Assess the Mobility and Health Impact of COVID-19 on Diverse Communities
or
Assessing the Mobility Impact of COVID-19 on Diverse Communities

Center for Transportation, Environment, and Community Health
Final Report

by
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Abstract

The COVID-19 pandemic has significantly impacted the lives of communities in many dimensions. In this research, mobility data is collected for before and during the pandemic to assess how transportation, a critical service to the community for both daily lives and the response to the pandemic, is affected while paying particular attention to equity using San Francisco, California, as a case study. San Francisco was chosen for being a diverse city comprised of communities from various racial backgrounds and economic standings and for the availability of public data. This study investigates the effects of COVID-19 on travel behavior using a Prais-Winsten model for daily bikeshare ridership over time to determine if ridership is significantly affected by demographics and COVID-19 related temporal data. The results show that trip origins in majority low-income and majority minority census block groups became more statistically significant after March 2020, which supports our hypothesis that different demographics would respond to the pandemic with their travel behavior in different ways. The importance of bikeshare membership on ridership and changes in trip durations during the pandemic are also apparent in the model. Although total ridership has recovered this year, this research aims to provide a better understanding if specific communities are increasing ridership at greater rates than others. Additionally, some groups may not have resumed their bikeshare ridership rates to pre-pandemic levels, and this research may provide insights into these scenarios to aid in future policymaking regarding bikeshare.

Introduction

The impact of the COVID-19 pandemic on the lives of communities cannot be understated. The United States has experienced an uneven response to the emergency due to its decentralized approach towards policymaking, resulting in implementing worse or insufficient monitoring of infection rates and many in the country lacking adequate medical care (Bergquist et al., 2020). Researchers have also identified that White people have been impacted at a lower rate of infections and deaths than others, while also being less likely to be an "essential worker" that were obligated to stay working at the onset of the pandemic. Researchers have studied the impact the COVID-19 pandemic has had on various aspects of transportation and the mobility of people during the pandemic responses. During the strictest periods of the lockdown because of the pandemic, it was noted that the air quality improved because of traffic drastically reducing. This observation considers weather conditions that could favor increased or reduced pollution even without a reduction in vehicle miles travelled (VMT) during the pandemic, and the analysis proved that the pandemic in combination with "shelter in place" orders resulted in improved air quality (Naeger & Murphy, 2020). However, as disadvantaged communities are less likely to have the freedom to work remotely at home, they will continue to have to travel and may not experience the same health benefits that others have experienced with the improvement in air quality in their communities. These results help to characterize health impacts and disparities these communities face relative to those that are not disadvantaged. This disparity is manifested in transportation, in which bikeshare has been touted as a preferable alternative for individuals wanting to social distance while commuting within cities (MJ et al., 2021).

In this research, mobility data is collected for before and during the pandemic to assess how transportation, a critical service to the community for both daily lives and the response to the pandemic, is affected while paying particular attention to equity using San Francisco, California, as a case study. This research aims to inspire ways to improve transportation services that promote robust responses to future pandemics and other disasters in equitable ways. As shown in Figure 1, daily vehicle miles traveled (VMT) for the city of San Francisco rapidly plummeted at the onset of the pandemic and did not fully recover to 2019 levels throughout 2020. As 2021 has progressed, the VMT of the city has been steadily climbing and approaching pre-pandemic levels (Caltrans, 2021). However, from Figure 2, transit options in San Francisco have not experienced the same recovery to pre-pandemic ridership as driving has recovered. The most popular mode, Motor Bus, has slowly increased in ridership since the initial drop beginning March 2020, but it is nowhere near the ridership before the pandemic. Similarly, the next two most popular modes, Light Rail Vehicle and Trolley Bus, are struggling to reach their prior ridership levels that now match current Motor Bus ridership (San Francisco Municipal Transportation Agency (SFMTA), 2021). Therefore, it seems relevant to further investigate the effects on ridership of alternative modes of transportation to driving and transit, such as bikeshare. San Francisco bikeshare data from Bay Wheels, operated by Lyft, is used to study the impact of COVID-19 on bikeshare ridership.

To assess the mobility and health impacts of the COVID-19 pandemic on diverse and vulnerable communities, this study measures the changes in transportation patterns in these communities during the pandemic. San Francisco was chosen due to the availability of data provided by government services and the publicly available bikeshare data. San Francisco is a diverse city comprised of communities from various racial backgrounds and economic standings. The city provides public data such as daily new COVID-19 cases and deaths on its public data platform DataSF (San Francisco Open Data Portal, 2021b; San Francisco Open Data Portal, 2021c). It is expected that the pandemic will have changed not only how much individuals travel within these communities, but also where they are traveling. With this data, the research team aims to study ridership changes with the demographics of the city to determine if ridership is significantly affected by these demographics, as well as COVID-19 related temporal data. Following the example set by prior research on time series bikeshare data (Wang & Noland, 2021b), this study investigates the effects of COVID-19 on travel behavior using a Prais-Winsten model for daily bikeshare ridership over time.

