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Impact of Covid-19 Prevalence in Seoul on Subway Usage

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Abstract

This article shows that there is a negative impact of government's social distancing policy, daily COVID-19 confirmed cases, daily volume of new articles related to COVID-19, and a weekend dummy on subway ridership in Seoul, Korea. Multiple regression with OLS is applied to 289 daily data mostly collected from the Open Government Data Portal during the early stages of COVID-19 pandemic, from January 1 to October 30, 2020. The model is run separately for four subway station categories: commercial, office, residential, and other area. Different impacts of explanatory variables across different area have some policy and managerial implications. This study concludes with future research.

Keywords: COVID-19, Pandemic, Subway, Public Transportation, Ridership, Korea

1. INTRODUCTION

Since the COVID-19 pandemic, there have been many changes, large and small, in society as a whole, including lifestyles, working styles, and government policies (Echegaray, 2021; Zhang et al. 2021). Wearing a mask and disinfecting hands has become a daily routine, and it has become difficult to imagine life before pandemic. Many activities, such as shopping and leisure, have been replaced online, and more and more businesses are working from home. In Korea, restaurant business hours are limited due to social distancing measures, and transparent partitions are installed and operated for each table to prevent the spread of droplets. These changes are related to efforts to reduce human-to-human contact as much as possible, which has led to a decrease in overall population movement. In particular, there has been a phenomenon of reluctance to use public transportation, which is usually frequented by many people. Figure 1 by Ministry of Land, Infrastructure and Transport (2021) shows that the average daily usage of transportation cards decreased by an average of 27.0% nationwide, and by region, the Gwangju area decreased the most with 31.5%, followed by the Daegu area with 30.8%, the Daejeon area with 29.2%, and the metropolitan area with 26.9%. The deficit problem of bus companies and the Seoul subway is emerging as a social problem due to the restraint of public transport use and the reduction of night public transport operation to prevent the spread of COVID-19.

Despite a lot of interest, there are few empirical studies on the effect of COVID-19 on the number of subway users. In this study, it is assumed that the change in the number of subway users due to COVID-19 is affected by public anxiety and fear about COVID-19. Therefore, the effect of the spread of COVID-19 on the number of subway users was empirically analyzed using factors that could affect the formation of public anxiety and fear as variables. Also, we want to create a model that predicts the rate of change in the number of subway users in the future. We analyze changes

in subway users by region due to various factors, and suggest regional quarantine policies based on this. The time when the public most refrained from going out and using public transportation for fear of Corona 19 was the early stage of the outbreak of COVID-19 in 2000, and the first confirmed case of Corona 19 in Seoul was on January 24. Considering this, this study analyzed data from January 1 to October 30, 2020.

