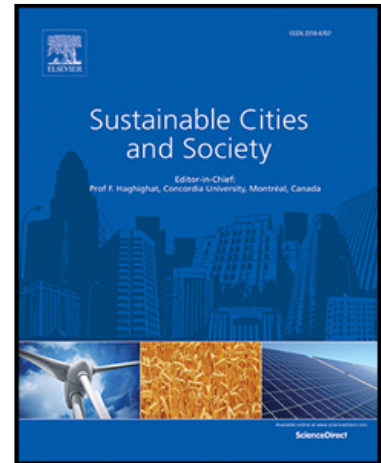# Journal Pre-proof

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The Impact of the COVID-19 Pandemic on the Behaviour of Bike Sharing Users

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Highlights

- Original and comprehensive bike sharing data set is used.
- Assesses the effect of the COVID-19 pandemic on shared bicycle user behaviour
- Illustrates how bike sharing offers supports resilience in transport networks

Abstract

Globally most governments implemented a 'Working from Home' (home office) strategy to contain the spread of the coronavirus in 2020 in order to ensure public safety and minimize the transmission of the virus. Unsurprisingly studies have found that COVID-19 has had a detrimental impact on urban transportation systems; however, the number of shared bicycle riders is progressively growing compared to other modes of public transit. The aim of this study is to investigate the influence of COVID-19 on the usage of shared bicycle systems in order to identify passenger travel patterns and habits. In addition, bicycle rentals are becoming more popular in some locations. This demonstrates that bike sharing as a transport option has a high level of social adaptability and is progressively being adopted by the general population in a fashion that promotes the resilience of transport systems.

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1. Introduction

The COVID-19 pandemic has had a significant detrimental influence on the social structure, urban economy, and urban transportation system. The first case in America of coronavirus (COVID-19) infection was reported in the United States in January 2020 (Ginai et al, 2020). All seven continents (Asia, North America, South America, Europe, Australia and even Antarctica) have confirmed cases, accelerated by human migration. There were 430,257.564 verified cases of COVID-19 worldwide as of February 2022, with 146,449,865 confirmed cases in the Americas (WHO,2021). There is a large-scale movement of people in this period of globalization, which promotes the rapid spread of contagious diseases (Tatem et al., 2006). As a result of the virus's spread, numerous governments and regions have closed borders or imposed restrictions on entry visas for foreign nationals to prevent people from travelling. To prevent the transmission of infections, most governments recommend keeping a social distance of at least one metre. Travel restrictions have been indicated in many studies to successfully reduce the spread of the virus throughout the world (Anzai et al., 2020).

COVID-19's pandemic has had a significant and nearly simultaneous influence on the worldwide urban system (Mu et al, 2020). When the virus first broke out, most nations went into lockdown mode, restricting large-scale meetings and stepping up public health precautions (Fernandes, 2020), causing significant economic dislocation (Guan et al, 2020).

Several large American cities, led by New York and Washington, were among the first to ask citizens to 'shelter in place' (i.e. remain at home) (NYC Office of the Mayor, 2020). Furthermore, research confirms that enclosed places enhance the likelihood of the virus spreading, and that healthy persons can become infected with the coronavirus (Yang et al., 2020). Approximately a fifth of the virus's propagation happens when using public transit (Muller et al., 2020). Transport alternatives that reduce face-to-face contact can thus help contain the virus. The shared bicycle system is built on the foundation of urban transportation networks, and it works in tandem with other modes of public transit to create a new urban transportation system (Villwock-Witte and van Grol, 2015). Bike sharing, which has been shown to promote transport resilience in the face of adverse weather events and other sources of unplanned public transport outages (Cheng et al, 2021), should have a similar effect during the pandemic. Although public transit has undeniably become the primary mode of transportation for travellers in high density urban areas and is the backbone of an effective transportation system, shared bicycles may complement other modes of mobility to promote sustainable societies (Mi and Coffman, 2019) and in particular to reduce air pollution (Chen et al, 2021).