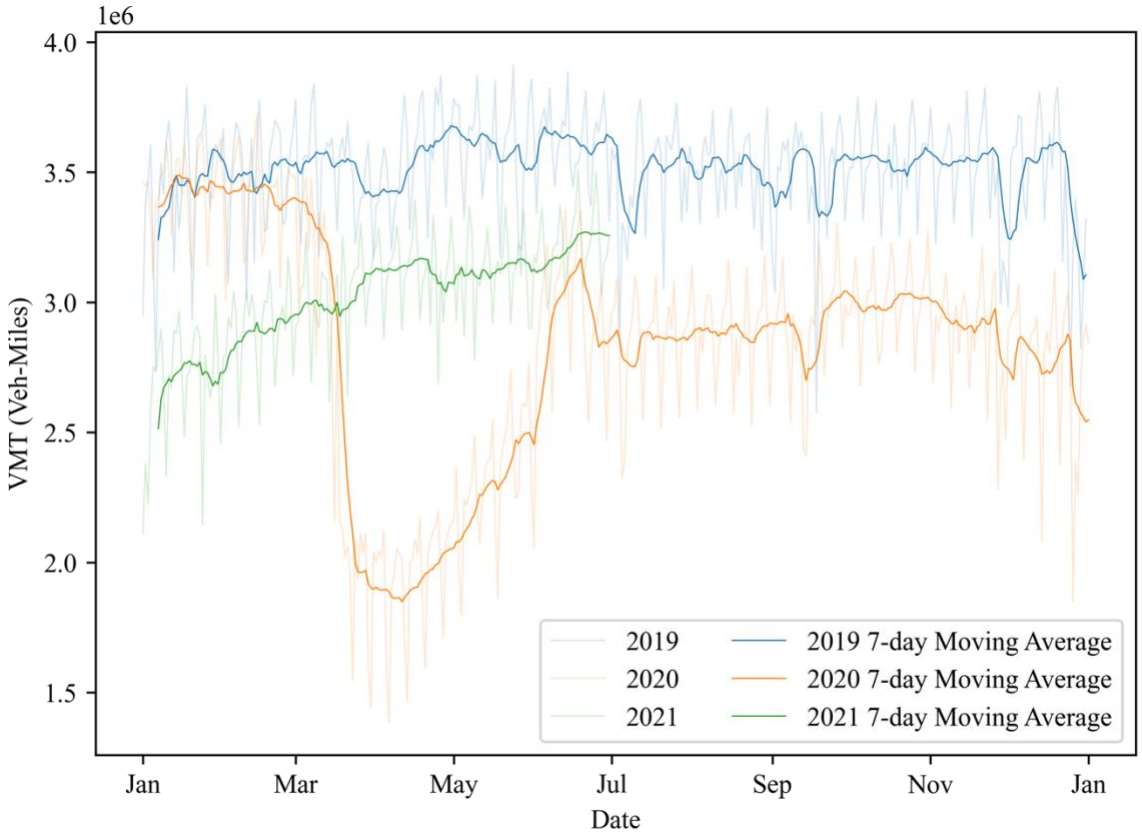

Figure 1: Daily VMT in San Francisco from Caltrans PeMS

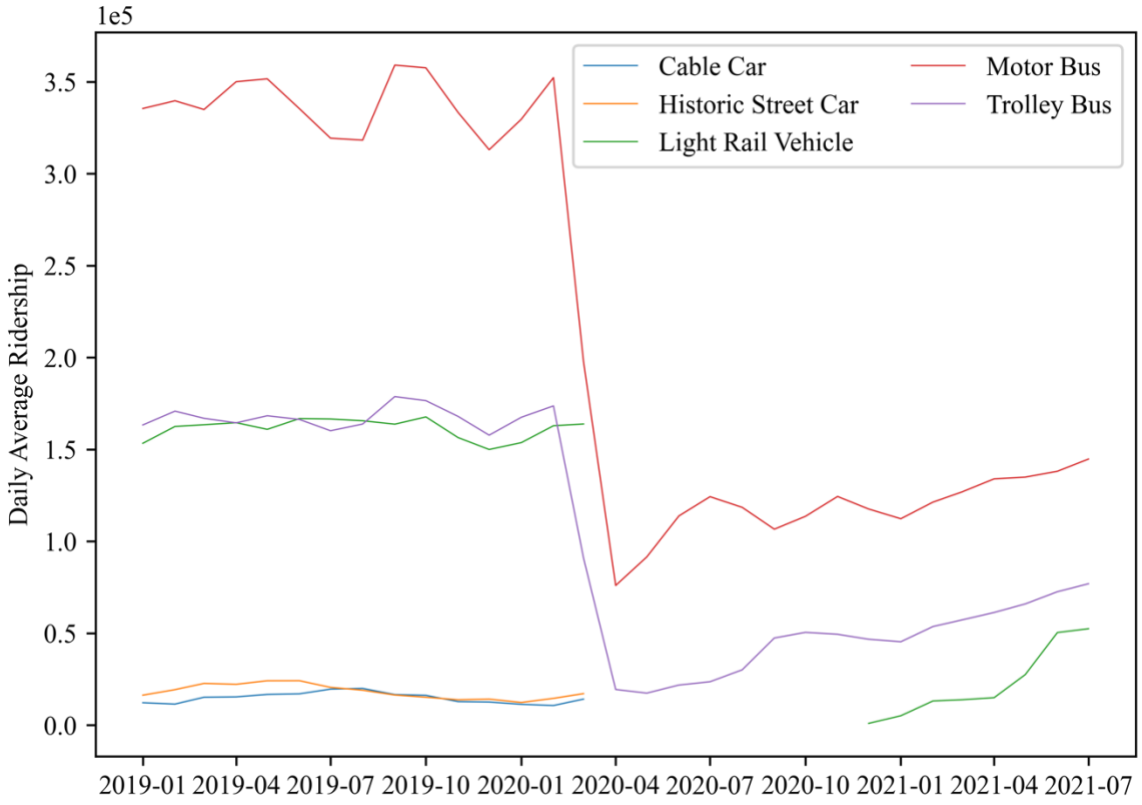

Figure 2: SFMTA monthly data for average daily transit ridership.

