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COVID-19 effects on shared-biking in New York, Boston, and Chicago

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A B S T R A C T

Coronavirus has had a large-scale impact on transportation. This study attempts to assess the effects of COVID-19 on biking. Bikeshare data was used to understand the impacts of COVID-19 during the initial wave of the disease on biking in New York City, Boston, and Chicago. As the cases increased, these cities experienced a reduction in bikeshare trips, and the reductions were different in the three cities. Correlations were developed between COVID-19 cases and various bikeshare related variables. The study period was split into three phases — no COVID-19 phase, cases increasing phase, and cases decreasing phase — to examine how the residents of the three cities reacted during the different phases of the coronavirus spread. While bike trips decreased, the average duration of the trips increased during the pandemic. NYC’s average trip duration was consistently less than that of Boston and Chicago, which could be due to its sprawl (NYC is considered as more compact and connected compared to the other two cities).

1. Introduction

The COVID-19 pandemic has had a tremendous effect on the world and the way we live. With over 17 million cases of COVID-19 worldwide and over half a million deaths (JHU, 2020), the virus has caused great anguish throughout the world. As of November 6, 2020, in the USA, the virus has killed over 236,000 people and has infected over 9.8 million people (JHU, 2020). In addition to the loss of life, this virus has had a substantial impact on transportation. This study attempts to assess the effects of COVID-19 on biking. Bikeshare data was used to understand the impacts of COVID-19 during the initial wave of the disease on biking in New York City, Boston, and Chicago. As the cases increased, these cities experienced a reduction in bikeshare trips, and the reductions were different in the three cities. Correlations were developed between COVID-19 cases and various bikeshare related variables. The study period was split into three phases — no COVID-19 phase, cases increasing phase, and cases decreasing phase — to examine how the residents of the three cities reacted during the different phases of the coronavirus spread. While bike trips decreased, the average duration of the trips increased during the pandemic. NYC’s average trip duration was consistently less than that of Boston and Chicago, which could be due to its sprawl (NYC is considered as more compact and connected compared to the other two cities).

Additionally, the coronavirus has had a substantial impact on transportation. With the nature of the virus, large cities have been hit harder by the virus than smaller cities or rural areas. The best example of this is New York City where there have been more than two hundred thousand cases of COVID-19 (JHU, 2020). With this being the case, people who live in cities are no longer traveling in large numbers on public transport such as subways or public buses. In New York City, there were roughly 365,000 subway trips on April 13th, which was down 94% from 5.56 million subway trips on an average weekday in April 2019 (Guse, 2020; Teixeira and Lopes, 2020). Perhaps one of the most hard-hit industries was the aviation industry. With travel bans being implemented, most international travel has ceased. In May, half of all the industry’s planes were parked in airports or desert airstrips (Chokshi, 2020). On March 22, 2020, airline capacity in Europe was down by almost 88 percent compared to the same day in 2019 (SRD, 2020). Household travel across America declined by 68 to 72 percent during the last two weeks of March and the first week of April, compared with the first week of March (Dutzi, 2020). Clearly, COVID-19 has affected the way humans are traveling and has had a significant impact on the transportation industry.

In contrast to the general reduction in transportation, a few studies and news articles state that cycling has increased dramatically during the COVID-19 pandemic (TREK, 2020; Sui and Prapavessis, 2020). However, it has also been observed that there has been a decrease in bike ridership in the bikeshare program, but the decrease has been less pronounced than in mass transit ridership (Kanik, 2020). In Wichita, Kansas, the operator of the bikeshare program was bankrupted due to the COVID-19 biking decline and, as a result, the bikeshare program was discontinued in the area (Lefler, 2020).
In this regard, this paper will focus on examining the effect of COVID-19 on biking across three major cities in the US: New York, Chicago, and Boston. This study utilizes correlation analysis and the random parameter least squares regression model in order to make conclusions regarding COVID-19’s effect on the shared bike trips. This study is important in the sense that the findings illuminate the changes in people’s travel behaviors in terms of biking, especially in big metropolitan cities during the pandemic such as COVID-19. More importantly, such findings will provide insights for city decision-makers, especially transportation officials, to make plans for adjustments on people’s travel needs if a similar pandemic happens in the future.

