younger than our sample as a whole, the lost riders have a lower percentage of respondents between 18 to 39 and a higher percentage of respondents above 65 compared with the rebounding frequent riders. The lost riders also have higher income than rebounding frequent riders, which is reflected in the higher percentage of high-income respondents (annual income >= $100,000). No significant differences are detected between these two groups considering race and whether they were an essential worker.

Table 2. Socio-demographics of *Lost Transit Riders* and *Rebounding Frequent Riders*

Attributes		**Lost riders (N=58)**	**Rebounding frequent riders (N=73)**
Age**	18-39	60%	80%
	40-64	33%	20%
	>=65	7%	0%
Income*	< $50,000	14%	25%
	$50,000-$99,999	21%	29%
	>= $100,000	65%	47%
Race	White	62%	67%
	Asian	17%	25%
	African American	3%	3%
	Other	17%	6%
Essential worker[2]	Yes	7%	8%
	No	93%	92%

*Note: * difference between 2 groups is significant at 10% level, ** significant at 5% level, Fisher's exact test.*

What is Their Attitude Towards Taking Transit?

In this section we compare attitudes towards taking transit in lost riders and rebounding frequent riders. Table 3 compares those attitudes between the two groups using a Wilcoxon rank-sum test, which is

[2] People who work in delivery or postal service, transportation, grocery, utilities (water, electricity, etc.), medical, and building maintenance and repair

commonly used for comparing two distributions of ordinal variables or two independent samples that are not normally distributed. The results show that both groups are unwilling to take transit during the pandemic. However, no significant attitudinal differences towards taking transit are discovered between the two groups. The results indicate that lost transit riders do not perceive riding transit as riskier than rebounding frequent riders do; both groups would not travel on a crowded bus, even when physical distancing measures are taken; and they both try to use transportation options that allow them to avoid contact with others. The attitudes towards taking transit partly explain respondents' transit use change *during* the pandemic, and might not be the reason why lost riders would not return to transit *after* the pandemic.

Table 3. Attitudes Towards Taking Transit for *Lost Transit Riders* and *Rebounding Frequent Riders*

Attitudes towards taking transit		**Lost transit riders (N = 58)**	**Rebounding frequent riders (N=73)**
Q1: Traveling by bus or light rail poses a risk to my health	Strongly disagree	0%	3%
	Disagree	9%	4%
	Somewhat disagree	3%	3%
	Somewhat agree	19%	26%
	Agree	28%	27%
	Strongly agree	41%	37%
Q2: I don't mind traveling on a crowded bus	Strongly disagree	69%	62%
	Disagree	19%	19%
	Somewhat disagree	9%	11%
	Somewhat agree	2%	6%
	Agree	2%	1%
	Strongly agree	0%	1%
Q3: I try to use transportation options that allow me to avoid contact with other people	Strongly disagree	2%	0%
	Disagree	4%	1%
	Somewhat disagree	2%	6%
	Somewhat agree	10%	6%
	Agree	21%	29%
	Strongly agree	62%	59%
Q4: I would travel by bus or light rail if physical distancing measures are enforced	Strongly disagree	12%	11%
	Disagree	16%	12%
	Somewhat disagree	9%	10%
	Somewhat agree	26%	30%
	Agree	17%	22%
	Strongly agree	21%	15%

*Note: ** difference between 2 groups is significant at 5% level, Wilcoxon rank sum test*

Where Would They Go After the Pandemic?

Finally, we discuss where lost riders would go, if they do not expect to return to transit after the pandemic.

Switching to private cars

If people would not use transit as much as before, could it be because they expect to turn to private cars as some researchers suspect (Gillingham et al. 2020; Wang et al. 2020)? The results show that expected driving frequency remains moderate, shifting from 2.1 days per week pre-pandemic to 2.4 days per week post-pandemic. A Wilcoxon rank sum test shows the difference is insignificant (Figure 3). This modest shift toward private cars does not explain the large reduction in expected transit use frequency post-pandemic.

