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Analyzing the impact of Covid-19 on movement patterns in Daegu using public transport data (June 2020)

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Abstract— **The impact and the stopping of the Covid-19 pandemic currently turning the world on its head is the most pressing issue of 2020. Movement of people is a large factor in the spread of the disease and is how it transformed from an epidemic into a pandemic. In this study, we have analyzed the effect of the Covid-19 outbreak in Daegu on the number of passengers in public transport. We showed that despite the lack of forced lockdown or wide-scale business closings, the Daegu populace showed a very rapid and determined response limiting their own movement in order to curb the spread. At a year-to-year decline of around 69%, a bottom plateau was reached where all non-essential movement was cut but commuting largely continued as normal. Given how quickly the outbreak was under control, this supports the idea that full-scale lockdowns may not be necessary. Evidence was found that during an initial outbreak, citizens are more influenced by he relative rise in new cases rather than the absolute rise or absolute number of infections. After the outbreak was put under control and the number of new daily infections was brought to under 10 per day, a very consistent linear trend was found spanning several months where the number of passengers slowly recovered to around -20% year-to-year during the end of the recorded period. This implies that when considering whether to resume daily activities as before the outbreak, sociological and psychological factors may be of more importance than actual risk values. Qualitative analyses including surveys could in the future provide more evidence for the particular reasons that move people to either stop or resume their daily movement.**

I. Introduction

The worldwide Covid-19 pandemic has, as of July 29, seen over 10 million people get infected and cause over 500,000 deaths. Considering the spread of the virus is largely dependent on movement patterns of the populace, it is crucial to study just how different populations react to an outbreak. Better predictions of whether people will restrain their movement or will continue life as normal is vital in providing governments with the information they need to make the decisions that have the biggest chance of reducing the spread of the virus. Additionally, the reasoning that people use when deciding to cut down on unnecessary movement or to not do so is valuable for its potential to create more effective information campaigns that aim to change the way people consider the risks of their actions.

Daegu is an especially interesting case because its peak in Covid-19 cases was very short lived and its increase was very rapid. There also was no general lockdown and forced closures of businesses by the government were limited to a very small number of categories such as gyms that were deemed to have a large potential of becoming outbreak hot spots. The lack of such forced government influence provides a unique opportunity to study how the population voluntarily restricted it movement in response to the outbreak off Covid-19. The very rapid decline after the peak especially sets Daegu apart from other regions in the world and can be used to investigate how quickly people are willing to go back to their normal lives and whether there are any lingering aftereffects.

Given that large-scale GPS tracking data will not be released publicly because of its enormous privacy implications, the next best data source to estimate how people have adjusted their lifestyle in response to the changing Covid-19 situation is public transportation data. Especially in Korea, public transportation is widely used, with almost 10 bus rides and 3 metro rides per month per Daegu citizen before the Covid-19 outbreak. Use of public transit is an extra important object of study given its potential for virus transmission with passengers sitting or standing in very close proximity to each other, often for 15 minutes or more. Furthermore, given that transit hubs are especially likely to be located near areas that are aimed at social contact, it provides a good proxy for the extent to which citizens avoid such contact.

II. Data Collection

The data sources used were the “Daegu BusInfo” as provided by the “Daegu City Traffic Information Service Center” and by the Daegu Metro service. The available bus data was the most detailed, having daily passenger data up until June 14. Metro data was unfortunately more sparse, only being available on a monthly basis with data for May and June not yet available.

Since the variable of interest was just how much the passenger numbers have been affected by the pandemic, it was chosen to calculate the relative difference between the number of passengers in the same month this year as compared to last year. This is a better solution than comparing directly to the previous month as public transit usage has seasonality effects, in Daegu’s case peaking in Spring and reaching a low in the summer, which needs to be taken into account to separate the effect of the pandemic. In the case of the daily bus data however, it was not possible to compare directly to the same date in 2019 since they would fall on different weekdays and public transport usage patterns vary wildly between e.g. the weekend and weekdays. To remedy this issue, it was decided to instead use the number of passengers during the previous 7 days, as this would include each day of the week once

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regardless of the exact date. This means that the relative decline in passengers on March 30 was calculated as

$$\frac{\sum_{i=1}^{7} p_{20}^{23+i} - \sum_{i=1}^{7} p_{19}^{23+i}}{\sum_{i=1}^{7} p_{19}^{23+i}}$$

where

$$p_y^d$$

is the number of passengers on day d of March in year 20y.