2. Data

To achieve the objectives of this study, the authors would need COVID-19 data and bicycle volume data. Almost all major cities have created COVID-19 dashboards, which have information such as hospitalizations, cases, deaths, etc. Both COVID-19 and bicycle volume data should be at the same granularity to conduct this study.

The first case of COVID-19 was reported in January 2020 in the US and the cases started increasing exponentially in the first week of March 2020. Hence, for this study, data from October 1st, 2019, to May 31st, 2020 (at the time the authors started the analysis, June data was not released), were considered in the analysis. This timeline allows the authors to study the trends pre-COVID-19 and during COVID-19.

A few cities have automated counters to estimate bicycle volumes. However, these data are not released to the public regularly. The other type of data that is readily available on bicycling is the bikeshare data. However, these data are not released to the public regularly. The other type of user, etc. The advantage of using bike-share data for this analysis is that the additional information this data provides is practically impossible to gather for all bicycle users; for example, the bikeshare data includes information such as the duration of the trip, the gender of the rider, origin and destination, type of user, etc.

Major bikeshare programs let the users download the data freely, and hence the authors were interested to include as many cities as possible in the analysis. Some cities’ bikeshare programs release the data quarterly. This factor limited the analysis period, so we eliminated those cities from the analysis. Further, cities such as San Francisco and Los Angeles have changed the data elements during the study period. With all these data limitations, the authors limited the analysis to New York City (NYC), New York, and Chicago.

NYC bikeshare (Citibike, 2020) has 14,500 bikes and nearly 900 stations. Close to 18 million trips were recorded in 2018. Chicago bikeshare (Divvybikes, 2020) has 6,000 bikes and 600 stations. In 2016, Divy provided 10 million trips that traveled over 20 million miles. Boston’s bikeshare (City of Boston, 2020) is called Bluebikes and has 3,500 bikes, 330 stations, and has provided more than 11.5 million trips.

The COVID-19 variables included in this study are:

- number of daily cases,
- number of daily deaths, and
- percent of positive COVID-19 cases among daily tested population.

NYC has data about all the above variables, while Boston has only cases data, and Chicago has both cases and deaths data. The bikeshare data variables include:

- start time of the trip,
- end time of the trip,
- user type (Customer = 24-hour pass or 3-day pass user; Subscriber = Annual Member)
- gender (unknown, male, female)

The bike data is available at the trip level, which was aggregated to the day level to match with the COVID-19 data. For a given day, the following variables were created using the raw data: total number of trips, total trip duration, average trip duration, number of trips by customers, and number of trips by subscribers. Eventually, the percentage of trips by customers for a day was estimated by dividing the number of trips by customers with the total number of trips on that day. Similarly, the percentage of trips by subscribers was also estimated.

3. Method

Correlation coefficients were estimated using the below equation.

\[ r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{n\sum x^2 - (\sum x)^2} \sqrt{n\sum y^2 - (\sum y)^2}} \]  

Besides correlation analysis, to further explore the marginal effects of COVID-19 cases on the number of shared bikes trips, the least-squares regression model (OLS) will be applied. However, as there could be other variables that could influence the dependent variable, the estimations may be biased due to the unobserved heterogeneity. To account for the unobserved heterogeneity and avoid potentially biased estimation results, random parameter regression models are recommended (Li et al., 2017; Washington et al., 2020; Lübbe et al., 2020). The formulation of random parameter least squares regression model is written as,

\[ y_i = \beta_1 x_i + \epsilon_i \]  

where \( y \) is the dependent variable (the number of shared-bike trips in each studies city); \( i \) represents the index of \( i \)th observation, and \( \beta \) is the vector of the estimated random parameters \( \beta_i \); \( x \) denotes the independent variables used to model the correlations between them and the dependent variable \( y \); \( \epsilon_i \) are the error terms usually following a normal distribution.

\[ \beta_i = \beta + \Lambda z_i + \Gamma v_i \]  

where \( \beta \) is the mean of the distribution; \( \Lambda = \) a matrix of coefficients; \( z = \) selected random variables; \( \Gamma = \) a lower triangular matrix; \( v_i = \) a randomly distributed term with normally distributed \( N(0, \sigma^2) \).

