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Covid-19 pandemic impacts on essential transit riders: Findings from a U.S. Survey

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ABSTRACT

The Covid-19 pandemic has decimated public transit service across the United States and caused significant decreases in ridership. Little is known about the reasons for unevenness in pandemic-era mode shifts and the impacts of pandemic-related transit reductions on riders' day-to-day lives. Using a national survey of U.S. transit riders (n = 500) conducted in fall 2020, this study examines changes in transit use since the pandemic began, the reasons for transit reductions, and the effects of reduced transit use and transit service on transit riders' ability to meet their travel needs. The Covid-19 pandemic has exacerbated existing transportation burdens for those who have limited mobility options, those facing socioeconomic challenges, Hispanic or Latinx riders, and female, non-binary or genderqueer people. We close with recommendations for strengthening transit service for these groups in the long term as we recover from the pandemic.

1. Introduction

The Covid-19 pandemic has decimated transit ridership across the United States. In the second quarter of 2020, subways, light rail, and commuter rail in the United States carried just 15% of the riders they did the year before; bus ridership dropped by two-thirds (Transit App and APTA, 2020; Vock, 2020). These reductions in transit use are driven by advisories against travel due and social distancing policies, as well as greater avoidance of transit travel due to concerns about Covid-19 exposure. Despite the acceleration of Covid-19 immunization, cases have continued to spike in many parts of the US through the end of 2021. At the same time, economic activity and day-to-day travel have gradually rebounded. However, diminished transit ridership persists.

In addition to plummeting ridership, transit agencies have also faced greater pandemic-related costs (EBP, 2021; Tirachini and Cats, 2020). The combination of higher costs and reduced revenues has led to reduced transit service in communities across the U.S. Persistently low levels of ridership continue to threaten the financial viability of transit service despite Congress providing short-term funding relief (EBP, 2021). Transit agencies have laid plans for lasting cuts that are significantly larger than those enacted during the Great Recession, the latter of which triggered the last ridership spiral (Boisjoly et al., 2018). For those who rely on transit, greatly diminished transit service will substantially reduce their ability to access critical destinations like work, groceries, health care, and education.

Recent work has evaluated Covid-19-related impacts on travel behavior. A subset of this analysis has focused on transit use, finding

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that areas with less pronounced ridership declines during the pandemic were more likely to be home to essential workers, low-income households, people of color, and women (Gartsman and Prescott, 2021; Hu and Chen, 2021; Liu et al., 2020). However, little is known about why travel adaptations to the pandemic have differed among and between different types of riders or about how the pandemic has affected different types of riders' mobility. Existing work focuses on the challenges facing people who stopped riding transit and attempted to switch modes (Palm et al., 2021), and not on those still riding.

The impacts of pandemic-induced service cuts are likely to fall more heavily on those with few options. Several decades of transportation research point to two distinct types of transit passengers. For some, using public transit is a choice. These "choice" riders use transit but have ready access to other convenient and viable travel options. For a second group of riders, often referred to as "captive" or "transit dependent", transit provides a critical lifeline to essential destinations, including access to jobs, schools, food, social services, recreation, and social connections needed to fulfill their day-to-day needs (Taylor and Morris, 2015). We define this latter group based on their use of transit to reach essential destinations (rather than defining them based on a lack of options), referring to them as "essential transit riders." This terminology grew in use throughout the pandemic (King County Metro, 2020; Transit App and APTA, 2020), reflecting some agencies' understanding of essential transit demand being broader and more inclusive than just the travel of essential workers. While essential transit riders can include people who lack other options, for example, those who cannot obtain a license (e.g., youth, older adults, people with disabilities, and recent immigrants) or those for whom owning a car is prohibitively expensive, it can also include riders who are less constrained but whose lives are structured around transit. These riders may have chosen their residential and workplace locations with transit in mind, forgone vehicle ownership, or experienced short-term barriers to switching to other modes. In sum, these are the people for whom transit is essential in some way. As transit service has declined during the pandemic, it is likely that these essential transit riders have suffered greater burdens than those with alternative travel options.

To better understand the effects of the pandemic on different types of riders, we conducted a survey of U.S. public transit users in fall 2020 ($n = 500$). Riders were recruited using multiple methods, with most responses coming from social media ads and posts. Our sample captures several key dimensions of U. S. transit riders, providing insights into differences in pandemic-related transit impacts on different types of riders. We examine the impacts of the pandemic on different groups by assessing respondents' self-reported changes in transit use during the pandemic, reasons for reducing transit use, and difficulty reaching essential destinations for those who reduced their transit use.

We find that the ways that different transit riders experience access to destinations and adapt to adverse circumstances vary with individual circumstances and identities. The findings of this study characterize the impact of Covid-19 on essential transit riders and riders with different ethnic, socioeconomic status, and gender identities, pointing to policy recommendations that can strengthen transit service as we recover from the pandemic.

2. Literature review

Transportation systems provide essential links between people and the opportunities they value. This connection is captured in the concept of accessibility—or the ease with which destinations can be reached (Handy, 2020; Levine et al., 2019; Martens, 2012; Martens et al., 2012). Prior work has demonstrated that accessibility is not equitably distributed across population groups or space (Allen and Farber, 2019; Grengs, 2015; Karner, 2018). Instead, one's level of access is determined by mode availability, transportation infrastructure conditions, land use, modal levels of service, and socioeconomic conditions like income and age (Cochran, 2020; Kwan, 2013; Shamshiripour et al., 2020).

Movements for transportation equity, transportation justice, and mobility justice in principle seek similar goals—ensuring that transportation systems enable access to opportunities for vulnerable groups—but they differ in their conceptual roots, their characterization of the causes of inequities, and in their proposed remedies (Karner et al., 2020; Sheller, 2018; Verlinghieri and Schwanen, 2020). For example, public agencies often use transportation equity framings and are motivated to act by legal requirements or guidelines that call for quantitative analysis of plan and project impacts (Karner and Levine, in press; Karner and Niemeier, 2013). On the other hand, activists and advocates more often use transportation and mobility justice frameworks to argue for more radical changes in decision-making priorities and funding allocations (Verlinghieri, 2019).

