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Travel Pattern Analysis on Switching Behavior in Response to the COVID-19 Pandemic

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Abstract

The COVID-19 pandemic has significantly affected people's daily life across the globe. This paper aims to understand the change of individual travel behavior during the pandemic. We administer a survey to record people's travel habits before, during and after the stay-at-home order in New York City. Respondents' information, including travel mode, travel frequency, trip purpose and demographics, is gathered to study switching behavior regarding travel patterns during the pandemic. Results show that among all travel mode choices, public transits are the most affected by the pandemic while bikes and automobiles are the least affected by the pandemic.

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Keywords: COVID-19, Travel Pattern, Switching Behavior

Introduction

In March 2020, the World Health Organization (WHO) declared COVID-19 as a pandemic. In response, the "stay-at-home" order was issued in New York state around late March. Fearing that the subway system accelerates virus spreading and infection, a majority of transit commuters have shifted to buses, private vehicles or bikes (Kamga, 2020; Zuo, 2020; Bernardes, 2020; Wang, 2020). The substantial drop in public transport ridership has led to tremendous adverse effects on the environment, traffic fatalities (Kessler, 2020), and disruptions of the urban economy. In this paper, we conduct a survey to explore the impact of the pandemic on individual travel mode choices. In particular, we study the switching behavior among different travel modes based on respondents' demographic and geographic information. This can help urban planners understand the individuals who are most likely affected by the COVID-19 policies and assist policymakers to assess the environmental impact of the pandemic.

Related Work

Existing studies focus on analyzing travel patterns based on social media data and aggregate mobility usage in open data. Geo-tagged tweets were leveraged to understand people's travel mode changes before and after Uber and Lyft withdrew their service from Austin, Texas (Shou, 2020). Social media check-in data was utilized to study the evolution of human mobility during the pandemic (Chen, 2022). A classifier was developed to identify travel modes from individual tweets and investigates public concern about public transits by making a comparison of social media and NYC open data (Chen, 2022). There are many other travel behavioral studies. Readers can refer to Chen *et al.* (2016) and Rashidi *et al.* (2017) for a comprehensive review. Compared to social media and aggregate mobility usage data, survey data provides more information about travel behavior of individual users, including travel frequency, travel distance and user demographics. A survey given to 12000 respondents in Sweden (Eliasson, 2022) showed that the pandemic had an significant effect on human mobility in March 2020, when aggregate travel time and travel distance decreased.

Survey Data

An online survey was administered by a group of faculty and students at Columbia University from 2020-2021, primarily focused on understanding people's travel behavior to improve traffic mobility and safety for future pandemics. The objective of this survey is to understand how people's travel patterns have been affected the three stages: the pandemic, the stay-at-home order, and the reopening. The length of participation in the study was approximately 10-15 minutes. This lets us analyze how the pandemic has affected travel habits in New York and by extension the environmental impacts it has caused.

A total of 671 respondents participated in the survey. A majority of respondents fall between the ages of 25 and 54 with the most common age category being ages 25 to 34 (24.4%). People from 35 to 44 years old are 21.8% of total respondents. The proportions of respondents aged 18-24, 45-

54, 55-64 and above 65 are 6.9%, 20%, 15.9% and 11%, respectively. A majority of respondents to this survey identified themselves as female (66.6%). Only around one third of respondents identified themselves as male (32.8%) and a small minority of respondents identified as some other gender. Respondents were asked to report the highest level of education that they had completed. Fig. 1 provides a full breakdown of responses. A large majority of respondents (83.2%) hold at least a bachelor's degree with a majority of respondents holding some type of graduate degree. This distribution of education levels may be reflective of the fact that sampling of the survey was done on or near Columbia University.

We also collect respondents' household sizes in Fig. 2. The most common household size is two people with around 40% of respondents followed by one person and three people, both with approximately 20% of respondents. Household income among respondents was distributed fairly evenly across different income categories. The most common household income category was $60,000-$89,999 with 15.5% followed closely by "Above $300,000" with 15.5% of respondents. Around seven percent of respondents chose to not report their annual household income. We would like to highlight that this survey mainly targeted the Columbia community, which reflects how the members from a high-educational institute responded to the pandemic in terms of commuting in the city. It represents the changes in travel patterns for other communities across the city with a similar structure and would offer insights into the emergency responses of the city.

