Facing the future of transit ridership: which riders bought a car; who is planning on riding less?

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1 **ABSTRACT**

2 Public transit agencies face a transformed landscape of rider demand and political support as the
3 COVID-19 pandemic continues. We explore people’s motivations for returning to or avoiding
4 public transit a year into the pandemic. We draw on a March 2021 follow up survey of over
5 1,900 people who rode transit regularly prior to the COVID-19 pandemic in Toronto and
6 Vancouver, Canada, and who took part in a prior survey on the topic in May, 2020. We model
7 how transit demand has changed due to the pandemic, and investigate how this relates to changes
8 in automobile ownership and its desirability. We find that pre-COVID frequent transit users
9 between the ages of 18-29, a part of the so-called “Gen Z,” and recent immigrants are more
10 attracted to driving due to the pandemic, with the latter group more likely to have actually
11 purchased a vehicle. Getting COVID-19 or living with someone who did is also a strong and
12 positive predictor of buying a car and anticipating less transit use after the pandemic. Our results
13 suggest that COVID-19 heightened the attractiveness of auto ownership among transit riders
14 likely to eventually purchase cars anyways (immigrants, twentysomethings), at least in the North
15 American context. We also conclude that getting COVID-19 or living with someone who did is
16 a significant and positive predictor of having bought a car. Future research should consider how
17 the experiencing of having COVID-19 has transformed some travelers’ views, values, and
18 behaviour.

19 *Keywords: Public Transit, COVID-19, Generation Z, immigrants, vehicle ownership,*
20 *transportation*

1 INTRODUCTION

2 After decades of attempting to attract higher income, car owning ‘choice riders’ (1) and
3 millennials (2), North American transit agencies are serving a decimated ridership of mostly
4 transit-dependent travelers due to COVID-19. The popularity of telecommuting and suppressed
5 discretionary trip-making signal long term difficulties for transit agencies seeking to attract
6 former riders (3, 4). This presents a major crisis for transit agencies in countries like Canada,
7 where over half of operating costs are traditionally covered by fares (5), leading advocates to call
8 for new means of transit finance to minimize service loss if ridership does not recover (6).
9 Changes in transit riders’ and lapsed riders’ changing views of transit and alternative modes are
10 thus important for decisionmakers to understand.

11 We report on a follow up survey of over 1,900 people who rode transit regularly prior to the
12 COVID-19 pandemic in Toronto and Vancouver, Canada. The original survey took place in
13 May 2020 (7–9), and the follow up occurred in March 2021. We asked these riders five main
14 questions: 1) whether they returned to transit in the intervening period; 2) how often they ride
15 transit now; 3) how the pandemic has changed their views on vehicle ownership; 4) whether they
16 bought a car; 5) and whether they anticipate riding public transit less after the pandemic
17 compared to before.

18 We add to a rapidly growing literature on the effects of the COVID-19 pandemic on public
19 transportation (10–12). First, it allows us to follow up on a survey conducted in the early stage of
20 the pandemic and observe how travel behaviors and attitudes have changed over a ten month
21 period (7–9, 13). Second, it allows us to compare differences between socio-demographic groups
22 on how they have continued to adapt to the crisis, and how they envision traveling in a post-
23 pandemic future. Unlike broader surveys (3, 4), we focus exclusively on formerly regular transit
24 users and their shifting attitudes about transit and vehicle ownership, as a switch to vehicle
25 ownership could have negative implications for sustainability (14).

26 The article is structured as follows. Section 2 provides a brief literature review on the
27 intersection between transport disadvantage, mode choice, and the COVID-19 pandemic. Section
28 3 details the data and methods used for the analysis. Section 4 presents findings. Section 5
29 provides the main conclusions around the choice-dependence dichotomy in the pandemic context
30 and future work to deepen our understandings based on our early findings.

31 LITERATURE

32 The earliest research on public transit and COVID-19 emphasized disparities in who needed to
33 continue using the mode despite possible health risks. The first wave of transit rider surveys and
34 stop-level analyses of boardings revealed that residents working in essential jobs and those with
35 low-incomes or without cars continued to ride to a much greater degree than others (15, 16).
36 This constituted an equity concern as it meant these populations had no choice but to risk
37 exposure to the COVID-19 virus via public transit despite public health agency advisories
38 discouraging transit use. Subsequent academic literature refined these portraits. Telecommuting
39 contributed to the class divide in who continued riding (3, 10). Consistent with these findings,
40 low-income riders did not reduce how often or how far they traveled by transit compared to other
41 riders, despite the risks (10). Communities overrepresented in essential work sectors were more
42 likely to keep riding, including Black, Indigenous, people of color, and immigrants (8, 17, 18).
43 Many riders with disabilities also had no alternative but to continue riding (19, 20). These
44 dynamics in turn influenced which alternative modes saw increased use, and by whom.

Mode Shift and Its Wellbeing Impacts

Transit riders who managed to stop riding adopted several different mobility strategies. Vehicle ownership strongly predicted changes in transit usage in both the U.S. and Canada (8, 18). In Toronto specifically, travelers that could be classified primarily as transit users pre-pandemic fell into one of three alternative mobility patterns: traveling strictly as drivers, mostly walking and occasionally driving, or as continued transit users who made more trips on foot (4). The study authors summarize these findings by stating that “among pre-pandemic transit users, those with alternative options for making non-mandatory trips are primarily turning to private vehicles and walking for their non-mandatory trips” (4). In other cities, like New York, the collapse of transit ridership corresponded with increased use of bike sharing (21). Bicycling volumes increased year-over-year in many cities (22), and residents told public opinion pollsters that they planned to bicycle more after the pandemic (23). However, many residents who managed to stop riding transit faced difficulties switching modes for essential trips, including seniors struggling to walk or bike with groceries and parents chaperoning children (8). In the U.S., the challenges of traveling without transit fell along racial lines, with Hispanic/Latinx respondents being more likely than others to report difficulty reaching essential destinations (18). Taken together, these findings highlight the limits of active travel as an alternative to transit for former riders from with diverse needs, comfort levels, and experiences, raising the question of whether those transit riders who can afford it may turn to the automobile instead.