Literature Review

As the global COVID-19 pandemic rapidly increased in severity in the first half of 2020, researchers had already began documenting the impacts of the changes in travel behavior to public transportation and identifying areas in which further research is required (Tirachini & Cats, 2020). Specifically, researchers voiced concerns that public transportation ridership might be unable to recover from the pandemic for a variety of reasons, such as: transit agencies becoming financially unsustainable under the reduced ridership numbers, service alterations made to reduce cost and adapt to pandemic travel behavior affecting who returns to transit, and health and safety concerns with a public service after being encouraged to pursue social distancing (Tirachini & Cats, 2020). As people avoid public transit to social distance, they must seek out active transportation alternatives to replace the health benefits of using public transit that they would no longer receive. However, many have replaced these trips by driving personal vehicles, which will have consequences on the health of the population over time if this mode is not discouraged (Laverty et al., 2020; Brooks et al., 2021). Recent work studied the lag effect in COVID-19 policies implemented in NYC and Seattle, and it was determined that different transportation modes have different lag effects when responding to new restrictions imposed due to the pandemic, as well as having different rates at which demand returns for that mode (Bian et al., 2021). This research helps understand when ridership declines in response to policies such as stay-at-home orders, and when pre-pandemic ridership numbers may return.

Specifically, bikeshare during the pandemic has been identified as a resilient component of a city's public transportation network. Notably, in New York City, both bikeshare ridership and subway ridership drastically fell as the pandemic triggered lockdown policies and remote work was implemented for many job sectors. Bikeshare ridership with the Citi Bike system was able to recover from the ridership drop and is now at pre-pandemic levels when comparing January to September ridership data from 2019 and 2020. However, subway ridership has not experienced this recovery, and the subway system still offers reduced service (Wang & Noland, 2021b). Researchers have demonstrated that bikeshare trips are negatively affected by increases in COVID-19 cases, and that this impact varies with the rate of new infections as well as the city observed (Padmanabhan et al., 2021). A previous study has defined a “mobility gap” that is apparent in urban centers in the United States, where the difference between high- and low-income levels also describes how mobile an individual is due to pandemic restrictions in place (Ruiz-Euler et al., 2020). Researchers performed a spatiotemporal analysis of bikeshare trip patterns in the first few weeks of the pandemic in New York City and noted that changes in activity were related to the

demographics of the area (Pase et al., 2020). These prior studies emphasize the need for more work in identifying the role and impact of mobility options during the pandemic, and beyond.

Methodology

This analysis models daily bikeshare trips to determine how trips are affected by various variables representing spatial characteristics of the trip, the weather, and travel behavior influenced by COVID-19. The data spans the time period from January 1, 2019, to June 30, 2021, and it is split into two scenarios. The scenario "Before COVID" is from January 1, 2019, to February 29, 2020, and the scenario "During COVID" is from March 1, 2020, to June 30. 2021. In San Francisco, bikeshare has been in operation since 2017, first under Ford and then later under Lyft as Bay Wheels. Lyft provides the trip data for all trips made since 2017 in the Bay Area on the Bay Wheels website. Each trip contains characteristics such as the start location, end location, start time, end time, whether the user is a member of the service, etc. Other characteristics, such as whether the bicycle used is an electric bicycle or if the trip originates or ends at a dock instead of dockless, are not consistently recorded in the data set provided and therefore is not considered in the analysis. For this analysis, the independent variables extracted from the trip data are the average trip duration for the day found by taking the difference of the end time of the trip and the start time of the trip, the daily percentage of trips taken by members, and whether the trip is taken on a weekend or weekday. Trips with negative durations are considered outliers and filtered out. Similarly, trips with a duration longer than 6 hours are also removed as they were also treated as outliers in previous studies (Teixeira & Lopes, 2020; Wang & Noland, 2021a). Trips that did not originate in San Francisco were filtered out by using the San Francisco County boundary (San Francisco Open Data Portal, 2021a). Aggregated daily ridership data collected is shown in Figure 3, where the drop in ridership following March 2020 and the slow recovery to pre-pandemic ridership is evident. However, just as previous research has shown in New York, Boston, and Chicago (Padmanabhan et al., 2021), average trip duration for bikeshare in San Francisco has increased during the pandemic, as seen in Figure 4. Notably, as trip duration has increased, the percentage of daily trips made by members has declined.