The simulated maximum likelihood method with 200 Halton Draws is used to estimate the parameters. The log likelihood function is formulated as,

\[ \log L = \sum_{i=1}^{N} \log L_i \]  

where \( N \) is the total number of observations. Conditioned on \( v_i \), the joint density for \( i \)th observation is,

\[ f(y_{1i}, \ldots, y_{Ti}) = \prod_{t=1}^{T} f(y_{ti} | x_{ti}, \beta_t) = (2\pi\sigma^2)^{-T/2} \exp \left[ -\frac{1}{2\sigma^2} \sum_{t=1}^{T} (y_{ti} - \beta_t x_{ti})^2 \right] \]  

where \( t \) represents the \( t \)th term in the density and \( T \) is the total number of terms in the density.

The log likelihood function is maximized by solving the following Eq. (6),

\[ \frac{\partial \log L}{\partial \theta} = \sum_{i=1}^{N} \frac{\partial \log L_i}{\partial \theta} = 0 \]
where $\theta = (\beta, \Delta, \Gamma)$ and only contains nonzero elements in the triangular matrix.

Since $v_i$ is unobserved, it is necessary to obtain the unconditional log likelihood using the expectation over the distribution of $v_i$. Estimation is done conditionally on an estimate of $\sigma^2$ using Monte Carlo simulation based on the following approximation strategy,

$$E_v[L(v)|x_i] = \frac{1}{R} \sum_{r=1}^R L(v_{ir})$$

(7)

where $E$ represents the expectation over the distribution of $v_i$; $v_{ir}$ is a random draw based on the distribution of $v_i$ with $R$ Halton Draws.

Then the log likelihood is computed as,

$$\log L = \sum_{i=1}^n \log \left( \frac{1}{R} \sum_{r=1}^R f(v_{ir}, \beta, x_i) \right)$$

(8)

where $f(v_{ir}, \beta, x_i)$ represents the joint density for the $i$th observation; $\beta$ is equal to $\beta + \Delta + \Gamma v_i$. More details of the random parameter OLS models are in Washington et al. (2020).

4. Results

Table 1 provides a descriptive analysis of the COVID-19 and bikeshare data for New York, Boston, and Chicago.

Table 1 shows the total number of bike trips and COVID-19 cases for each city by month and also provides summary statistics for some of the interested variables. New York has the highest number of bike trips and also has the highest COVID-19 cases. The lowest number of bike-trips and the highest number of cases in all the three cities were recorded in April.

To eliminate day-of-the-week variations, the trip frequency and COVID-19 data were plotted at the week-level, as shown in Fig. 1.

Seasonal variations can be seen in the graph, and, as expected, people were biking less during holiday weeks and colder months. Moreover, as the number of cases increased, the frequency of bikeshare trips decreased. The COVID-19 peak is clearly visible in all three graphs. NYC’s and Boston bikeshare trips represent the lowest trip frequency, which occurred shortly before the COVID-19 peak. However, Chicago’s COVID-19 peak does not align with the trough in bikeshare trips. For NYC, from March 23 till the end of the study period, the trend is upwards for the frequency of bike trips. Whereas for Boston, the graph stagnates for almost a month. Once these cities passed the COVID-19 peak, the number of daily bike trips showed a rebound. While this effect is seen in all three cities, it is most clearly seen in the case of New York City. Further, NYC’s drop-in bikeshare trips did not happen until a large increase in cases, whereas for Boston and Chicago, the drop can be seen even before COVID-19 hit these cities. This could be because NYC is the first to experience COVID-19 in the US (in terms of the scale at which cases rose) and it therefore took time to respond to the pandemic while other cities learned from NYC and were prepared.

While Fig. 1 visually demonstrates how COVID-19 and bikeshare trips varied over the study period, Fig. 2 plots the average trip duration and the number of COVID-19 cases for the study period. For each trip, the start and end times were recorded. The authors estimated trip duration from these two variables. Again, as trips durations vary by day-of-the-week, to limit this variation, the average trip duration for a week is estimated by summing up the trip duration for that week and dividing it with the total number of trips that week.