Vehicle Ownership

COVID-19 has increased the appeal of vehicle ownership among car-less households, although the limited evidence suggests that greater appeal may not translate into mass car buying too much beyond what would normally take place. Roughly 18% of respondents without cars in a Boston sample of 500 reported that the pandemic impacted their car purchase intentions (14). The researchers noted, however, that half of those with ‘enhanced intention’ of purchasing a car were “willing to wait and watch developments over the next year,” although those developments were not named (14). Notably, the authors managed to follow up with 10 households that purchased a vehicle in the following six months and found that both COVID-related concerns and non-COVID-19 issues like service reliability motivated the car buyers. The conclusions emphasize that car ownership increased in the region prior to the crisis, and that a spike in vehicle ownership due to the pandemic may only be short term. National trends buttress this caution. Cox Automotive reports that U.S. certified pre-owned vehicle purchases in the first half of 2021 increased 18% year-over-year, but only 4.8% compared to 2019 (24). Similar analyses are not yet available for Canada, but a recent national survey of recent car buyers found 15% of respondents had purchased a vehicle to avoid riding public transit (25). In Australia, younger adults tell researchers that COVID-19 did not alter their life plans vis a vis their mobility, but merely accelerated them, particularly car-buying (26).

Telecommuting

The orientation of North American transit systems around commuting makes telecommuting a threat to transit’s post-COVID-19 recovery. Even before the pandemic, telecommuting correlated negatively with transit ridership across Canada (27). In the United States, researchers estimate that transit commuting may decline by roughly 40% after the pandemic, with half of this decline attributable to a reduction in commute frequency (3). Nearly 80% of Canadians who started telecommuting during COVID-19 told Statistics Canada that they hope to continue

telecommuting for at least half of their hours post-pandemic (28). Employee preferences for telecommuting are just part of the reason for companies to embrace this change. A growing evidence base suggests that telecommuting increases productivity and has the potential to decrease costs like commercial rents in downtown cores (29, 30).

Understanding Who Will Return

This rapidly emerging research offers a compelling picture of transit-related travel behavior changes during COVID-19: people are riding transit less and driving and telecommuting more. However, few of these studies focus specifically on regular riders of public transit, the likely base of ridership emerging out of the pandemic, and fewer still consider regular riders' views of the future, and investments in other options (i.e., car buying). This paper asks: which transit riders started returning to public transit and to what extent? It also asks: how has COVID-19 changed transit riders' perceptions of automobile ownership, and who anticipates riding less after COVID-19?

DATA AND METHODS

Data comes from waves 1 and 2 of the Public Transit and COVID-19 Survey. Wave 1 ran in May of 2020 in Toronto and Vancouver. Recruitment took place via community listservs and social media advertising. Participation was restricted to adults who took transit more than once a week in Toronto or Vancouver pre-pandemic, to establish a sample of regular transit riders. Details on the limitations and implications of initial data collection are available in prior publications and their technical appendices (8, 9).

Wave 2 took place in March 2021 to capture changes in travel before an anticipated vaccination effort in late spring. Individuals were invited via an email with each respondent receiving a unique link to take the wave 2 survey. This Qualtrics survey was further protected by preventing multiple entries from the same IP address and requiring respondents to complete a captcha. The median respondent took 8.4 minutes to complete the wave 2 survey, which contained 38 questions separated into five sections.

Our methodological strategy is aimed at answering our primary research questions: who is planning on returning to transit and who is not, and what are the implications for an equitable transportation system after the pandemic? To assess this question, we derive from the data six quantitative measures of changes in attitudes and use of public transit, and changes in attitudes towards and ownership of a vehicle. Each of these outcomes is regressed on a set of variables including the rider's socio-demographics, wave 1 attitudes, travel resources (or lack thereof), and built form context.

Dependent Variables

We asked riders to respond to several statements about their travel attitudes and plans using a five-point Likert that ranged from strongly agree to strongly disagree. We converted each of these into a binary indicator where a 1 indicated agreement or strong agreement and modeled these outcomes using Poisson regression. We also explored ordered logistic models on the original variables using all five points on the Likert scale, but these models failed the Brant test for the assumption of proportional odds (31). Binary logistic regression was inappropriate due to the high frequency of positive responses. The statements are summarized in Table 1. Two statements focused on anticipated changes to travel behavior after the pandemic, and two

concerned attitudes about vehicle ownership. We also asked respondents if they bought a car in between survey waves, creating a fifth dependent variable where a 1 indicated a vehicle purchase. Finally, we asked respondents to report the number of times they boarded a transit vehicle in the last seven days. We modeled this variable using zero-inflated negative binomial logistic regression, as it is a count variable and it contained a high proportion of zeros (i.e., people who did not use transit at all in the prior week). Finally, we compared this variable of transit boardings in the last seven days to a similar question asked in wave 1 about a typical pre-pandemic week in March 2020. The change in weekly boardings is our sixth dependent variable, modeled using Ordinary Least Squares as it is numeric. Data analysis was conducted in R.

Table 1: Dependent Variables

Survey Question/Input	Dependent Variable	Model
“After the crisis ends, I will probably ride transit less than I did before COVID”	Binary. 1= Strongly Agree or Agree; 0= all other answers.	Poisson regression with IPAW weights & robust standard errors
Change in transit boardings in March 2021 (wave 2) compared to May 2020 (wave 1)	Numeric. Number of boardings for a week in March 2021 minus number of boardings in May 2021.	Ordinary Least Squares with IPAW weights & robust standard errors
“How many public transit boardings have you made over the last seven days?”	Numeric. Number of boardings for a week in March 2021.	Zero-inflated negative binomial regression
“COVID-19 has made owning a car more appealing”	Binary. 1= Strongly Agree or Agree; 0= all other answers.	Poisson regression with IPAW weights & robust standard errors
“Because of COVID, I have looked into buying a car”	Binary. 1= Strongly Agree or Agree; 0= all other answers.	Poisson regression with IPAW weights & robust standard errors
“Have you or your household purchased a car in the last 12 months?”	Binary. 1=yes, 0=no.	Poisson regression with IPAW weights & robust standard errors

All models are complimented by relative weights analysis implemented in R using the package *RWA*. Relative weights analysis enables researchers to understand the contributions of each predictor variable in explaining an outcome from a multivariate model (32), effects that may be masked to due to the complex interrelationships between predictor variables. RWA involves the transformation of predictors such that they are orthogonal to each other so the analyst can re-compute standardized beta coefficients (33). The method produces raw weights, or the contribution each variable makes in predicting the outcome, that can be interpreted as relative effect sizes for each predictor.

