

The Impact of Lockdown on Bicycle Usage in Edinburgh

1 Overview

Governments across the world have introduced restrictive measures, such as enforcing “lockdown” periods, to reduce social interaction and halt the spread of the COVID-19 virus. To analyse the impact of these lockdown periods on bicycle usage in Edinburgh, data from the shared bicycle hire service Just Eats Cycles was used. A predictive model was used to measure the change in bicycle use and test whether a lockdown period, where home confinement was required, implied a decrease in the number of trips throughout 2020. The use of descriptive and inferential statistics, such as bootstrap, allowed evaluation of changes in trends, patterns, and intentions regarding bike usage. This study identifies a correlation between a pandemic context and an increase in hired bicycle services. Further analysis has found a change in cycling purposes and patterns, with a higher frequency of recreational cycling in parks and an increased popularity in outskirt areas of Edinburgh.

2 Introduction

Context and motivation The novel coronavirus disease (COVID-19) outbreak originated in China in December 2019, and rapidly propagated across the world [1]. This escalated into a worldwide pandemic which required strict social measures and quarantine protocols, as millions of people were infected and thousands of deaths were reported daily. The World Health Organization (WHO) officially announced the seriousness of the situation declaring the pandemic in March 2020 [2].

In an attempt to reduce social contact and thus reduce the spread of the COVID-19 virus, many Governments across the world have imposed restrictions that limit social interaction. Such restrictions were imposed in Scotland, where the different levels of restrictions included measures such as wearing face masks and social distancing to only allowing individuals to leave their homes for exercise or basic food and health needs.

This data science study explores the effect of the COVID-19 national lockdown on hired bicycle services in the city of Edinburgh (Just Eat rentals) throughout the year 2020. Namely, through analysing and visualizing cycling patterns of Edinburgh citizens we aim to explore the changes in trends, attitudes, and daily practices that people had to undergo in order to adapt to such an unprecedented situation, and analyse bike rents to infer usage patterns and purposes.

Additionally, we explore what are the implications in the daily lives of individuals of imposing human mobility restrictions. By exploring the changes and patterns in cycling usage throughout 2020, from the first confirmed case in the United Kingdom on the 1st of February to the declared lockdown in Scotland and the United Kingdom in the 24th of March [3], the overall effect and impact of both the novel coronavirus and its subsequent restrictions can be visualised and measured.

Previous work Research papers in the literature discuss the effect of hire cycling schemes in different cities during the pandemic period. Some papers show that there is an increase preference for walking or cycling as the main means of transport due to a widespread awareness and fear of contracting the virus. The Institute for Transportation and Development Policy stated that in Guangzhou, only 34% of

people who regularly use public transport kept doing so during the pandemic [4]. A paper in Oslo showed that the exercising activities increased during the pandemic [5]. Other studies focus on showcasing a statistical relationships between different means of transport and frequency. A study about New York City's Citibike usage demonstrated that cycling proved to be more "resilient" than using other means of transport during the COVID-19 pandemic, while stating that the mean duration of hires in bicycle increased [6]. Furthermore, other researches proceeded to analyse the increase of bicycle usage while arguing the influence of an increasing need to exercise during lockdown, such as the study from Park, Kim and Lee [7], which found a statistically significant correlation between social distancing and public bicycle uses.

Objectives As current studies indicate, there has been an increase in bicycle usage during the COVID-19 pandemic. However, an in-depth investigation is necessary to be able determine if this surge in hires is due to COVID-19. This study aims to reveal the relationship between bicycle usage and lockdown, by comparing data collected before and after the COVID-19 pandemic. While "lockdown" might refer to an enforced home confinement, this study focuses on the effects on bicycle usage throughout the pandemic period where a "stay at home" policy is encouraged. We aim to first discard seasonality as a potential variable which could be attributed to this latter increase in bike rents. Furthermore, we aim to analyse usage patterns through bicycle rental data from pre-pandemic and pandemic periods, in order to infer how people's behaviour and daily routines were altered.