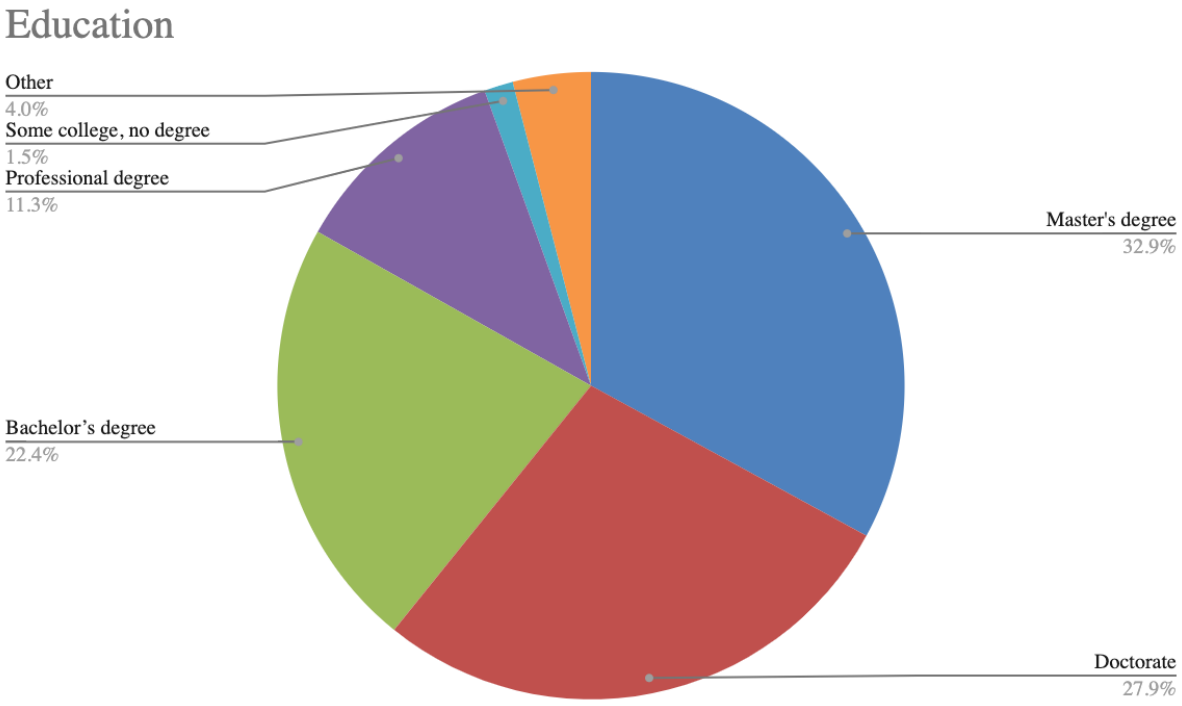

Figure 1: Education background

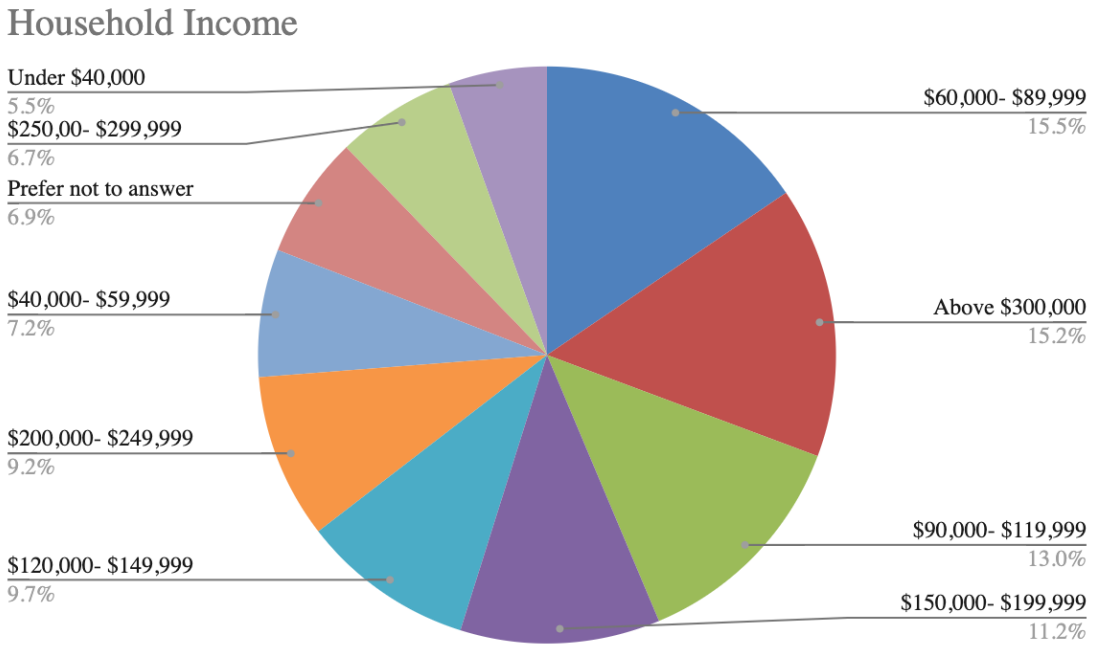

Figure 2: Household income

Travel Behavior Analysis

This study analyzed how respondents' travel modes have changed over the course of the pandemic (Fig. 3). The most popular travel modes before the pandemic were the subway, buses, and walking with most people using the subway as a mode of transportation. Since the pandemic, most people have shifted to teleworking and are using less traditional modes of transportation. This effect has lingered even after the stay-at-home order was lifted, with telework remaining the most popular transportation mode even after the order was lifted. Telework is included as a "transportation mode" because it represents the lack of commute for work.

One notable trend is the decline in the number of people taking buses. Before the stay-at-home order around 250 respondents reported using the bus as one of their modes of transportation. This number fell to 25 respondents during the stay-at home order and has recovered little even after the order was lifted. The subway has seen a similar decline in usage although has seen a higher recovery after the stay-at-home order. Interestingly, this trend does not seem to extend to shuttles although the number of people taking shuttles has slightly declined since the beginning of the pandemic.

Cars, bikes and Ubers seem to be the transportation modes that have been the least affected by the pandemic. Cars and bikes have even seen an increase in usage after the stay at home order was lifted. This is likely due to the fact that those two modes are seen as safer than public transportation since they carry a lower likelihood of disease transmission.

It is important to note that respondents were allowed to record multiple modes of transportation. Therefore the total number of transportation uses is higher than the total number of survey respondents. This may also help explain why a transportation mode like walking has declined despite the fact that it is one of the safer transportation modes with regard to disease transmission. Many respondents are likely not using walking as their primary mode of transportation and are instead walking in conjunction with using public transportation and therefore are walking less frequently as a result of choosing to use less public transportation.

The environmental implications due to these shifts in travel mode are two-fold. The shift towards telework implies a reduction in energy use and carbon emissions, given that most studies find that teleworking lowers overall energy consumption (Hook, 2020). The increase in bike-related travel also suggests an overall reduction of energy use. However, the movement away from public transportation and the increase in car-based transportation modes implies an increase in greenhouse gas emissions (Dirgahayani, 2013). Given the much larger shift towards telework in the aftermath of the pandemic, our data suggests an overall reduction in energy use and carbon emissions due to changes in travel mode. However, the increase in car usage could suggest an overall increase in emissions in the long run should people eventually move away from teleworking.