Predictors and Covariates

1 We sought to understand how the experience of difficulties travelling without transit, or with
2 minimal transit, influenced riders' attitudes and future travel plans. In wave 1, we asked
3 respondents who had stopped riding completely in the early months of the pandemic whether
4 avoiding transit made it more difficult to reach one of five different types of destinations (7, 8).
5 We coded respondents on a 0 to 5 scale that counted how many of these destinations they found
6 it somewhat or much harder to reach without public transit. Respondents who were not asked the
7 question in wave 1 because they continued to ride received a score of zero, and this is further
8 controlled for with a nested indicator of whether the respondent stopped riding completely in
9 wave 1.

10 Several demographic covariates were pulled from wave 1 of the survey, including gender
11 (Male, Female, Non-Binary), ethnicity/race (aggregated to White, Black, Indigenous, other
12 Persons of Color), 2019 income (numeric, in thousands), physical disability (yes/no),
13 immigration to Canada in last five years (yes/no), age (18-29, 30-50, 50-64, 65+), and city
14 (Vancouver, Toronto). We opted for 2019 income as, in preliminary modelling, 2020 annual and
15 March 2021 monthly incomes were not at all correlated with any outcomes, and we suspect this
16 is due to some respondents' having unstable or inconsistent employment throughout the period.

17 We also include several covariates from our wave 2 survey. We asked respondents whether
18 they or a householder had tested positive for COVID-19 at any point during the pandemic and
19 whether they had received a dose of a vaccine. Car ownership from wave 1 fell into three
20 categories: respondent owned a car, had access to a car, or had no access at all. We also included
21 a variable pertaining to the built environment, specifically a measure of transit accessibility to
22 jobs. This measure was borrowed from Allen & Farber (34) and additionally accounts for
23 competition to employment. It ranges from 0 to 1, where a one is the greatest possible
24 accessibility accounting for competition, and zero is the least. This was linked to respondents
25 based on their home Dissemination Area during wave 2. We then calculated the change in
26 competitive transit access scores to account for people who moved: post-move competitive
27 transit access minus pre-move, while keeping the value for non-movers at zero. We also included
28 several variables on changing circumstances including change in employment (gained
29 employment between the two waves, lost employment, or no change) and change in auto
30 ownership between waves 1 and 2 (included only in our models on transit, as it is an outcome of
31 interest in our models on the automobile).

32 *Limitations*

33 Wave 2 had a lower completion rate, with 55.5% of respondents with complete and valid wave 1
34 answers participating (1,954 out of 3,518). We address this attrition using inverse probability
35 attrition weighting (IPAW). IPAW is a method that uses a set of variables (covariates) predictive
36 of attrition to generate weights to create a pseudo-population that mimics the underlying cohort
37 (including those who were lost to follow up) (35). To apply the method to attrition, we select
38 participation in the second wave as our exposure and develop weights that correct for in the
39 second wave.

40 Based on modeling of who completed wave 2, we generated IPAW weights using the
41 predictors from wave 1 that are included in our models: city, ethnicity/race, 2019 income, age,
42 recent immigrant indicator, essential worker indicator, having a disability, wave 1 vehicle access
43 status, difficulty with physical distancing in wave 1, competitive transit accessibility score,
44 whether or not the respondent stopped riding transit in response to COVID-19 in wave 1, and the

number of destinations the respondent had trouble reaching without public transit in wave 1. Ideally, we would include wave 1 answers to our dependent variables in weight generation, but these were not asked in wave 1 so we could not do this.

Two major concerns with deploying this method include weights with extreme values or a mean that deviates significantly from one, which could indicate misspecification of the weight model (35). Our estimation, however, yielded weights averaging 1, with a minimum of 0.54 and a maximum just over 2.56 (Table 2).

Table 2: Distribution of weights

Minimum	1st quartile	Median	Mean	3rd quartile	Max
0.5411	0.8392	0.9460	1.0002	1.1180	2.5636

While these weights correct for attrition from our first survey wave, we cannot specify population-level estimates of attitudes and changed behavior as the original wave was gathered as a large, online convenience sample through social media recruitment (8). This makes any effort on our part to generalize results to the broader population speculative, and so our analytical strategy consciously avoids such claims and instead relies on differences between groups within our sample to offer new insights. However, our data can reproduce known relationships between demographic, built form, and travel behaviour variables (8, 9), lending confidence in the data to offer useful insights. Additionally, we note that our study does not consider uptake in active travel and telecommuting, although the unavailability of the latter for respondents is captured to some extent in our variable on essential workers. To minimize response burden and increase completion rates, we kept the wave 2 survey focused primarily on public transit. Finally, our overall modelling strategy contains limitations. We had to dichotomize our dependent variables. We did not ask our dependent variables in wave 1, information that would have provided more robust attrition weights.

The State of the Pandemic During Wave 2

The second wave ran in both cities from March 16 to April 6, 2021, a period of rapid increase in cases and severe restrictions on social gatherings in both places. This coincided with an increase in COVID-19 reported cases in Toronto, the weekly average of which rose from 0.4 cases per 100,000 people the week of March 1st to 33.9 cases per 100,000 people on the week starting April 6th (36). A week before the survey ran, Toronto moved into Ontario's 'Grey Zone,' after several months of strict lockdown in which all but essential businesses were closed (37). The Grey Zone meant that indoor gatherings of five people and outdoor gatherings of 24 could occur, and religious ceremonies could take place at 30% capacity. Non-essential services remained closed. In Vancouver, the weekly average case rate rose from about 13 per 100,000 the day the survey was released, to 27.4 per 100,000 the day the survey closed (38). British Columbia had similarly remained under a state of emergency since November 2020, with residents asked to only socially gather or travel with people within the same household (37), although restaurants and other non-essential amenities were open at limited capacities.