Mobility justice perspectives that stem from both humanities scholarship and the experiences of Black, Indigenous, and people of color (BIPOC) transportation professionals require examining a much broader and multi-scalar set of considerations to achieve justice (Sheller, 2018; Untokening Collective, 2017). These include elevating the lived experiences of BIPOC communities and individuals rather than defining populations based on what they lack, challenging historical and ongoing systemic racism that reinforces and perpetuates inequities, centering the perspectives of people of color in decision-making, and looking globally at the forces perpetuating automobile dependence, such as the fossil fuel industry. When applied to accessibility, a mobility justice-informed emphasis on travelers' identities points to shortcomings in traditional notions of access to opportunities that have focused on transportation and land use systems and infrastructure rather than people and their unique and varied lived experiences. Alongside the impact of built environment factors such as land use, accessibility is affected by many social factors that are not commonly studied, including perceived and actual safety, the presence of law enforcement, immigration status, gender presentation, race/ethnicity, and disability status (e.g., Church and Marston, 2003; Loukaitou-Sideris, 2014; Lubitow et al., 2017, 2020). The focus on lived experience acknowledges the differences in transportation patterns between groups. For instance, gender socialization and inequities have well-established effects on travel patterns, with women taking on a greater share of household-serving trips, including those related to child care (Taylor et al., 2015). These patterns are additionally shaped by overlapping identities like class and ethnicity (Gilow, 2020; Matsuo, 2020). These differences mean that access is experienced differently based on individual and social characteristics.

It is clear from each of these distinct but related frameworks that disparities in transportation access are deeply problematic. Indeed, the confluence of poor transportation resources and low access can lead to transportation-related social exclusion in which individual activity participation is curtailed and it becomes difficult to engage in the activities needed to lead a meaningful life, leading to impacts on health and quality of life (Duvarci et al., 2015; Lucas, 2012; Ryvicker et al., 2020). Those relying on public transit for most or all trips are at particular risk in the U.S. since transit service is often infrequent and inconvenient.

The Covid-19 pandemic has undoubtedly put these riders at a heightened risk of injustice and exclusion by placing public transit agencies in a precarious funding position (Tirachini and Cats, 2020). In the aftermath of the lockdowns that began in March 2020, public transit ridership and fare revenues declined precipitously (Hu and Chen, 2021; Liu et al., 2020). Transit agencies had to allocate resources to enhance cleaning protocols and many suspended fare collections to minimize interactions between riders and operators (Tirachini and Cats, 2020). Because of the nature of public transit— with passengers sharing space in close proximity—ridership has not recovered. A year after pandemic lockdowns began, transit ridership returned to just 50% of pre-pandemic levels (Transit App and APTA, 2020) even as vehicle travel fully recovered (BTS, n.d.).

Returning service and ridership to pre-pandemic levels and safeguarding essential transit service will require overcoming structural fiscal shortcomings and investments at multiple levels. Historically, transit agencies have prioritized investments in more expensive rail service that serves wealthier White choice riders commuting to job centers at the expense of bus service that provides a lifeline for vulnerable riders (Taylor and Morris, 2015). This imbalance in transit funding priorities can be attributed to misaligned incentives rooted in the need to obtain significant levels of subsidy on top of fare revenue, which often covers only a small share of transit operating and capital expenses (Taylor and Morris, 2015). Federal funding generally supports large capital improvements like rail infrastructure. These investments have historically been justified using optimistic ridership projections that fail to materialize (Voulgaris, 2020). They then require operation and maintenance funding, which may come at the expense of bus service. Intra-regional competition for these funds often means that low-income communities with lower civic or advocacy capacity are less likely to receive funding (Lowe et al., 2016). The mechanisms of federal funding and regional transportation planning through metropolitan planning organizations (MPO) have clearly stated equity requirements, but funding decisions at the state and local level can bypass projects with an equity focus or introduce regressive funding mechanisms that lessen the positive impacts (Lowe, 2014; Lowe and Hall, 2019).

In the context of the pandemic, differences in riders' mobility options have taken on heightened importance, as some riders have avoided transit by telecommuting or using other travel modes (Salon et al., 2021), while others remain on transit despite perceived risks or experience hardship when they reduce their transit use. Moving forward, transit agencies are faced with the short-term challenge of providing adequate service in the face of pandemic-related risk management, reduced fare revenues, and labor disruptions, as well as the long-term challenge of anticipating when and where ridership will return. At the same time, these agencies must now determine how to spend a recent influx of infrastructure funds in ways that will affect their systems for years to come (Bliss, 2020). Understanding who has remained on transit and why, as well as the degree of hardship experienced by those who reduced their transit use, can inform the allocation of transit investments so that they can serve those most in need and avoid reinforcing a disproportionate focus on serving "choice" riders.

It is already clear that the mobility challenges presented by Covid-19 fell harder on groups who have already been marginally served by transportation systems, reflecting broader societal disparities (e.g., Adams-Prassl et al., 2020). Lower-income transit riders continue to travel more and travel greater distances on transit compared to other riders (Parker et al., 2021). In multiple studies, seniors and riders with disabilities reported that many agency responses to the pandemic, such as backdoor boarding, made it more difficult to use public transit (Cochran, 2020; Ravensbergen and Newbold, 2020). Among riders avoiding transit in Canada, women, people with disabilities, and those with chronic health problems were more likely to experience difficulty accessing essential destinations (Palm et al., 2021). Digital alternatives to essential travel, such as online grocery shopping and app-based food delivery, did not universally ameliorate these problems. Low-income and Hispanic or Latinx households in Portland, Oregon, were significantly less likely to have food delivered to their homes during the pandemic (Figliozzi and Unnikrishnan, 2021). Evidence from Chicago suggests that lower-income residents saw the greatest increases in spending on groceries, with researchers suggesting that the inability to travel forced many low-income riders to shop at more expensive local stores (Shamshiripour et al., 2020). Additionally, telecommuting ability divided starkly along class lines, with white-collar workers being significantly more likely to telecommute than others (Saad and Jones, 2021).

While previous research has provided an indication of the populations that have remained on transit (Gartsman and Prescott, 2021; Hu and Chen, 2021; Liu et al., 2020), little is known about why travel adaptations to the pandemic have differed among and between different types of riders or about how the pandemic has affected different types of riders' ability to get around. In the Canadian context, immigrants and people with disabilities reported greater difficulties reaching specialized amenities without transit, and women's travel burdens increased due to gendered household travel expectations (Palm et al., 2021). Many older adults and people with disabilities also found it difficult to switch to active travel, as did those needing to chaperone children. However, this study focused only on those who stopped riding transit in response to the pandemic and not those who continued depending on the mode. And although broader surveys have started to document changes in transit usage (Conway et al., 2020; Parker et al., 2021), to date, no surveys have focused on transit riders' lived experiences during Covid-19 in the U.S. context. To understand the equity and justice implications of the pandemic on essential transit riders and riders with different gender, race, and ethnic identities, we conducted a nationwide survey of public transit users during the pandemic. Understanding differences in the effects of the pandemic on different types of transit riders' mobility can inform how we recover from the current pandemic-related funding crisis. These insights also point to the need to protect essential transit service and strengthen transit service financing models in the long term.