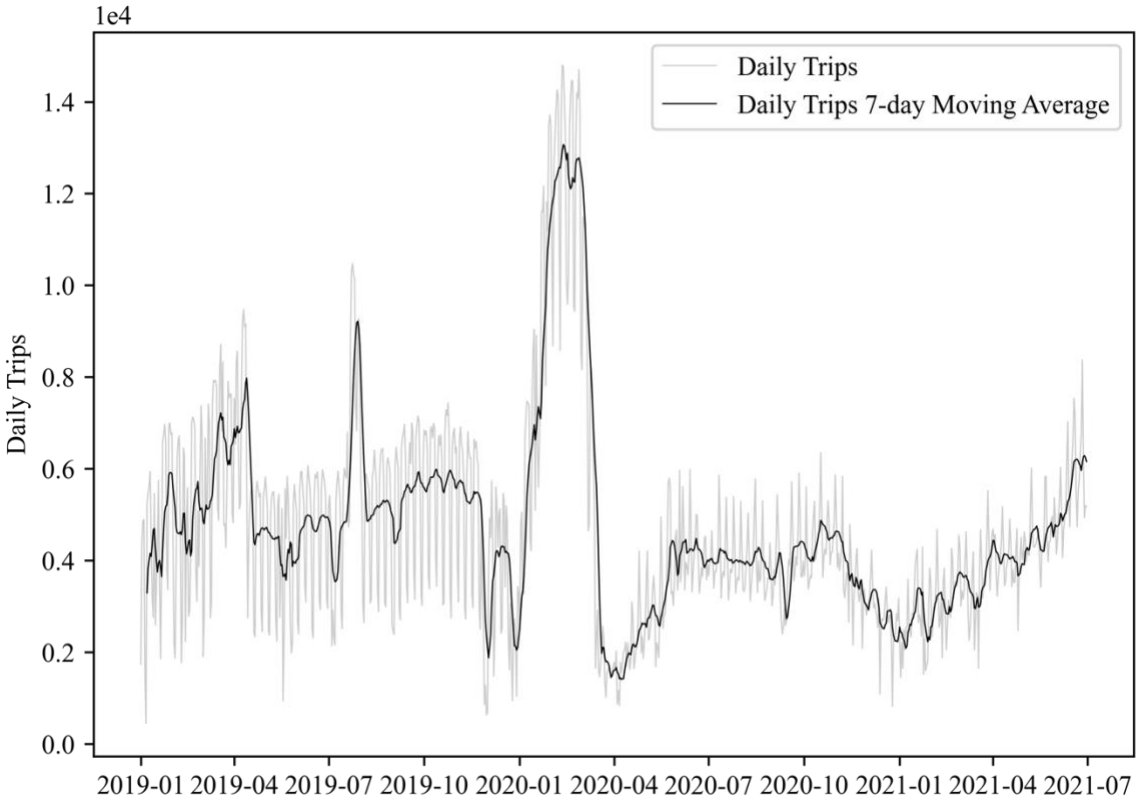

Figure 3: The total number of Bay Wheels trips per day in San Francisco with a 7-day moving average.

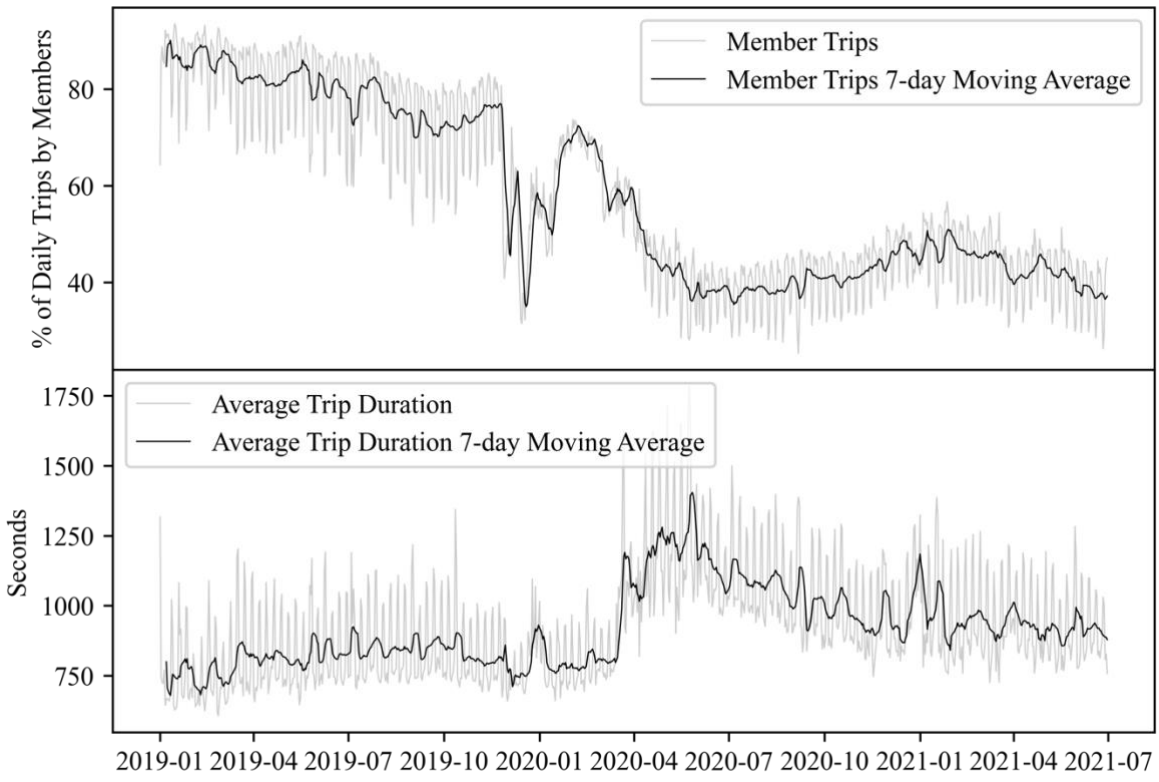

Figure 4: The percentage of daily Bay Wheels trips made by members and the daily average trip duration.

To identify community characteristics, U.S. Census Bureau data was collected about household income and race for each census block group. The American Community Survey (ACS) 5-Year data for the year 2019 was chosen to represent the demographics of the communities over the analysis period (United States Census Bureau, 2020). The census block group is the smallest geographical unit available for the estimated data based on periods of survey results. This data was selected to identify trips originated and terminating in locations that are considered majority low-income or majority minority to consider if the travel mode responses to the pandemic are equal across demographics. Using household income data, if more than fifty percent of the households in the block group are classified as low-income, then that block group is considered low-income by this analysis for determining if the trip originated or terminated in a low-income location. For this analysis, low-income is defined as all household incomes at or below the census $75,000 to $99,999 income threshold (City and County of San Francisco, 2021). Similarly, if less than fifty percent of the population identifies as “White only”, then the census block group is classified as majority minority. The percentages of daily trips by these categories are shown in Figure 5.