RESULTS

Overall, just 32% percent of transit riders planned on riding transit less after the pandemic (see Table 3). However, 54% also agreed that the pandemic has made owning a vehicle more appealing. Still, this did not translate into mass car buying: only 26% reported looking into

buying a vehicle, and 11% actually purchased one between survey waves. This compares with 1.9 million vehicle purchases in Canada in 2019 equating to about 5% of the population (39). The average respondent boarded a transit vehicle just 4.7 times over the past seven days, and this was 1.99 more times than in May 2020. This may reflect the relative ease that most riders in the sample experienced trying to reach destinations without transit. The average respondent found it harder to reach just under one out of five destination types while avoiding the mode. Notably, about 4% of riders either got COVID-19 or lived with someone who did. In contrast, total positive tests in Toronto equal 5.8% of the population (40), and 3% in British Columbia (38), where statistics are not reported at the city level. These summary statistics, while illustrative, do not illuminate whether these factors explain the bifurcation of attitudes about future transit use among respondents. We turn to those questions next.

Table 3: Summary statistics (n=1954)

<i>Variable</i>	Min	Mean	Max
<i>Dependent Variables</i>			
Agree/Strongly that “COVID-19 has made owning a car more appealing”	0	0.54	1
Agree/Strongly that “Because of COVID, I have looked into buying a car”	0	0.26	1
Bought a car between survey waves	0	0.11	1
Agree/Strongly that “After the crisis ends, I will probably ride transit less than I did before COVID”	0	0.32	1
Transit vehicle boardings in last 7 days	0	4.7	80
Change in transit vehicle boardings in March 2021 (wave 2) compared to May 2020 (wave 1)	-40	1.99	63
<i>Demographic Predictors</i>			
City is Vancouver	0	0.48	1
City is Toronto	0	0.52	1
<i>Gender (ref: Female)</i>	0	0.64	1
Male	0	0.28	1
Non-binary	0	0.08	1
<i>Age (ref: 18-29 years old)</i>	0	0.34	1
30-50 years old	0	0.44	1
50-64 years old	0	0.16	1
65+ years old	0	0.07	1

Immigrated in last five years	0	0.10	1
Essential worker (wave 1)	0	0.20	1
Employment Change (<i>ref: had a job in both waves</i>)	0	0.58	1
Gained employment between waves	0	0.20	1
Lost employment between waves	0	0.3	1
No employment either wave	0	0.19	1
Have a physical disability	0	0.03	1
<i>Ethnicity/Race (ref: white)</i>	0	0.66	1
Black	0	0.03	0
Indigenous	0	0.03	0
Non-Black or Indigenous POC	0	0.28	0
2019 income (\$000s)	0	72.84	150
Household size	1	2.53	13
<i>Transportation & built form variables</i>			
<i>Wave 1 Vehicle Ownership (ref: no vehicle)</i>	0	0.41	0
Had access	0	0.24	1
Owned a car	0	0.35	1
Hard to physically distance in my neighbourhood (wave 1)	0	0.39	1
Competitive transit access score	0.01	0.25	0.63
Change in competitive transit access score	-0.51	0.001	.48
Got COVID-19 or someone in household did	0	0.03	1

Changes in Transit Travel and Views on Future Transit Use

Our modelling results on questions of transit travel behaviour suggest that the sociodemographic composition of transit ridership will continue to change as cities exit the pandemic. These findings are summarized in Table 4. The first column presents incident risk ratios on agreement with the statement “After the crisis ends, I will probably ride transit less than I did before COVID-19.” The second column provides coefficients from an OLS model estimating the change in weekly vehicle boardings between March 2021 and May 2020. The third column shows odds ratios predicting whether someone did not take a transit trip at all in March 2021, a

1 step in the zero-inflated, negative binomial count model. The fourth column presents the second
2 step incident risk ratios for the count model. P-values across all models are included in
3 parentheses. All models use inverse probability attrition weights and all but the negative
4 binomial model report robust standard errors. Table 5 reports results from the relative weights
5 analysis.

1 **Table 4: Results from IPAW-weighted models with robust standard errors for predicting changes in transit usage, and views on post-**
2 **pandemic transit use**

	<i>Agree/Strongly “After the crisis ends, I will probably ride transit less than I did before COVID-19”</i>	<i>Change in the number of weekly transit boardings March 2021 – Pre-COVID</i>	<i>Number of transit vehicle boardings in last seven days (March 2021)</i>	
	<i>IRRs</i>	<i>Estimates</i>	<i>Odds Ratios</i>	<i>IRRs</i>
(Intercept)	0.24 (0.15, 0.38)***	0.41 (-2.11, 2.93)	0.50 (0.22, 1.14)^	3.86 (2.67, 5.59)***
Weekly boardings pre-COVID	1.01 (1.00, 1.01)	0.04 (-0.02, 0.09)	0.97 (0.96, 0.99)***	1.02 (1.02, 1.03)***
City is Vancouver (<i>ref: Toronto</i>)	0.94 (0.8, 1.1.00)	0.27 (-0.61, 1.14)	0.55 (0.41, 0.74)***	0.90 (0.79, 1.02)
<i>Gender (ref: Female)</i>				
Male	0.95 (0.80, 1.13)	-0.10 (-1.03, 0.84)	0.76 (0.56, 1.04)^	1.12 (0.98, 1.28)^
Non-binary	0.92 (0.69, 1.24)	0.19 (-1.39, 1.77)	0.90 (0.57, 1.41)	1.04 (0.84, 1.29)
<i>Age (ref: 18-29 years old)</i>				
30-50 years old	1.13 (0.95, 1.34)	0.42 (-0.56, 1.40)	1.43 (1.04, 1.96)*	1.14 (0.99, 1.32)^
50-64 years old	1.04 (0.80, 1.33)	0.99 (-0.30, 2.27)	1.06 (0.69, 1.64)	1.24 (1.02, 1.50)*
65+ years old	0.61 (0.37, 1.00)^	1.33 (-0.28, 2.95)	0.80 (0.42, 1.51)	1.44 (1.10, 1.88)**
Immigrated in last five years	1.08 (0.84, 1.39)	1.45 (-0.36, 3.25)	0.56 (0.35, 0.91)*	1.08 (0.90, 1.30)
Essential worker (wave 1)	0.83 (0.66, 1.04)	-0.06 (-1.41, 1.29)	0.59 (0.4, 0.87)**	1.76 (1.5, 2.07)***
<i>Employment Change (ref: had a job in both waves)</i>				
Gained employment between waves	0.68 (0.55, 0.85)***	1.71 (0.42, 3.01)**	0.77 (0.54, 1.11)	1.57 (1.31, 1.87)***
Lost employment between waves	1.16 (0.75, 1.79)	-3.12 (-5.28, -0.96)**	0.78 (0.32, 1.88)	0.63 (0.46, 0.86)**
No employment either wave	0.82 (0.64, 1.06)	-0.81 (-1.91, 0.29)	0.95 (0.62, 1.44)	0.88 (0.72, 1.07)
Have a physical disability	0.83 (0.52, 1.32)	1.28 (-1.16, 3.72)	0.69 (0.32, 1.51)	1.22 (0.85, 1.76)
<i>Ethnicity/Race (ref: white)</i>				
Black	0.64 (0.34, 1.22)	1.25 (-1.09, 3.58)	1.20 (0.59, 2.44)	1.48 (1.09, 2.02)*