3. Data and methods

3.1. Survey design and sampling

During fall 2020, we conducted a nationwide online survey of 500 people who indicated that they used transit at least once per week for part or all of 2020. The survey built on a similar instrument implemented in Toronto and Vancouver, Canada (Palm et al., 2021) and included questions about:

- travel behavior before and during the pandemic, including transit mode, frequency of transit trips, and self-reported changes in transit use;
- individual and household characteristics, including race, ethnicity, vehicle ownership, monthly income, disability, age, driver's license, and residential location;
- attitudes about public transit and Covid-19, including reliance on transit to meet daily travel needs and reasons for reducing transit; and
- self-reported difficulty reaching essential destinations.

The survey was conducted in English and Spanish through Qualtrics, an online survey platform, from 9/17/2020 through 11/20/2020. Respondents were recruited using five methods:

1. Facebook ads,
2. posts to transit-related Facebook groups,
3. posts on transit-related subreddits (Reddit topics),
4. emails to transit advocacy groups, and
5. a link that could be shared by respondents.

We excluded responses that incorrectly selected the answer for either of two filter questions that asked respondents to select a particular response to screen out those who were clicking through without reading the survey prompts. Out of 898 total responses, 500 were usable in this analysis, with over 85% of those recruited through Facebook ads and Reddit. Fig. 1 displays the geographic distribution of survey responses in the United States.

We compare our survey respondents to the population of U.S. transit riders, as estimated using the weighted subsample of 2017 National Household Travel Survey respondents who are over 18 and reported using transit at least once in the past 30 days (Table 1). Overall, our survey is relatively consistent with U.S. transit riders in terms of the characteristics examined, although our sample skews toward transit riders that are young, middle income, White, male, and do not have vehicle access. Because our survey instrument is

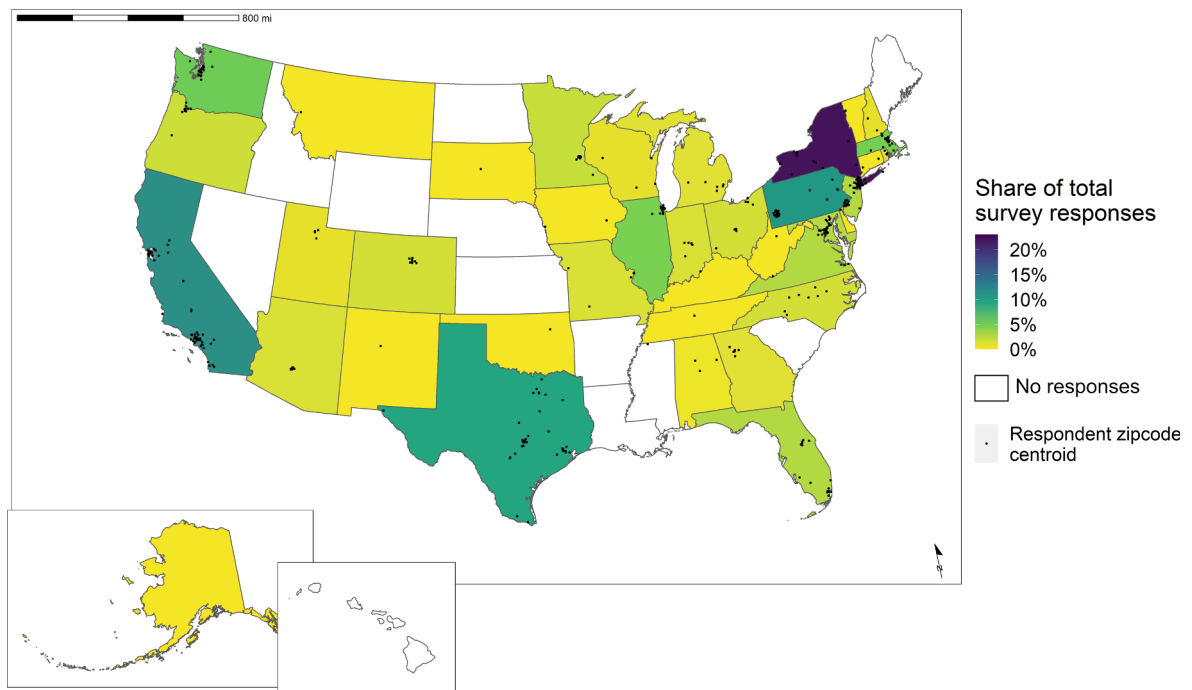


Fig. 1. Locations of survey responses aggregated by zip code.

Table 1
Characteristics of survey respondents and U.S. transit riders.

	Survey respondents	U.S. transit riders
Age (<i>n</i> = people)	494	39,766,841
18–29	39%	25%
30–49	40%	37%
50–69	20%	31%
70+	1%	7%
Annual pre-tax income (<i>n</i> = people)	499	38,771,955
Less than \$14,999	20%	20%
\$15,000 to \$34,999	20%	17%
\$35,000 to \$74,999	31%	20%
\$75,000 to \$124,999	16%	19%
\$125,000 or more	14%	24%
Race and ethnicity (<i>n</i> = people)	500	39,643,219
Non-Hispanic American Indian or Alaska Native	0.2%	0.4%
Non-Hispanic Asian	6%	9%
Non-Hispanic Black	6%	19%
Non-Hispanic other race	3%	1%
Non-Hispanic White	63%	49%
Non-Hispanic multiple races	2%	2%
Hispanic or Latinx	19%	19%
Gender (<i>n</i> = people)	495	36,697,170
Female	40%	52%
Male	56%	48%
Non-binary genderqueer, or other gender identity	3%	–
Vehicle access* (<i>n</i> = people)	496	39,766,841
Owns car	36%	72%
Can borrow a car	21%	
Carshare	6%	3%
No vehicle access	43%	26%
Transit mode* (<i>n</i> = trips)	7,423	25,029,138
Bus	53%	52%
Light rail	34%	34%
Heavy rail	7%	8%
Other	5%	6%

* Survey respondents could select multiple responses to vehicle access and mode questions, so columns sum to more than 100%.

internet-based, it likely overrepresents respondents with internet access at home or on mobile devices and underrepresents transit riders without internet access. Additionally, our relatively small sample limits our ability to make inferences about some populations. In particular, the number of Black, senior, and nonbinary and genderqueer respondents was relatively small, making their evaluation infeasible in portions of the analysis that use a subset of the survey data (those that reduced how much they use transit) and limiting confidence in the robustness of results observed in the portions of the analysis that relied upon the full sample (all respondents). Additional detail about the survey methods and respondent characteristics is included in the [supplementary material](#). Because we are estimating statistical models controlling for these population characteristics, weighting is not necessary to achieve insightful results.

