

A Case Study of COVID-19 Impact on Public Transportation Ridership in Seattle

— From Social Demographic Perspective

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Abstract

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From the beginning of 2020, the coronavirus has caused varying degrees of impact on countries around the world. Many cities all over the globe have implemented shutdown policies to curb the spread of the virus. Economic shutdowns, telecommuting, reducing outings, and maintaining social distancing have become the new normal in people's lives. However, the negative impacts are not evenly distributed among citizens; the disadvantaged groups faced more challenges according to the existing studies. The lack of stable income and serious diseases have caused a heavy negative impact on people's lives. This paper focuses on the pandemic impacts on bus ridership and people's lives in Seattle based on social demographics. The result shows that each route has experienced a sharp ridership drop. However, it tends to remain at a relatively higher level within the neighborhoods with lower income and a higher proportion of ethnic minority populations.

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Introduction

The widespread pandemic of COVID-19 all over the world has caused a series of problems, which not only caused a heavy blow to public health but also caused great challenges to social economy and social equity. Many industrial sectors, including manufacturing, tourism, and retail, have suffered severe performance declines. Among them, the public transportation sector is one of those that have been affected deeply because of the pandemic impact. The ridership and fare revenue has dropped significantly in all means of transport. For instance, Canada experienced an approximately 52% reduction in transit activities because of COVID-19 from mid-March to the end of April (Google, 2020).

In one word, the whole world has experienced big challenges and huge losses since the beginning of the year 2020. COVID-19 has significantly impacted people's lives and has created an unprecedented scenario as most of the world is locked down. Businesses, government, and private institutions have been kept closed for a while. In addition to these visible impacts on the economy, the coronavirus has also caused an invisible and serious blow to the existing achievements in equity. Seeing from the existing studies, many of those suggest that the vulnerable group, who may suffer from physical, mental, or social disadvantages, can have a higher positive rate of COVID-19 compared with the others. These people have been more affected by the pandemic and have a higher unemployment rate during the shutdown period. Because vulnerable groups usually rely more on public transportation for their daily commute, they are more likely to be exposed to the virus and be infected during the ride.

In the context of the drastic reduction of bus frequency, the daily travel of those who do not have other alternatives has been greatly affected, which indirectly caused them to lose their jobs and

lower their income levels. The purpose of this paper is to study the pandemic impacts on bus ridership in Seattle. In addition, the paper also intends to explore which groups of people are more dependent on buses by studying the related social demographic factors, including median household income, age groups, and ethnic composition of residents in the areas where the routes operate.

Literature Review

The focus on accessibility, mobility, transportation justice, and transportation equity has now become a cliché in the study field of transportation planning. However, previously, transportation planning goals were almost entirely mobility-based, with a focus on congestion reduction and time savings for motorists, and safety. That was partly due to the considerations concerning with equity are not enough operationalized in urban transportation planning or in the value and goals of the Capital Improvement Projects (Manaugh, Badami, and El-Geneidy 2015, 167); it has been a tough task for a long time. Referencing the study of equity in transportation Network Design Problem (NDP) by Caggiani et al. (2017), the NDP is one of the most popular optimization problems regarding transportation planning. As equity refers to the distribution of impacts and whether that distribution is considered fair and appropriate, however, it is commonly related to economic factors only. To enrich the means of transportation and increase accessibility, especially the lives of those who must rely on public transportation to become more convenient, it is particularly important to improve equity in this process.

Looking back to the research taken in Western countries, the existing study (De Barbier 2017, 1103-1104) pointed out that transportation planning was at first beneficial to the white people living in suburban areas. As the cities developed, the benefits and burdens of establishing public

transportation systems were still not evenly distributed among the citizens. Federal law equity requirements have not been well translated into transportation equity in practice. It is the responsibility of the local governments and planners to balance the benefits and burdens among its citizens. For a long time, there have always been long-standing interests for planners to improve the conditions faced by vulnerable groups. That always refers to the senior citizens, people of color, low-income people, etc. The topic can be found in several transportation studies or literature, the problems are coming with a keyword or the phrase “transportation equity”. In the perspective of social equity, social vulnerability refers to the demographic and socioeconomic factors which are related to a community’s ability to prepare, respond, and manage urgent events; in other words, the vulnerability to some extent shapes a community’s resilience (CDC, 2018). Therefore, even in the same community, the impact of urgent disaster or events can be different, which may also be inequitable and fall largely along racial and economic lines (Flanagan et al. 2011, 16). When it comes to transportation planning and constructions, these can cause huge differences in the equity perspective. As people rely on their means of commuting for food, jobs, recreation, and all the other forms of demands in daily life; and among all demands above, the access to opportunities is widely accepted as the most important benefit of a transportation system. The studies on transportation equity are also commonly related to the differential share of benefits, burdens, and all the other potential externalities, which are caused by transportation planning and infrastructure, among citizens and different communities (Karner et al. 2020, 441-442). It is widely acknowledged that there are disparate impacts across the demographic groups, more burdens and difficulties are faced by low-income groups and people of color, it can get worse when these two features overlap.