III. Areas of Interest

There are many potential questions that could become the focus of this analysis. A difference between changes in metro and bus usage may reveal that citizens consider one "less safe", or that one transportation type is used for different purposes than the other. Comparing the relation between a decrease in public transport usage and new Covid-19 cases as well as active Covid-19 cases may provide answers as to which needs to be emphasized when warning the populace. Another important question is whether the initial effect of an outbreak of Covid-19 on movement patterns is similar to the effect of the quelling of such an outbreak, or whether the attitudes towards temporarily halting normal daily life and resuming normal daily life are different.

IV. Peak Decline

A. *Exploratory Analysis*

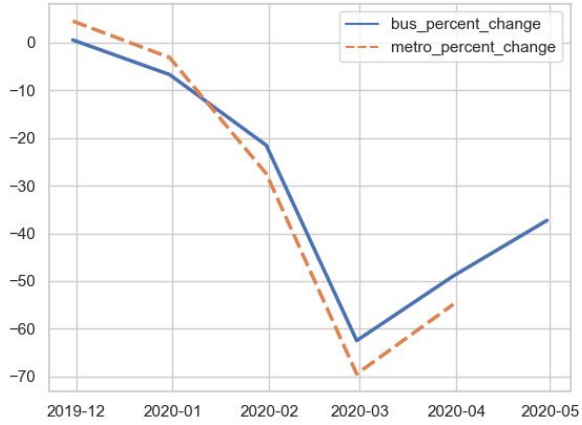


Fig. 1, year-to-year % change in monthly ridership of Daegu bus and metro

The year-to-year change in monthly ridership of Daegu buses and metros is shown in Fig 1. While the first confirmed case of Covid-19 in Korea was on January 21, the first case in Daegu was not until February 18. Yet it can be seen that while in December ridership was still up 0%~5% year-to-year, it was down by 3%~7% in January, showing that Daegu citizens were already starting to limit their movement before the pandemic had hit the city. Changes in metro and bus usage followed similar trends although metro has been affected worse with an additional 6 to 7 percentage point decline in passengers compared to the bus.

The relative decline was the largest in March at respectively 62.5% and 69.5% less passengers for bus and metro, less than half of March 2019. Metro data for May was not yet available at the time of the study and for the rest of 2020 was only available on a monthly basis. Since both methods of transportation show very similar trends in usage and daily bus data was available up to June 14, the more complete bus data will be used in most of the analyses in this paper.

The thirty percent decrease in late January and the similar increase in early February can be explained by the different timing of the Seollal national holiday, taking place one week earlier in 2020 compared to last year. The relative similarity of the effect of this holiday in both years shows that the emergence of Covid-19 in the country did not significantly affect Daegu yet at that point.

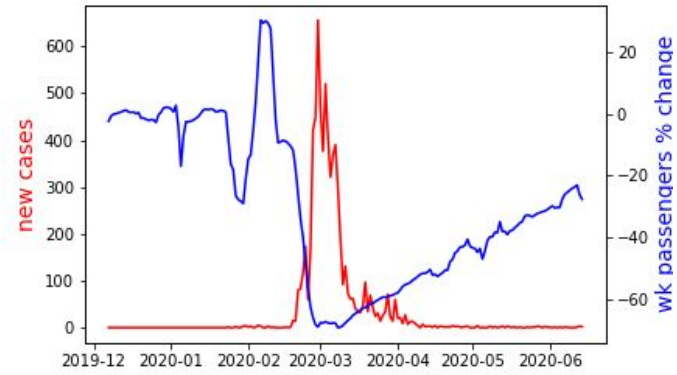


Fig. 2, YTY % change in weekly ridership of Daegu buses vs. new Covid-19 cases in Daegu

A comparison of the weekly number of passengers with the number of new cases in Daegu shows that ridership was clearly the lowest during the period with the most new Covid-19 cases. However it can also be seen that the recovery of passengers after the peak of the decline has been much more gradual than the very steep decline in the number of infections.

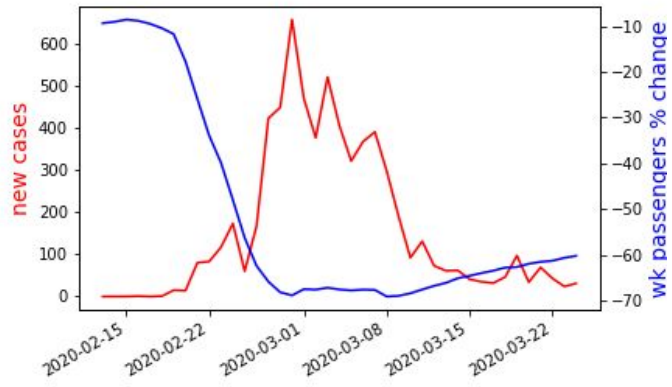


Fig. 3, YTY % change in weekly ridership of Daegu buses vs. new Covid-19 cases in Daegu around the peak

Exploring the graph around the peak more closely shows that starting February 19, the first day that more than 1 new case was confirmed in Daegu with 15 new cases, daily ridership entered an almost perfectly linear decline. This daily decline of 6~8 percentage points lasted for one week until February 26, when the decline slowed down. During these 7 days, the number of bus passengers decreased from a decline of 12% to one of 62% compared to the same week in 2019.