COVID-19 is mostly carried through the air, and maintaining sufficient social distance is an excellent strategy to prevent it. As a result, it is not surprising that more commuters used shared bicycles than other transport choices throughout the pandemic (Bergantino et al., 2021). The COVID-19 pandemic has had a profound impact globally, particularly on the form of transportation chosen by travelers. Due to the widespread belief that public transportation provides a substantial risk of viral transmission, some people may see private transportation and shared modes as a paradigm shift towards a safer travel mode. For instance, rickshaws and auto-rickshaws are seen as safer options (Zafri et al., 2022). Thomas et al (2022) investigated the correlation between the frequency of bulletin use and the number of illnesses in the United States. They discovered that an increase in bus and rail travel in the area during the early days of the COVID-19 pandemic contributed to an increase in illness rates. Among these, trains are the most susceptible to contamination. During the COVID-19 pandemic in New York, Teixeira and Lopes (2020) analyzed subway and shared bicycle utilization statistics. Early in the pandemic, passenger traffic on shared bicycles and subways both declined, according to their data, with steep drops of 71 percent and 90 percent respectively. However, the average riding duration for shared bicycle programme participants grew from 13 to 19 minutes. Shang et al. (2020) performed a survey in Beijing to determine

the average intensity of bicycle sharing systems and user behavior. While bike sharing may benefit from its physical distance, proper system management and communication are also required to prevent the COVID-19 outbreak. Jobe et al., (2021) explores the responses of numerous bike sharing systems (BSS) in the United States to the pandemic and includes survey data from San Antonio's bike share users in order to have a better understanding of the range of responses. If restrictions on the Coronavirus are abolished, moderate-frequency users (1–2 times per month) may witness the highest increase in bike sharing, from 22% to 34%. They found that during the pandemic, the average usage duration of each order was longer than usual. These studies confirm a growing sense that the shared bicycle system is more adaptable than other transport choices and can increase the urban transportation system's resilience to catastrophic occurrences (Kim, 2021).

Although there is considerable research on bike sharing in general, only a relatively few case studies have looked at the effects of COVID-19 on bike-sharing systems, despite its promise sustainable means of transportation. The adjustment of consumer travel patterns and emergency reaction behaviors of persons in areas when the pandemic strikes, which contributes in the deeper understanding of COVID-19's impacts on human civilization and the continuing pandemic's adaption, benefits from as many case studies as possible, as different urban geographies, cultural norms, and socioeconomic systems may produce different phenomenon.

1.1. The objectives of this study

As a result, the focus of this research is on bike-sharing user behaviour during the pandemic in the American capitol, Washington D.C., which is half as densely populated than New York City or and a tenth that of Beijing. Developing a fuller picture is also potentially helpful to planners. Because of the pandemic's progress, using shared bicycles can help to slow the transmission of the virus while maintaining acceptable social distance and thus might be an appropriate target for government subsidy. The primary objective of this paper is to investigate the structural characteristics of the bike-sharing network in the city of Washington D.C, as well as to investigate the behavioral patterns of travelers prior to and during the pandemic, to investigate the relative changes in the use of shared bikes by travelers by analyzing the temporal and spatial patterns of bike-sharing. Demonstrate that shared bicycles are a robust mode of transportation. The intensity and behaviour of utilizing bike-sharing to travel during the pandemic are discussed in this study, which examines user trip data using Washington D.C. as an example.

2. Literature Review

COVID-19 spreads through the nose, eyes, and saliva. Skin-to-skin contact or indirect contact with contaminated things in a confined environment can infect healthy persons (Kampf, 2020). Because coughing is one of the symptoms of infection, it is important to avoid putting infected and non-infected people in direct contact (Teixeira and Lopes, 2020). Many governments and localities throughout the world thus instituted lockdown procedures in response to the outbreak of COVID-19 (Kim, 2021). The K-assessment evaluated the possible role of containment measures in slowing the transmission of the virus and rapidly lowering the number of patients. Border controls and blockades at the national or local level can help to prevent the spread of the pandemic virus (Kharroubi and Saleh, 2020). While the most successful technique for preventing such spread is social separation, either by quarantining or isolation, such measures have a large economic cost (Guan et al, 2020). Maintaining an active involvement in the economy entails staying mobile for many people. Policy measures adopted by various nations to prevent COVID-19's proliferation have a disastrous effect on travel habits. People's perceptions of social obligation, their risk perceptions and their attitudes may play an important role in influencing travel decisions in an outbreak of a pandemic rather than worries about travel time and expense, as in normal circumstances (Chen et al., 2022). Throughout the globe, cities have recently seen a comeback in cycling as an important method of transportation (Chibwe et al., 2021). Public transportation, with its high occupancy density and confined facilities, provides ideal circumstances for person-to-person transmission, presumably at a significantly greater rate than other means of transportation (Kim, 2021).