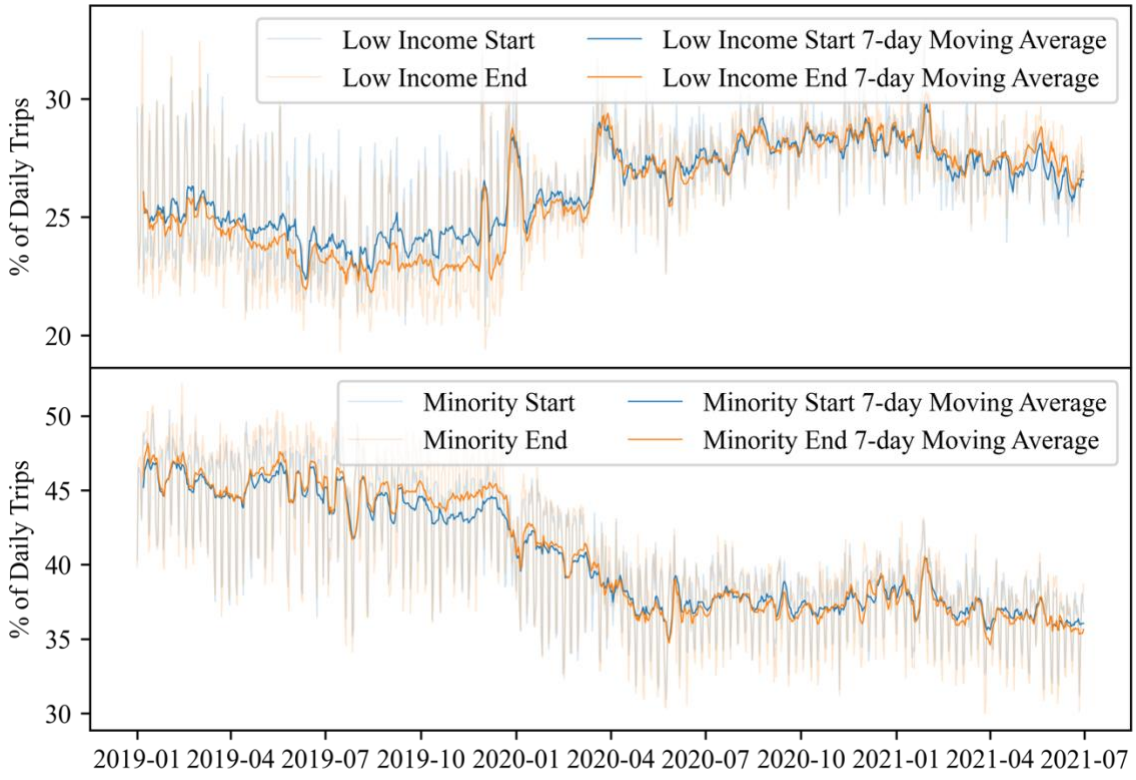

Figure 5: The percentages of daily trips starting and ending in low-income or minority census block groups.

In addition to characteristics of the trip, there are variables in both models to account for daily weather conditions. Using the National Oceanic and Atmospheric Administration (NOAA) Climate Data Online dataset, information about the daily precipitation, maximum temperature, and minimum temperature for each day in the study period was collected (NOAA, 2021). Weather data was collected from Downtown San Francisco to represent the conditions across the entire city. The weather data used in the analysis are shown in Figure 6.

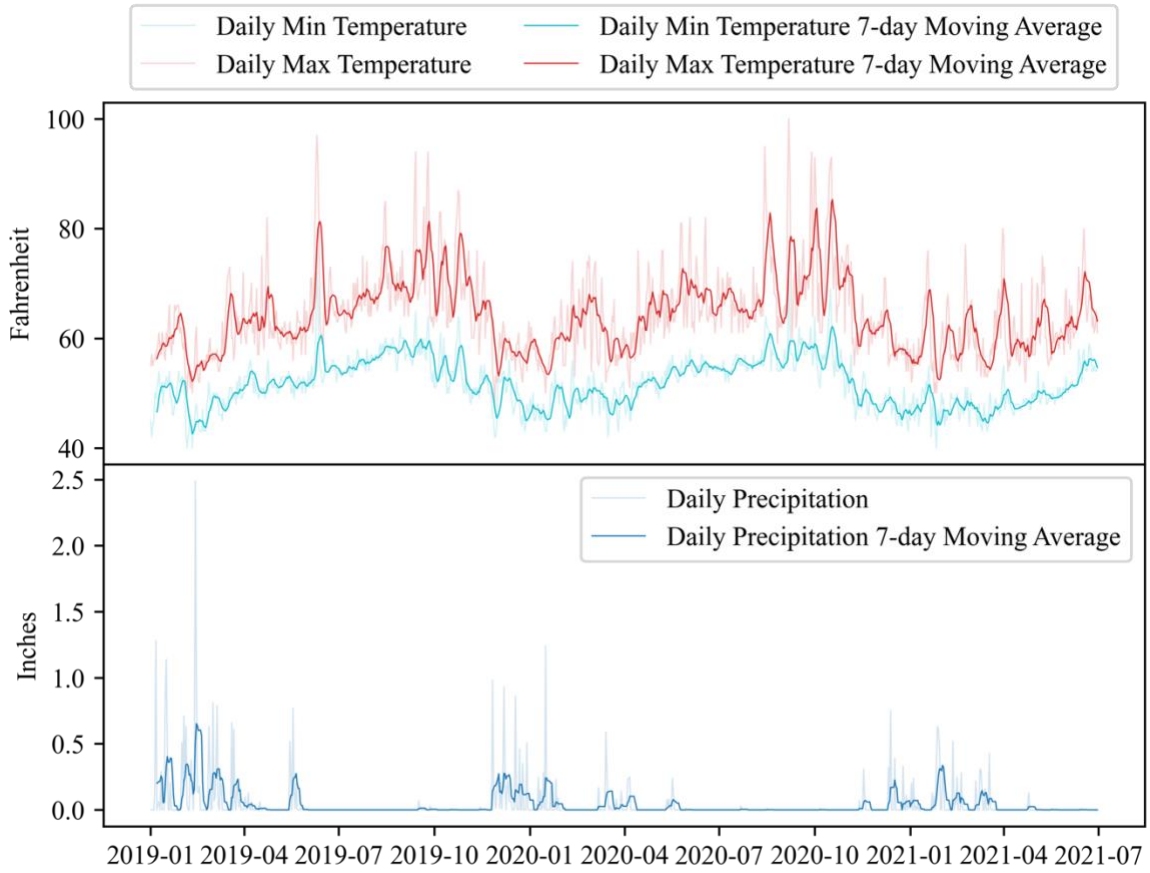

Figure 6: NOAA temperature and precipitation data for San Francisco with a 7-day moving average.