In the United States, the vulnerable groups are bearing disproportionate displacement burdens caused by public transit infrastructures like highways, toll bridges, and other constructions. In Lovell's dissertation (2012) on the case of West Seattle about transit planning, it demonstrates that public transit agencies face difficult decisions about how to allocate transit infrastructure and service to balance competing priorities including geographic coverage, equity, and maximizing ridership and efficiency. By applying comparative analysis on different groups and performing quantitative analysis with the data from King County Metro, the findings indicate that transport disadvantaged communities are more likely to rely on public transportation. According to Fan et al. (2012), their study topic was the impact of light-rail implementation on labor market accessibility, the study performed both descriptive analysis and regression analysis on the impact of transit services on job accessibility among different groups and suggests that a massive transit system can improve the accessibility, and the vulnerable groups can get benefits from that. A similar study, which was aiming at analyzing the social equity of the US public transportation system based on job accessibility, that taken out by Yeganeh et al. (2018) suggests that, throughout the 45 largest Metropolitan Statistical Areas, except a certain MSAs, it is obvious that the access to jobs by taking public transportation is generally higher for low-income and non-white populations, who are generally regarded as the vulnerable groups. Besides, the study also illustrates the finding that public transportation has a higher attraction to those populations, which means the disadvantaged groups rely largely on the public transportation systems to save money and complete their daily routines.

Except for the studies and literature that are performed before the pandemic of COVID-19, there is also a number of research focusing on the additional influences on social equity that may be caused by the COVID-19. As most of the major cities all over the world have experienced

'lockdown' in the first and second quarter of 2020, it caused heavy losses on the economy across the world. The lockdowns left a deep impact on a lot of sectors, including the manufacturing sector, tourism sector, retail sector, etc. Besides, with the negative influence of international travel restrictions in many countries, the global economy, as well as the economic activities in North America, have experienced a huge loss since the beginning of 2020 (Gray 2020, 239). Among all, the transportation sector is one of those that has been influenced most, because the shutdowns and travel bans have limited and changed people's mobility behaviors to a great extent (Fatmi 2020, 270-271). In Nižetic's study (2020) on the air transport industry, it suggests due to the numerous travel restrictions implemented in airline transport during the pandemic of COVID-19, the reduction in the number of flights in the EU region reaching the peak at more than 89% in April 2020. The losses were huge; however, the travel bans contributed a lot to implement the spread of coronavirus among countries on different continents.

Apart from the sharp reduction in air transport ridership, all means of public transportation have experienced a severe decrease in ridership during the time of the pandemic. With the consensus in the 'stay home stay healthy' order, people have reduced the unnecessary outgoings from early March, therefore, many major metropolitan areas have experienced a severe reduction in public transportation services. People who are used to rely largely on public transportation and have fewer commute alternatives are largely influenced, as the requirement from Centers for Disease Control and Prevention (CDC), social distancing only allows a few people to share the service at the same time, which means the buses are limited to 12-18 passengers depending on the size of the coach to support physical distancing and to prevent the spread of COVID-19. A study in Korea analyzed the changing trend of ridership in the subway in Seoul, Park (2020) applied data of the Seoul Metropolitan Subway network between January 1, 2020, and March 31, 2020, and

the result suggested that the drop rate was high and reached a peak in February, while it slightly increased in March. The trend indicates that people who rely largely on public transportation have a higher risk of being indoors and exposed to coronavirus, and they need stronger support to reduce the reliance on public transportation.

According to the report from Congressional Research Service, due to the service reduction and free-ride policy (in some places, like D.C, Seattle), the COVID-19 pandemic has reportedly resulted in a swift and large loss of public transportation ridership and fare revenue. In the early days of the crisis, New Jersey Transit had experienced an 88% loss of ridership; the situation was quite similar in New York and Bay Area, the former one had a 60% drop in ridership while the latter even had a 90% drop. The reduction was not limited to the geographic region, despite the metropolitan areas in the East and West Coast, Denver's Regional Transportation District also had a 60% loss in ridership. In King County, the transit operation during the pandemic time was not optimistic as well, the daily drop rate in ridership reached a peak of nearly 80% in late April and early May, and the estimation of loss from farebox is about \$80 million. According to John Resha, who is the Metro assistant general manager for finance and operations from King County Metro, the forecast also suggests that there will be a huge loss in revenue this year, which is approximately to reach \$185 million. Besides, the trend of revenue loss seems to be continuing as the COVID-19 is still influencing people's life and macroeconomic activities in the long term.

There are several studies that focused on the pandemic impact on vulnerable populations across the world, a study performed in the UK brings together data that are related to existing dimensions of inequalities, including employment rate, education background, investment in health, gender, and ethnical groups (Blundell et al. 2020, 292-294). Oleschuk (2020) performed a case study in Canada, which studies gender equity considerations for tenure and promotion

during COVID-19. It emphasizes that it is not a piece of news that the inequalities are shaping women's and men's academic careers differently. During the pandemic times, the inequality seems more obvious, for instance, remote working and a lack of childcare, women were bearing more pressure from both family and their professional career lives. A group of researchers studied the pandemic impacts on the indigenous people living in New Zealand, which suggests that the number of positive cases in COVID-19 among Maori people is much higher than that of the white (McLeod et al. 2020, 253-255).