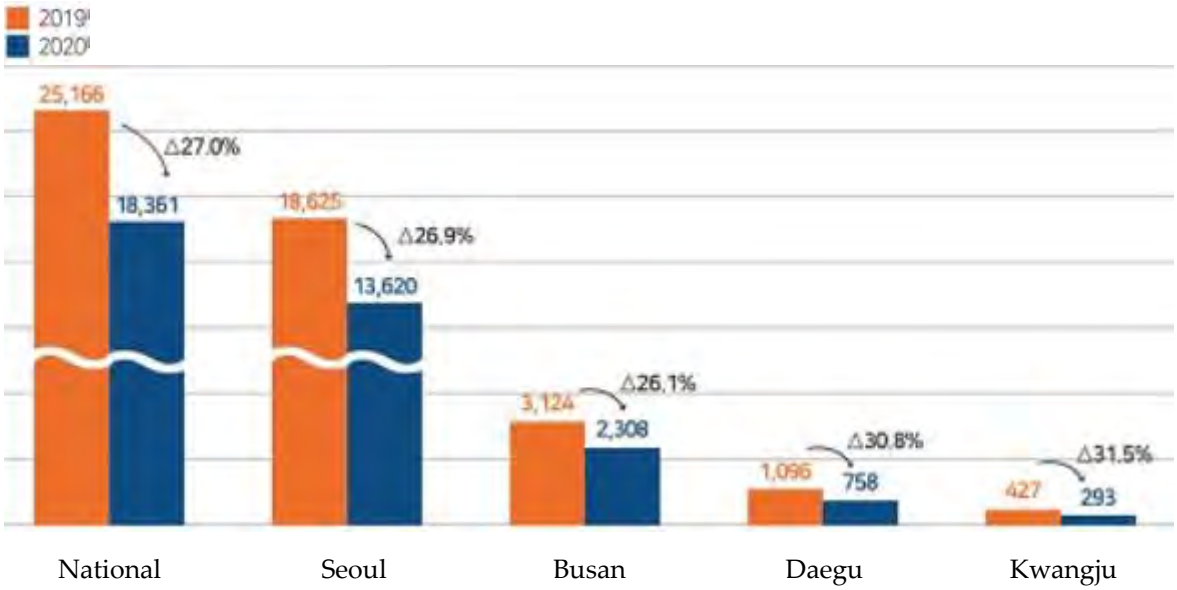

Figure 1. Changes in average daily traffic volume by region across the country

This paper aims to examine the impact of COVID-19 on the daily use of public subway in Korea during the 2020 pandemic. The rest of the paper is organized as follows. We review the prior literatures in the following section and then describe the methodology and dataset. In section four, we present and discuss the findings and results. We conclude the study with managerial implications and potential future research.

2. LITERATURE REVIEW

To the best of our knowledge, there are few empirical research on the impact of COVID-19 on the use of public transportation. Gkiotsalitis and Cats (2021) and Tirachini and Cats (2020) overview the literatures, issues and research needs associated with the pandemic crisis and public transport system. A study on the impact of covid-19 on public transportation was conducted in various countries based on different data and methodologies. Research on the impact of COVID-19 on public transport can be divided into two main research area: determinants of decrease in public transport use and socioeconomic disparities in public transport use.

2.1. Determinants and Impact of the Public Transport Use

A recent study found that public transport use has declined in a variety of countries since COVID-19 pandemic (Bureau of Transportation Statistics, 2022). Various reasons are identified as determinants of decline in public transportation use since COVID-19 pandemic through prior research. Using validated ticket and passenger volume data in Sweden, Jenelius and Cebecauer

(2020) find that the decline in public transport use is due to the fact that many travelers have switched from 30-day to one-time tickets and that short-term ticket sales are close to zero. Wielechowski et al. (2020) show that the Polish government's quarantine or social distancing

policy is a major factor influencing public transport use. Using the survival analysis approach, Murano et al. (2021) examine the effect of domestic travel restriction on the public transport use in Japan. In emerging economies such as Nigeria, Mogaji (2020) find that government policies such as lockdowns or movement restrictions do not have a significant impact on reducing public transport use due to lack of public transport infrastructure. Teixeira and Lopes (2020) show that in New York City, the bike share system (BSS) appears to be less affected by COVID-19 than the subway during 2020 pandemic. The decrease in BSS users (71%) was less than the decrease in subway use (90%), and the average BSS use time increased from 13 minutes to 19 minutes. They also prove that many users change their means of transportation from the subway to the BSS.

2.2. Socioeconomic Disparities in Public Transport Use

Hu and Chen (2021) analyze the 20 years daily transit ridership data from the Chicago area to examine if there is a difference in socioeconomic variables regarding the decrease in public transportation use due to the impact of COVID-19. They employ Bayesian structural time series model, controlling other possible confounding effects such as seasonality, weather, and holiday. They find that Passenger declines were most affected by white, educated, high-income, commercial land areas, with fewer declines in areas with more jobs in trade, transportation and utilities. Their research helps policy makers and transit agencies how to provide better public transport to different socioeconomic groups. Jenelius and Cebecauer (2020) find that there are regional differences in the extent of the decline in public transport users. The three most populous cities in Sweden were surveyed. In Stockholm, the number of users on public transport decreased by 60%, while in Västra and Götaland it decreased by 40%. Wilbur et al. perform a spatio-temporal analysis of public transport usage decline throughout Nashville and Chattanooga, Tennessee USA and show that There was a significant difference in rider decline between high and low income neighborhoods in Nashville (77% versus 58%). They explain this phenomenon as low-income families have fewer vehicles than high-income families, and there are many blue colors that require commuting to work rather than telecommuting. Tan and Ma (2021) employ a logistic regression to understand which socio-economic variables have an influence on the commuters' choice of rail transit using questionnaires data. They find that occupation, how they commuted before COVID-19, how long they walk to the nearest metro station from where they live, and their perception of the potential for infection on public transport have a huge impact on commuters' rail choices.