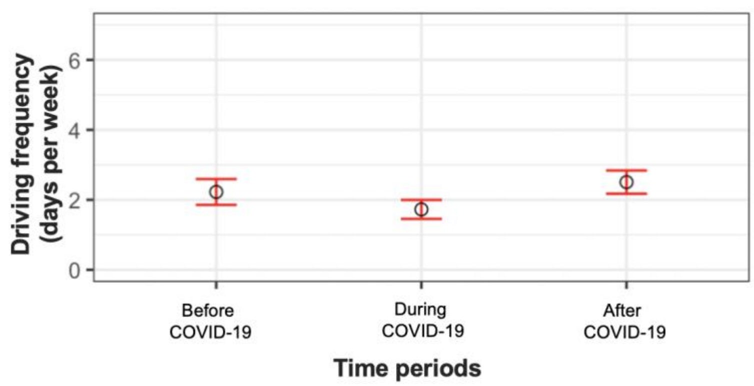

FIGURE 3. Driving alone frequency of lost transit riders

*Note: **difference between before and after COVID-19 is significant in 5% level, Wilcoxon rank sum test; black circles are average values; red lines are error bars representing 95% CI for the means*

Switching to other modes

People may switch from transit to other transportation modes like carpooling and biking. Figure 4 shows the travel frequency of other modes for lost transit riders in pre-, during-, and post-pandemic times. No modes saw a significant change in travel frequency between before and after the pandemic, ruling out the possibility that lost transit riders mainly would expect to switch to other travel modes.

But if they would not switch to other travel modes, where would they go?