3 Data

Data provenance The data used to analyse the effect of the COVID-19 pandemic on hired bicycle schemes was obtained from the Just Eat Cycles website. This service allows bicycles to be hired at any of the Just Eat Cycles stations, and the relevant trip information is recorded. The freely accessible monthly files contain anonymised information of trips, recording data such as starting and ending points or the hire duration.

Data description The monthly records from the Just Eat Cycle Website record all trips with duration of at least 1 minute and within Just Eat Cycles regular opening times (excluding cancelled trips). The months chosen span from January 2019 to December 2020, with the number of entries ranging from around 2000 trips per month to 17000. The anonymised data contains the time and date of the start of the trip, the duration, start and end stations, as well as coordinates (longitude and latitude) of those stations, for which a short description and a unique ID is also provided.

Data processing Using the Pandas library, the monthly data was imported and adequately added to two dataframes, one for each year, namely 2019 and 2020, such that a fair comparison could be made between pre-pandemic and pandemic periods. The data was checked for cleanliness and additional relevant variables were added to classify the data according to date and seasonality parameters.

4 Exploration and analysis

The evolution of the pandemic has had a clear effect on the number of hired bikes throughout 2020 (Figure 1). The pandemic's progression can be visualized through the bike rental visualization. Hence, Figure 1 showcases the evolution of the pandemic through 2020 by plotting weekly bike rents. The number of weekly rentals spike and decrease in accordance with the National announcements in Scotland regarding COVID-19 updates. There is a clear increase spike in the overall number of hires per week in 2020 as opposed to 2019, especially between the weeks 15 to 43. On the 1st of March 2020, the first positive case of COVID-19 was confirmed in Scotland, and on the 23rd of March 2020, National Lockdown was declared on the UK. These two dates are key as they initiate the turmoil on the graph and represent the