3.2. Research framework and modeling approach

This study evaluates three research questions:

1. How has the Covid-19 pandemic affected transit use among different types of transit riders?
2. For riders who have reduced or stopped transit use, how do their reasons for stopping or reducing transit use differ across different types of riders?
3. For riders who have reduced or stopped transit use, does the difficulty accessing essential destinations posed by reduced transit use vary across different types of riders?

To address the first question, we evaluated both transit use in fall 2020 (number of trips conducted by all modes of public transit last week during the pandemic, including bus, light rail, heavy rail, paratransit, and other modes) and the change in transit use during the Covid-19 pandemic (whether a rider reported reducing or stopping their use of transit as of fall 2020, relative to their transit use just before the pandemic began.) We use a negative binomial model to evaluate the relationship between rider characteristics and fall 2020 transit use. Due to the non-normal distribution of the dependent variable and the magnitude of the mean value, which is smaller than the standard error, a negative binomial model formulation is a better option than Poisson regression. We use logistic models to evaluate the likelihood that different rider types have chosen to reduce or stop transit use given the binary nature of the dependent variable modeled, which is formulated as “reduce or stop transit use” or “no change or increase in transit use.”

We asked riders who reduced or stopped their transit use to rate the importance of each of several factors in their decision to ride

less. We used these responses to evaluate the second research question. Reasons include no longer going to destinations that they would use transit to reach, concerns about the risk of exposure to Covid-19, changes in transit service, the expense of transit trips, relocating during the pandemic, and concerns about experiencing harassment or interacting with police or Immigration and Customs Enforcement (ICE). Responses describing how important each reason was in deciding to reduce or stop transit use included “not important”, “a little important”, “somewhat important”, “very important”, and “not applicable”, which was treated as “not important”.

We examined the third research question using responses to questions that asked the subset of riders who reduced or stopped their transit use to indicate the extent to which those reductions made it harder to reach several essential destinations, including work, groceries, healthcare, prescriptions, caring for family and friends, and taking children to childcare. Possible responses included “not harder at all”, “a little harder”, “somewhat harder”, and “much harder”, with an option to select “not applicable” if it did not apply to the respondent (these responses are excluded).

We evaluated each of the three research questions using relevant individual demographic characteristics (race and ethnicity, physical disability, poverty status and income, income reduction, age, household size, and gender). Respondents were asked to provide their monthly take-home pay before and during the pandemic. These values were converted to annual pre-tax income (as described in [supplementary material](#)) and were then used to derive the income > \$100 K and change in income >10% variables. Poverty status was estimated based on pre-pandemic income and household size using double the poverty threshold level. For the gender category, we included categories for male; female; and non-binary, genderqueer and other gender descriptions. We evaluated mobility characteristics through vehicle access and driver’s license. We also constructed two binary variables for the transit mode(s) most frequently used before the Covid-19 pandemic. Mode options included bus, rail, and other, with “bus” and “rail” being the most prevalent mode that respondents indicated that they used most frequently. We created two binary variables, each representing “bus” and “rail” as the most frequent transit mode used, with ties receiving a 1 for both binary variables such that the “bus” and “rail” variables are not exhaustive or mutually exclusive. For example, a person riding the bus four times per week and rail four times per week was coded as a bus rider and a rail rider, a person riding the bus four times per week and rail twice per week was coded as a bus rider, and a person riding paratransit six times per week was coded as neither a bus rider nor a rail rider. An increase in telecommuting was coded based on the most frequently used mode to get to work before and during the pandemic; if it was not telecommuting before the pandemic and is telecommuting during the pandemic, a respondent was coded as increased telecommute.

We also controlled for zip code-level population density and county-level cumulative number of Covid-19 infection cases. Population density is based on the 2018 American Community Survey 5-year estimates of the number of people living in the respondent’s ZCTA area (U.S. Census Bureau, n.d.). Cumulative infections are based on positive Covid-19 cases reported in the respondent’s county since the beginning of the pandemic (1/22/2020) up to the respondent’s survey response date using infection data from Johns Hopkins University (Dong et al., 2020). Summary statistics for all modeled variables are included in [Table 2](#) and [Table 3](#).

Table 2
Summary of independent variables.

Variable	Data description	Summary of distribution				
		N	Mean	St. dev.	Min	Max
Driver’s license	1 = Have driver’s license (n = 356)	500	0.71	0.45	0	1
Vehicle access	1 = Have a vehicle, or can borrow, or use carshare program (n = 291)	499	0.58	0.49	0	1
Gender presentation	1 = Male (n = 279) 2 = Female (n = 201) 3 = Non-binary, genderqueer, or other gender identity (n = 16)	496	–	–	–	–
Disability	1 = Physical disability that prevents walking (yes or sometimes) (n = 57)	498	0.11	0.32	0	1
Race & ethnicity	1 = Non-Hispanic White (n = 316) 2 = Non-Hispanic Black or African American (n = 29) 3 = Non-Hispanic Asian (n = 31) 4 = Non-Hispanic other races (n = 23) 5 = Hispanic or Latinx (n = 98)	497	–	–	–	–
Poverty status before the pandemic	1 = Below twice poverty threshold (n = 193)	500	0.39	0.49	0	1
Increased telecommute	1 = Commute mode changed to telecommuting during pandemic (n = 139)	492	0.28	0.45	0	1
Income <100 K before the pandemic	1 = Household income below \$100 K before pandemic (n = 403)	500	0.81	0.4	0	1
Income reduction	1 = Household income reduced over 10% during pandemic (n = 144)	500	0.29	0.45	0	1
Children	1 = Household with at least one child (n = 102)	405	0.25	0.43	0	1
One adult	1 = Household with only one adult (n = 154)	483	0.32	0.47	0	1
Age group	1 = 24 years or younger (n = 100) 2 = 25 to 44 years old (n = 260) 3 = 45 to 64 years old (n = 114) 4 = 65 years or older (n = 20)	494	–	–	–	–
Bus user before the pandemic	1 = Bus is the most frequently used transit mode	500	0.67	0.47	0	1
Rail user before the pandemic	1 = Rail is the most frequently used transit mode	500	0.44	0.5	0	1
Population density	Population per square mile in home zip code	487	18,381	24,696	1.1	152,215
Cumulative Covid-19 infections (Log)	Log (infections since pandemic began)	487	14.76	1.46	7.27	17.3

Table 3
Summary of dependent variables.