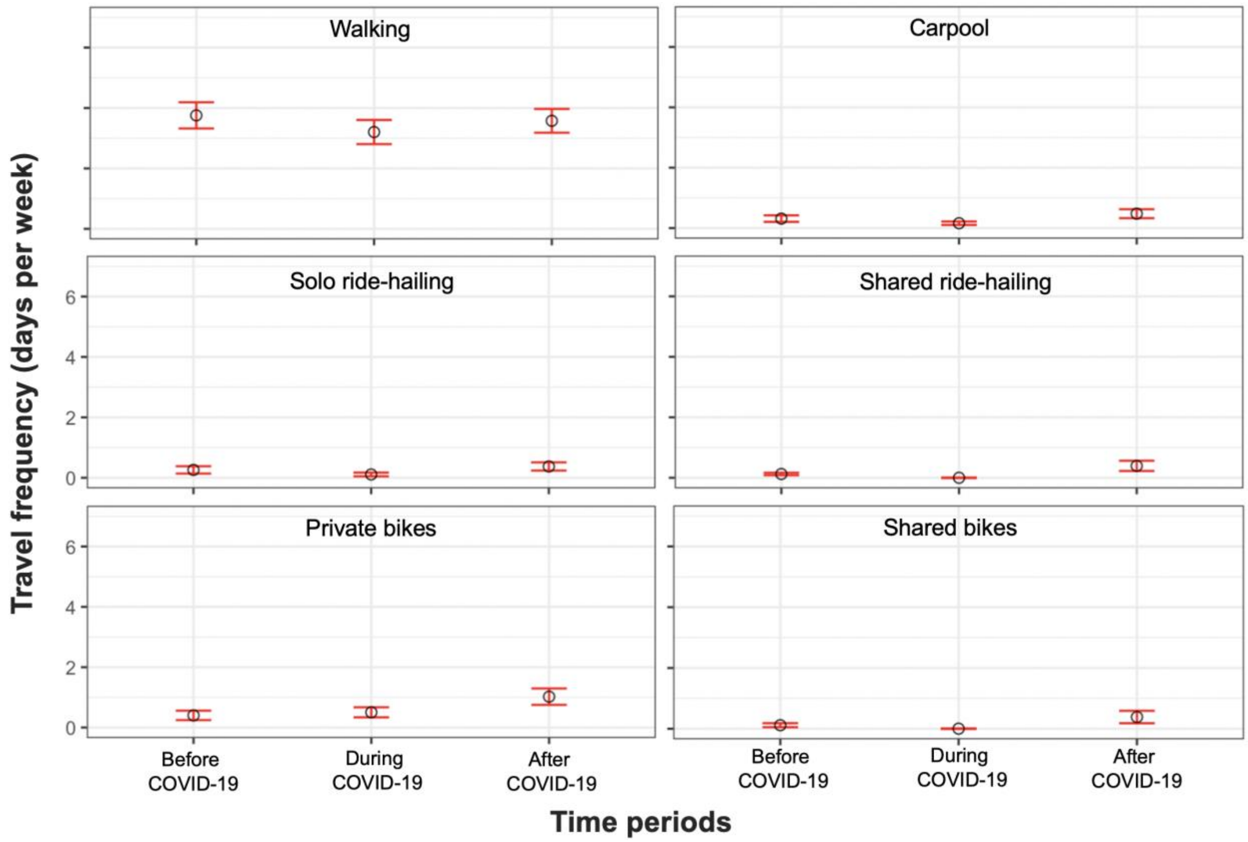

FIGURE 4. Travel frequency of alternative modes of lost transit riders

*Note: ** difference between before and after COVID-19 is significant in 5% level, Wilcoxon rank sum test; black circles are average values; red lines are error bars representing 95% CI for the means*

Reducing travel

Another possibility is that people expect to reduce their amount of travel post-pandemic (Figure 5). We calculated overall frequency of travel as the sum of travel frequencies made by each mode, and therefore some values unintuitively are larger than 7 days a week. A drop in overall travel frequency is most visible from before pandemic to during the pandemic, when the lost riders reported a reduction of 8.3 days per week in overall travel frequency. After the pandemic, the expected overall travel frequency would rebound to 10.8 days per week, with a significant decrease of 3.4 days per week than the pre-pandemic.

It is possible that lost transit riders reduce some of their activities entirely, yet a big part of the travel frequency reduction is likely to be caused by the availability of information communication technologies (ICT) as discussed in the next section.

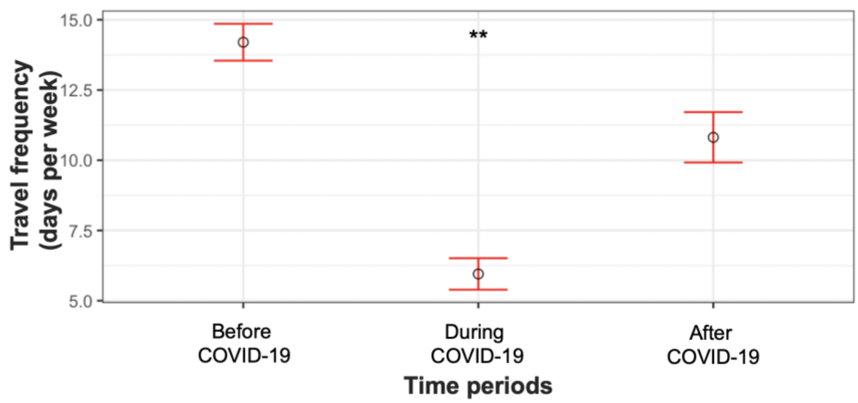

FIGURE 5. Overall frequency of travel across all modes for lost transit riders

*Note: ** difference between before and after COVID-19 is significant in 5% level, Wilcoxon rank sum test; black circles are average values; red lines are error bars representing 95% CI for the means*

The use of information communication technology (ICT)

As COVID-19 brings sharp reduction in physical travel, the availability of ICT enables online activities that could replace in-person trips to some degree. In this section, we mainly include working from home and engagement in e-commerce (online shopping and online food delivery) as activities replacing in-person trips.