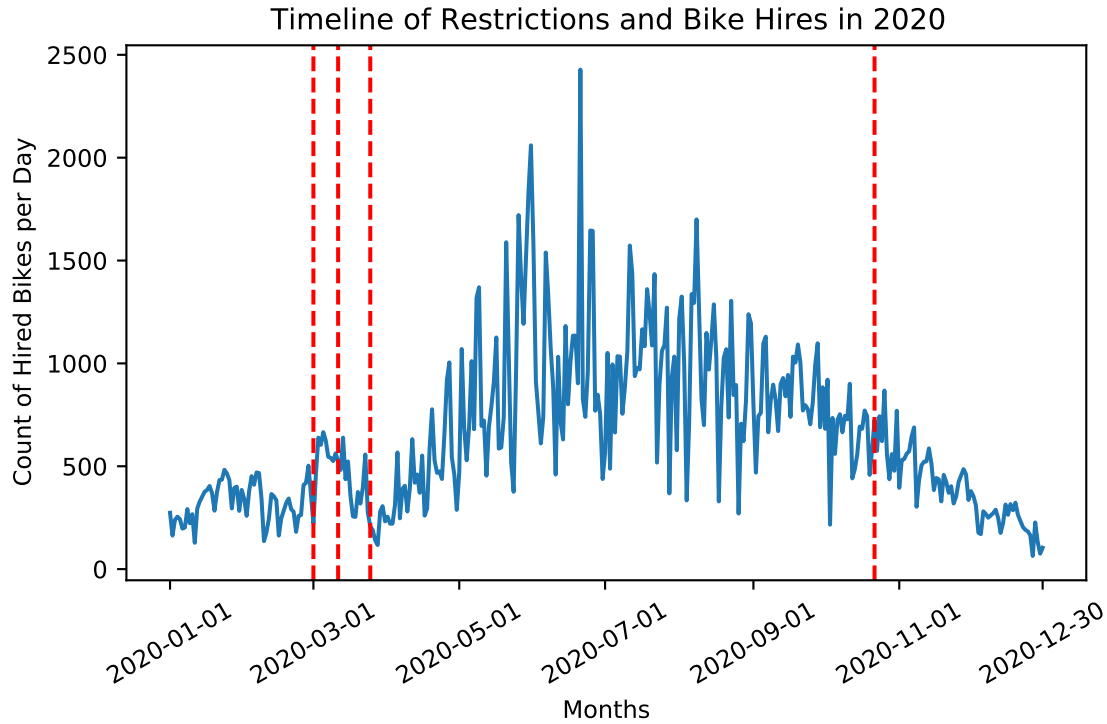


Figure 1: Timeline of the COVID-19 virus in Scotland and the most relevant restrictions against the total number of hired bicycles per day. The marked dates include the first confirmed case of COVID-19 in Scotland (1st of March), WHO declaration of pandemic (11th March), and the start of UK National Lockdown (24th March and 21st of October).

starting point of the following study. From then on-wards, drastic fluctuations will define the pattern of the bike rents graph, showcasing the unprecedented times that the world had to undergo, altering people's daily lives, affecting their behaviour and routines.

Due to the strict Government restrictions establishing and/or encouraging a "stay-at-home" policy, it would be reasonable to think that bicycle usage would decrease, especially since "bicycle-sharing" might present a higher contagion risk. The strict limitations, such as only allowing 1 hour of exercise outdoors, or only being able to leave the house for food or medical needs, indicate that the frequency of activities such as daily commutes or cycling to do errands might be reduced. Hence, the stated null hypothesis is that there is a decrease in bicycle usage in Edinburgh since the start of the pandemic. The alternative hypothesis would state that the need for social-distancing measures would incite a spike in bicycle usage because of other means of transport, such as buses, being avoided due to the fact that respecting social distancing measures present a bigger challenge.

As seen in Figure 1, within a pandemic (March to December 2020) context, there was a clear spike in the overall number of hires per week between the weeks 15 to 43. These weeks largely include the seasonal periods of Spring and Summer. To understand whether this sudden increase might be a trend in certain months rather than because of COVID-19, the total number of hires per day was regressed on the date (53 weeks in total) (Figure 2). The Linear Regression model was trained on pre-pandemic data which corresponds to the data available from the 53 weeks in 2019. Moreover, this trained model was tested using two test sets.

The first test set, comprising January and February of 2020, was used to test the "goodness of fit" of the model; this test set was chosen because the first confirmed case of COVID-19 in the United Kingdom was not until the 31st of January, but the 11th of March in Scotland, the same day the World Health Organisation announced that the novel coronavirus propagation can be characterized as a pandemic. The second test set includes data concerning the number of hires from the remaining months of 2020.