Variable	Data description	Summary of distribution				
		N	Mean	St. dev.	Min	Max
Transit use during the pandemic	Number of weekly transit trips in fall 2020	500	7.19	10.51	0	96
Reduced transit use during the pandemic	1 = Reduced or stopped transit use as of fall 2020 (n = 355)	500	0.71	0.45	0	1
Reasons for stopping or reducing transit use during the pandemic		N	Not important/ not applicable	A little important	Somewhat important	Very important
	No longer going to places that I would use transit to reach	327	59	54	99	115
	Concern about exposure to Covid-19	354	25	46	87	196
	Moved and transit is not convenient at my new location	354	288	13	29	24
	Transit service changed and is no longer convenient	353	184	63	73	33
	Can't afford to use transit as much as I used to	354	286	26	21	21
	Concern about harassment or being physically hurt	355	216	64	38	37
	Concern about interacting with police	354	257	49	27	21
	Concern about interacting with ICE	355	216	64	38	37
Effect of transit reductions on ability to reach essential destinations during the pandemic		N	Not harder at all	A little harder	Somewhat harder	Much harder
	Getting to work	271	160	52	37	22
	Getting groceries	316	211	54	28	23
	Accessing healthcare	316	203	44	44	25
	Getting prescriptions	300	229	42	15	14
	Taking care of family/friends	255	177	28	26	24
	Taking kids to childcare	128	111	8	3	6

We conducted Wilcoxon-Mann-Whitney tests to evaluate the statistical significance of differences between different types of transit riders who reduced their transit use in terms of their reasons for reducing their transit use and their ability to reach different types of essential destinations: work, grocery, health care, pharmacy, care for family, and childcare.

4. Results and discussion

4.1. Research question 1: How has the Covid-19 pandemic affected transit use among different types of transit riders?

We first evaluate how the Covid-19 pandemic has affected transit use among different types of transit riders. Results from the negative binomial model of trips taken last week during the pandemic are summarized in Table 4. Higher trip counts are associated with transit riders who do not have access to a vehicle, riders who experience permanent or temporary disability, people living under double the poverty threshold, people in households that lost income during the pandemic, people with only one adult in their household, and people who report bus and rail as their most frequent modes of transit before the pandemic. Female riders are associated with significantly fewer transit trips. We also find that people who have access to a vehicle were more likely to reduce or stop using transit, while people living under double the poverty threshold were less likely to reduce or stop using transit (Table 5). These findings are consistent with prior findings about essential riders' behavior pre-dating the pandemic. In short, reducing or ceasing public transit use was not a viable or desirable option for all riders.

4.2. Research question 2: For riders who have reduced or stopped transit use, how do their reasons for stopping or reducing transit use differ across different types of riders?

Next, we examine differences in the reasons cited by riders who reduced or stopped using transit (Table 6). We examine differences along dimensions that we have a theoretical reason to believe may differ. For example, we evaluate respondents' reports of the importance of the expense of using transit when deciding to leave transit, in terms of differences exhibited by those whose income was reduced (versus those whose income was unchanged) and those living below twice the poverty level (versus those living above twice the poverty level), but we do not evaluate differences in this reason for transit riders of different ages or gender identities. Table 6

Table 4

Negative binomial model of transit use during the pandemic (the number of transit trips taken last week in fall 2020).

Dependent Variable: Transit use during the pandemic (trips/week)	Coef.	Robust St. Err.	p-value ¹
Vehicle access (1)	-0.95	0.13	<0.01
Gender (reference Male)			
Female	-0.58	0.15	<0.01
Non-binary, genderqueer, or other gender identity	-0.30	0.34	0.17
Disability (1)	0.50	0.20	0.01
Race & ethnicity (reference Non-Hispanic White)			
Non-Hispanic Black or African American	0.33	0.22	0.13
Non-Hispanic Asian	0.08	0.33	0.82
Non-Hispanic other races	-0.10	0.22	0.65
Hispanic or Latinx	0.04	0.21	0.85
Poverty status (1)	0.35	0.17	0.05
Income < \$100 K before pandemic (1)	-0.15	0.20	0.48
Income Reduction (1)	0.39	0.15	0.01
Children (1)	0.29	0.19	0.12
One adult (1)	0.32	0.16	0.04
Age (reference < 25 yrs)			
25–44 years old (2)	-0.00005	0.16	1.00
45–64 years old (3)	0.17	0.21	0.42
65 years and older (4)	-0.23	0.34	0.49
Transit mode used most often			
Bus (1)	0.74	0.20	<0.01
Rail (1)	0.51	0.20	<0.01
Population density (Log)	0.04	0.06	0.56
Cumulative Covid-19 infections (Log)	0.11	0.07	0.11
Constant	-0.61	0.83	0.46
/lnalpha	0.54	1.00	
alpha	1.71	0.63	

Number of Observations = 395; Wald Chi2 (20) = 112.01.

Prob > Chi2 = 0.000; Log pseudolikelihood = -1067.80; Pseudo R2 = 0.04.

1. **Bold** font indicates variables with statistically significant effects at the 95% level.**Table 5**

Logistic model of reduction in public transit use during the Covid-19 pandemic.

Dependent Variable: <i>Reduced transit use-1, Otherwise -0</i>	Odds Ratio	Robust St. Err.	p-value ¹
Vehicle access (1)	2.84	0.76	<0.01
Gender (reference Male)			
Female	1.10	0.29	0.73
Non-binary, genderqueer, or other gender identity	0.67	0.38	0.48
Disability	0.56	0.21	0.12
Race & Ethnicity (reference Non-Hispanic White)			
Non-Hispanic Black or African American	0.40	0.20	0.06
Non-Hispanic Asian	2.11	1.34	0.24
Non-Hispanic other races	2.24	1.47	0.22
Hispanic or Latinx	1.14	0.43	0.73
Poverty status (1)	0.54	0.16	0.04
Income < \$100 K before pandemic (1)	1.06	0.40	0.87
Income reduction (1)	1.12	0.30	0.68
Children (1)	0.99	0.32	0.96
Household with one adult (1)	0.93	0.26	0.80
Age (reference < 25 yrs)			
25–44 years old (2)	1.11	0.37	0.74
45–64 years old (3)	0.77	0.29	0.49
65 years and older (4)	1.08	0.74	0.91
Transit mode used most often			
Bus (1)	0.75	0.28	0.43
Rail (1)	0.77	0.28	0.48
Population density	1.20	0.13	0.09
Cumulative Covid-19 Infection (Log)	0.92	0.10	0.43
Constant	1.88	2.94	0.69

Number of Observation = 395; Wald Chi2(20) = 40.79;

Prob > Chi2 = 0.000; Log Pseudolikelihood = -207.28; Pseudo R2 = 0.109.