Working from home (WFH), or telecommuting, has been long discussed as a future possibility after the telephone was invented to enable long-distance communications in the 19th century (Mokhtarian 2009). With 288 million internet users in the US (Kemp 2020), a recent report finds that 37% of the jobs in the US can be completely replaced by working from home (Dingel and Neiman 2020). And Washington State's *Stay home, stay healthy* order during the pandemic makes WFH a reality (Herz and Vandor 2020; Washington State Coronavirus response 2020).

This is also reflected in our results (Figure 6). In general, WFH frequency[3] pre-pandemic averaged 0.7 days per week, which increased to 3.1 days per week during the pandemic. For lost transit riders, the frequency of WFH was 0.6 days before the pandemic, showing that lost transit riders barely worked from home in normal times. During the pandemic, they work from home 4 days per week on average. Their expected WFH frequency decreases after the pandemic to 2.1 days per week, still much higher than that in pre-pandemic times. The difference of WFH frequency between before and after pandemic times is found significant by using a Wilcoxon rank sum test.

Other ICT use such as online grocery shopping, other-purpose online shopping and online food delivery indicate little changes between before and after pandemic times. Lost riders have slightly higher frequency in these online activities during the pandemic, but they expect to return to their previous levels of use when the pandemic is over. One thing worth noting is that the data were collected in June/July 2020, early in the stage of staying at home. The expected frequency of various ICT use after the pandemic could be higher as people become accustomed to the quarantine life and are dependent on using communication technologies – or could be lower due to fatigue with virtual interactions.

[3] In the context of work-related questions, "every day" is interpreted as 5 days a week (every working day), while it is interpreted as 7 days a week for other transportation questions.

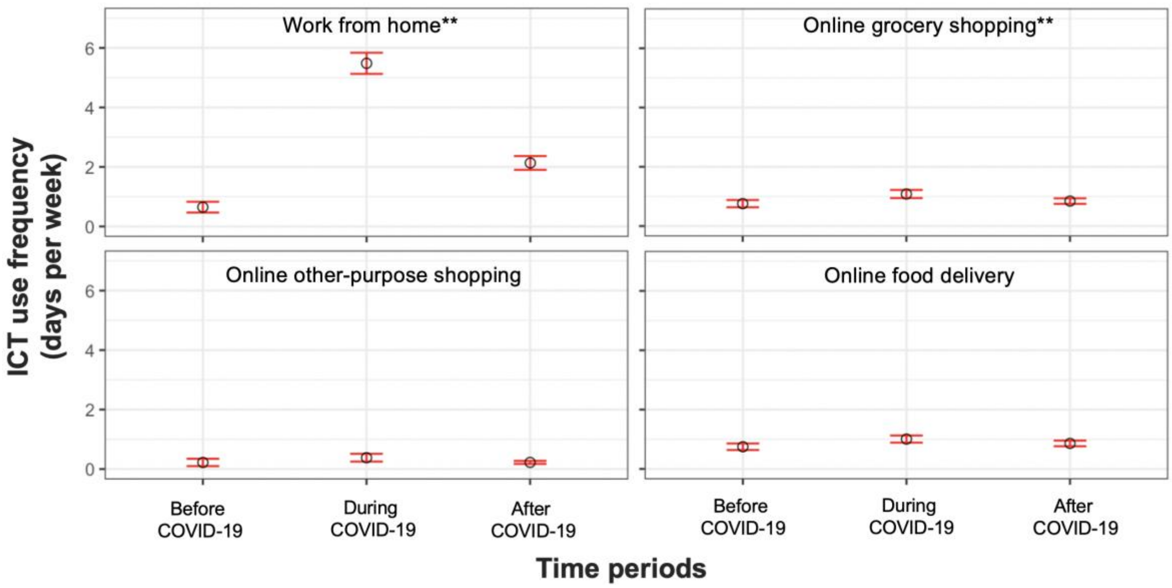

FIGURE 6. The ICT use frequency for lost transit riders

*Note: ** difference between before and after COVID-19 is significant in 5% level, Wilcoxon rank sum test; black circles are average values; red lines are error bars representing 95% CI for the means*

