**Impact of COVID on bus ridership in King County, Is there any recovery pattern?**

**Abstract**

* 1. **Introduction**

Resolutions to increase the percentage of trips taken by transit have been established by city planners around the United States, with some of the most pioneering being Boston (over 40% by 2030), Portland (25% by 2035), and Seattle (). These goals are connected to a wide variety of purposes, such as easing traffic, enhancing air quality, and cutting carbon emissions. In fact, not only does public transportation maximize roadway space utilization, but each passenger also uses far less energy than when driving alone (add citations). Nevertheless, despite attempts to attain the potential benefits of public transportation, transit ridership has been declining in nearly all U.S. cities over the previous decade (cite). The situation even got worse in the past few years and Transit ridership on public transportation has experienced an unprecedented decline in recent years, with the well-acknowledged cause being the COVID-19 pandemic.

Beginning in late 2019, the globe has been gripped by one of the biggest health crises in history due to the rapid spread of the Coronavirus (COVID-19) pandemic. Wide-ranging effects on public health, the economy, and daily life have resulted from COVID-19. In the early phases of the pandemic, transit operators and authorities were forced to implement limitations on public transportation in order to reduce the spread of the virus and protect the safe travel of vital workers. The considerable drop in ridership is attributable but not limited to the aforementioned regulations and passengers' own preferences.

There is an important need for transportation authorities and the general public to gain insight into the causes and effects of declining ridership. The ability to accurately predict demand and schedule future services is essential for transportation systems, hence such insights are vital. To address this, various research has been conducted in the past few years to investigate underlying factors affecting bus ridership during COVID (references). There is clear evidence from these studies that the decline in ridership varies by both geographic area and demographic characteristics (cite from paper 1). The effect of various factors on ridership reduction patterns, including income, race, education, and jobs was found to be significant. Now, after three years as the restrictions are waning and people are adjusting to the “new normal”, it appears that ridership is recovering from the drop caused by COVID. It is expected that the ridership recovery would vary at different stops such as the ridership reduction.

These significant changes in ridership patterns in the past few years indicate that transit agencies can no longer run the status quo, meaning that the transit system cannot be run with the same norms as before. While previously, transit agencies geared toward commuters coming to central business districts, this is no longer applicable due to the changes in ridership patterns. In the post-COVID era, the importance of non-commuters and non-working trips is highlighted, so transit agencies should serve these trips as well. As a result, it is important to keep a close eye on ridership trends over time in order to identify shifting travel habits and better accommodate users.

Moreover, adapted public transport services may have significant effects on the mobility and social exclusion of disadvantaged communities and on sustainable travel. Hence, knowing ridership recovery is crucial as the future of local public transport financing is contested due to lingering issues with transit usage (cite). Although various studies have focused on ridership reduction patterns, literature investigating ridership recovery patterns from COVID is scarce.

This study utilizes four years of the APC dataset to investigate ridership changes in the pre-COVID, COVID, and recovery era. The main questions that the present study aims to cover are:

* What is the temporal pattern of ridership recovery in King county? Using time-series model, few dummy variable such as omicron. (total ridership)
* What is the spatio-temporal pattern of ridership recovery in King County?
* What spatiotemporal factors were attributed to uneven recovery pattern?
* How does recovery patterns defer from weekday to weekends?
* How will the recovery pattern evolve in the future?

In order to answer these questions, First, the ridership at each stop was compared in each era. Then, we zoomed in on those areas and characterized the associated area profiles…

The rest of the paper is structured as follows. The next section provides a literature review of relevant studies that investigated ridership changes in COVID and the pre-COVID era. It is then followed by Section 3, which describes datasets, processing, and preliminary data analysis. Next, Section 4 represents the proposed methodology and statistical modeling framework. Major findings and results are presented in Section 5. Finally, Section 6 provides discussions and concluding remarks.

**Results**:

1. Daily Ridership in 2019-2023

Chart, scatter chart

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* As can be seen a sharp decrease happened during covid
* Weekend ridership might have recovered, but the weekday ridership seems to be far from recovery
* outlier points in weekdays might be holidays (should be looked into)

1. Monthly Ridership in 2019-2023

Chart, line chart

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* Sharp decrease right before January in each year

1. Ridership pattern in stops during weekdays

Chart

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* A part of the stop data is missing (in the late 2021)
* Big difference in ridership between different stop stations (we are not able to see stops with lower ridership in this figure)
* maybe we could cluster in terms of level of ridership
* We can investigate the difference in the recovery speed between stops with higher and lower ridership (does crowdedness of the stop before COVID has an effect in its recovery pace?)

1. Ridership pattern in stops during weekends

Chart, scatter chart

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**Literature on recovery period ridership pattern:**

**Can continued anti-epidemic measures help post-COVID-19 public transport recovery? Evidence from Taiwan (2022):**

* Used survey data mostly to investigate the change in the mode choice of passengers in recovery period (mixed logit model)
* Investigated change in ridership using ANOVA during three eras:

Before COVID: the time before official declaration on the pandemic

During COVID: when the government imposed policies such as mandatory masks and temperature screening

After COVID: from the time that government started to relax some of the COVID related bans

* Divided the data into two categories:

Loyal transit users (those who used transit at least once during each era)

Non-loyal transit users

(Question: wouldn’t it be biased if we use smart card data to determine loyal users?)

* Factors investigated:

lifting mandatory policies: Although lifting the mask-wearing policy may lower riding inconvenience and discomfort, the perceived transmission risk may increase, and thus, the willingness to take metro may decline

service rate: Changes in waiting time and transfer availability were found not to affect post-COVID-19 metro use

loyalty to transit: the post-COVID-19 metro use frequency recovery from the in-COVID-19 phase was found only from loyal metro users who did not wholly escape from metro use in each phase.