The two local minima in passengers occurred during the weeks from February 23 until February 29 and the week of March 2 to March 8. Each of these weeks saw a decline passengers of around 69 percent compared to the previous year. Meanwhile the days with the highest numbers of new Corona cases in Daegu were February 29 with 656 new cases and March 3 with 520 new cases.
Importance to note is that this peak in new cases actually came a day after the decrease in passengers stabilized on February 28, staying within one percentage point until March 11th.

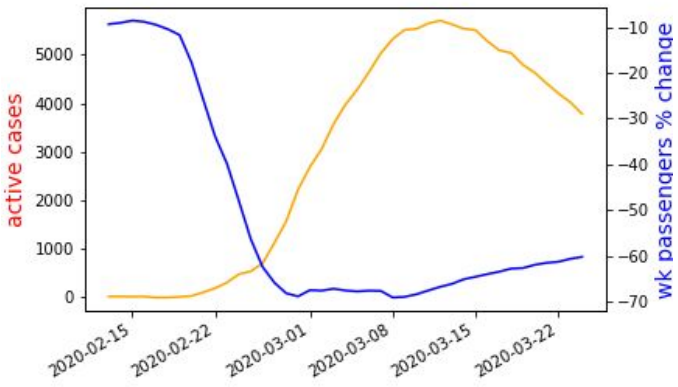


Fig. 4, YTY % change in weekly ridership of Daegu buses vs. active Covid-19 cases in Daegu around the peak

The relation of bus passengers and the number of active Covid-19 cases in Daegu looks to be less significant. Ridership started recovering from March 10, whereas the number of active cases peaked on March 12 and stayed relatively constant until March 16. The later acceleration of the decrease in active cases also does not seem to have boosted the recovery of ridership.

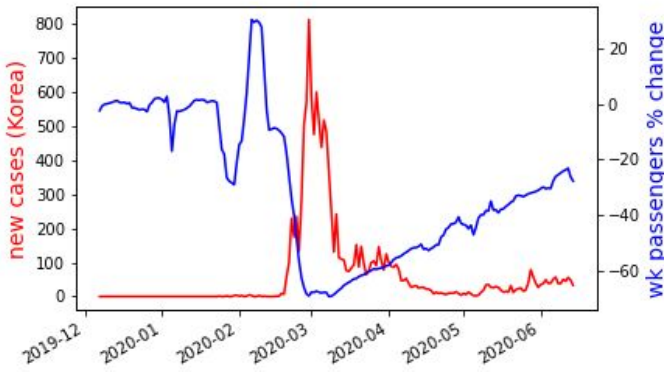


Fig. 5, YTY % change in weekly ridership of Daegu buses vs. new Covid-19 cases in Korea

The new Covid-19 cases in Korea were dominated by Daegu until the end of March, after which the center changed to Seoul and the Gyeonggi-Do area. The lowest number of new cases was on May 6th with only 2 cases in the country, after which it has increased to 30 to 60 new cases in June. We can see that these new outbreaks in and around Seoul have not affected the use of public transport in Daegu.

B. Interpretations

The most likely theory that would explain the slightly bigger decrease in metro passengers is that a relatively smaller share of its traffic is comprised of commuters as compared to bus traffic. Since Daegu did not at any point instate a full-scale lockdown offices and factories generally did not shut down, leading to the expectation that commuter traffic was less affected than other, less essential traffic.
The peculiarly linear decline of passengers during the start of the first peak of new cases its interpretable in many ways. One possibility is that different people have different thresholds that need to be reached before they are willing to limit their movement. It could also be that people started out limiting there outside activities only a little, but restricted themselves more and more as the number of Covid-19 cases increased. Despite the linearity of the decline, the rapidness at which it took place makes clear that the Daegu public was very rapid in their actions and committed to showing self restraint in order to stop the spread of the virus. On February 26, the number of bus passengers had declined by more than fifty percent compared to the previous week.