The Table 2 shows the foregoing phases of the three cities. COVID-19 variables, e.g., cases, deaths, hospitalizations, percent positive, etc., had very strong correlations between each other; therefore, hereafter only the number of COVID-19 cases is considered for studying the effects of COVID-19 on bicycling. Table 3 shows that the correlation values between the COVID-19 variables and bikeshare related variables for all three cities. As there will not be any COVID-19 cases in the PC phase, the correlation coefficients were presented only for UC and DC phases.
COVID-19 cases were negatively correlated with the number of bikeshare trips. Such a correlation was even stronger during the UC-phase, which implies that an increase in daily cases had a greater effect on people biking. This could be due to a host of factors such as stay at home orders in place, closure of non-essential business, media publicity about COVID-19 spread, social-distancing, and face mask orders. Interestingly, the magnitude of such negative correlations decreased slightly during the DC-phase which could be again due to the relaxation of some of the local ordinances and people returning to their new-normalcies as cases started to decline. As the number of trips decreased, a decrease in the total trip duration clearly results, and hence it is negatively correlated to cases.

It is quite interesting to see a very strong, significant, and positive correlation between cases and average trip duration. This is likely because the number of short trips declined more than the longer trips. Public transportation has come to an almost standstill during the pandemic which might have forced people to use bikes for their longer trips as well. As the trips decreased, the number of customers and the number of subscribers also decreased, and hence both variables had a negative correlation in both the phases. However, the percent-

Fig. 1. COVID-19 Cases and Bikeshare Trips by Week.
Table 2
Phases for the Three Cities.

| City     | Pre COVID-19 (PC) Phase | Uphill COVID-19 (UC) Phase | Downhill COVID-19 (DC) Phase |
|----------|------------------------|---------------------------|-------------------------------|
| NY       | 10/1/2019 - 2/28/2020  | 2/29/2020 - 4/6/2020      | 4/7/2020 - 5/31/2020         |
| Boston   | 10/1/2019 - 3/5/2020   | 3/6/2020 - 4/24/2020      | 4/25/2020 - 5/31/2020        |
| Chicago  | 10/1/2019 - 2/27/2020  | 2/28/2020 - 4/22/2020      | 4/23/2020 - 5/31/2020        |

Table 3
Correlation Coefficients between Cases and Bikeshare Variables.

| Phase       | NY UC-phase | NY DC-phase | Boston UC-phase | Boston DC-phase | Chicago UC-phase | Chicago DC-phase |
|-------------|-------------|-------------|-----------------|-----------------|-----------------|-----------------|
| Trip frequency | −0.79*       | −0.62*       | −0.42*          | −0.49*          | −0.58*          | −0.52*          |
| Total trip duration | −0.47*   | −0.56*       | −0.29*          | −0.27           | −0.22           | −0.53*          |
| Average trip duration | 0.7*     | 0.19         | 0.07            | 0.20*           | 0.33*           | −0.34*          |
| # Customer    | −0.35*       | −0.58*       | −0.28*          | −0.40*          | −0.24           | −0.58*          |
| # Subscriber | −0.8*         | −0.64*       | −0.42*          | −0.58*          | −0.62*          | −0.43*          |
| % of Customers | 0.45*     | −0.53*       | 0.05            | −0.34*          | 0.23            | −0.75*          |
| % of Subscriber | −0.45*    | 0.53*        | −0.05           | 0.34*           | −0.23           | 0.75*           |

Note: * indicate statistically significant correlations at the 95 percent confidence level.

Table 4
Random Parameter OLS Model Estimations for UC and DC phases.