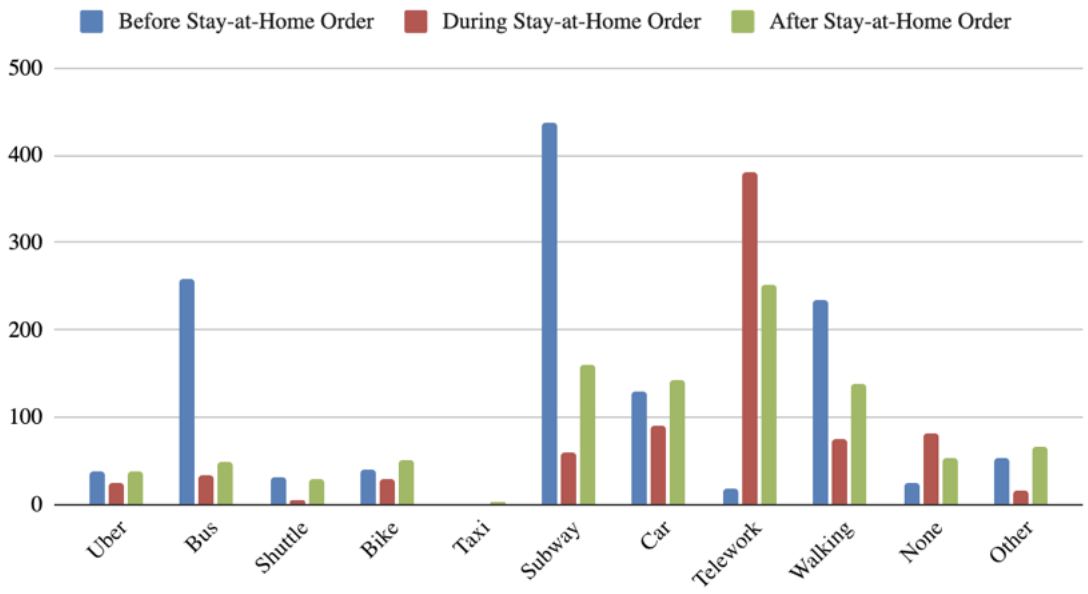

Figure 3: Travel mode choices

Respondents also noted changes in their number of daily trips as well as their trip purpose (Figures 4 and 5). They were asked to report even short trips such as running errands or going out to exercise. Prior to the pandemic, most respondents reported taking two trips per day with only a small minority saying that they did not make a daily trip. This flipped during the pandemic with the vast majority of respondents saying that they did not make a trip daily during the stay-at-home order. After the order was lifted a majority of respondents were still not making a daily trip. Fewer respondents have taken two or more trips after the start of the pandemic including after the end of the stay at home order. However, more respondents reported taking one trip after the end of the stay at home order which may be a result of people choosing to do more things in a single trip as opposed to taking multiple trips. The reduced number of trips is likely having an overall reduction in emissions and energy use. Although these gains may be offset to some degree by increased energy use within the home, studies related to the environmental impacts of telework still suggest an overall energy reduction from reduced travel (Hook, 2020).

Prior to the pandemic, the most common trip purpose was for work with around 600 respondents reporting making a work-related trip. During the stay at home order this number fell to 160 respondents which was tied for the third most common trip purpose along with bulk shopping. Instead exercising was the most common reason that respondents reported taking a trip during the stay-at-home order. After the order was lifted, work-related trips returned to being the most common trip purpose for respondents.

Exercising and bulk shopping appear to be the transportation modes that were the least affected by the pandemic. More respondents actually reported making trips for bulk shopping during the stay-at-home order versus before it was enacted and after it was lifted. Trips for dining and social/recreational purposes have seen the largest decreases since the start of the pandemic. These two purposes are likely related and may be the reason that both purposes have seen similar declines.

The survey also asked respondents to report their transportation costs to reach their workplace during the three timeframes. The average transportation cost before the pandemic was $12.26 compared to $3.06 during the stay-at-home order and $5.86 after the stay-at-home order. Overall, the pandemic seems to have reduced transportation costs which is understandable given that respondents reported traveling to work less. Most of the transportation savings are likely driven by an increase in telework which allows respondents to maintain their employment with no transportation costs. It is also possible that the lower costs are due to people losing their jobs and therefore are spending nothing on work travel, however this seems unlikely given that only 1.5% of respondents reported losing their job due to the pandemic.