The stabilization of the number of passengers occurring before the peak of new Covid-19 cases suggests that by February 28 all use of public transport except for commuting and otherwise non-essential travel had already come to a standstill, leaving

no room for a further decline despite the increase in new cases. This theory is supported by the relative decline remaining stable for as many as 13 days, staying between -67.5% and -69.2%. It suggests that even if the number of new cases had risen even further, this would not have been matched with a similar decline in passengers unless businesses had been forced to shut down.

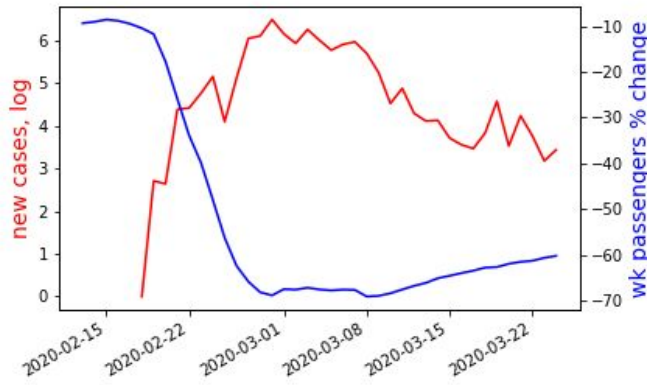


Fig. 6, YTY % change in weekly ridership of Daegu buses vs. log of new Covid-19 cases in Daegu around the peak

Plotting the log of the daily new Covid-19 cases shows signs of a negative relationship. This indicates that it might be the rate of increase and decrease in the number of new cases that is a better predictor of public transport usage than the absolute number of new cases. The relationship is the clearest for the decline and the plateau, while being less certain in case of the recovery, which we will cover in the next section of this report.

V. Recovery

A. Exploratory Analysis

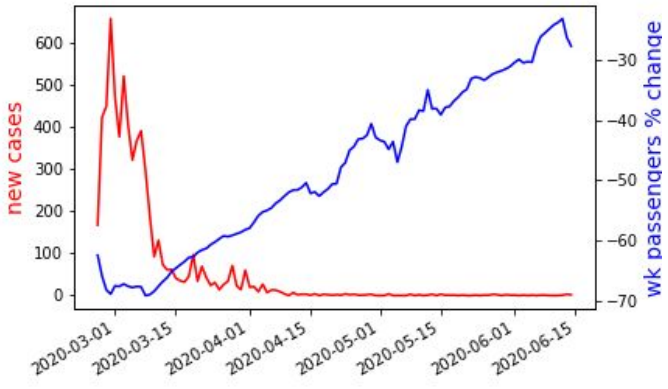
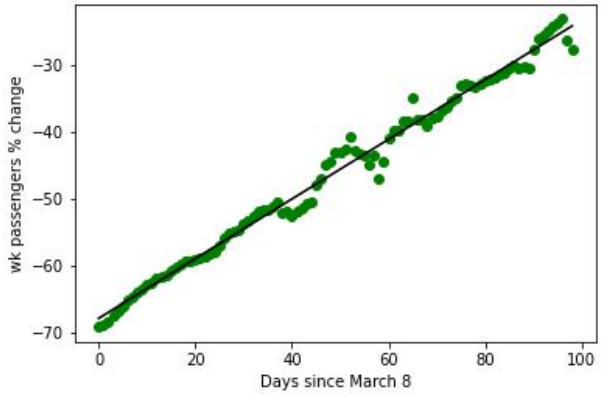


Fig. 7, YTY % change in weekly ridership of Daegu buses vs. new Covid-19 cases in Daegu, recovery period

The recovery of passenger numbers began after March 8 when the lowest relative number of passengers was recorded at -69.2% compared to the same week in 2019. During the following days, the number of new Covid-19 cases in Daegu slowed down to 50-100 per day, down from its peak of 656. The number of new cases has kept declining ever since and has stayed under 10 for every day after April 7. This continuous decline in new cases did not show a clear relation with the pace of the recovery in passengers which has stayed relatively constant throughout.

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Coefficients:
 [-8.08012029]
Mean squared error: 160.09
Coefficient of determination: 0.41
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Fig. 8, Regression analysis of YTY % change in weekly ridership of Daegu buses vs. the number of days since the start of the recovery in passenger numbers (March 8)

Just like the decline, the recovery showed a remarkably consistent linear trend. Starting on March 8 of there was an average daily recovery of roughly 0.45 percentage points, reaching a maximum of -23.1% on June 11. The simple linear regression shown above with the number of days since March 8 taken as the independent variable had an R squared of 0.99, showing an almost perfect fit.