| Dependent Variable: Daily trip frequency | NYC | Boston | Chicago |
|-----------------------------------------|-----|--------|---------|
| Coef. | S.E. | Coef. | S.E. | Coef. | S.E. |
| Constant | 48039.2* | 14.42 | 41349.7* | 4.91 | 5449.9* | 10.2 |
| Daily number of COVID-19 cases | −27.8* | 0.02 | −11.3* | 0.03 | −1.83* | 0.01 |
| Weekend | 2972.7* | 17.86 | 1076.8* | 7.55 | −1414.9* | 12.1 |
| Scale parameters for the distribution of random parameters | Constant | 14219.8* | 8.15 | 2789.5* | 5.50 | 3377.8* | 12.6 |
| COVID-19 cases | 0.98* | 0.19 | 0.83* | 0.02 | 0.19* | 0.01 |
| Weekend | 5631.5* | 14.29 | 1453.8* | 6.22 | 1206.9* | 9.04 |
| Variance parameter sigma | 77.3* | 4.87 | 4.87 | 2.09 | 46.57* | 3.00 |
| Summary statistics | Obs. | 93 | 87 | 94 |
| LL(0) | −1048.53 | −783.38 | −895.47 |
| LL(β) | −1010.7 | −748.4 | −868.74 |
| AIC | 2035.5 | 1516.8 | 1757.5 |
| MAE | 33.87 | 9.25 | 13.53 |
| RMSE | 53.94 | 12.92 | 18.88 |

Notes: Coef. = Coefficient; S.E. = Standard Error; Obs. = number of observations; LL(0) = log likelihood at null model; LL(β) = log likelihood at model convergence; AIC = Akaike Information Criterion; MAE = Mean Absolute Error; RMSE = Root Mean Squared Error; * represent the significance levels at 99%.
age of customers has a positive correlation during the UC-phase and a negative correlation during the DC-phase (customers can be considered as short-term users of the bikeshare system whereas subscribers are regular users as they purchased a yearly subscription). The drop in the use of bikes by regular users was very strong compared to that of short-term users, and hence the percentage of customers had a positive correlation.

The signs of the correlations among the variables are the same in Boston and NYC; however, the extent of the effect is different. Also, the correlation between trip frequency and total trip duration changed between the two phases in NYC. However, it remained almost the same for Boston. The average trip duration did not seem to increase during the UC-phase in Boston as it did in NYC, but there is a significant positive correlation found during the DC phase. Overall, Boston DC-phase was similar to that of NYC (in terms of COVID-19 effects on bicycling), but not during the UC phase (the average trip duration did not increase, and the percent of customers did not increase as the COVID-19 cases increased).

![Graphs](image)

**Fig. 3.** Normal distribution of the random parameters for the daily number of COVID-19 cases and weekend in the study period.
Chicago is very similar to that of Boston in terms of COVID-19 impacts on bicycling. The only difference is observed in trip duration and average trip duration variables. Overall, NYC has seen the greatest hit compared to that of Boston and Chicago. This could be due to the severity (number of cases and number of deaths) of COVID-19 in NYC.

Fig. 3 (continued)
4.2. Random parameter least squares regression model

To further explore the marginal effects of COVID-19 cases on the number of shared-bike trips in UC-phase and DC-phase (combined), the random parameter least squares regression model (OLS) was developed.

The random parameter models are built separately for each of the studied cities. The dependent variable is the daily number of shared bike trips, and two of the key independent variables are the number of confirmed COVID-19 cases and the weekend indicator. According to the model results presented in Table 4, the daily number of COVID-19 cases was significantly and negatively associated with the daily shared bike trip frequency for all three studied cities. Furthermore, the magnitudes of the mean of this parameter also indicate that the association is even stronger in NYC (−27.8), while they are a bit lower for Boston and Chicago (−11.3 and −1.83, respectively). The elasticity effects show that if 100 more COVID-19 cases were identified each day during the study period, then there would be 2780, 113, and 18 reduced shared bike trips for NYC, Boston, and Chicago, respectively. This means that the impact of COVID-19 on decreased shared bike trips is greater in NYC as compared to the effect in the other two metropolitan cities.

Fig. 3(a)–(c) further reveal that the daily number of COVID-19 cases was not found to have a consistent magnitude of correlation with the daily shared bike trip frequency. Instead, on some days during the UC-phase and DC-phase, the magnitude of association was found to be even stronger. This could be due to the implementation of the stay-at-home orders, mandatory face mask, etc. Such a finding further confirms the appropriateness of applying the random parameter regression approach to capture the unobserved heterogeneity.