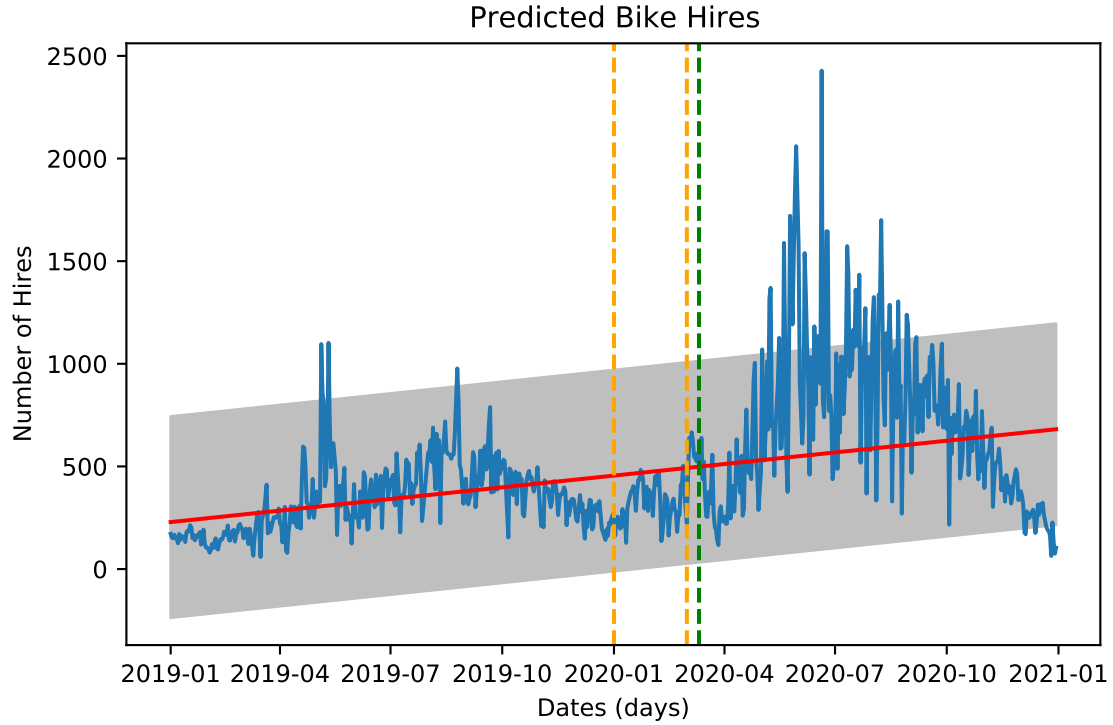


Figure 2: Predicted Number of Hires against the true number of hires in 2020. A considerably larger amount of true values in periods certain (May 2020 to September 2020, December 2020) deviate considerably from the predicted values and outside the Confidence Interval. We analyse the influence of seasonality in these results. The marked dates (2020-01-01 to 2020-03-01) indicate the "pre-pandemic" dates of 2020 (prior to WHO's announcement of pandemic (marked in green)).

Despite the fact that the regression model's Correlation coefficient (also known as the Coefficient of determination) for the 2020 prediction is $R^2 = 0.62$ (the regression red line in Figure 2), which indicates a reasonable fit, we find considerably differing values for the fit in the different test sets. The first test, which comprises the first two months of 2020, which correspond to a pre-pandemic context, had a Mean Squared Error (also known as MSE) of 31040, and a RMSE (Root Mean Squared Error) of 176. The second test set, which includes the rest of 2020, thus including the pandemic months, had an MSE of 170299, and a RMSE of around 413.

These results show that the regression line has a "better fit" in the months classified as "pre-pandemic", with a noticeable error increase for the second test set. This shows that the prediction model is, overall, accurate, and it shines light on the abnormal data (spike) that commences in March 2020, since the RMSE gives an indication of how far the data points deviate from their predictions in absolute terms. Furthermore, the visualisation in Figure 2 includes a confidence interval for the regression line, showing how a noticeable number of values can be found outside the confidence interval for the predicted values of the 2020 pandemic months (from March on-wards).

Indeed, this visualization (Figure 2) has several "lurking variables", like the recent number of confirmed COVID cases or coronavirus-related deaths, with the most notable one being seasonality. Indeed, while in 2019 a few values can be found outside this confidence interval (within the Spring and Summer months), this effect is very noticeable in the Spring and Summer months of 2020. Before rejecting the null hypothesis and analyse whether during the pandemic months, the number of bike rents had changed due to lockdown, we will proceed to explore whether this increase could be attributed to seasonality.

In order to analyse whether seasonality is significant, a comparison between the average (mean) duration of bicycle hires throughout the seasons was made. This comparison (Figure 3) was done on the average duration because of the very different total number of bicycles hired in 2019 and 2020, namely 28882