3. METHODOLOGY

3.1. Data

We obtained our primary data set of this study through the Open Government Data Portal, which provides APIs so that the public can use public data held by the government easily and conveniently. The Open Government Data Portal provides various types of data that the Korean government has. This applies to virtually every sector in which government is involved, including education, transport, construction, tourism, industrial employment, and health care etc.

For the data on the daily number of subway users, the number of daily users of each Seoul subway station provided by the Open Government Data Portal was used. Although this data provides information on subway users from 2015 to 2020, this study selected 2 years data set from January 1, 2019 to October 30, 2020 because we aim to analyze changes in subway users in 2019 and 2020, the year before the outbreak of COVID-19. In the raw data, data of passengers on board and getting off were separated, so one variable was created by summing the data of

passengers on board and getting off. In this study, since the decrease in subway users is of interest, the relative change in the number of passengers compared to the previous year was calculated and used as the focal variable instead of the absolute number.

This study adopts a multiple regression model with OLS to examine the impact of COVID-19 on public transportation usage, subway in Seoul, Korea. In this study, the 'total number of passengers' per day was calculated by adding the 'number of passengers' and 'number of departure passengers', which were separated in the raw data. Since the main concern of this study is the decrease in the number of subway users, the relative change in the number of daily users compared to the previous year was used as a focal variable.