As for the associations for the weekend indicator, Table 4 shows diversified results for three metropolitan cities. The parameter means as well as the standard deviations are all estimated to be statistically significant at the 99% confidence level for three metropolitan cities. From a global correlation perspective, weekends in NYC and Boston are indeed positively associated with shared bike trips, while, for Chicago, the relationship was found to be negative. However, from a local correlation perspective, the daily changes in the shared bike frequency could be affected by many unobserved factors. Such a diversified relationship between shared-biking frequency and weekend indicator cannot be attributed to just one weekend indicator. There are always certain unobserved factors that would affect such a correlation. For example, weather conditions may be a significant factor that impacts a person's travel choice, especially the shared biking mode for various trips. Fig. 3(d)–(f) further illustrate that the standard deviations of the estimated weekend parameter may significantly diverge the final parameter estimation from its mean parameter estimation. The results indeed show that in general, most of the estimations are positive for weekends for New York, but on some weekend days, the estimated parameter of the weekend is negatively correlated with the daily shared bike trip frequency. Similarly, for Boston, while on most weekends the parameter is estimated to be positive, on some weekends it is estimated to be negative. Chicago does not have a similar trend as Boston or NYC. For example, on some Saturdays in early UC-phase and late DC-phase, the correlations were found to be positive, but on most other weekends, they are estimated to be negative.

5. Discussion & conclusions

In the past few months of the pandemic, public transportation and airlines experienced the largest reduction in use, as the possibility of social distancing in these modes of transportation is not practically possible. With the closure of schools and businesses and the availability of working from home, a significant drop in automobile trips was also noticed throughout the country. Some news articles claim that biking has increased during these challenging times since it does not involve getting in close to proximity to others (TREK, 2020; Sui and Prapaivessi, 2020). However, this study's results contradict these claims. The graphs plotted and the statistical analysis in the study further demonstrate that bike trips were negatively impacted by COVID-19. Additionally, a difference during the weekdays and weekend trips was also noticed.

However, as cities passed the highest peak of COVID-19 cases, bike trips started to increase. It would be interesting to see if they will increase beyond the normal or expected trips for that time. Even if they increased, will they last even after the pandemic ebbs? These are the questions researchers and transportation professionals must further explore. People will consider the risk of traveling in buses, subways, or Uber and Lyft and will choose less-contact modes of transportation in situations like the COVID-19 pandemic. Biking and other micro-mobility could be the key to sustainable travel in such scenarios to meet people's needs. To encourage biking, cities should consider taking advantage of a bad situation (COVID-19) and explore approaches and activities that reduce driving. Converting a travel lane to a bike lane and providing longer and frequent bike and pedestrian signal times could encourage people to bike more often.

Another interesting finding of this study is the increase in the average trip duration during COVID-19 times. The increase in the average trip duration could be due to numerous reasons: short trips were more affected due to COVID-19 than long trips, and an increase in longer bike trips actually occurred, which is perhaps owing to the decrease in other modes of transportation to opt for. This COVID-19 experience should prompt transportation professionals such as planners, engineers, and analysts to think beyond the regular design of the cities and its transportation infrastructure to accommodate for any future pandemics.

Besides the findings explored above, the authors acknowledge the limitations of this study. Especially with the COVID-19 data. The number of cases reported on a given day is highly influenced by the testing and reporting rates. More testing on a given day might produce a sudden increase in the COVID-19 case numbers. However, the recorded COVID-19 cases are the best information available to assess the spread of the pandemic and therefore represent the ideal variable to achieve the objectives of this study.

Methodologically, the random parameter approach can be further extended to incorporate the heterogeneity in the means as well as the variances of random parameters. In the future, the authors plan to extend this study by further examining the impacts of COVID-19 on biking by specifically studying the impacts of various crucial timelines (stay at home orders, mandatory face mask, 6ft social distancing norms, etc.) on biking.

CRediT authorship contribution statement

Vyas Padmanabhan: Writing - review & editing. Praveena Pennmetsa: Resources, Conceptualization, Methodology, Writing - review & editing. Xiaobing Li: Methodology, Visualization, Methodology, Writing - review & editing. Fatema Dhondia: Resources, Conceptualization, Writing - review & editing. Sakina Dhondia: Writing - review & editing. Allen Parrish: Supervision, Writing - review & editing.

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