Looking back to the study taken in the United States, Gaynor and Wilson (2020) investigated the disproportionate impact of COVID-19 on vulnerable populations in the United States, especially African Americans. Not surprisingly, the result is similar to the Maori people's study. The studies have examined that the pandemic health crisis together with the impact of economic lockdown has deteriorated the existing inequitable problems and caused new fissures in the community; vulnerable groups are suffering from more serious problems caused by the negative chain reaction of COVID-19. Similarly, Wright and Merritt (2020) studied the impact of COVID-19 with the case of African Americans. The preliminary data suggest that the pandemic of COVID-19 is infecting and killing African Americans in the United States at disproportionately high rates. The paper mentioned a series of perspectives, from health, food, finance, to public engagement. The people of color, especially those who earn less and have lower education backgrounds lack a platform to express their needs, and the situation was getting worse during the pandemic. Even though it is too early to sum up all the impact of the COVID-19, it is certain that the negative impact of the pandemic on the whole society is huge.

Materials and Methods

Research Question

According to the existing literature, the negative impact of COVID-19 is shared disproportionately among the population. Therefore, the hypothesis is that disadvantaged groups have been more severely affected by the pandemic. They can depend more on public transit even during the pandemic shutdown. In addition, those neighborhoods that remained higher ridership may have more low-income populations or more ethnic minority groups living in.

The purpose of this paper is to study the pandemic impacts on bus ridership in Seattle. Which routes have experienced more decrease in ridership? Which census tracts do these routes service? Besides, does the change in ridership related to the social demographic factors in each neighborhood? To learn on the questions, the study first figured out the ridership change rates of all routes then filtered out the 10 of those with the most changes and 10 with the smallest changes. After that, by learning the census tracts where the selected routes service through, these places are marked separately and entered in SPSS as new variable categories. Then, the study performs correlation analysis on the marked census tracts with the social demographics to measure how closely these variables are related. Next, to see what the combination of social demographics is that can be applied to estimate the change in the ridership in a certain neighborhood, the study performs multiple regression analysis to test these demographics and tries to quantify the impacts and the relationships among all factors.

Data Collection

To study the changes in bus ridership in the City of Seattle during the pandemic, the study applies the bus ridership records in operation season Spring 2019 and Spring 2020¹ from the King County Metro². The table below describes the ridership data by operation season.

Table.1 Descriptions of Ridership Data

Operation Season	Description
Spring 2019	It refers to the annual ridership of each route from March 2018 to June 2019.
Spring 2020	It refers to the annual ridership of each route from March 2020 to June 2020.

These data cover the ridership records from the year before the pandemic, which can be compared with the records during the shutdown period of the pandemic and learn the changes in the bus ridership. The paper calculates the annual change rate of ridership according to the annualized ridership of each route based on the ridership records of the previous year to obtain the general change of the ridership of all bus routes. Spring 2020 covers the very first three months of pandemic lockdown and the comparison with the previous year can illustrate the short-time changes in ridership under the impact of the shutdown.

To explore which groups of people are more dependent on buses during the pandemic, the study also applies the demographic statistics from Seattle GeoData. The demographic data includes median household income, the population from families consisting of only one racial group, the number of people from different age groups, and the male/female ratio for further analysis. These

¹ Summertime has a different schedule which is not included in the analysis of the paper. The data for Fall 2020 was not complete by the time the analysis starts, therefore, the record of Fall 2019 and Fall 2020 are not included either.

² The ridership data is got from Jacob Armstrong, who serves as Transportation Planner in King County Metro.

social demographics are the common factors when studying the features of a certain group according to existing studies. All social demographic data are in the unit of the census tract. The table below provides detailed descriptions of the demographic data.

Table.2 Descriptions of Social Demographic Data (Seattle GeoData, 2020)

Demographic Category	Description
Median Household Income	The data refers to the median value of household income in each census tract.
White Alone Population	The data refers to the families consisting only of White populations in each census tract. Because the total population of each census tract are different, it was converted into the percentage of white alone population for further analysis.
Black Alone Population	The data refers to the families consisting only of Black populations in each census tract, and it was converted into the percentage in the same way as the data of white alone population.
American Indian and Alaska Natives (AIAN) Alone Population	The data refers to the families consisting only of AIAN populations in each census tract, and it was converted into the percentage.
Asian Alone Population	The data refers to the families consisting only of Asian populations in each census tract, and it was converted into the percentage.
Population Under 17	The data refers to the number of minor populations in each census tract and it was converted into the percentage.
Population Over 65	The data refers to the number of senior populations in each census tract and it was converted into the percentage.
Male Female Ratio	The data was recorded as the number of each gender in each census tract, and for the conveniences of further analysis, it was recorded as the ratio.