1. **Bold** font indicates variables with statistically significant effects at the 95% level.

Table 6

Wilcoxon-Mann-Whitney test for group comparisons of the reasons for reducing transit use (for those who reduced or stopped using transit).

Reason for stopping transit use	Individual characteristic with a posited relationship		Sample size	% reporting reason ¹	z score ² (p value)
Harassment concern	Ethnicity	Hispanic or Latinx (1)	67	56.7%	-4.77
		Non-Hispanic	229	20.0%	(<0.01)
	Gender	Female and other gender identities (1)	149	48.3%	-3.41
Police concern	Ethnicity	Male	203	31.5%	(<0.01)
		Hispanic or Latinx (1)	66	45.5%	-4.52
	Non-Hispanic	229	20.0%	(<0.01)	
ICE concern	Ethnicity	Hispanic or Latinx (1)	66	27.3%	-5.68
Move	Income (before the pandemic)	Non-Hispanic	228	4.5%	(<0.01)
		Household income below \$100 K (1)	275	18.9%	-0.251
	Income change (during the pandemic)	Household income at least \$100 K	79	18.7%	(0.802)
Expense	Income change (during the pandemic)	Income reduced by more than 10% (1)	105	27.6%	-2.89
		Income not reduced by more than 10%	249	14.9%	(<0.01)
	Poverty status (before the pandemic)	Income below 2x poverty threshold (1)	113	34.9%	-4.13
No longer going to destination	Telecommute change	Income above 2x poverty threshold	241	13.3%	(<0.01)
		Telecommute increased (1)	128	88.3%	-3.75
	Telecommute not increased	195	78.5%	(<0.01)	
Covid-19 concern	Age	65 years old or above (1)	13	69.2%	0.46
		Younger than 65 years old	337	93.8%	(0.645)
Change of service	Driver license	People with a driver's license (1)	270	44.4%	2.91
		People without a driver's license	83	59.0%	(<0.01)
	Vehicle access	Have vehicle access (have, borrow, or carshare) (1)	230	48.3%	0.91
		Do not have vehicle access	123	47.2%	(0.11)

1. The Wilcoxon-Mann-Whitney test evaluates the distribution of the ordered “reason” responses to determine which group is more likely to report higher values. For ease of illustrating differences, responses are summarized here as either reporting the reason (“a little important”, “somewhat important”, or “very important”) or not reporting the reason (“not important”, or “not applicable”).

2. **Bold font** indicates test statistics and p values that are significant at the 95% level.

includes results from Wilcoxon-Mann-Whitney tests, which evaluate the between-group differences in the distribution of the reported importance of each reason for reducing or stopping transit use, while accounting for the order of responses. Z-scores indicate the difference in the reported importance of each reason between the groups compared, and the p-value shows the level of significance for each result. A positive z-score indicates that the group listed first was less likely to report that a reason was more important when compared with the group listed second, while a negative score indicates that the group listed first was more likely to report that a reason was more important when compared with the group listed second. For example, in the evaluation of the “change of service” reason, those with a driver’s license less frequently reported that this reason was more important in deciding to leave transit when compared with those without a license. On the other hand, in the evaluation of the “expense” of transit as a reason, those with income reduced more often cited the reason as of greater importance when compared with the reference group (income not reduced).

We expect that higher income may indicate the ability to relocate during a pandemic when people may wish to leave crowded cities while travel to work and school is limited. At the same time, a reduction in income may increase the likelihood of a move due to necessity for those seeking less expensive housing. Hispanic and Latinx people may be more likely to encounter difficulty relocating due to housing discrimination or (for a subset) immigration status, both of which may limit housing options. We find that, as expected, people who have lost income during the pandemic were more likely to indicate that they reduced or stopped transit use because they moved during the pandemic. Counter to our hypothesis, Hispanic and Latinx riders were more likely to cite a move as a reason for reducing transit use. This may reflect a correlation with income reduction, a change in school or employment, or other factors that result in a change in home location.

We also expect that those with fewer non-transit transportation options are less likely to stop riding transit due to changes in transit service. However, we find that riders without a driver’s license were more likely than those with a license to cite the change of service as a reason for reducing or stopping transit use. This may relate to the timing or location of service changes. For example, if service cuts primarily occurred during off-peak hours or in areas that are not job centers, those with other transportation options might be less affected by service cuts if they only use transit for a 9-to-5 commute to a job center.

Concerns about harassment and interactions with police and ICE may be greater during the pandemic in areas where reduced ridership means that transit vehicles are less crowded, leading to greater feelings of isolation and vulnerability for those remaining. The pandemic also coincided with a growth in racial and ethnic tension manifesting as anti-Asian sentiment centered on the pandemic’s origins, anti-immigrant rhetoric in the months leading up to the 2020 Presidential election, and growing concerns about the treatment of people of color by law enforcement spurred on by the murders of George Floyd, Breonna Taylor, and many other Black people in the U.S. As expected, we find that Hispanic or Latinx riders are more likely to cite concerns about interactions with police and U.S. Immigration and Customs Enforcement (ICE). Additionally, Hispanic or Latinx riders, female riders, and nonbinary and

genderqueer riders are more likely to cite concerns about harassment.

Not surprisingly, riders who lost income during the pandemic and with an income below double the poverty threshold are more likely to report reducing or stopping transit use because of the expense. The effects of costs and transit service changes on riders who have lost income during the pandemic are of particular concern, as the ability to reach jobs and other destinations is a critical foundation for personal economic recovery.

When evaluating the role of concern about exposure to Covid-19 as a reason for reducing transit use, we do not observe a significant difference between senior riders (65 years old or older) and younger riders, however our sample size for senior transit riders is relatively small. A study in Canada indicated that seniors were not more likely than young riders to leave transit (Palm et al., 2021), which may reflect the sampling frame of regular transit users. While seniors may be less likely to ride transit among the general population and may have had elevated concern about the pandemic, seniors who rode transit regularly before Covid-19 may depend on the service more than working-age people using transit to commute and so may be less likely to leave transit in general.

Unsurprisingly, we find that transit riders who reported an increase in how much they telecommute were more likely to cite no longer going to their destination as a reason for reducing or stopping transit use. In addition to our findings of differences in the ability to shift modes (e.g., to driving) or to relocate, the ability to adapt to the pandemic by meeting one's needs virtually represents a growing source of differential mobility that has come into focus during the pandemic.