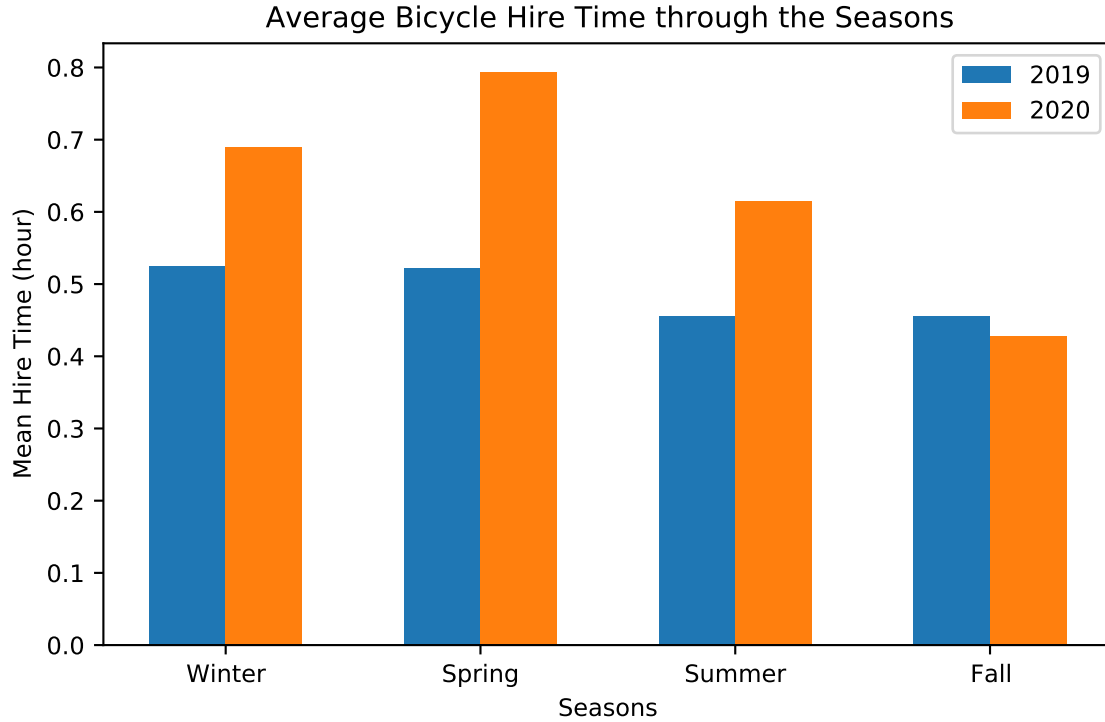


Figure 3: Mean hire duration throughout the Seasons (2019 and 2020). Spring-time average cycling hire time is almost 1 hour, which resonates with the 1 hour exercise allowance during the strict lockdown period beginning in March 2020.

for Spring and 39644 for Summer in 2019, and 55036 for Spring and 88113 for Summer in 2020. This different number of hires, alongside the different number of available hiring stations and their updated locations, require that the overall mean duration is measured. As seen in Figure 3, there is a significant increase in the overall average cycling duration throughout the seasons in 2020; however, it is possible that these observations might be attributed to a larger number of hires in 2020 propagating the increase in the mean duration.

Thus, to disprove or maintain the first hypothesis, the apparently considerable spike in trip duration 2020 could be a consequence of a larger number of hires (almost double in 2020), so the inferential statistic method of bootstrap was applied to a different number of samples with $k = 50000$ replications. Through an arbitrary number of iterations, with a randomly generated number of samples, for each replication k_i , the calculated duration mean \bar{y} of the values of every 2020 sample was subtracted from the calculated duration mean \bar{x} of the values of every 2019 sample. A 95% confidence interval was generated for each sample number; the fact that the value of 0 does not lie within the interval allows us to infer that there is an actual increase in bicycle usage during the pandemic months but that seasonality itself is not significant (does not particularly influence this increase in 2020). Hence, we are now able to reject the initial null hypothesis. The findings favour the alternative hypothesis, where distancing measures would incite a spike in bicycle usage.

Following from the latter findings, we now aim to analyse and understand the impact and effect of lockdown on Edinburgh citizen's attitude and daily routines, through their cycling patterns. We aim to understand how people's habits and behaviour were modified and significantly adjusted to accommodate both national restrictions and safeguard themselves from the coronavirus, since we now know that there was, indeed, an increase on the bicycle usage.