Method Overview

To explore the general change in the ridership, the first step is to calculate the change rate in ridership with these two operation seasons. This measurement can tell the ridership changes of

all routes in general when the pandemic started. Next, according to the value of the annualized change rate in ridership, the bus routes are sorted by the change rate from high to low. From the new sorted list, the 10 routes with smaller changes in ridership rate and the 10 routes with larger changes in ridership rate were selected for the key analysis. Due to the impact of the shutdown and social-distancing regulation, all of the routes should have experienced ridership decline in Spring 2020; therefore, those 10 routes at the top of the list were able to retain more passengers, while the bottom 10 routes lost more passengers than the others.

After filtering out these 20 routes, the paper then marked their operation areas according to the census tracts. The marked census tracts are prepared as one of the variables in correlation analysis and dependent variables in the multiple regression analysis.

Correlation Analysis

After getting the general trend of the ridership changes, the correlation analysis focuses on the selected routes. After summarizing the service areas of the selected routes separately, the places are recorded by the unit of census tract for the analysis afterward. Then, together with the demographic data, all the data are brought into SPSS for correlation analysis.

The study conducted two correlation analyses. The first was to analyze the correlation between the service areas of the 10 routes that maintained high ridership during the pandemic and the demographic data listed above. The second time is to analyze the correlation between the service area of the routes with the sharp drops in the ridership rates, together with the demographic data. This step allows us to understand the interrelationships between each variable, thereby laying the foundation for the regression analysis following.

Regression Analysis

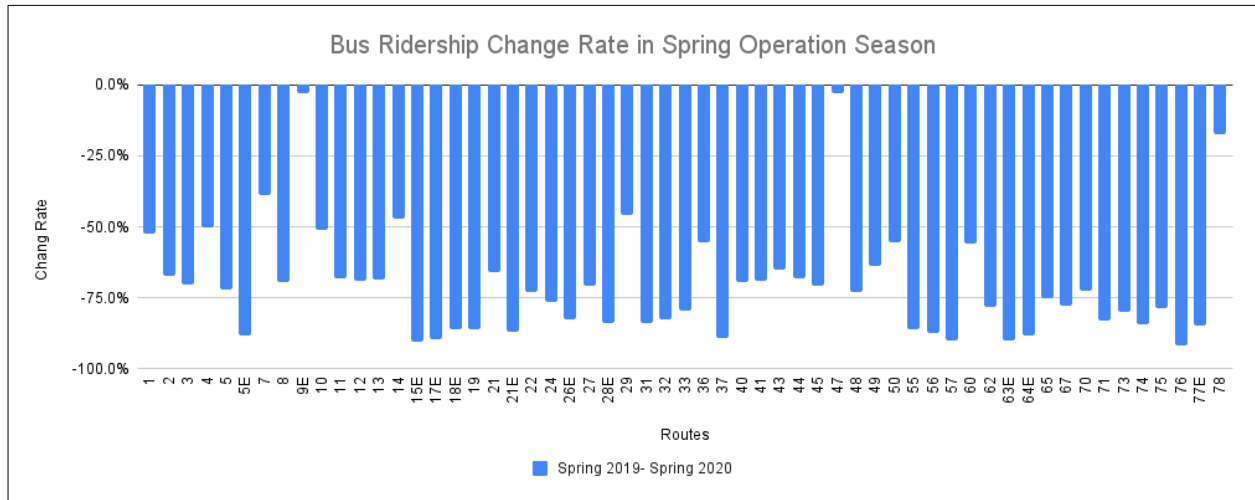
The changes in the ridership rate in each census tract are often related to multiple demographic factors. According to the existing studies, people who earn lower household incomes or are from racial minority groups are more likely to depend on buses. In addition, these people were also facing more challenges during the pandemic. With the hypothesis that the combination of these demographic factors can have a better result of the interrelationships, the study conducted two multiple regression analyses. In the two regression models, the census tracts where ridership remained or lost ridership were set as dependent variables separately. And the other demographic factors were entered as the independent variables.

Results

General Change in Bus Ridership

Affected by the free-ride policy, shrinking funding, and social distancing regulations, some routes have been suspended and haven't been in service yet. Under the influence of the pandemic shutdown and travel restrictions, all buses have experienced a great decline in ridership rates in Spring 2020 compared with Spring 2019. The average decline rate reached -70%. About half of the bus routes experienced a ridership drop of over 50% in the first three months of the pandemic shutdown, and over 20 routes even faced a drop exceeded 75%. It can be concluded that due to the impact of the pandemic, the ridership of most of the bus routes has dropped significantly. The column chart below shows the percentage of ridership change by each route.

Fig.1 Bus Ridership Change Rate



After obtaining the changes in the ridership rate of all routes, the paper sorts the bus routes according to the change rates of ridership during the pandemic period from high to low. Then select the 10 routes with smaller ridership change rates during the pandemic period and the other 10 routes with the most decline in ridership rates from operation season Spring 2019 to Spring 2020. The table below shows the list of route numbers.