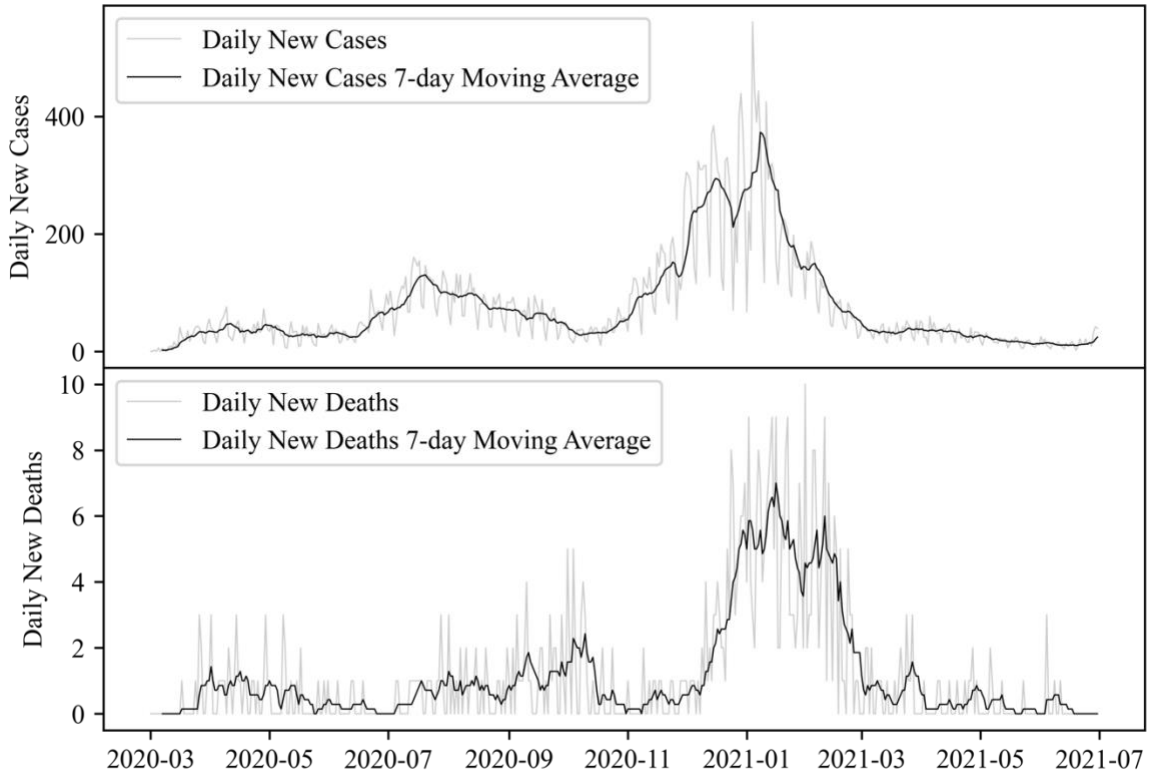

Figure 7: COVID-19 Daily Cases and Deaths in San Francisco with a 7-day moving average.

For the model representing the scenario During COVID, additional variables were considered to represent the impact of the pandemic on ridership. First, DataSF was used to obtain data for daily new COVID cases (San Francisco Open Data Portal, 2021b) and daily new COVID deaths (San Francisco Open Data Portal, 2021c). The daily new cases and deaths are shown in Figure 7. In addition, the Apple Mobility Trend Reports data (Apple Inc., 2021) was used to represent the daily relative volume of mode share between driving, transit, and walking during the pandemic. The change in mode choice between driving, transit, and walking relative to a pre-pandemic baseline volume can be seen for the city of San Francisco, California, in Figure 8. The data from the Apple Mobility Trend Reports contain relative volumes of daily trips for each mode for specific cities, counties, and countries using anonymized Apple Maps directions requests on iPhones. The data shows a shift in mode choice towards driving or other alternatives away from transit and walking during the pandemic. Bikeshare is often considered as an alternative to driving in the city, and it is sometimes expected that it replaces or is chained with transit and walking trips. Dramatic changes in these volumes by mode may help explain some of the changes in bikeshare ridership during the pandemic. Finally, variables used to explain travel behavior during the pandemic were included by using the data from Google's COVID-19 Community Mobility Reports (Google, 2021). This data (Figure 9) uses anonymized data collected from users of the Google Maps platform to help explain how people are moving during the pandemic relative to a pre-pandemic median value between January 3, 2020, and February 6, 2020. Changes in shopping behavior and remote work as a result of pandemic policies will manifest in this data.