Following from the increase of the average duration per trip in 2020 [Figure 3], we wanted to further understand if the increase of the average duration per trip had incurred any influence on the purpose of the trips. As for this, there was an attempt to verify whether the most common hiring stations differed

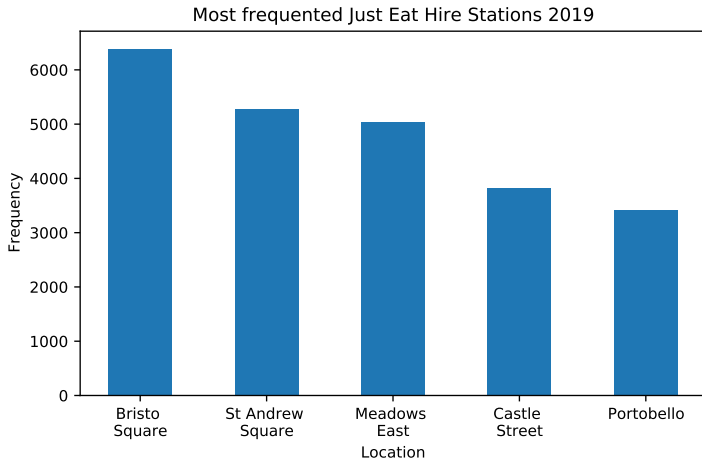


Figure 4: The most frequented stations in 2019 are mainly central locations, especially near touristic landmarks and university areas.

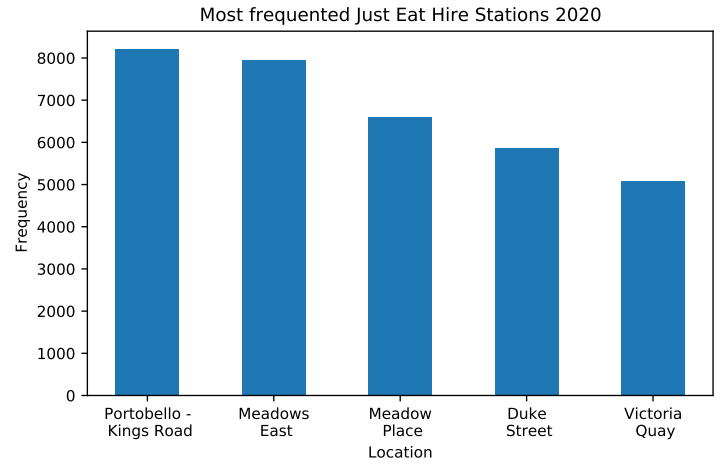


Figure 5: Most frequented stations in 2020. Mostly locations near large parks, with a marked increase in the visit frequency.

between 2019 to 2020, and infer any significant impact that the pandemic could have had on these changes. Identifying the most frequented stations in 2019 and in 2020, as we can see in Figure 4 and Figure 5, the most common station in 2019 is Bristo Square, with yearly visit frequency of over 6000, followed by St. Andrew Square, Meadows East, Castle Street and Portobello with a frequency of nearly 4000. These (most-frequented) stations showcase the true representation of Edinburgh's populations; indeed, Bristo Square and Meadows East stations are located near University campuses, and it is sensible that these are frequented given the number of students that Edinburgh welcomes, being Edinburgh the city with the "second highest number of students in higher education per 1,000 citizens of any UK city" [8]. Secondly, St. Andrew Square and Castle Street faithfully represent an insight into the touristic charm of the city, being Edinburgh the second UK city to draw more overseas visitors per year [8].

Contrary to this pattern, the frequency in any of the most common stations in 2020 completely outpace 2019's and allows inferring on the drastic change in people's routines. The most common cycling station is Portobello, whose frequency nearly doubles in size from 2019. All other stations take place on big parks (Meadows), and most prominently, overall, the vast majority in 2020 lay on the outskirts of the city. The pandemic led to a drastic lockdown which affected both the student life and the tourists, with the uncertainty urging them to "stay home". This second graph (Figure 5) draws attention to Edinburgh's outskirts' population that was masked by the hustle of the city centre. We can infer that residents largely exchanged commuting rides for green spaces, which might be motivated by the fact that, despite a decrease from 163 (2019) to 118 (2020) in the number of stations, the Scottish Government granted Edinburgh £5m for the creation of routes for walking and cycling [9].