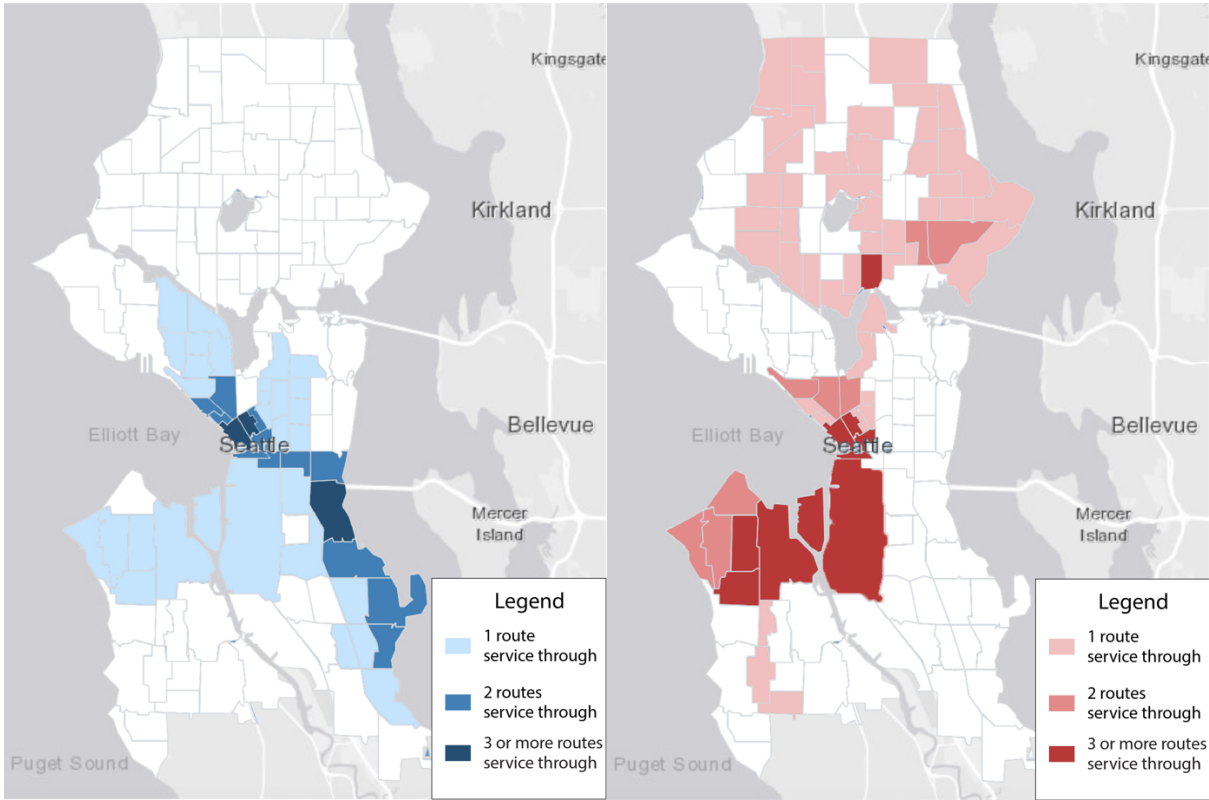
Table.3 Routes with Small and Large Change Rate from Spring 2019 to Spring 2020

Small Changes	9E	47	78	7	29	14	4	10	1	36
Change Rate (%)	-2.8	-3.1	-17.4	-38.8	-45.9	-47.0	-50.4	-51.2	-52.2	-55.5
Large Changes	76	15E	57	63E	17E	37	5E	64E	56	21E
Change Rate (%)	-91.7	-90.6	-90.2	-90.1	-89.7	-89.1	-88.5	-88.3	-87.5	-87.1

The first row shows the bus routes with smaller ridership change rates from Spring 2019 to Spring 2020, which means these routes maintained more passengers than the other routes even during the pandemic shutdown. The third row shows the routes with larger ridership change rates. It can indicate that these routes can have only a few passengers. Apart from that, the second and the fourth row shows the detailed change rate accordingly. To have a deeper understanding of the characteristics of people living in these places, this paper marks the service

areas of these repetitive routes by census tract. As all routes experienced declines in ridership, therefore, the census tracts, where the 10 routes retained ridership service through, tend to have more residents choosing public transit for daily commute; while the service areas for the bottom 10 routes suggest those tracts can have fewer residents commute by bus. The maps below show the service areas. The darker the color, the more frequently that the bus routes service through.

Fig.2 Service Areas of the Routes Remained Higher Ridership (Left) and Service Areas of Routes with Lower Ridership (Right)



Seeing these two maps, it's clear that the service areas of these bus routes have certain similarities. However, there are also many differences. The city center has the densest public transportation network, it is the service area of most bus routes. Therefore, in these two maps, the downtown area is marked in the darkest colors.

Seeing the map on the left-hand side, the blue-colored census tracts are concentrated in central Seattle and the southeast part of Seattle. While seeing the map on the right-hand side, the red-colored census tracts are distributed from the very north to the southwest part of the city. This indicates the routes that remained higher ridership are more likely to be short-line services compared with the ones that lost ridership. Except for the concentration in downtown areas, the bus routes that remained higher ridership also concentrate the service areas in most of the neighborhoods in Rainier Valley, which suggests that residents living in these places can rely more on buses during the pandemic shutdown. However, in sharp contrast, the routes that lost largely in ridership are more likely to service through West Seattle, where residents can be less dependent on buses.