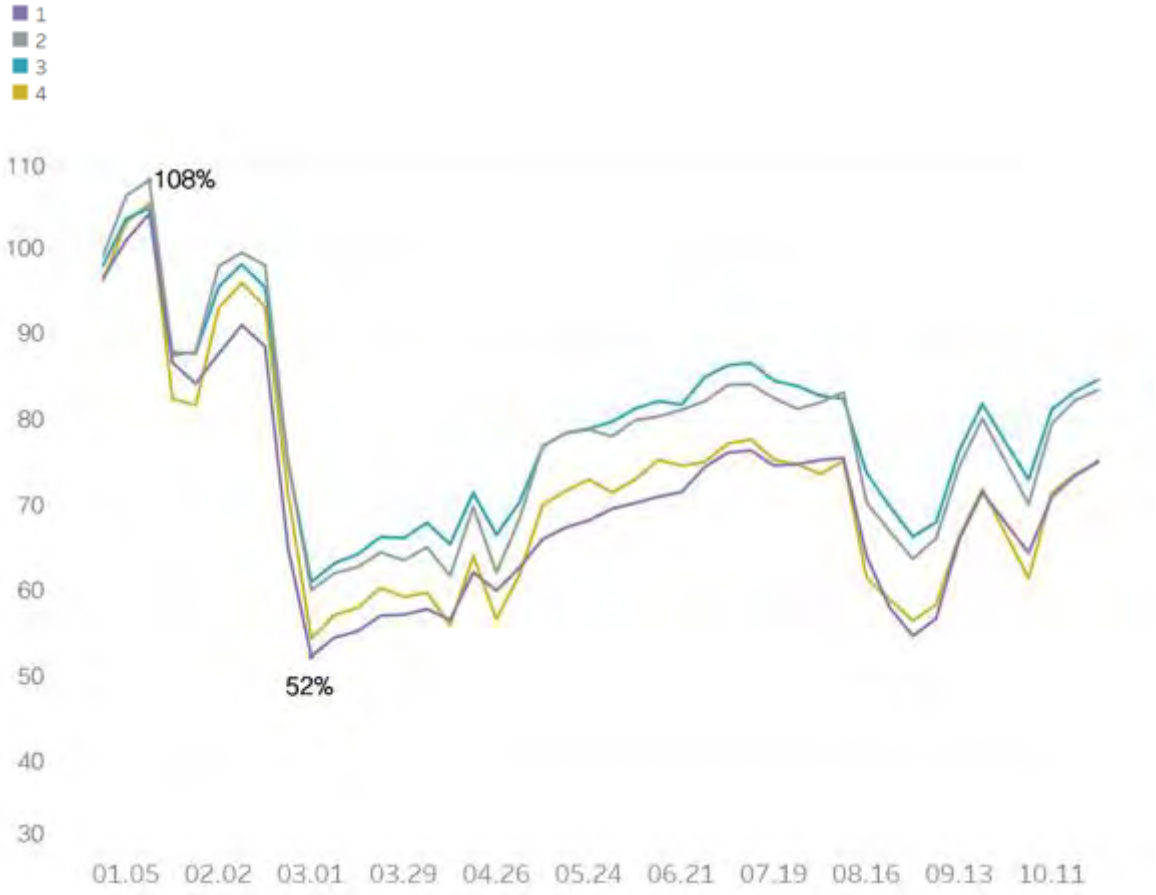

Figure 2. Average change in number of passengers per week by station group

The daily number of confirmed COVID-19 cases was calculated by adding up the number of confirmed cases in Seoul and Gyeonggi Province reported the previous day. Since the Seoul subway is used a lot by citizens commuting to and from the Seoul metropolitan area, the number

of confirmed cases in Gyeonggi-do as well as Seoul is included. The data was obtained from Seoul Open Data Portal and Gyeonggi-do public data portal.

Media reports related to COVID- 19 is considered that the news of the previous day have an effect on the movement of the day rather than the news of the day. The number of daily media articles related to COVID-19 was collected and calculated using the search term 'corona 19' in the Bickins News search and analysis program (Bickins, 2022).

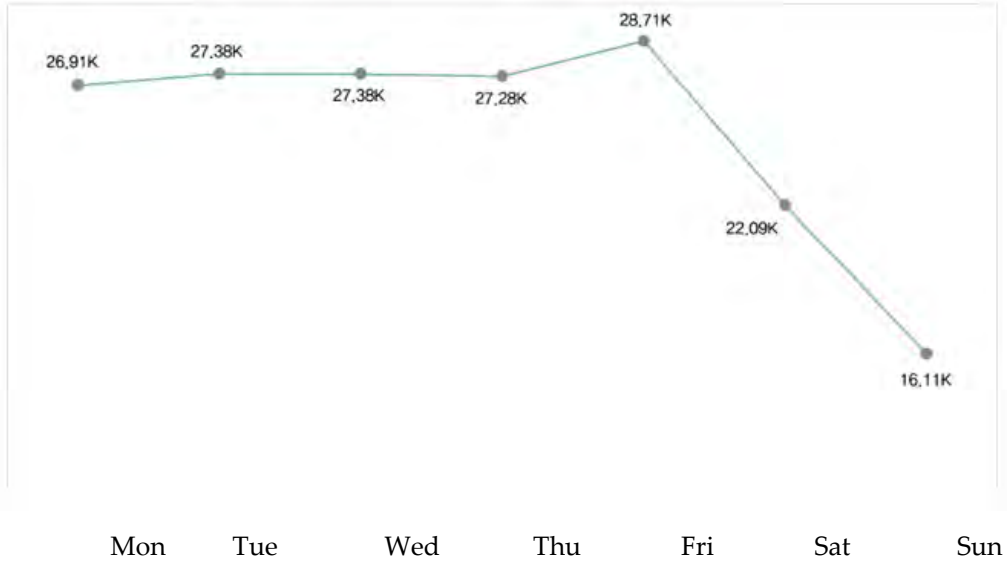

Figure 3. Average number of passengers per day

The government's social distancing policy is known to have affected the use of public transportation in 2020, the early stage of the COVID-19 outbreak (Jung, 2020). The data for steps 1, 2, and 2.5 of the distance measures implemented in Seoul from January to October 2020 were collected by date from the Center for Disease Control and Prevention website.