Indigenous	0.99 (0.66, 1.48)	0.47 (-2.47, 3.41)	0.82 (0.37, 1.81)	1.23 (0.93, 1.62)
Non-Black or Indigenous POC	0.97 (0.81, 1.16)	0.11 (-0.81, 1.03)	1.24 (0.90, 1.70)	1.07 (0.92, 1.24)
2019 income (\$000s)	1.00 (1.00, 1.00)	0.00 (-0.01, 0.01)	1.00 (1.00, 1.01)*	1.00 (1.00, 1.00)
Wave 1 Vehicle Ownership				
Had access	0.85 (0.68, 1.06)	0.01 (-1.07, 1.08)	1.21 (0.85, 1.73)	1.01 (0.86, 1.18)
Owned a car	1.09 (0.90, 1.34)	-0.93 (-1.90, 0.04)^	2.28 (1.60, 3.26)***	0.86 (0.71, 1.04)
Bought a car between waves 1 and 2	1.65 (1.36, 2.01)***	-1.92 (-3.23, -0.62)**	2.2 (1.38, 3.52)***	0.88 (0.68, 1.13)
Hard to physically distance in my neighbourhood (wave 1)	1.24 (1.05, 1.45)**	-0.34 (-1.21, 0.52)	1.14 (0.86, 1.51)	0.96 (0.84, 1.09)
Competitive transit access score	0.40 (0.20, 0.79)**	0.91 (-2.83, 4.64)	0.44 (0.13, 1.48)	1.37 (0.76, 2.45)
Got COVID-19 or someone in household did	1.07 (0.71, 1.60)	0.15 (-1.87, 2.17)	0.73 (0.36, 1.50)	1.09 (0.79, 1.51)
Stopped riding when COVID began (wave 1)	2.18 (1.71, 2.78)***	0.97 (-0.01, 1.95)^	5.86 (4.04, 8.49)***	0.64 (0.53, 0.76)***
Experienced difficulty without transit (wave 1)	0.96 (0.90, 1.03)	0.32 (-0.01, 0.65)^	0.94 (0.84, 1.06)	1.04 (0.97, 1.12)
Household size (n)	0.96 (0.90, 1.02)	-0.11 (-0.48, 0.27)	0.88 (0.79, 0.98)*	1.03 (0.98, 1.08)
Degrees of freedom	1550	1550	1558	
Test Statistics	2004 (AIC)	0.03 (Adj R^2)	7003 (AIC)	

^ $p < 0.10$ * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$; [†]did not use robust SEs

Table 5: Relative Weights Analysis of transit models

	<i>Agree/Strongly “After the crisis ends, I will probably ride transit less than I did before COVID-19”</i>	<i>Change in the number of weekly transit boardings March 2021 – Pre-COVID</i>	<i>Number of transit vehicle boardings in last seven days (March 2021)[†]</i>
Weekly boardings pre-COVID	0.017	0.076	0.264
City is Vancouver (ref: Toronto)	-0.06	-0.036	0.004

<i>Gender (ref: Female)</i>				
Male	-0.032	-0.015	0.042	
Non-binary	-0.005	-0.001	0.025	
<i>Age (ref: 18-29 years old)</i>				
30-50 years old	0	0	0	
50-64 years old	0.09	-0.025	-0.009	
65+ years old	-0.015	0.015	0.035	
Immigrated in last five years	-0.105	0.005	0.018	
Essential worker (wave 1)	0.009	0.027	0.081	
Employment Change (ref: had a job in both waves)	-0.074	-0.056	0.292	
Gained employment between waves				
Lost employment between waves	-0.054	0.102	0.056	
No employment either wave	-0.004	-0.035	0.01	
Have a physical disability	-0.068	-0.039	-0.068	
<i>Ethnicity/Race (ref: white)</i>				
Black	-0.022	0.035	0.018	
Indigenous	-0.001	0.035	0.018	
Non-Black or Indigenous POC	-0.03	0.022	0.061	
2019 income (\$000s)	0.006	0.009	0.101	
Wave 1 Vehicle Ownership	-0.001	-0.022	0.023	
Had access	0.104	-0.032	-0.157	
Owned a car	0.104	-0.06	-0.209	
Bought a car between waves 1 and 2	-0.038	0.028	-0.029	
Hard to physically distance in my neighbourhood (wave 1)	0.139	-0.071	-0.057	
Competitive transit access score	0.072	0.029	-0.013	
Got COVID-19 or someone in household did	-0.038	0.013	0.004	
Stopped riding when COVID-19 began (wave 1)	0.008	0.003	0.004	
Experienced difficulty without transit (wave 1)	0.23	0.09	-0.397	
Household size (n)	0.071	0.122	-0.1	
	0.019	-0.027	0.005	

1 [†]relative weights produced on an OLS regression of boardings due to statistical package limitations

1 *Who anticipates riding less after the pandemic?* Living in a neighbourhood with strong transit
2 accessibility pre-COVID-19 blunts respondents' likelihood of agreeing that they will ride transit
3 less post-pandemic, as does gaining employment and being over the age of 65. In contrast, those
4 who bought a car, who have trouble physical distancing in their neighborhoods, and those who
5 gave up transit in wave 1 all plan on riding less in a post-pandemic future. The relative weight
6 analysis points to car buying and giving up transit in the prior wave as explaining the greatest
7 variance in anticipated future transit use, however, reflecting the 'stickiness' of some
8 respondents' new travel habits (3). It also points to income as a positive predictor.