Correlations with Demographics

To study further on the residents living in the census tracts mentioned above, the census tracts colored in the two maps above were recorded as variables separately in SPSS. The blue-colored tracts are named 'remained_tract', the red ones are 'decreased_tract'. Then, together with the demographic data, all the data are brought into SPSS for correlation analysis. The table below shows the correlation results between areas that remained higher ridership and demographics.

Table.4 Correlation Results between Areas Remained Ridership and Demographics³

	MHI	White_per	Black_per	AIAN_per
Pearson Correlation	-.174*	-.237**	.243**	.295**
Sig. (2-tailed)	.046	.006	.005	.001
N	132	132	132	132
	Asian_per	MF_ratio	Under17_per	Over65_per
Pearson Correlation	.190*	.296**	-.233**	.262**
Sig. (2-tailed)	.029	.001	.007	.002
N	132	132	132	132

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Seeing from the table above, these 8 variables all correlate with the areas, where remained higher ridership, at a significance level of 0.01 or 0.05. Among all variables, the percentage of White alone, Black alone, and AIAN populations, male-female ratio, and the proportion of minor and senior populations correlate with these service areas at a significant level of 0.01. The other two factors are at the significance level of 0.05.

The Pearson Correlation of MHI, the percentage of the White alone populations, and populations under 17 are negative, which suggests these variables correlate negatively with the distribution of these service areas. It indicates that fewer minors live in these areas, and people who live in these places tend to be those who have lower income levels or those who are not white. Meanwhile, in the census tracts that remained a higher ridership change rate, there tends to be a higher percentage of Black, AIAN, and Asian populations. In addition, the percentage of males and senior citizens can be higher in these places.

³ MHI refers to median household income; White_per, Black_per, AIAN_per, and Asian_per refer to the percentage of population from a certain single racial group in each census tract; MF_ratio refers to male female ratio; Under17_per and Over 65_per refer to the percentage of minor and senior population. Variable with the same name in the following contents have the same meaning.

Table.5 Correlation Result between Areas Lost Ridership and Demographics

	MHI	White _per	Black _per	AIAN _per
Pearson Correlation	.025	.224**	-.240**	-.202*
Sig. (2-tailed)	.776	.010	.006	.020
N	132	132	132	132
	Asian _per	MF_ratio	Under17 _per	Over65 _per
Pearson Correlation	-.100	-.129	.027	-.081
Sig. (2-tailed)	.255	.139	.758	.357
N	132	132	132	132

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Taking similar measurements, the table above shows the correlation result between the areas where lost greatly in ridership with demographic factors. Only three factors among all correlate significantly to the distribution of these service areas. While the percentage of White alone and Black alone populations are significant at 0.01 level, and the percentage of AIAN populations are significant at 0.05 level.

The Pearson Correlation of the percentage of White alone populations is a positive value at 0.224. However, the Pearson Correlation value of the proportion of black alone and AIAN alone populations are all negative. It suggests that the areas lost more in ridership during the pandemic are more likely to have more white alone residents and fewer black alone or AIAN alone populations.

Multiple Regression with Demographic Factors

For further in-depth research, the study then performed regression analysis on these variables. First, set these areas that remained ridership as dependent variables and all other factors as independent variables. The result of the regression analysis shows in the following three tables.

Table.6 Model Summary of Areas Remained Ridership with all variables

R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	Change Statistics			
					F Change	df1	df2	Sig. F Change
.540 ^a	.292	.246	.25976	.292	6.336	8	123	.000

- a. Predictors: (Constant), Under17_per, Over65_per, AIAN_along_per, Asian_along_per, MF_ratio, Black_alone_per, MHI, White_alone_per

Table.7 Analysis of Variance (ANOVA ^a) of Areas Remained Ridership Model

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.420	8	.428	6.336	.000 ^b
	Residual	8.300	123	.067		
	Total	11.720	131			

- a. Dependent Variable: Remained_tract
 b. Predictors: (Constant), Under17_per, Over65_per, AIAN_along_per, Asian_along_per, MF_ratio, Black_alone_per, MHI, White_alone_per

Seeing the model summary table, the value of the adjusted R square is only 0.246, which is not at a relatively high level. It shows that the interpretation of this model is also relatively limited.

Then, the result from the ANOVA table shows the value of F is 6.336 and the p-value is smaller than 0.01. Therefore, it indicates that the fitted multiple linear regression equation is statistically significant. The third table provides more detailed figures of each factor in the model.