Additionally, we analysed if the fact that there were more active users on the outskirts (where there is a larger concentration of "green spaces") might have changed the patterns of usage of bike rents during the pandemic compared to the usage on a pre-pandemic context. Indeed, an increase of bike rents in stations near "green spaces" might alter people's attitudes towards transport, and hence, the purposes of the trips. Figure 6 and Figure 7 show two distributions, where the x-axis represents the longitude of the bike-hiring stations (end stations) across Edinburgh, hence the edges of the x-axis represent the stations on the outskirts of the city. For both years, two overlapping distributions show trips that ended at different stations of with <30 minutes duration (orange distribution), and those which were longer than 30 minutes (blue distribution).

In 2019, the vast majority of both longer and shorter trips took place within the city centre, and only fewer longer trips are seen to take place further away. In fact, we can infer that these longer trips, although overall are less frequent, sometimes take place in touristic places which were found farther away from the city, such as Portobello, which we found (Figure 3) to be very common in 2019. However, most short

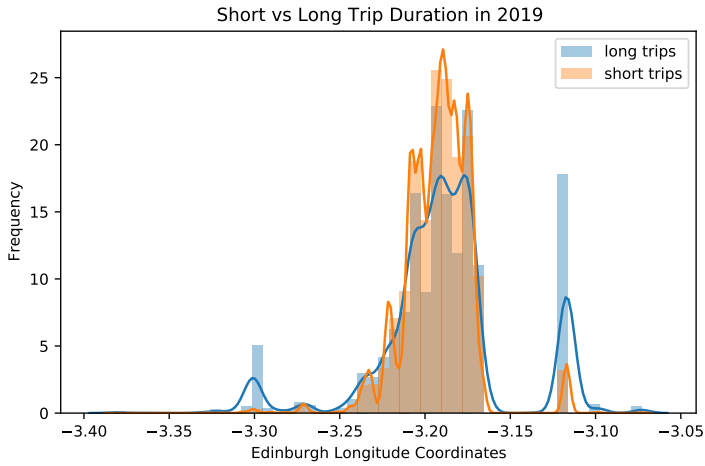


Figure 6: Short and Long Trip comparison in 2019. Trips in 2019 are mainly short (duration < 30 minutes), generally within the city centre.

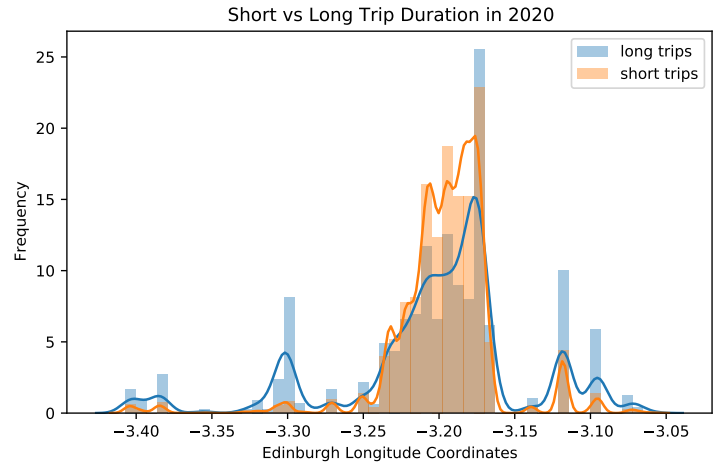


Figure 7: Short and Long Trip comparison in 2020. Longer trips within the city centre and in the outskirts become more common.

trips are within the inner city centre, supporting the latter argument that residents on the outskirts were less encouraged to make use of bike rents in 2019, either relying on public or private transport. However, the 2020 graph shows a significant shift of activity on the outskirts, with more active users renting bikes for shorter trips (<30 minutes) and also an increase of longer trips even farther away from the city centre than in 2019. We deduce that, in 2020, residents started renting bikes on the outskirts, with shorter trips being more frequent, which might suggest an increase of hiring bikes for running small errands.