9 *What predicts changes in transit boardings between May 2020 and March 2021?* The second
10 column of Table 5 indicates that only a couple of factors mitigated against further decline in a
11 rider's use of transit during the pandemic. This included gaining employment in between survey
12 waves and experiencing difficulty without public transit in the early days of the crisis. Giving up
13 transit in the early months of the pandemic is associated with an .97 increase in trips between
14 waves, suggesting that most riders had returned to the mode. In contrast, car buyers, car owners,
15 and those who lost employment rode less in March 2021 compared to the early months of the
16 pandemic. Experiencing difficulty without public transit registers the greatest effect in the
17 relative weight analysis, highlighting that many transit dependent riders who could not make
18 satisfactory use of other modes came back to transit.

19 *What predicts number of boardings per week in the middle of a pandemic?* The third column in
20 Table 5 presents the odds ratios of a binary model predicting that a respondent did not board
21 transit at all in the prior week. Car owners and car buyers were significantly more likely to have
22 made zero transit boardings, as were 30 to 50-year olds. Essential workers, immigrants, males,
23 and residents of Vancouver were significantly less likely to have made zero boardings. The more
24 someone boarded transit pre-COVID, the less likely they were to make zero boardings in March
25 2021. Conditional on these results, column 4 shows incidence risk ratios for a count model of
26 boardings made in the reference week. Black respondents, essential workers, people over the age
27 50 and those who gained employment boarded more transit vehicles in March 2021, while those
28 who lost employment and those who stopped riding in the early months of the pandemic boarded
29 less. Pre-COVID boardings are also a powerful explainer of variation in March 2021, as
30 demonstrated by the RWA. In sum, demographic differences in responses to the pandemic have
31 held among transit riders (8, 17, 18).

32 *Modelling car-purchases and attitudes towards vehicles*

33 Our second set of models demonstrate that immigrants and twentysomethings are more
34 attracted to vehicle ownership than other groups and are taking steps to purchase vehicles. Each
35 dependent variable is modeled twice, once using the entire sample, and once using the subsample
36 of respondents who did not own a vehicle in wave 1 (i.e. those who had other access to a vehicle
37 or those with no access at all). This enables us to evaluate who among pre-pandemic non-car
38 owners bought vehicles, allowing us to better discern the long-term implications of COVID-19
39 for sustainable transportation. All these results are presented as incidence risk ratios derived from
40 Poisson regression models in Table 6, 95% confidence intervals in parentheses. All models were
41 calculated using IPAW weights and robust standard errors. Table 7 reports results from the
42 relative weights analysis.

1

2 **Table 6: Odds ratios on IPAW-weighted models with robust standard errors for vehicle purchase and attitudes towards vehicle ownership**

	Agree/Strongly: "COVID-19 has made owning a car more appealing"		Agree/strongly: "Because of COVID, I have looked into buying a car"		Bought A Car Between Waves	
	All	No Car Wave 1	All	No Car Wave 1	All	No Car Wave 1
(Intercept)	0.57 (0.46, 0.70)***	0.59 (0.44, 0.8)***	0.26 (0.17, 0.4)***	0.28 (0.17, 0.46)***	0.1 (0.05, 0.20)***	0.1 (0.04, 0.27)***
City is Vancouver (ref: Toronto)	0.95 (0.87, 1.04)	0.94 (0.82, 1.06)	0.96 (0.8, 1.15)	0.89 (0.72, 1.09)	1.22 (0.89, 1.66)	1.09 (0.72, 1.64)
Gender (ref: Female)						
Male	0.86 (0.78, 0.95)**	0.79 (0.68, 0.91)**	1.16 (0.97, 1.39)	1.11 (0.90, 1.37)	0.99 (0.71, 1.39)	1.2 (0.78, 1.86)
Non-binary	1.02 (0.88, 1.18)	1.07 (0.88, 1.30)	0.75 (0.51, 1.11)	0.74 (0.47, 1.15)	0.77 (0.39, 1.53)	0.64 (0.23, 1.74)
Age(ref: 18-29 years old)						
30-50 years old	0.86 (0.79, 0.94)***	0.82 (0.73, 0.93)**	0.89 (0.75, 1.07)	0.92 (0.75, 1.13)	0.71 (0.51, 0.99)*	0.68 (0.45, 1.05)^
50-64 years old	0.60 (0.5, 0.71)***	0.50 (0.37, 0.67)***	0.37 (0.24, 0.57)***	0.39 (0.23, 0.66)***	0.87 (0.53, 1.43)	0.91 (0.46, 1.80)
65 years and older	0.49 (0.37, 0.65)***	0.42 (0.26, 0.67)***	0.33 (0.16, 0.68)**	0.4 (0.17, 0.96)*	0.27 (0.08, 0.87)*	0.25 (0.03, 1.85)
Immigrated in last five years	1.19 (1.05, 1.36)**	1.25 (1.06, 1.47)**	1.32 (1.05, 1.66)*	1.49 (1.17, 1.91)***	1.57 (1.00, 2.45)*	1.52 (0.89, 2.60)
Essential worker (wave 1)	0.94 (0.83, 1.07)	0.89 (0.75, 1.07)	1.12 (0.88, 1.42)	1.02 (0.77, 1.34)	1.3 (0.89, 1.89)	1.41 (0.88, 2.28)
Employment Change (ref: had a job in both waves)						
Gained employment between waves	1.05 (0.95, 1.16)	1.02 (0.89, 1.18)	0.92 (0.73, 1.15)	0.91 (0.71, 1.17)	1.05 (0.71, 1.54)	0.93 (0.56, 1.56)
Lost employment between waves	1.17 (0.96, 1.42)	1.05 (0.8, 1.39)	1.05 (0.7, 1.58)	1.01 (0.64, 1.59)	1.14 (0.55, 2.34)	0.56 (0.17, 1.81)
No employment either wave	0.93 (0.81, 1.06)	0.9 (0.74, 1.10)	0.92 (0.69, 1.22)	0.86 (0.62, 1.20)	0.75 (0.45, 1.24)	0.49 (0.24, 0.99)*
Have a physical disability	1.04 (0.82, 1.32)	1.02 (0.72, 1.42)	0.78 (0.39, 1.58)	0.63 (0.24, 1.61)	1.19 (0.44, 3.18)	0.62 (0.08, 4.72)
Ethnicity/Race (ref: white)						
Black	1.16 (0.93, 1.45)	1.15 (0.88, 1.49)	1.2 (0.78, 1.85)	1.14 (0.71, 1.83)	1.05 (0.46, 2.37)	0.57 (0.16, 1.99)
Indigenous	0.95 (0.73, 1.23)	0.91 (0.64, 1.29)	1.24 (0.8, 1.93)	1.28 (0.76, 2.13)	1.65 (0.85, 3.21)	1.28 (0.47, 3.52)
Non-Black or Indigenous						
POC	1.04 (0.95, 1.14)	1.05 (0.92, 1.2)	1.21 (1.01, 1.47)*	1.19 (0.96, 1.48)	1.19 (0.84, 1.68)	1.23 (0.77, 1.95)
2019 income (\$000s)	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)	1.00 (1.00, 1.01)^	1.00 (1.00, 1.01)