**Who is returning to public transport for non-work trips after COVID-19? Evidence from older citizens’ smart cards in the UK’s second largest city region (2023)**

* Smart card transactions record for each passenger the exact date and time of boardings, the service used and several operational details. The records can be linked to anonymous cardholder databases, which hold data on gender, age, ethnic group and residential area of passengers.
* Sociodemographic and social inequalities: male, younger and non-White passengers are more likely to return to public transport as soon as movement restrictions were lifted, whereas passengers from White ethnic background and affluent areas do not return to public transport within the first year after the outbreak. Pronounced social inequalities persist into the middle of 2021, and only thence they began to attenuate as part of a wider return to public transport among passengers post retirement age. In 2022, 80% of these passengers have returned to public transport but the frequency of use has remained lower than prior to the pandemic.

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Important Events:

* January 21, 2020: First confirmed U.S. case in Snohomish County. King County stood up Public Health Seattle & King County Health and Medical Area Command (HMAC).
* February 27, 2020: The first confirmed case of COVID-19 is observed in King County.
* February 28, 2020: First recognized COVID-19 death in King County, the first in the United States
* April 1, 2020: Free transit
* October 1, 2020: The free transit is no longer available
* February 1, 2021: Two mass vaccination sites for COVID-19 opened in South King County.
* Over $4.8 million was disbursed by Adult Services Division Coronavirus Relief Funds (CRF).
* November 26, 2021: WHO declared that the world was facing a new variant of concern: Omicron. It would go on to change the trajectory of the COVID-19 pandemic.
* February 16, 2022: With new COVID-19 cases and hospitalizations decreasing, and nearly 80% of all King County residents fully vaccinated, the county is [ending its local health order](https://publichealthinsider.com/2022/02/16/vaccination-verification-policy-to-end-as-of-march-1/) requiring proof of COVID-19 vaccination or negative test for entry into restaurants and bars, indoor recreational events and establishments or outdoor events. Starting on Tuesday, March 1, vaccine verification will no longer be required at Bellevue parks facilities, including community and recreation centers.
* February 28, 2022: With declining case rates and hospitalizations across the west, California, Oregon and Washington are moving up the date for indoor mask requirements to be lifted from March 21 to March 11. After 11:59 p.m. on March 11, Masks will no longer be required in restaurants, grocery stores, bars, gyms or schools. County mask requirements are lifting at the same time. Masks will continue to be required in health care and corrections facilities. State policies do not change federal requirements, which still include masks on public transit.
* March 4, 2022: In response to the lifting of the county and state mask mandates, the public will no longer be required to wear masks indoors at most city facilities starting Saturday, March 12.
* April 4, 2022: The City of Bellevue returns to pre-pandemic operations at City Hall and other facilities. The transition comes after the modification of state and county health directives in March, high vaccination rates in the community and dropping COVID-19 infections.
* Amazon announcement (in person work)

Missing data:

10/31/2021 to 11/21/2021

**Previous studies:**

Executive orders or public fear: What caused transit ridership to

drop in Chicago during COVID-19?

Jesus Osorio, Yining Liu, Yanfeng Ouyang

The daily ridership data

1. A Bayesian structural time-series (BSTS) model, which considers the historical trend of transit ridership, including seasonality and holidays, to predict counterfactual transit ridership after March 15, 2020.

2. A dynamics model for daily transit ridership loss, inspired by Wang (2014), which captures the impacts of both people’s risk perception and external regulatory factors. The former includes objective risk measurements, e.g., daily confirmed cases and daily deaths (Wang, 2014), as well as media attention, e.g., Google Trends (Fenichel et al., 2013; Rogers, 2016). The latter includes executive orders, school closures, and remote working policies.

3. A linear regression analysis module, which builds connections between socioeconomic characteristics of city neighborhoods and people’s reactions toward the pandemic, using output from the dynamics model for daily ridership loss.

We cannot use the first two models because they had training data from 2001. Furthermore, they investigated the obvious effects.

Who left riding transit? Examining socioeconomic disparities in the impact of COVID-19 on ridership

Songhua Hu, Peng Chen

The daily ridership data

1) *BSTS fitting*: First, a set of Bayesian structural time-series (BSTS) models were fitted for each “L” \_station, where various time-varying contemporaneous covariates, including weather, holidays, and seasonality were accounted for.

2) *Impact inferring*: Based on the BSTS model trained by data before the intervention (i.e. the COVID-19), the counterfactual ridership could be predicted in a synthetic control of no intervention took place. Then, by comparing the observation and the prediction, the relative impact was obtained, which could be interpreted as the proportional decrease in ridership caused by COVID-19.

3) *PLS regression*: Partial least squares (PLS) regression was fitted using station-level relative impact as the dependent variable, incorporating various independent variables such as land use, COVID-19 related features, socio-demographic factors, and transit services (see Table 1). PLS was employed here to address the multicollinearity among the independent variables without losing important information.

Impacts of COVID-19 on Bus Ridership and Recovery Trends in Syracuse, New York

Michael Ammoury; Baris Salman; Carlos E. Caicedo Bastidas; and Shubham Kumar

APC

They compared the data of 2020 with 2019 and considered four phases:

Timeline phases: (1) the pre-pandemic period for the months of January and February, (2) the month of March that marked the beginning of the outbreak in Onondaga County, (3) the three months stretching from April to June, where the bus service was limited in most of the period and where pandemic related restriction policies were in place, and (4) the last six months of the year from July up to December, signaling the recovery following the last phase of re-opening when the bus service returned to normal, and the policy restrictions were lifted.