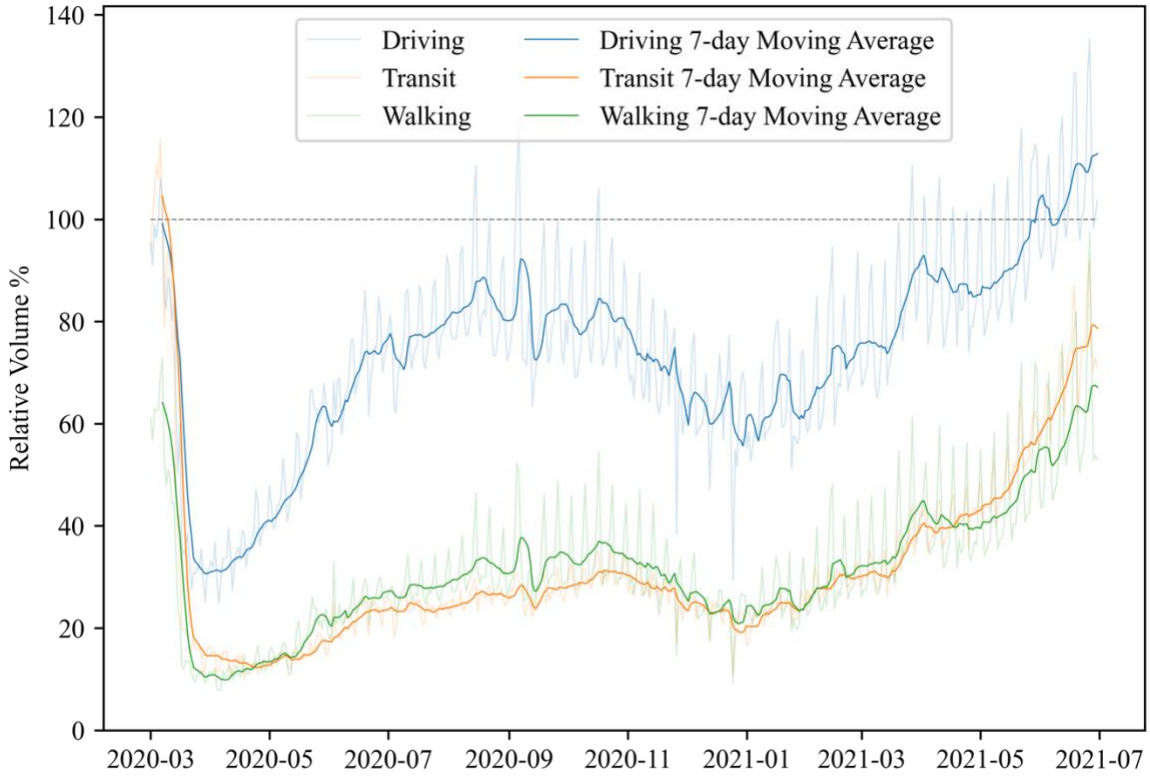

Figure 8: Volume of trips per mode in San Francisco relative to baseline volumes recorded on January 13th, 2020.

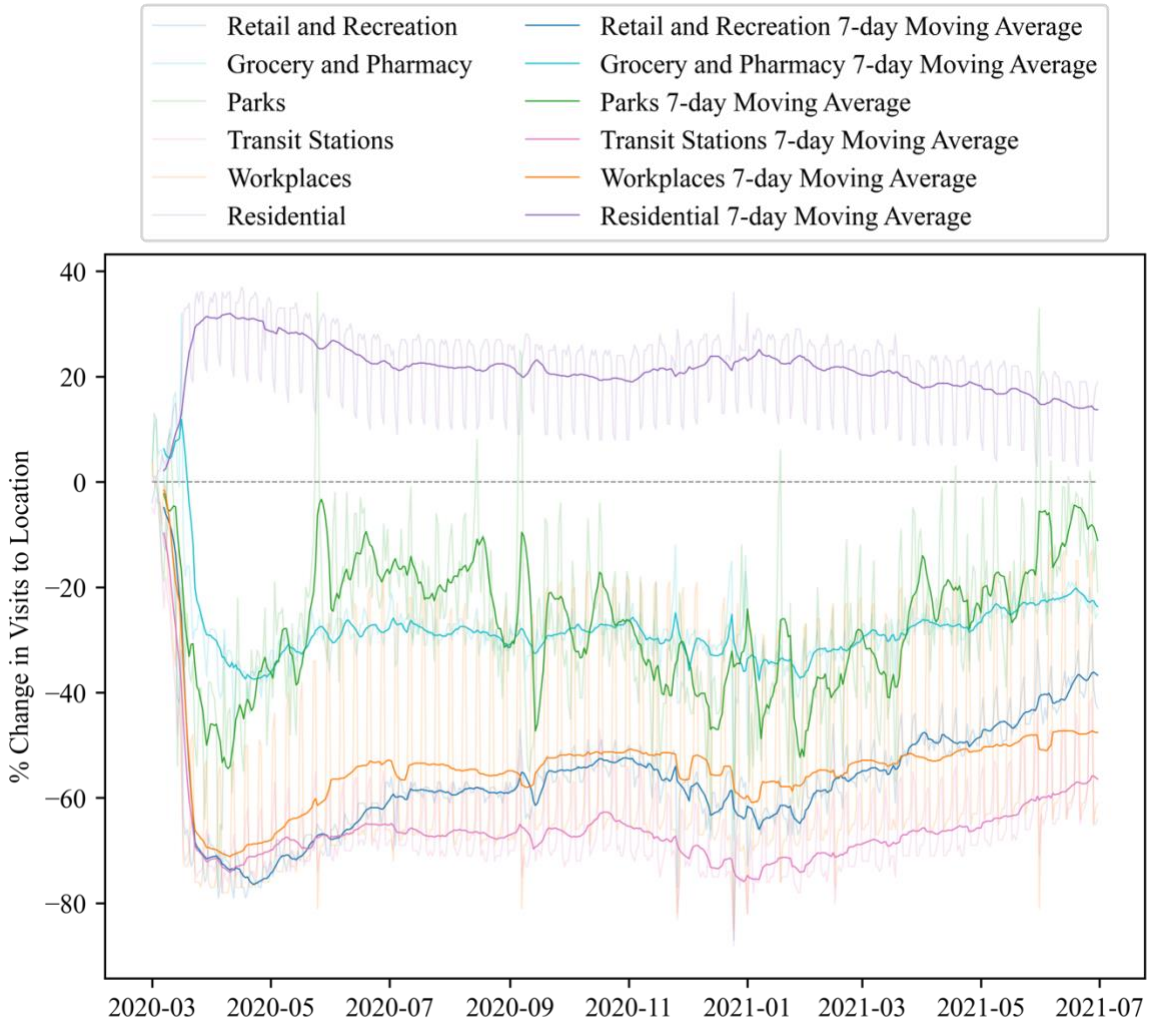

Figure 9: Percent change in visits to location types relative to a pre-pandemic baseline by Google.