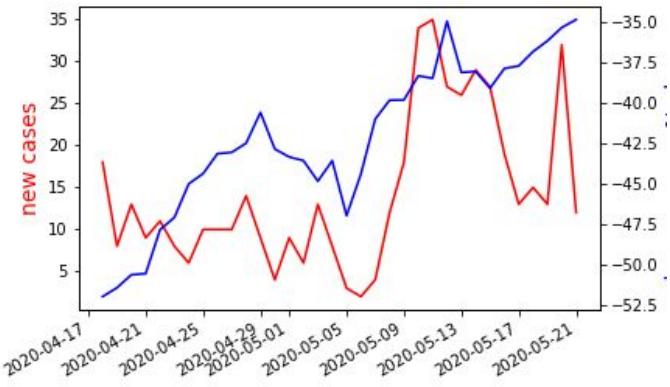

Fig. 9, YTY % change in weekly ridership of Daegu buses vs. new Covid-19 cases in Korea, middle of recovery period

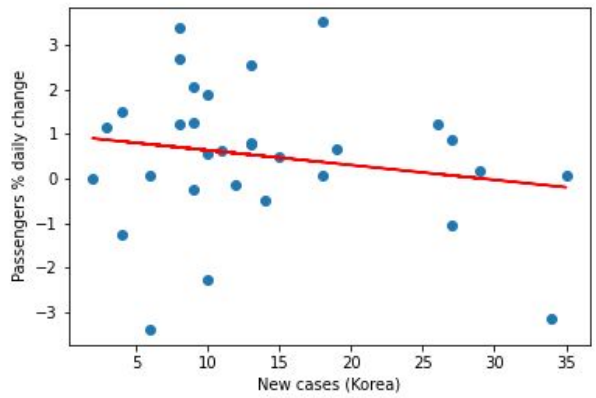

Fig. 10, Regression analysis of YTY % change in weekly ridership of Daegu buses vs. the number of new Covid-19 cases in Korea, recovery period

Around the middle of the recovery during late April - early May, a pattern is visible with two similar peaks and throughs. Occurring on different weekdays, no relation was found with the time of the week here, and with new Covid-19 cases in Daegu staying close to zero during the time period, the remaining factor to investigate were the outbreaks on a national level. The initial plot showed some similarities which lead to the attempt to capture a relation in a linear regression. The dependent variable was chosen to be the difference of the change in weekly passengers compared to the previous day, with the independent variable being a time-lagged version of the number of new cases in Korea. Lags of 1 to 5 days were considered to allow the public to react to outbreaks. The 2-day and 3-day lags showed most promise but ultimately none of them was significant.

B. Interpretation

Compared to the decline, the recovery of passenger number showed less of a relation to the Covid-19 numbers. The time-linearity of the recovery, which has shown the same trend over more than three months, gives rise to the idea that psychological and sociological factors play a bigger role here. Just like the spread of the virus, there may be a “spread” of returning to a normal lifestyle. It first starts with those who are the least worried, which in turn shows the people in their vinicity that it may be safe to increase their movement again, with an increased sense of security slowly spreading over the 2.5 million-big social network that is the community of Daegu.

This is based on the same idea mentioned when discussing the initial decline, based on the fact that people likely have different thresholds for what they consider safe. It could be that the threshold for “danger” and thus *restricting* movement is more based on the number of Covid-19 cases, whereas the threshold for “safety” and going back to old movement patterns relies more on seeing what others are doing.

VI. Conclusion

The outbreak of Covid-19 in Daegu has had a large impact on the usage of public transport. Despite the lack of lockdown or closing of offices and factories, bus usage reached a maximum of a 69.5% decrease compared to normal times. This shows that the citizens of Daegu took the risk of further spread very seriously and quickly adjusted their movement patterns without needing to be forced to do so. This shows that given that the response of the populace is rapid, much consideration would be needed before implementing a lockdown, as it would solely prevent commuting given that no other movement is taking place any more.

There does however also lie a danger in the recovery trend. While the number of new daily Covid-19 cases in Daegu has remained near zero for many weeks, the linearity of the bus passenger trend during this period shows that the resuming of daily life and normal movement patterns is not guided by actual risk of Covid-19 spread. The implication is that it is instead more based on sociological and psychological factors, which is something that needs to be tackled if a second wave of outbreaks occurs to both flatten the curve while yet at the same time not imposing unnecessary methods that provide limited risk reduction while causing economic harm that could have long-term negative effects.