Conclusions

To provide a safe environment for passengers during the pandemic, transit agencies have been making huge efforts such as rear-door boarding, fare-free rides, and reduced capacity on transit vehicles (WSDOT 2020). They have also implemented more frequent cleaning of the transit vehicles (Baruchman and Lindblom 2020; Therrien 2020). Nevertheless, there appears to be a sizable contingent of transit riders who do not expect to return to their prior levels of transit use post-pandemic. These lost riders, who represent 28% of pre-pandemic transit riders in our sample, do not report different attitudes toward traveling on crowded buses or the perceived health risks of riding transit than respondents who plan to return to their pre-pandemic transit usage. Rather, the lost riders expect to make fewer in-person trips overall, and in particular expect to continue working from home more in the post-pandemic phase. They are also wealthier and older than the rebounding transit riders who expect to return to prior transit use patterns.

These results suggest that measures to woo these riders back with better cleaning or lower fares are unlikely to succeed. These riders expect to reduce transit use because they are reducing travel overall. They are not disproportionately concerned with crowding or infection risk and are likely to be less price-sensitive than other riders in any case.

As travelers and transit agencies emerge from the shadow of the pandemic, transit agencies may need to reassess their goals and how they provide service. Therefore, if lost riders are truly lost, agencies may not want to devote resources to winning them back. Transit lines and stations that serve large number of lost transit riders destined for sustained reductions in ridership. This would be a good time for service planners to consider reoptimizing routes and frequencies to provide high-quality, reliable transit to those who are interested in riding it. Such a decision would not represent a failure. Public transit in the US serves the goals of providing a basic level of access to all and enhancing sustainability (Manville, Taylor, and Blumenberg 2018). Working from home, a workstyle that replaces commuting travel, is effectively emissions-free. Environmental goals can be advanced by this group working from home, and transit resources can be reallocated to better serve other riders.

This study has some limitations. One is the sample size is small for transit users. Only 204 out of 1,300 survey respondents are recognized as transit riders, reflecting the general mode shares in the Puget Sound Region. Second, this study is based on respondents' expectations for post-pandemic behaviors, not actual choices. Respondents may not fully anticipate the situation when COVID-19 is over. Finally, this survey was conducted in June/July 2020, in the early stages of the COVID-19 pandemic. To monitor the change of people's perceptions over the long term, our team is also collecting two further waves of data from travelers in the Puget Sound Region. These will provide an interesting comparison and check on the results in this paper once they are collected.

References

Baruchman, M., and M. Lindblom. 2020. “Metro Will Sanitize Frequently Touched Bus Surfaces Daily in Battle against the Coronavirus.” The Seattle Times. March 3, 2020. https://www.seattletimes.com/seattle-news/transportation/seattle-area-transit-agencies-pledge-to-increase-bus-and-train-cleaning-against-coronavirus/.

Charrad, M., N. Ghazzali, V. Boiteau, and A. Niknafs. 2014. “NbClust: An R Package for Determining the Relevant Number of Clusters in a Data Set.” *Journal of Statistical Software* 61 (6). https://doi.org/10.18637/jss.v061.i06.

Dingel, J., and B. Neiman. 2020. “How Many Jobs Can Be Done at Home?” w26948. National Bureau of Economic Research. https://doi.org/10.3386/w26948.

Gillingham, K., C. R. Knittel, J. Li, M. Ovaere, and M. Reguant. 2020. “The Short-Run and Long-Run Effects of Covid-19 on Energy and the Environment.” *Joule* 4 (7): 1337–41. https://doi.org/10.1016/j.joule.2020.06.010.

Herz, K., and J. Vandor. 2020. “Washington State Issues ‘Stay Home — Stay Healthy’ Order | Davis Wright Tremaine.” 2020. https://www.dwt.com/blogs/employment-labor-and-benefits/2020/03/washington-state-stay-at-home-order.

Kemp, S. 2020. “Digital 2020: The United States of America.” DataReportal – Global Digital Insights. 2020. https://datareportal.com/reports/digital-2020-united-states-of-america.