Using K-means clustering analysis, an unsupervised machine learning technique, Seoul subway stations are divided into four categories: "transfer or commercial area, business area, residential area, and other areas". The subway station variable was not used as an independent variable, but was used as a filter criterion for the dependent variable so that the model could be applied separately by station category. The graph of the weekly average passenger number change by station group in Figure 2 show that the trend of the change rate by station group is generally similar, but there is a difference in the decrease by more than about 10%. Group 3, that is, the residential area, has a small decrease in the number of passengers, and on the contrary, the decrease in the number of passengers in the commercial area (group 1) is the largest.

Figure 3 shows that the number of subway users by day of the week decreases significantly on weekends compared to weekdays. Weekend dummy variables (0 for weekdays and 1 for weekends) are used to control the effect of the number of subway users on weekdays and weekends. While in the case of weekdays, the decrease was expected to be low because there is a required amount of movement due to commuting to work and school, a large decrease was expected due to a decrease in leisure activities and events on weekends, as there were relatively few essential movements.

Table 1. Summary Statistics (N=289)

	Mean	Std	Min	Max
Passengers	75.444	15.343	35.836	119.223
Step 1	.446	.497	.000	1.000
Step 2	.097	.296	.000	1.000
Step 2.5	.270	.444	.000	1.000
COVID-19 Cases	38.156	53.028	.000	279
News Volume	3393.066	1980.357	.000	7355
Weekend	.280	.449	.000	1.000

Table 2. Correlations

	Pass	S1	S2	S2.5	COVID	News	Week
Passengers	1.000						
Step 1	.076	1.000					
Step 2	-.122	-.294	1.000				
Step 2.5	-.547	-.545	-.199	1.000			
COVID-19 Cases	-.285	-.131	.663	-.014	1.000		
News Volume	-.327	-.063	.075	.401	.193	1.000	
Weekend	-.419	-.017	.003	.037	-.007	-.397	1.000

Table 1 and 2 present summary statistics and correlations for each variable in our data set. Data collection process in 3.1. ends up with 289 daily data.

3.2. Empirical Model

To model the effects of government's social distancing policy, number of COVID-19 cases, media reports related to COVID-19, and weekend on the decrease of subway ridership, we fitted the multiple linear regression model as follows:

We fitted the multiple linear regression model as follows:

$$Passengers_t = \alpha_1 S1_t + \alpha_2 S2_t + \alpha_3 S2.5_t + \alpha_4 COVID19_t + \alpha_5 News_t + \alpha_6 Weekend_t + \epsilon_t \quad (1)$$

where *t* refer to daily time point. *S1*, *S2*, and *S2.5* are government's social distancing policy step 1, step 2, and step 2.5 respectively. *COVID19* is the daily COVID-19 cases, *News* is the number of daily media articles related to COVID-19, and *Weekend* is a weekend dummy variable (0 for weekdays and 1 for weekends). *Passengers* is the relative change in the number of daily passengers compared to the previous year. The parameter α_i is estimated using OLS regression. The ϵ_t term is independent and identically distributed with zero mean and a constant variance.

After fitting linear regressions for the entire data, linear regressions were again fitted for each of the four categories of data of subway stations: "transfer or commercial area(*D1*), office area(*D2*), residential area(*D3*), and other areas(*D4*)". VIF test result (Mansfield & Helms, 1982) indicates that there is no multicollinearity issue in our data.

4. EMPIRICAL RESULTS

The empirical results are partitioned into five estimation as presented and discussed as follows in Table3. OLS is run for all districts and the same work is repeated for each district: "transfer or commercial area(*D1*), office area(*D2*), residential area(*D3*), and other areas(*D4*)".

Results of Table 3 show that our explanatory variables predict a subway ridership very well. Adjusted r^2 for each model is quite high and all independent variables in the model are statistically significant. Next, we discuss in detail how each variable has an impact on subway ridership and if there is any difference of these impacts across each district.