Table.8 Coefficients ^a of Multiple Regression Model with Areas Remained Ridership

	Unstandardized Coefficients B	Std. Error	Standardized Coefficients	t	Sig.	Lower Bound	Upper Bound
(Constant)	-.412	.426		-.967	.335	-1.254	.431
MHI	1.233E-6	.000	.132	1.098	.275	.000	.000
White_alone_per	.001	.004	.042	.153	.879	-.008	.009
Black_alone_per	.012	.006	.340	2.174	.032	.001	.023
AIAN_along_per	.058	.036	.144	1.631	.105	-.012	.128
Asian_along_per	.002	.005	.081	.443	.658	-.007	.012
MF_ratio	.184	.136	.133	1.353	.178	-.085	.454
Under17_per	-.013	.005	-.301	-2.543	.012	-.023	-.003
Over65_per	.017	.005	.287	3.569	.001	.008	.027

a. Dependent Variable: Remained_tract

Seeing the Sig. values above, only the p-values of the percentage of Black alone, younger, and senior populations are smaller than 0.05. The other variables are not statistically significant in this regression model. It suggests that only these three factors can count in the final linear equation. However, the value of the adjusted R square is relatively low. It indicates that there can be several possible factors not included in the fitted multiple linear regression equation.

Although the unstandardized coefficient of the proportion of senior populations shows the highest, the standardized coefficient reached its top, among these three factors, when it comes to the percentage of the Black alone population. For independent variables with a larger impact on the dependent variable, their unstandardized coefficients are not always the greatest. It is the absolute value of their standardized coefficient that matters. Therefore, the percentage of the Black alone population can hold a deeper influence on the areas that remained bus ridership. By taking similar steps, the study performs multiple regression analyses on the census tracts with seriously decreased ridership. The tables below show the results.

Table.9 Model Summary of Areas with Decreased Ridership with all variables

R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	Change Statistics			
					F Change	df1	df2	Sig. F Change
.403 ^a	.162	.100	.108	.44441	.162	2.975	8	.004

- a. Predictors: (Constant), Under17_per, Over65_per, AIAN_along_per, Asian_along_per, MF_ratio, Black_alone_per, MHI, White_alone_per

Table.10 Analysis of Variance (ANOVA ^a) of Areas with Decreased Ridership Model

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4.700	8	.587	2.975	.004 ^b
	Residual	24.292	123	.197		
	Total	28.992	131			

- a. Dependent Variable: Decreased_tract
 b. Predictors: (Constant), Under17_per, Over65_per, AIAN_along_per, Asian_along_per, MF_ratio, Black_alone_per, MHI, White_alone_per

The value of the adjusted R square is 0.100 in the model summary table, which is at a relatively low level. It shows that the interpretation of this model is quite limited compared with the model above. There can be several other potential factors not included in this model.

Then, the result from the ANOVA table shows the value of F is 2.975, and the p-value is smaller than 0.01. It indicates that the fitted multiple linear regression equation is statistically significant, however, it is not an ideal model. The third table provides more detailed figures of each factor in the model.

Table.11 Coefficients ^a of Multiple Regression Model with Areas with Decreased Ridership

	Unstandardized Coefficients B	Std. Error	Standardized Coefficients	t	Sig.	Lower Bound	Upper Bound
(Constant)	-.476	.728		-.654	.514	-1.918	.966
MHI	-5.547E-6	.000	-.378	-2.886	.005	.000	.000
White_alone_per	.016	.007	.636	2.105	.037	.001	.030
Black_alone_per	-.005	.009	-.086	-.508	.613	-.024	.014
AIAN_along_per	-.094	.061	-.148	-1.543	.125	-.214	.027
Asian_along_per	.013	.008	.318	1.603	.111	-.003	.030
MF_ratio	.012	.233	.006	.052	.959	-.449	.474
Under17_per	.015	.009	.221	1.721	.088	-.002	.032
Over65_per	-.005	.008	-.057	-.652	.515	-.022	.011

a. Dependent Variable: Decreased_tract

Seeing the Sig. values above, the p-value of MHI is smaller than 0.01 and the p-value of white alone populations is under 0.05. It suggests the median household income and the percentage of the white alone populations are the statistically significant factor. Similar to the previous regression model, the value of the adjusted R square is relatively low. It indicates that there are possible factors not included in the fitted multiple linear regression equation.

Seeing the value of standardized coefficients, it's clear that the percentage of white alone populations can have a deeper influence on the distribution of the places with less ridership. It indicates that there tend to be more white populations living in these places and fewer African American residents. Overall, the interpretation effect of the factors in the model with areas with seriously decreased bus ridership is not ideal. This suggests that the census tracts with decreased ridership can be affected by more potential factors that are not in the model.

Discussion

Under the influence of the ‘stay-at-home’ order and the rules of maintaining social distancing, the ridership of all bus routes in Seattle has dropped significantly. However, in further analysis, the degree of correlation between changes in ridership and social demographics is not as high as expected. That might be because the study area is limited within the City of Seattle. The number of all census tract records is only 132, which is a relatively small-size sample. Social demographics can only be a small part of the potential causes of ridership changes, the simple models cannot include all potential variables comprehensively. Besides, the analyses were only based on bus routes operated by King County Metro, the other means of transportation are not included. Therefore, the results of the models are not as ideal as expected. The accuracy of the results can be influenced to some extent.

Vulnerable Populations Relies More on Bus

According to the literature review, disadvantaged groups are more likely to be infected with the coronavirus and have a higher dependence on public transportation. The reliance on the bus is also reflected in the result of correlation analysis in this study, which verified the hypothesis mentioned above. The result also indicates there tend to be more people with lower income levels or those who are not white in the census tracts where remained higher ridership. Meanwhile, in the census tracts that remained a higher ridership, there tends to be a higher percentage of Black, AIAN, and Asian populations. Apart from that, the areas with serious ridership drops during the pandemic can have more white alone residents and fewer black alone or AIAN alone populations.