Results and Discussion

The results of the Prais-Winsten models are shown in Table 1. This model was selected due to the data having autocorrelation in the residuals, violating an assumption of linear regression. This autocorrelation is shown to exist with a Durbin-Watson test, the results of which are shown in Table 1. The test statistics for the Durbin-Watson test are originally less than 2 and close to 0, therefore there is a positive serial correlation. The transformed test statistics after running the Prais-Winsten models are much closer to 2 (Zach, 2021). When comparing the two models, we can observe that some variables change their influence on the number of daily trips with the introduction of COVID-19. Trip origins in majority low-income and majority minority census block groups became more statistically significant after March 2020, which supports our hypothesis that different demographics would respond to the pandemic with their travel behavior in different ways. Both the pandemic, a low-income area was negatively correlated with the number of trips and decreases the total number of trips. This is even more true during the pandemic. The trip destination being in a majority low-income or majority minority census block group is no longer significant in the During COVID model as it was in the Before COVID model. Not only is it less significant, but before COVID, destinations in majority minority census block groups were a positive influence on the number of trips; during the pandemic it reduces the number of trips. Also, the percentage of daily trips by members also became statistically significant and more negative. This aligns with the observations in Figure 4, where the percentage of number of trips by members of the bikeshare service decreased since the start of the pandemic. However, precipitation and temperature variables became less significant during the pandemic. This could be a result of the addition of new variables to the model. The day being a weekend still suppresses the total number of daily trips in both models and is statistically significant for both. Average trip duration became a positive influence on the number of daily trips during the pandemic compared to before. This matches with other research results that show that users are taking longer bikeshare trips now after the pandemic began.

Table 1: Results of the Prais-Winsten models for before COVID and the time since COVID arrived.

	Before COVID		During COVID	
Variable	Coefficient	t statistic	Coefficient	t statistic
(Intercept)	1814.7605	(0.792)	6333.2183	(5.509) ***
Average Trip Duration	-0.2301	(-0.322)	0.4600	(1.457)
Origin in Low-income	-2798.5158	(-0.695)	-4441.1030	(-2.422) *
Destination in Low-income	-9210.8652	(-2.428) *	-2703.6717	(-1.400)
Origin in Minority	-1550.4265	(-0.454)	4180.1721	(2.375) *
Destination in Minority	15035.3241	(4.540) ***	-2768.1417	(-1.526)
% Trips by Members	-111.5370	(-0.123)	-4761.1429	(-6.352) ***
Weekend	-1131.6845	(-6.870) ***	-1682.8965	(-7.687) ***
Daily New COVID Cases	-	-	0.5324	(1.350)
Daily New COVID Deaths	-	-	11.2236	(1.069)
Relative Volume Driving	-	-	3.6801	(0.787)
Relative Volume Transit	-	-	46.1574	(7.372) ***
Relative Volume Walking	-	-	7.6247	(0.885)
% Change in Retail and Recreation	-	-	-71.7386	(-9.361) ***
% Change in Grocery and Pharmacy	-	-	36.8815	(8.759) ***
% Change in Parks	-	-	15.3908	(5.402) ***
% Change in Transit Stations	-	-	36.3337	(4.108) ***
% Change in Workplaces	-	-	11.0081	(1.947) .
% Change in Residential	-	-	-64.2332	(-4.801) ***
Precipitation	-2314.3250	(-14.874) ***	-455.1485	(-2.301) *
Maximum Temperature	51.9263	(6.218) ***	7.1801	(1.962) .
Minimum Temperature	-30.4564	(-1.729) .	4.9870	(0.668)
Signif. codes: 0 ‘ *** ’ 0.001 ‘ ** ’ 0.01 ‘ * ’ 0.05 ‘ . ’ 0.1 ‘ ’ 1				
Number of Observations	425		487	
Adjusted R-squared	0.8143		0.8474	
Durbin-Watson (original)	0.7763		1.138	
Durbin-Watson (transformed)	2.165		1.991	

Conclusions

Bikeshare has become an increasingly important mode of travel that can help replace vehicle trips to reduce greenhouse gases from the transportation sector and improve the health of people by increasing daily activity (Laverty et al., 2020; Brooks et al., 2021). However, COVID-19 has impacted ridership levels across demographics, and this impact may not be felt equally. Although total ridership has recovered this year, this research aims to provide a better understanding of how ridership is recovering, and if specific communities are increasing ridership at greater rates than others. Additionally, some groups may not have resumed their bikeshare ridership rates to pre-pandemic levels, and this research may provide insights into these scenarios to aid in future policymaking regarding bikeshare. Notably, the results show that majority low-income census block groups are more significant as a trip origin during the pandemic as opposed to being more significant as a trip destination before the pandemic. Despite these census block groups being a negative influence on bikeshare ridership, this signals a change in ridership behavior that may persist in the future. Policymakers and planners may want to pay closer attention to the changes in who is riding bikeshare during and after the pandemic as opposed to before, because this may warrant changes in incentives for bicycling or a reconsideration of future cycling infrastructure. Precipitation and maximum temperature influence ridership differently during the pandemic compared to before. Rainy days still discourage bikeshare trips, however it is less important. Similarly, warmer weather is still a positive influence, but not as strong of an influence. This may be due to the prevalence of remote work during the pandemic. If bikeshare is a mode of commuting to work in the city, these trips are now reduced except for essential workers. Also, during bad weather, a commuter might search for an alternative to cycling to stay warm or dry. However, if bikeshare is more influenced by the introduction of remote work, and more trips are taken for leisure or chores, the decision to bike that day may be made regardless of the weather. An increase in leisure trips may explain the positive influence of trip duration during the pandemic, as opposed to before when longer trips were less frequent.

COVID-19 brought more attention to policies regarding slow streets, open air dining, and removing passenger vehicles from streets to provide more infrastructure for bicycling and walking. This research aims to aid in making these decisions. Future work should incorporate more spatial data to characterize the destinations that these bikeshare trips might be made for, using land use data. This may be especially important for bikeshare trips during the pandemic as cities have begun introducing slower streets and safety measures for cyclists and pedestrians, as well as closing streets to passenger vehicles and allowing for outdoor dining and parklets in the streets.

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