Together, these results demonstrate dramatically different effects of the Covid-19 pandemic on the travel behavior of different groups of riders, as well as differences in transit riders' ability to adapt to the pandemic. Some of these echo extant findings in the literature, like the differential experiences of harassment and threat faced by women and people of color while traveling in public spaces (Loukaitou-Sideris, 2014; Lubitow et al., 2019). But others are more novel, including the effects of service changes on different groups. In addition to disparities in the baseline levels of service and accessibility afforded to different groups, the results reported here suggest that public transit service cuts implemented as a necessity by fiscally constrained agencies may have had an outsized effect on travel behavior for those who lack a driver's license. There is overlap between the reasons for transit reductions, but given sample size constraints, it is not possible to account for them simultaneously in a multivariate modeling framework.

4.3. Research Question 3: For riders who have reduced or stopped transit use, does the difficulty accessing essential destinations posed by reduced transit use vary across different types of riders?

We also evaluate the effects of pandemic-related transit use reductions on riders' ability to reach important destinations. Among riders using transit less or not at all during the pandemic, we again find differential impacts. In Table 7, we evaluate differences in the reported difficulty accessing essential destinations (including work, grocery, health care, pharmacy, family care, and childcare) exhibited by populations that rely on transit or are thought to be vulnerable in one or more dimensions and for which we have a sufficient sample. The Wilcoxon-Mann-Whitney tests provide insight on how the difficulty accessing destinations differs between groups. Similar to above, z scores indicate the difference in reported difficulty accessing each destination due to the reduction of transit use between the groups compared, and the p-value shows the level of significance for each result. A positive z score indicates that the group listed first reported less difficulty in accessing the destination than the reference group, while a negative z score indicates that the group listed first reported greater difficulty in accessing the destination than the reference group.

Notably, Hispanic or Latinx riders, riders who live under double poverty threshold before the pandemic, and riders without a driver's license were more likely to report greater difficulty in accessing all destinations examined, including work, grocery, healthcare, pharmacy, childcare and caring for family, when compared with their counterparts.

All other groups evaluated reported significant differences in the difficulty accessing at least four of six destination types when compared with their counterparts. People with a physical disability were more likely to report greater difficulty accessing grocery, healthcare, pharmacy, and family care destinations, while people who have lost income during the pandemic were more likely to report greater difficulty accessing work, grocery, healthcare, and pharmacy destinations. Transit riders without vehicle access reported significantly greater difficulty accessing grocery, healthcare, pharmacy, family care, and child care destinations. On the other hand, those who were able to increase how much they telecommute reported less difficulty accessing jobs, grocery, healthcare, pharmacy, and childcare.

Female, nonbinary and genderqueer riders were more likely to report greater difficulty accessing grocery, healthcare, pharmacy, and child care destinations when compared with male riders. This finding corresponds to inequities in labor distributions between gender groups and their manifestation in travel patterns (Taylor et al., 2015), which has been exacerbated by pandemic-related school and daycare closures in many regions and the "work from home era" during the Covid-19 pandemic.

For many transit riders, the impact of ceasing or reducing public transit use is not benign. As one respondent without access to a car put it in response to an open-ended survey prompt, "transit is my lifeline to appointments and getting around." Many of our survey respondents also described how a loss of transit service in their neighborhood would affect them in an open-ended survey prompt. Some riders without alternatives indicated that the effects would be catastrophic ("I would be 100% trapped..."), noting that it would be difficult or impossible to get to work and other important destinations such as health care or groceries. Some essential riders mentioned challenges associated with alternatives to transit, including long walking distances, spending money on rides, or obtaining rides from others. For many of these riders, the connections provided by transit are critical for meeting their day-to-day needs. These results reinforce the impacts of Covid-19's broad economic and transportation-specific impacts on essential public transit users.

Table 7

Wilcoxon-Mann-Whitney test for group comparison of the effect of transit reductions on the ability to reach essential destinations during the Covid-19 pandemic (for those who reduced or stopped using transit).

Groups		Work			Grocery			Healthcare			Pharmacy			Family care			Child care		
		N	% harder	z score (p-value)	N	% harder	z score (p-value)	N	% harder	z score (p-value)	N	% harder	z score (p-value)	N	% harder	z score (p-value)	N	% harder	z score (p-value)
Ethnicity	Hispanic or Latinx (1)	53	50.9%	-2.50 (0.013)	59	49.2%	-3.96	59	53.5%	-4.04	58	43.1%	-4.76	51	41.2%	-2.10	31	32.3%	-3.60
	Non-Hispanic	177	38.4%		208	26.9%	(<0.01)	207	28.5%	(<0.01)	196	15.3%	(<0.01)	168	25.6%	(0.036)	80	0.06%	(<0.01)
Gender	Female, nonbinary, or genderqueer (1)	109	45.8%	-1.54 (0.123)	131	40.5%	-2.82	132	49.2%	-4.44	127	31.5%	-2.72	98	34.7%	-1.36	48	22.9%	-2.58
	Male	160	37.5%		182	28%	(<0.01)	181	26.0%	(<0.01)	170	17.6%	(<0.01)	155	27.7%	(0.175)	78	6.4%	(<0.01)
Disability	People with a disability (1)	17	47.1%	-0.47 (0.63)	27	51.9%	-2.27	29	63.1%	-3.73	29	58.6%	-4.77	23	52.2%	-2.59	10	30%	-1.75
	People without a disability	253	40.3%		288	31.3%	(0.023)	286	32.9%	(<0.01)	270	19.6%	(<0.01)	231	28.1%	(<0.01)	117	11.1%	(0.081)
Poverty (before pandemic)	< 2*poverty threshold (1)	75	53.3%	-2.82 (<0.01)	99	42.4%	-2.80	100	48%	-3.33	97	35.1%	-3.49	84	41.7%	-3.20	42	26.2%	-3.09
	≥ 2*poverty threshold	196	36.2%		217	29.0%	(<0.01)	216	30.1%	(<0.01)	203	18.2%	(<0.01)	171	25.1%	(<0.01)	86	7.0%	(<0.01)
Income change (during pandemic)	Income reduced (1)	79	54.4%	-2.99 (<0.01)	101	47.5%	-3.65	95	47.4%	-3.11	91	38.5%	-4.12	78	37.2%	-1.39	39	20.5%	-1.63
	Income not reduced	192	35.4%	4.82 (<0.01)	215	26.5%	(<0.01)	221	30.8%	(<0.01)	209	17.2%	(<0.01)	177	27.7%	(0.164)	89	10.1%	(0.103)
Tele-commute	Telecommute increased (1)	106	22.6%	1.12 (0.262)	118	19.5%	3.99	119	29.4%	2.25	116	13.8%	3.27	94	24.5%	1.55	46	4.3%	2.29
	Telecommute not increased	165	52.7%		196	41.4%	(<0.01)	194	39.7%	(0.025)	181	29.8%	(<0.01)	160	34.4%	(0.122)	82	18.3%	(0.022)
Car access	With car access (1)	187	39.6%	1.12 (0.262)	208	24.5%	4.32	211	28.0%	4.26	201	17.9%	3.46	179	26.3%	2.59	87	9.2%	2.11
	Without car access	84	44.0%		108	48.1%	(<0.01)	105	51.4%	(<0.01)	99	35.4%	(<0.01)	76	43.0%	(<0.01)	41	22.0%	(0.035)
Driver's license	With license (1)	215	35.8%	3.86 (<0.01)	242	25.3%	5.77	243	28.0%	5.69	228	16.7%	5.31	198	26.3%	3.15	101	9.9%	2.31
	Without license	56	60.7%		74	59.5%	(<0.01)	73	61.6%	(<0.01)	72	45.8%	(<0.01)	57	45.6%	(<0.01)	27	25.9%	(0.021)