Wave 1 Vehicle Ownership						
Had access	1.44 (1.29, 1.61)***		0.97 (0.75, 1.25)		1.43 (0.92, 2.22)	
Owned a car	1.09 (0.97, 1.23)	1.1 (0.97, 1.25)	1.43 (1.15, 1.76)***	1.48 (1.19, 1.85)***	1.3 (0.85, 2.00)	1.33 (0.84, 2.10)
Hard to physically distance in my neighbourhood (wave 1)	1.17 (1.07, 1.28)***	1.2 (1.06, 1.35)**	1.33 (1.12, 1.57)***	1.37 (1.13, 1.67)**	1.07 (0.77, 1.49)	0.98 (0.63, 1.52)
Competitive transit access	0.69 (0.48, 0.98)*	0.73 (0.44, 1.23)	0.41 (0.2, 0.82)*	0.38 (0.17, 0.86)*	0.19 (0.06, 0.62)**	0.24 (0.04, 1.28)^
Got COVID or someone in household did	1.10 (0.92, 1.31)	1.02 (0.78, 1.34)	1.4 (0.99, 1.98)^	1.34 (0.9, 2.02)	1.93 (1.11, 3.36)*	2.51 (1.34, 4.69)**
Stopped riding in May 2020 (wave 1)	1.15 (1.02, 1.30)*	1.02 (0.87, 1.20)	1.19 (0.93, 1.52)	1.13 (0.86, 1.48)	1.07 (0.69, 1.66)	1.24 (0.73, 2.11)
Number amenities harder to reach without transit (wave 1)	1.02 (0.98, 1.06)	1.05 (1, 1.10)^	1.08 (1.00, 1.16)*	1.06 (0.98, 1.16)	1.09 (0.93, 1.27)	1.03 (0.84, 1.25)
Degrees of freedom	1751	1123	1531	1327	1577	1015
AIC	3021	1961	1845	1387	1075	671

^ $p < 0.10$ * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

Table 7: Relative weight analysis of auto models

	Agree/Strongly: "COVID-19 has made owning a car more appealing"		Agree/strongly: "Because of COVID, I have looked into buying a car"		Bought A Car Between Waves	
	All	Not prior owners	All	Not prior owners	All	Not prior owners
City is Vancouver (ref: Toronto)	-0.03	-0.071	-0.015	-0.027	0.033	0.021
Gender (ref: Female)						
Male	-0.047	-0.1	0.033	0.031	0.006	0.035
Non-binary	-0.037	0.044	-0.038	-0.04	-0.03	-0.048
Age (ref: 18-29 years old)						
30-50 years old	0.029	0.003	0.036	0.036	-0.022	-0.027
50-64 years old	-0.111	-0.169	-0.15	-0.152	-0.01	-0.018

65 years and older	-0.061	-0.137	-0.109	-0.105	-0.07	-0.068
Immigrated in last five years	-0.017	0.08	0.098	0.12	0.049	0.075
Essential worker (wave 1)	-0.075	-0.064	0.006	-0.013	0.032	0.042
Employment Change (ref: had a job in both waves)						
Gained employment between waves	0.077	0.08	0.011	0.018	0.016	0.007
Lost employment between waves	0.028	0.01	0.017	0.011	0.024	-0.009
No employment either wave	-0.091	-0.103	-0.055	-0.073	-0.058	-0.084
Have a physical disability	-0.027	-0.032	-0.038	-0.058	-0.01	-0.039
<i>Ethnicity/Race (ref: white)</i>						
Black	-0.028	0.028	0.025	0.008	0.009	-0.022
Indigenous	-0.033	-0.029	-0.004	-0.017	0.041	0.007
Non-Black or Indigenous POC	-0.029	0.051	0.11	0.118	0.043	0.073
2019 income (\$000s)	0.103	0.028	-0.027	0.03	0.056	0.053
Wave 1 Vehicle Ownership						
Owned a car	0.143		-0.066		0.057	
Had access	-0.009	0.087	0.12	0.12	0.022	0.066
Hard to physically distance in my neighbourhood (wave 1)	0.071	0.133	0.077	0.089	-0.005	-0.021
Competitive transit access core	-0.022	-0.029	-0.065	-0.073	-0.086	-0.069
Got COVID-19 or someone in household did	0.044	0.028	0.067	0.069	0.06	0.075
Stopped riding in May 2020 (wave 1)	0.146	0.13	0.081	0.108	0.04	0.043
Number amenities harder to reach without transit (wave 1)	0.04	0.127	0.11	0.107	0.021	0.023