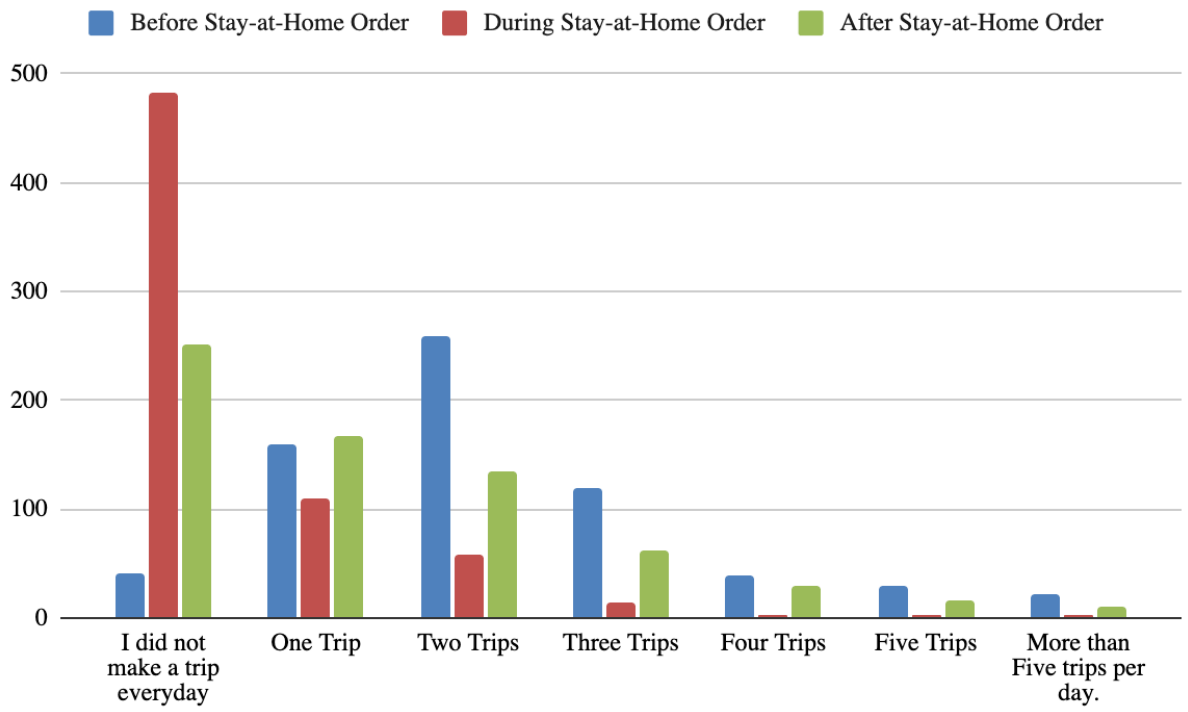

Figure 4: Travel frequency

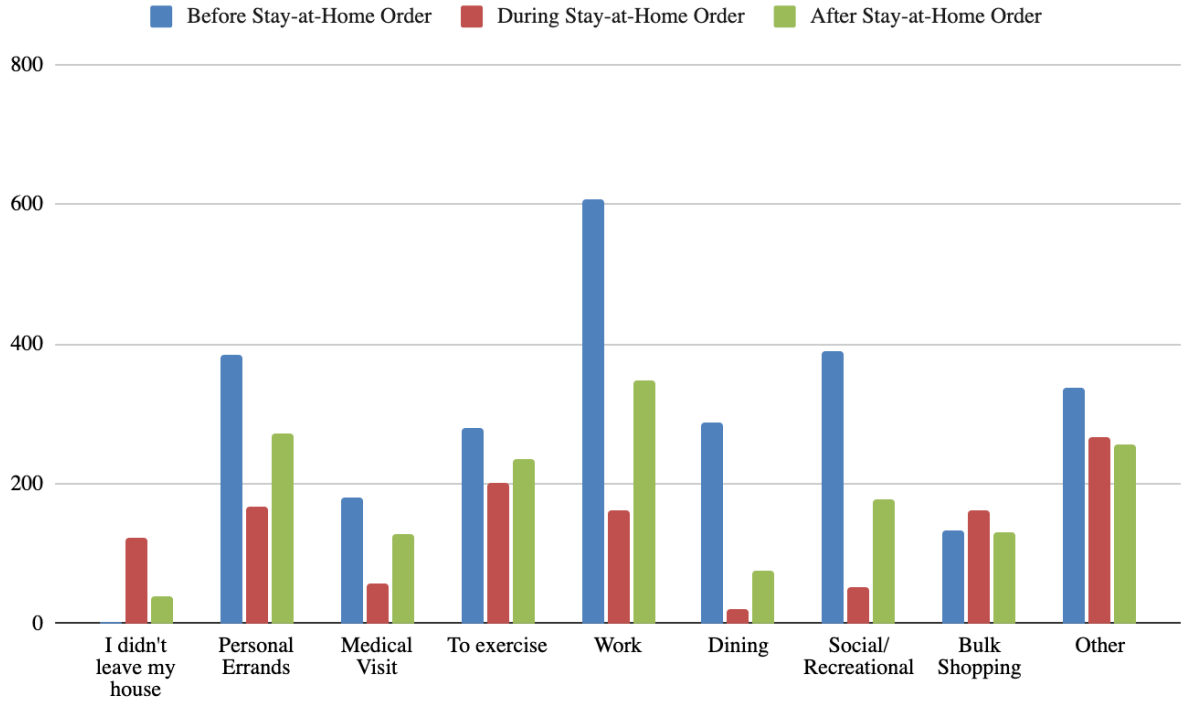

Figure 5. Trip purpose.

Switching Behavior

This section details our analysis of the switching behavior of respondents. Switching behavior refers to the tendency of respondents to change their transportation mode after a disruption (Di et al., 2017; Danczyk et al., 2017), such as the stay-at-home order in New York City in this study. Since respondents were allowed to record multiple modes of transportation, a respondent was labeled as a switcher if they changed one of their transportation modes from before the stay-at-home order to after the stay-at-home order. For example, a respondent that noted both the subway and walking as a transportation mode before the stay-at-home order and just walking after the stay at home order would be labeled as a switcher. Respondents that reported no change in their transportation modes are labeled as stayers.

Not all respondents recorded a transportation mode before and after the pandemic. Therefore not all respondents could be categorized as switchers or stayers which means that the switching analysis contains fewer observations. The table below shows some general statistics for switchers versus stayers. Of the 420 respondents that could be labeled, there were a total of 100 stayers and 320 switchers. Given the large number of switchers, it is evident that the pandemic has had a large impact on travel behavior in New York which has persisted even after the stay-at-home order was lifted.