The number of rides that started and ended on the same station went from 11639 in 2019 to 39339 which might account for the increase in bike rides across parks, but equally importantly, the number of rides that started and ended on the different stations went from 109471 in 2019 to 187208 in 2020. The usage of bike rides has increased overall, and that the need for exercising has also increased across green areas. Additionally, the fact that the number of rides ending at different stations might suggest that lockdown has encouraged people to rent bikes to run errands, since lockdown restrictions only allowed leaving the home for essential purposes. The fact that the orange distribution, which shows shorter trips, has increased during the novel coronavirus epidemic suggests residents renting bikes to exercise or to run errands during lockdown, or renting them in an attempt to safeguard themselves from contracting the virus, suggesting a possible extended fear of using public transport.

5 Discussion and conclusions

Summary of findings The COVID-19 pandemic has incited restrictive measures regarding social interaction and human mobility to reduce contagion. The findings in this study show that the extended periods of time during which such measures have been in place have altered the cycling habits of the citizens in Edinburgh. Through data acquired from the bicycle-sharing scheme Just Eats Cycles, this study has focused on analysing the origins of a found increase in bicycle usage and average cycling duration when comparing data from 2019 and 2020. Disproving seasonality as the driver of this change, this study finds a correlation between the lockdown period in 2020 and these changes. Furthermore, analysis on the data allowed inferring a shift in cycling purposes, with a larger number of users cycling for leisure or exercise in green spaces rather than exclusively commuting within the city centre, as well as a surge in short bicycle hires in the outskirts of the city because of increased awareness of social-distancing measures.

Evaluation of own work: strengths and limitations The main limitation in this study is the lack of data. We have used the data of just one bicycle-sharing service (Just Eats Cycle) as a way to analyse changes bicycle usage in Edinburgh, but there are many other bicycle renting services in the city (albeit the scarce availability of data) which might perhaps rival the Just Eats Cycle service and thus we do not appreciate the full scope of the changes in bicycle usage. Furthermore, the linear regression model was trained only on 2019 data, which might make the R^2 coefficient biased. While we were able to discard seasonality as a significant factor in the increase of the number of trips in 2020, which allows us to infer that indeed lockdown has induced this increase, we have not been able to prove the relationship between the spread of the coronavirus and the number of trips. This was due to the lack of data regarding the true COVID-positive cases (the freely available data used to test this was obtained from the Scottish data portal (statistics.gov.scot)), as while the bias in the COVID case numbers changes over time, the number of tests has dramatically increased as the months progressed, and thus we believe that the observed behaviour in cycle hires would have been different, perhaps with a marked inverse relationship between the number of cases and the number of hires.

Comparison with any other related work As mentioned in the introduction, previous papers have drawn conclusions as to how public bicycle usage has been affected during the pandemic. Indeed, our findings align with the previous studies. In fact, The New York Study showed the resilience of bicycle usage compared to other public transport. Our results not only support this argument, but even show that there has been an increase of their usage. Moreover, through the visualizations, it was shown that, similar to the Oslo study, recreational activities on parks and green spaces increased, probably as a way of exercising during lockdown. This follows the argument from Park, Lim and Lee which demonstrates a statistical correlation between exercising during the pandemic and bicycle usage. Lastly, we extended on these findings, and analysed the effect of restrictive measures on Edinburgh citizens, explore the changes in trends, attitudes, and daily practices that people had to undergo in order to adapt to such an unprecedented situation, and analyse these rents to infer usage patterns and purposes. While the Institute for Transportation and Development Policy study concluded that the use of public transport decreased during 2020, our findings correlate with this research, as we unveil the change in bicycle patterns, more drastically on the outskirts. Our results suggest an increase not only of longer trips (around parks) but also of shorter trips on the outskirts, which suggests the meaningful impact of COVID-19 on the purpose of bicycle rents.

Improvements and extensions Due to the successive "waves" that the spread of the virus is experiencing and a better knowledge of infection rates is being acquired, data from periods with similar testing levels could be explored to map a correlation between the number of confirmed cases and the frequency of bicycle hires. Additionally, a possible extension could collect data from other Scottish regions in order to investigate the location-based impact of the pandemic in commuting needs, analysing the evolution and use of public transport and bike sharing systems in different environments.

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