1. The Wilcoxon-Mann-Whitney test evaluates the distribution of the ordered “harder” responses to determine which group is more likely to report higher values. For ease of illustrating differences, responses are summarized here as either reporting that it is harder to reach the destination (“much harder”, “somewhat harder”, or “a little harder”) or not harder (“not harder at all”).

2. **Bold font** indicates test statistics that are significant at the 95% level.

4.4. Implications for transit funding

Our results indicate that transit riders with fewer resources (below twice the poverty threshold, lost income during the pandemic), limited transportation options (without a driver's license, without vehicle access, have not increased their telecommuting, have a physical disability that prevents walking), Hispanic or Latinx people, female, nonbinary and genderqueer people reported greater hardship when they reduce their transit use. Our finding that cuts in transit service were a factor in the decision to reduce transit use is also of concern considering pandemic-era revenue shortfalls and service cuts. For many riders, the connections to jobs, social services, and other critical destinations afforded by transit are critical for recovering from pandemic-era economic hardship.

As of mid-2021, the U.S. Congress has responded (and continues to respond) to this fiscal crisis with influxes of recovery funding. Our results point to the importance of strengthening public transit connections to neighborhoods with vulnerable riders to ensure that burdens on these riders are minimized in the aftermath of Covid-19. Strengthening bus services, which provide access to a range of destination and trip types and disproportionately serve low-income, Black, and Hispanic or Latinx riders, is also a promising investment strategy (Higashide, 2019).

However, short-term funding injections and service changes do not address long-term underinvestment in transit that serves essential transit riders. The pandemic has exacerbated a wide array of pre-existing societal challenges, and the current public transit funding crisis is no different. Pandemic-related revenue declines and subsequent service cuts add to decades of chronic underinvestment in essential transit services that have been brought on by shortcomings in transit financing mechanisms. There are notable alternative transit funding models that are designed to support the needs of vulnerable riders. Federal subsidies for elderly, disabled, and rural transit operations provide lifeline services for these populations despite the high cost of doing so. And Congress's transit rescue packages have supported operating costs, which allows for a greater share of funds to reach bus riders than capital-heavy funding programs. In fact, when faced with tough choices about service cuts since the onset of the pandemic, many transit agencies have prioritized transit service routes and modes that serve vulnerable riders (Vock, 2020).

5. Conclusion

The ways that different transit riders experience access to destinations and adapt to adverse circumstances vary across situational contexts and individual resources, needs, and identities. We find that transit riders who lack access to a vehicle and who live below twice poverty threshold were less likely to reduce their use of transit during the pandemic. Riders who reported higher transit use include those without access to a vehicle, people with a disability, those who live under twice the poverty threshold, those who lost income during the pandemic, those who live in households with only one adult, and those more frequently using bus or rail. At the same time, female riders were less likely to use transit during the pandemic.

For those who reduced or stopped using public transit, the reasons for reductions vary across different types of riders. For example, Hispanic or Latinx riders were more likely to state that they reduced their transit use due to concerns about interactions with law enforcement relative to their non-Hispanic counterparts, while those who lost income and those with a limited income were more likely to cite the expense of transit relative to their counterparts. Riders who increased how much they telecommute were more likely to cite no longer going to their destination. Notably, of those who reduced their transit use, three groups of riders experienced greater difficulty in accessing all essential destinations examined in this study (work, groceries, healthcare, pharmacy, family care, and childcare): Hispanic or Latinx riders, riders who lived under double poverty threshold before the Covid-19 pandemic, and riders that do not have a driver's license. Furthermore, all five other groups of riders evaluated (female and nonbinary genders, people with a disability, those whose income was reduced during the pandemic, those that do not have access to a vehicle, and those that did not increase how much they telecommute) indicated greater difficulty accessing at least four of the six essential destinations evaluated.

One notable finding is that service cuts may be causing reductions in transit use among many transit riders (and particularly for those who lack a driver's license), which is particularly concerning considering the pandemic-era transit funding crisis and the impacts of reduced transit use on transit riders' day-to-day lives. The pandemic provides an opportunity to revisit the way that we plan transit in the long run so that we can strengthen service for those that need it most. For example, with high telecommuting rates likely to remain, agencies may need to reconsider service designed for traditional peak-period commuters. Strengthening bus service and providing all-day connectivity to many different destination types is likely to be critical for the success of future transit. Rethinking longstanding models of transit service delivery will be necessary as agencies program an influx of infrastructure funding during the pandemic recovery. In addition to raw levels of service, our results also demonstrate how important individual perceptions are for encouraging users to return to public transit. Creating rider environments that are free from harassment or the threat of law enforcement are ongoing challenges with no simple solutions. Experimentation with policies aimed at encouraging riders to return as well as outreach to affected communities and research on policy effectiveness will be helpful for agencies as the pandemic eases.

Overall, our survey results highlight differences in how the pandemic has affected different types of transit riders, many of whom have reduced their transit use despite their continued need to travel and their reliance on transit to reach essential destinations. The pandemic has highlighted how transit riders from different backgrounds adapt to major disruptions as well as disparities in the impacts they experience. It also highlights how existing revenue models can put riders' access to essential destinations in jeopardy during a crisis.

Credit Authorship Contribution Statement

Qian He: Conceptualization, Data curation, Methodology, Formal analysis, Software, Validation, Writing – original draft. **Dana Rowangould:** Project administration, Supervision, Conceptualization, Methodology, Resources, Validation, Writing – original draft. **Alex Karner:** Funding acquisition, Investigation, Supervision, Conceptualization, Methodology, Resources, Validation, Writing – original draft. **Matthew Palm:** Conceptualization, Methodology, Resources, Validation, Writing – original draft. **Seth LaRue:** Data curation, Software, Validation, Writing – original draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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