In Table 1, an analysis of the transportation cost savings of stayers versus switchers show that switchers seem to benefit financially from changing their transportation mode. Stayers saw few savings in regard to their transportation cost with an average of $0.30 saved and a median of $0.00 saved. This is to be expected as many respondents reported using public transportation whose prices are relatively constant. Therefore the only things that could influence stayer savings are gas prices or other minor factors. Switchers on the other hand saved an average of $4.00 and a median of $2.05 on transportation costs per trip. Much of these savings are likely due to an increase in teleworking which allows switchers to work without spending any money on transportation. We would also like to point out that savings of $0.30 for stayers and $4.00 for switchers represent 9.7% and 36.9% of savings, respectively, compared to the pre-pandemic cost. Those are probably attributable to less frequent trips made and more telecommuting persisting even after the order was lifted.

The savings by switchers due to increased telework may suggest that the trend of increased teleworking will persist beyond the time frame of this study. Switchers to telework could be incentivized to continue teleworking in the long term due monetary and time savings. This suggests that there is potential for longer- term energy savings and carbon reductions with regards to transportation. Given the relatively large number of switchers as shown in Table 1, these impacts could be quite significant.

Statistics	Stayers	Switchers	Total
Distribution			
Counts	100	320	420
Percentage (%)	23.8	76.2	100
Average TNC cost per trip			
Before	3.08	10.83	13.9
After	2.77	6.83	9.6
Cost savings			
Average	0.30	4.00	—
Minimum	-5.5	-797.25	—
Maximum	22.50	450.00	—
Median	0.00	2.05	—
Percentage (%) Saved on Average	9.7	36.9	