Manville, M., B. Taylor, and E. Blumenberg. 2018. “Transit in the 2000s: Where Does It Stand and Where Is It Headed?” *Journal of Public Transportation* 21 (1): 104–18. https://doi.org/10.5038/2375-0901.21.1.11.

Mokhtarian, P. 2009. “If Telecommunication Is Such a Good Substitute for Travel, Why Does Congestion Continue to Get Worse?” *Transportation Letters* 1 (1): 1–17. https://doi.org/10.3328/TL.2009.01.01.1-17.

PSRC (Puget Sound Regional Council). 2020a. “Regional Data Profile: Population and Households | Puget Sound Regional Council.” 2020. https://www.psrc.org/rdp-population.

PSRC (Puget Sound Regional Council). 2020b. “Regional Data Profile: Transportation.” Puget Sound Regional Council. 2020. https://www.psrc.org/rdp-transportation.

Shafer, D. 2018. “Seattle Is Climbing National Rankings as a Top Transit City and Leads the Country in Ridership Growth.” Seattle Business Magazine. February 23, 2018. https://www.seattlebusinessmag.com/seattle-climbing-national-rankings-top-transit-city-and-leads-country-ridership-growth.

Therrien, A. 2020. “Here’s How Seattle Transit Is Being Cleaned to Limit Spread of Coronavirus (VIDEO) | Urbanized.” 2020. https://dailyhive.com/seattle/seattle-transit-coronavirus.

Wang, D., B. He, J. Gao, J. Chow, K. Ozbay, and S. Iyer. 2020. “Impact of COVID-19 Behavioral Inertia on Reopening Strategies for New York City Transit,” 20.

Washington State Coronavirus response. 2020. “Stay Home, Stay Healthy.” Washington State Coronavirus Response. 2020. https://coronavirus.wa.gov/what-you-need-know/stay-home-stay-healthy.

WSDOT (Washington State Department of Transportation). 2020. “2020 Transit Integration Report.” https://wsdot.wa.gov/sites/default/files/2020/11/30/2020-Transit-Integration-Report.pdf.

About the Authors

Yuanjie (Tukey) Tu (*yuanjt2@uw.edu*) is a PhD student at Civil and Environmental Engineering at University of Washington. She is a research assistant in the Sustainable Transportation Lab. With a background in transportation engineering (PhD) and urban planning (Master), her research interests involve public transportation, automated mobility, and energy and climate issues.

Andisheh Ranjbari (*ranjbari@uw.edu*) is a Research Scientist in Civil and Environmental Engineering at University of Washington, and Manager of the Urban Freight Lab, a public-private research partnership focused on developing and testing solutions around urban freight management and operation problems. She has over a decade of research experience in multiple areas of transportation including public transportation, automated and shared mobility, and urban freight and logistics.

Parastoo Jabbari (*jabbari@uw.edu*) is a PhD Candidate in Civil and Environmental Engineering at the University of Washington. She is a research assistant in the Sustainable Transportation Lab and is interested in energy and environmental aspects of transportation systems, particularly vehicle electrification, vehicle automation, and their relationships with public policy.

Don MacKenzie *(dwhm@uw.edu)* is an Associate Professor in Civil and Environmental Engineering at University of Washington. He leads the Sustainable Transportation Lab, which develops and evaluates technical and policy solutions for making our transportation system more economically-viable and environmentally-benign while providing access to opportunities for all.

APPENDIX

TABLE A.1. Clustering Quality Indices Used in this Study

ID	Index	ID	Index
1	KL	14	Pseudot2
2	CH	15	Beale
3	Hartigan	16	Ratkowsky
4	CCC	17	Ball
5	Scott	18	Ptbiserial
6	Marriot	19	Frey
7	TrCovW	20	McClain
8	TraceW	21	Dunn
9	Friedman	22	Hubert
10	Rubin	23	SDindex
11	Cindex	24	Dindex
12	DB	25	SDbw
13	Silhouette	26	Duda