Discussion on the Results of Multiple Regression Analysis

Seeing from the results, the values of the adjusted R square of the two regression models are both at a relatively low level. It is much lower in the model with areas with seriously decreased ridership.

According to the previous literature review, the level of median household income and the proportion of different races can correlate significantly with the distribution of the service areas. However, in the first regression model, only 3 of the 8 social demographic factors have a p-value of less than 0.05, which is statistically significant. These three factors are the percentage of Black alone, minor, and senior populations; the proportion of people of different ages has a more obvious impact on the distribution of these areas than expected. For independent variables with a larger impact on the whole model, the absolute value of their standardized coefficient matters. Therefore, the percentage of the Black alone population has the deepest influence on the areas that remained bus ridership among these three factors.

When it comes to the regression model with areas with seriously decreased ridership, the model shows a weaker interpretation. Even though median household income and the percentage of the white population are statistically significant, the model did not include enough potential factors for the final regression equation.

Except for the limited case numbers, there are two possible reasons for that. First, the cause of changes in bus ridership can be complicated. However, the study only focuses on social demographics. The King County Metro was experiencing a slight decrease in ridership before the pandemic, but the change rate was relatively reasonable. However, the ridership dropped seriously since Spring 2020. All routes service in Seattle showed negative growth in ridership

rate. The King County Metro established a reduced schedule of bus routes after the pandemic shutdown. Therefore, the decrease rate of ridership was partly due to the schedule adjustment itself. Affected by the pandemic, many bus routes have been reduced or even suspended. The free ride policy during the pandemic has made funding even tighter. Among all, approximately 10 routes have been suspended and planned to resume no earlier than October 2021 due to the tight budget. And second, car ownership can be another major cause. However, there is a lack of car ownership data and leave a certain proportion of the problem unexplained.

Conclusion

When it comes to the regression model with areas with seriously decreased ridership, the model shows a weaker interpretation. Even though median household income and the percentage of the white population are statistically significant, the model did not include enough potential factors for the final regression equation.

The pandemic has caused a huge negative impact on public transportation, reflecting as rapidly decreasing ridership and revenue losses. Since the beginning of the pandemic, the bus ridership has dropped sharply to varying degrees. Among all routes that mainly run through Seattle, those long-distance buses passing through the northern part and West Seattle areas can have fewer passengers when the shutdown began. In contrast, those short-line buses passing through the Rainer Valley neighborhood have relatively higher ridership.

The selected social demographics correlate to the ridership changes to some extent, especially in the census tracts that remained higher ridership during the pandemic. People living in these places tend to have lower incomes or those who are not white. Meanwhile, in these census tracts,

there tends to be a higher proportion of Black, AIAN, and Asian populations. The regression analysis results show that African Americans and senior citizens may rely more on buses during the pandemic. These populated areas tend to have higher bus ridership rates during the shutdown of the pandemic, while the neighborhoods with higher household incomes have experienced a sharp decrease in ridership.

However, for the limited study area and data, the result of this study cannot be applied generally. The change in ridership can be the result of a series of complicated factors working together, which is much more than social demographics. Apart from those above, the correlation analysis can only show the general relationships among the variables. The deeper causes may be excluded in these analyses. Therefore, it is also the reason why the two regression models with low R square values.

Further Thoughts

The soaring unemployment rate accompanied by the economic shutdown has had huge impacts on people's lives. Leaving aside the issues related to public transportation, the vulnerable groups themselves have already faced more challenges and suffered from more problems. From a macro perspective of public health, the shutdown of the economy and all recreational activities during the pandemic is correct and can effectively curb the spread of the virus. However, the stagnation of economic activities has increased the unemployment rate and the burden of living for the disadvantaged. The vulnerable groups have paid a greater price for the economic shutdown than the other groups. As the Matthew effect indicates, the gap between different groups will continue widening, and vulnerable groups will inevitably face much more difficulties and challenges after the pandemic is over.

In addition, the conflict of racial discrimination reached a peak with the outbreak of BLM⁴ in June 2020. The block of CHAZ⁵ Capitol Hill also spread the coronavirus and left a negative impact on social safety. The outbreak of BLM together with the recent rally of ‘Stop Asian Hate’ reflects the long-lasting discrimination to the minority groups. And it is the pandemic that became the catalyst that aggravated the gaps and caused destructions in equity.

In response to the impact of the pandemic on the lives of all residents, the federal government has issued subsidies to citizens to reduce the pressure caused by unemployment. This measurement has indeed helped some people to a certain extent. However, the granting of subsidies caused too much liquidity has poured into the market. Now, many cities have seen price increases of varying degrees, and the CPI is also rising. Rising prices will make the lives of disadvantaged groups more difficult. If this problem is not resolved properly, the negative impact of the pandemic will continue to be worse.

⁴ Black Lives Matter.

⁵ Capitol Hill Autonomous Zone.

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