Table 1: Travel cost

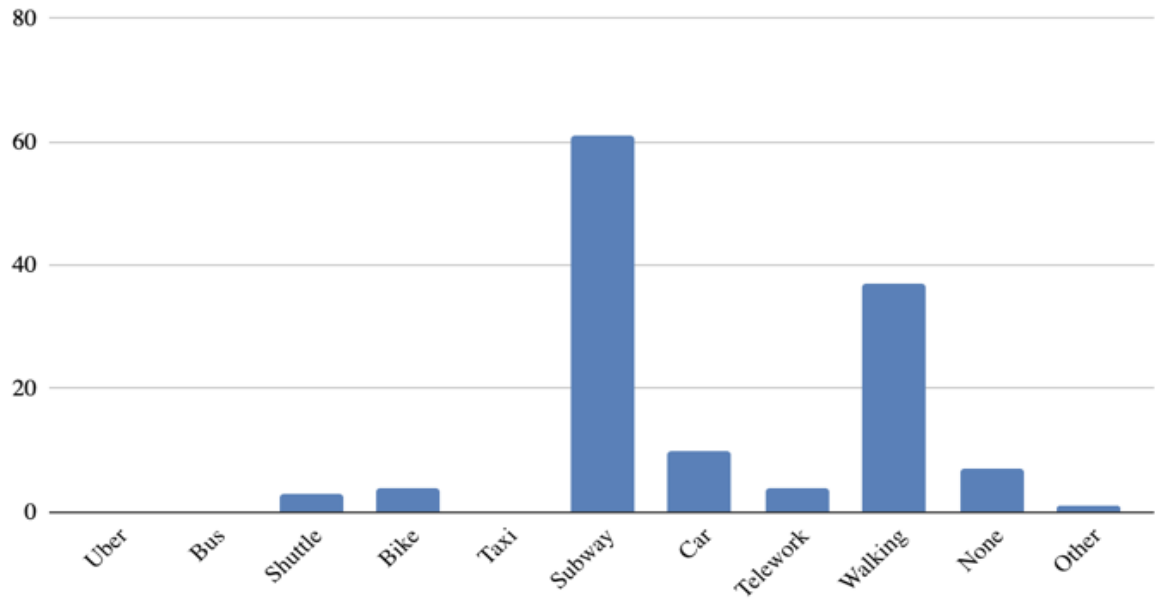

Figure 6: Travel mode-Stayer

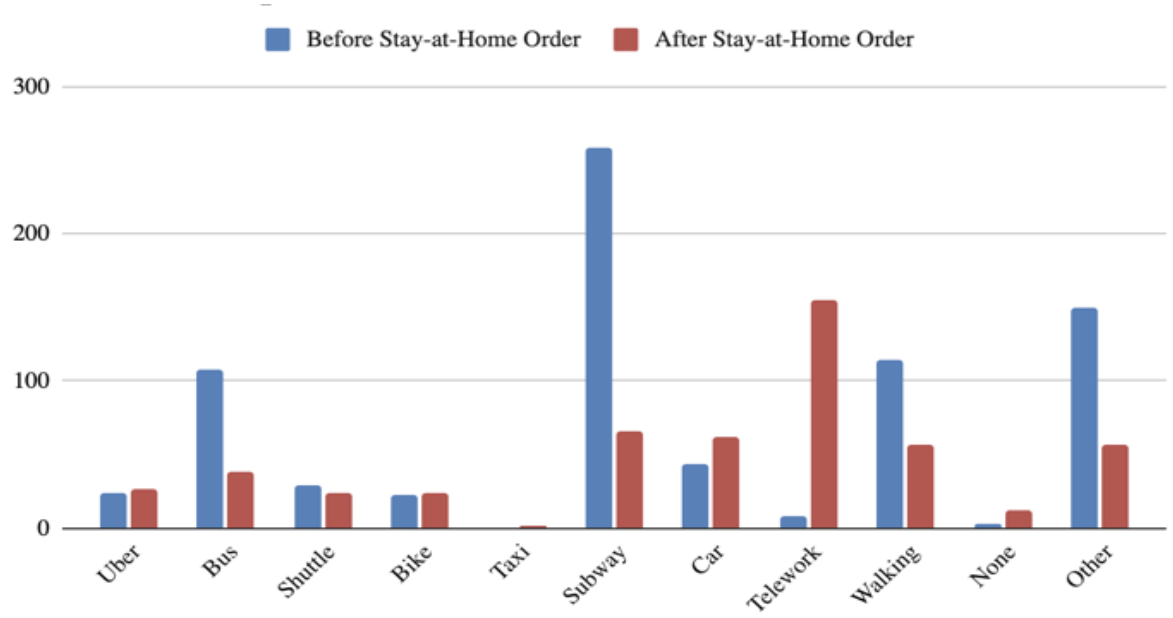

Figure 7: Travel mode-Switcher

Figures 6 and 7 show the transportation modes used by stayers and switchers, respectively. Most stayers take the subway which is likely a result of the large number of people who reported taking the subway before the stay-at-home order. Even if a large number of people switched from using the subway in some fashion there would likely still be enough for the subway to be the most common mode of transportation among stayers. The next most common transportation modes for stayers are cars and walking which were also some of the more common modes before the pandemic and are also considered safer with regards to disease transmission. Both of these factors are likely an influence on the number of stayers.

The most popular transportation mode among switchers before the stay-at-home order was the subway. Following the stay-at-home many respondents switched off of using the subway although it is still the second most popular transportation mode among switchers behind teleworking and just ahead of cars. Buses and walking also saw similar declines in users after the stay at home order was enacted. Aside from telework, cars saw the largest number of users switch to using the transportation mode. This is likely because cars allow users to travel long distances while avoiding close contact with other people. Respondents also switched to using no transportation mode which may be the result of them losing their job or perhaps an alternate form of remote work aside from telework. The increasing usage of cars has already led to worse traffic congestion, compared to the pre-pandemic level (Brachfeld, 2022). As a consequence, the more frequent encounters between cars and pedestrians and cyclists has led to surging traffic fatalities after the pandemic (Julianne, 2020). With these travel behavioral changes, the policymakers and city planners need to rethink the city planning and traffic management post the pandemic for improved traffic safety and efficiency.

Next we examine the percent of switchers versus respondent income levels to see how income may influence switching behavior (Figure 8). For the most part there does not appear to be a clear pattern between household income and switching behavior, as respondents with a household income of $40,000 and above seem to have similar numbers of switchers. The glaring exception is the bracket of respondents with an income of less than $40,000. This group has a far lower percent of switchers which suggests that income may play some role in switching behavior although the effect disproportionately impacts people in the lowest income bracket. This may be due to the fact that respondents in lower income jobs are less able to switch to telework and therefore must maintain the transportation mode they used before the pandemic.