1 *For whom has vehicle ownership become more appealing?* Recent immigrants, those who had
2 trouble with physical distancing in their neighbourhoods, car owners, and those who stopped
3 riding transit when the pandemic began are all more likely find automobility more appealing in
4 the wake of the crisis. These results hold when we repeat the model just among those who did
5 not own a vehicle pre-pandemic. In contrast, men and older transit riders, including everyone
6 over the age of 30, are significantly less likely to report that the pandemic has increased the
7 appeal of vehicle ownership. Higher transit access is also associated with a lesser likelihood of
8 finding vehicle ownership more appealing. Among all of these significant variables, however,
9 the relative weight analysis points to age factors, prior vehicle ownership and giving up transit
10 early on in the pandemic as indicators offering the greatest explanatory power. However, recent
11 immigration is also a major factor when the analysis is limited to people who did not own pre-
12 pandemic.

13 *Who looked into buying a car because of the pandemic?* Recent immigrants, people who had
14 trouble maintaining physical distancing, and people who had trouble reaching destinations
15 without public transit are all more likely to have investigated buying a car. Notably, those who
16 got COVID-19 or lived with someone who did were also significantly more likely to have
17 investigated buying a car. In comparison, people over the age of 50 are less likely to have, at
18 least relative to twentysomethings. The relative weights analysis mirrors these results, except in
19 the case non-Black people of colour, which shows as a relatively important factor. This
20 discrepancy may be due to over-representation of non-Black people of colour among recent
21 immigrants in the sample.

22 *Who bought a car?* Recent immigrants and people in a household where someone got COVID-19
23 are both significantly more likely to have bought a car. In contrast, people over 30 were less
24 likely to have bought a car, although this was only significant for the 30-50 year old and 65 and
25 up groups. As with the other auto focused models, transit accessibility correlated negatively and
26 significantly with car purchasing. Only presence of COVID-19 in the household retains
27 significance in a model of those who did not own a vehicle pre-pandemic. The relative weight
28 analysis, however, suggests that transit access, being a recent immigrant, and being a non-Black
29 person of colour explain the most variance in the outcome.

30 **CONCLUSIONS**

31 COVID-19 forced millions of North American transit riders to choose between possible
32 exposure to a new disease or having to give up a key mobility resource (8). In this follow up
33 survey we find that the challenges associated with the latter choice of increased the appeal of
34 vehicle ownership among some transit riders, while inducing others to start riding again.
35 Inequities in mobility thus remain at the forefront of understanding transit travelers' behaviour
36 changes coming out of the COVID-19 pandemic. Groups more likely to use transit at the onset of
37 the pandemic, such as people of color, essential workers, and recent immigrants (8, 17, 18),
38 continued to use transit at relatively higher rates nearly a year into the crisis. Vehicle owners
39 have continued to stay away, and people who bought cars during the pandemic have joined them.
40 Our results suggest that transit has lost its so-called 'choice' riders (1), and they have much less
41 desire to return than others.

42 Twentysomethings and recent immigrants are two rider segments that are consistently more
43 turned off public transit and more interested in vehicle ownership as a direct result of the
44 pandemic. This does not necessarily mean that transit has lost a generation of potential riders, as

these are also the riders most likely to transition into vehicle ownership as they age or, in the case of immigrants, as they begin to adopt the mobility patterns of North America (41, 42). Our results on age may also reflect our unique sampling frame: those who ride transit regularly later in life are more dependent upon it than younger frequent users, pandemic or no pandemic. We thus conclude that the pandemic merely hastened some rider's adoption of automobility, similar to conclusions drawn by Basu and Ferreira in their analysis of Boston (14) and Delbosc and McCarthy in their interviews around Melbourne (26). But our work shows that current twentysomethings, often referred to colloquially as "Gen Z," may not be as transit friendly as Millennials were promised to be (2).

Our results demonstrate why maintaining high quality transit service should be the primary focus of policy efforts to recover ridership. In nearly all our models, those with greater transit accessibility are less likely to be attracted to vehicle ownership, are less likely to have bought a vehicle, and are less likely to anticipate riding transit less often post pandemic. This variable may also be expressing the impact of the cost or lack of parking in transit rich urban cores where transit accessibility is high, but it nonetheless shows that those in areas with higher transit accessibility are more committed to using these services.

We find evidence that the experience of getting COVID-19, or living with someone who did, increased a transit rider's likelihood of buying a car. This is consistent with the findings of Dong et al. (12), who mention that riders who perceive the virus as "close" have higher levels of anxiety and, as a consequence, may reduce their transit travel. Our other modeling suggests that the experience of COVID-19 in the household has changed attitudes towards transit and auto-ownership, though the coefficients are insignificant. Insignificance may be due in part to a small number of positive cases in the sample (65). This topic merits further attention from researchers and decisionmakers, as it is something that transit agencies will have to reckon with despite having no control over it.

Our analysis contains several limitations stemming mostly from a low completion rate of our second survey. We had to dichotomize our outcome variables and a few predictors, and we had to rely on weights to correct for significant attrition between survey waves. However, our findings point to clear hypotheses that broader surveys and bigger datasets can confirm or deny.

Our future work will be focused on text mining and content analysis of 1,400 comments from respondents on why they anticipate riding transit less often (or not) after COVID-19. This analysis is expected to give a better understanding on how people envision the post-pandemic era, the reasons behind their expected travel behaviour. Building on this work, cluster analyses will be performed to identify different user profiles considering their previous, actual, and expected travel behaviour. Finally, we aim to conduct a third wave in 2022 that will measure travel behaviour and attitudes in a Canada where most residents are (hopefully) vaccinated and comfortable riding transit again.

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