Table 3. Model estimation results for all and each district

	All Districts	*D1*	*D2*	*D3*	*D4*
Step 1	-15.165**	-15.344**	-14.331**	-12.859**	-18.125**
Step 2	-17.670**	-16.811**	-17.380**	-15.220**	-21.269**
Step 2.5	-27.467**	-26.362**	-28.187**	-25.359**	-29.937**
COVID-19 Cases	-0.030**	-0.033**	-0.024*	-0.022*	-0.039*
News Volume	-0.001**	-0.002**	-0.001**	-0.001**	-0.001**
Weekend	-16.052**	-15.328**	-15.470**	-12.705**	-20.705**
AIC	8113	1909	1980	1917	1985
r^2	0.725	0.806	0.759	0.759	0.807
Adj. r^2	0.724	0.802	0.754	0.753	0.803

** = p<0.001, * = p<0.05

Parameter estimates of government's social distance policy variables (-15.165 for *Step 1*, -17.670 for *Step 2*, -27.467 for *Step 2.5*) show that the strengthened social distancing policy has the effect of further suppressing the number of subway passengers. Empirical results for all districts indicate that the government's strengthened social distance policy has the effect of curbing the number of subway ridership. That is, the results imply that the government's social distancing policy which tried to contain the spread of COVID-19 by restraining the movement of people was quite effective.

Parameter estimates for *COVID-19 Cases* and *News Volume* are statistically significant for all districts (-0.030 and -0.001 respectively). This suggests that the number of confirmed COVID-19 cases and the amount of media coverage related to COVID-19 had a negative impact on subway use. This is because the increase in the number of confirmed cases and related media reports may have the effect of limiting the use of public transportation by raising public fears in the early stages of the pandemic. The weekend coefficient (-16.052) indicates the weekend effect of the Seoul subway that there are fewer subway users than weekdays because they do not commute on weekends.

Comparing the impact of the government's social distancing policy on regions, it was found that the number of subway users decreased more in commercial areas than in residential areas as social distancing was strengthened, and this phenomenon was most pronounced in office areas. It is interpreted that this is because the use of public transportation in commercial and office areas is lower than in residential areas as more companies are working from home as social distancing is strengthened.

The effect of daily COVID-19 confirmed cases on the decrease in subway users was lowest in residential areas (-0.022) and highest in commercial areas (-0.033). It is interpreted that people react sensitively to the number of daily confirmed cases of COVID-19 in the early stages of the pandemic, and refrain from socializing activities that can be done in commercial facilities on days when there are many confirmed cases. The effect of the search volume for news articles on COVID-19 on the decrease in subway use also seems to have had the greatest impact on the decrease in subway users in commercial areas for reasons similar to the number of daily COVID-19 confirmed cases.

The weekend effect was greatest in office areas, where the amount of weekend public transport movement was bound to decrease because people do not commute to work (-15.470), and the lowest in residential areas (-12.705).

5. CONCLUSION AND FUTURE RESEARCH

This study examines the impact of government's social distancing policy, daily COVID-19 confirmed cases, daily volume of new articles related to COVID-19, and a weekend dummy on subway ridership in Seoul, Korea using multiple-regression during the early period of pandemic from January 1 to October 30, 2020. Findings reveal that our explanatory variables have a negative impact on the subway ridership in Seoul, Korea. Estimation and comparisons of four different area imply that government's social distancing policy works best in office area, daily COVID-19 confirmed cases and daily volume of news articles have a highest impact on the decrease of subway use in commercial area, and weekend effect is highest in office area.

Our findings have some policy and managerial implications. First, the government's social distancing policies actually affect people's use of public transport. If it becomes necessary to adjust the amount of public transportation as part of quarantine measures, it shows that social distancing policy can be one of the ways. Second, the subway operator should pay attention to the fact that the passenger reduction effect of each variable is different across the commercial area, office area, and residential area. A subway operator should establish a passenger attraction strategy and minimize customer decrease that takes into account regional characteristics.

There are some avenues for future research. Although our study aimed to investigate the impact of government social distancing policies, daily confirmed cases of COVID-19, daily volume of new articles related to COVID-19, and weekend dummy on subway passengers, the A study on how it affected the -19 cases will also be a meaningful study in establishing quarantine measures.

Methodologically, various non-linear machine learning techniques such as random forest and support vector regression (SVR) could be applied to the analysis of our dataset instead of linear regression.

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