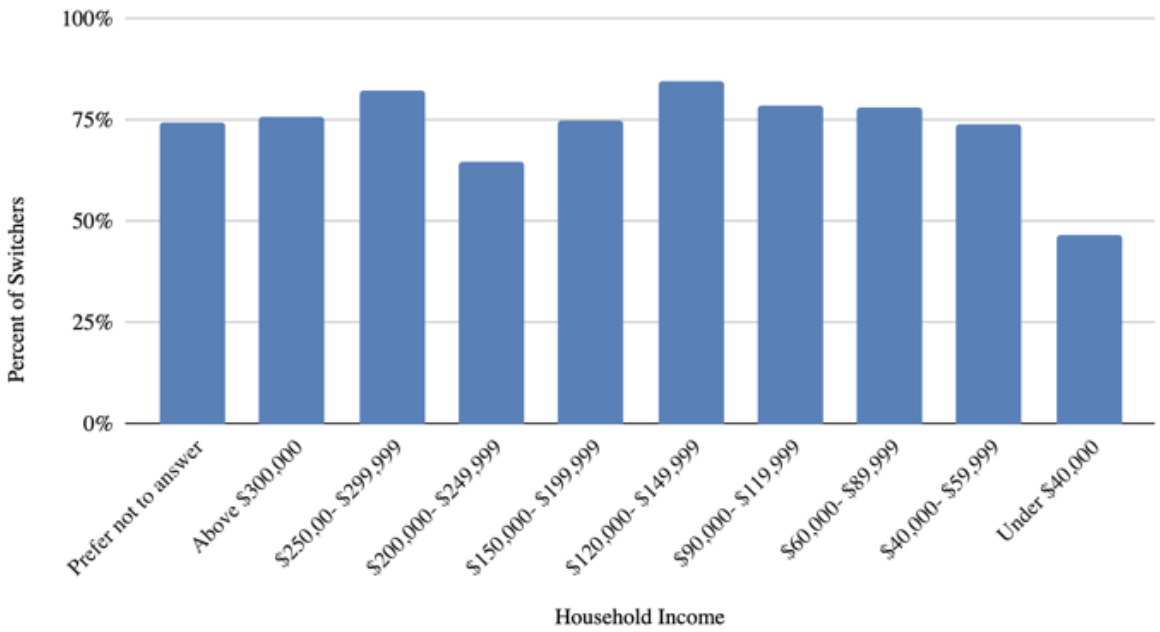

Figure 8: Percentage of Switchers

We also conduct a spatial analysis of switching behavior across New York (Figure 9 and 10). Survey respondents were asked to record their residential zip code which allows us to look at the areas of the city in which most switchers reside. The map below shows a more complete distribution of respondents by zip code. We use ArcGIS Pro for spatial visualization. The bars marked in red represent travel mode choices. It is shown that the usage of bikes and buses increased significantly after the stay-at-home order. As with other variables in this survey, the spatial distribution of switchers is likely a byproduct of the fact that this survey was administered near Columbia University which means that a large proportion of respondents are likely affiliated with Columbia in some respect. Specifically we can see that the zip codes with the lower proportions of switchers are centered around Columbia. If respondents are affiliated with the university, those closer to it may be able to rely less on public transportation and therefore would be more likely to maintain the modes of transportation they used before the pandemic.

While this spatial analysis is somewhat limited to individuals who work at Columbia University, it may have implications for the behavior of workers in different settings. Workers who reside closer to their workplace may be more likely to maintain their transportation modes after disruptions than workers who live farther away. A factor in this may be the fact that teleworking would not be as convenient for people who live close to their workplaces and they also may have chosen a residence close to their workplace specifically because it would allow them to use a more preferable transportation mode to navigate to their workplace.

Figure 9: Travel mode choices and respondents in 11 zip codes

Figure 10: Travel mode choices and median household income in 11 zip codes

Conclusion

The biggest takeaway is that people are maintaining their telework despite the fact that the stay-at-home order has been lifted. People are moving away from public transportation with subways being especially hard hit, while cars and bikes are some of the few modes that have seen an increase in usage due to the pandemic. This shift provides important implications for New York City from both an economic and environmental perspective.

The move towards telework has far reaching consequences for small and large businesses that previously relied on in-person work and frequent commuting. This shift could transform the city's economy should these new attitudes towards transportation persist long term. The move to telework, as well as a reduction in overall trips taken, has likely helped the city reduce greenhouse gas emissions and energy use in the short term. This could transform into a longer term effect if people continue to telework and commute less. This seems plausible due to the monetary savings of people who switched off traditional modes of transportation. However when this trend reverses, the increased use of cars could result in higher emissions long term if telework subsides but people continue to prefer them over public transportation.

The findings from this survey help us understand the transportation modal shifts and could assist policymakers, public transportation operators and planners, which will further help residents of the metro area get to work and school more quickly and more safely. In addition, these findings will help prepare the communities in emergency response for future pandemics and assist the public transportation planners to prepare a more resilient transit system. Although the pandemic has been declared over by the federal government, this study would shed light on the redesign of public transportation post-pandemic or if the coronavirus has a resurgence. With the rising traffic congestion and public transit still struggling to restore the pre-pandemic ridership worldwide, the environmental concerns remain. The analysis of stayer and switcher characteristics would offer insights into whom the transit system should target and how to attract these switchers back to preserve the environment with green transportation.

A limitation of this study is that the participants are disproportionately connected to the Columbia community. The potential bias could be the relatively high proportion of employees being telecommuting, in contrast to the cities' some other communities from which members had to commute to work even during the pandemic. The future direction is to compare the changes in travel patterns during COVID-19 across communities with different demographics.

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Appendix

Survey URL:
https://docs.google.com/forms/d/e/1FAIpQLSekpbJOi1CU6gK1Ute40b17yRRR7aH7C_hHi8E1KmmGKpjJyA/viewform)