Because of its high occupancy density and enclosed locations, public transport offers causes disease transmission at a far higher rate than other forms of transit (see Table 1). COVID-19's ability to survive on modern materials for a few hours increases the danger (Taylor et al., 2020). The lockdown policy imposed during COVID-19 has had an impact on public transportation. Global mobility fell precipitously during the pandemic (Hu et al., 2021). Tarasi et al (2020) discovered that at regular hours in Greece, four out of ten travelers preferred to drive or walk, whereas one out of ten commuters chose buses. The mode of transport of travelers changed early into the third week of the COVID-19 period, with the number of persons choosing to ride increasing by 9.4 percent. Hu et al (2020) discovered that during the Chicago outbreak, the number of shared bicycle orders initially grew, then declined, and then recovered as usage stabilized. Bucsky (2020) reported similar findings in

Hungary. During the first year of the pandemic, public transportation demand in Budapest fell by 80%, while cycling hires (including bike sharing) reduced by just 2%. Bike-sharing systems may help cities adjust to the needs of individuals who are unable to go about during COVID-19. Additionally, it may assist transportation planners in enhancing the system's resilience (Simić et al., 2022). The suggests that shared bicycle networks are a more versatile means of transportation.

A region's transportation system plays a significant role in meeting the needs of mobility. Additionally, it plays an important role in the transmission and control of epidemics (Manzira et al., 2022). Bike sharing systems can improve the transport system's resilience, or its capacity to continue moving people and products in the face of external disruption (Mattsson and Jenelius, 2015; Cheng et al, 2021). The larger issue of sustainable development necessitates achieving long-term viability in shared transportation (Shokouhyar et al., 2021). Most transportation methods are based on a complete urban transportation network, but the reality is that some urban network systems have unreliable designs, which require a lot of investment to improve and update them. On the other hand, bicycle lanes are an integral part of the urban transportation system, though their safety needs are often ignored in favour of vehicles and pedestrians. Likewise, contemporary examples of paved cycle paths and other strategic activities available such as the 'open roads campaign', which have appeared in response to the coronavirus, demonstrate the flexibility of the bicycle (The Guardian, 2020b). This reallocation of the automobile access to roads might assist public bicycle systems significantly (Marshall et al., 2016), especially since it tackles among the most frequently cited arguments because of not running or cycling, i.e. shortage of 'safe facilities' (Fishman, 2016). Furthermore, as compared to conventional forms of transport, bike sharing systems are extremely flexible, as evidenced by the present adoption of innovative BSS rail stations facilities to provide healthcare personnel with a transit choice (NYC DOT, 2020). Saberi et al. (2018) investigated the use of shared bicycles during the 2015 London Underground strike. According to their findings, the subway strike resulted in an increase of 85 percent in the number of passengers opting for the bike-sharing scheme. The number of trip orders surpassed one million, while the mean journeys duration climbed from 23 to 43 minutes.

Table 1

Summary of the available studies during COVID-19 of cycling user behaviour.

Author (s)	Year	Research focus	Trip orders (per day)	Average trip duration (min)	Main findings	Countries/cites
Teixeira et al	2020	Bike share systems	-	19	Outperforms the metro system.	New York city
Lock	2020	Cycling behaviour changes	-	-	Increased imperative for new cycle.	Sydney
Nikiforiadis et al	2020	Bike-Sharing Usage	-	-	COVID-19 will have little impact.	Thessaloniki, Greece
Shang et al	2020	User behaviors	197, 350	22.16	Avoid harsh regions.	Beijing
Hu et al	2021	Spatiotemporal changing patterns	3,287	27.12	Increase-decrease-rebound.	Chicago
Chibwe	2021	An exploratory analysis	27,054.18	-	Exploring the variability in the demand for the London bike-sharing system over the study period.	London
Kubaľák	2021	Shared mobility service	532.9	9.22	Use low-risk transport.	Slovakia
Schwizer	2021	Outdoor cycling activities	-	-	Increase by 81% in Apri	German
Bergantino	2021	Influencing factors	-	-	Change travel habits	Italy

3. Methodology

3.1. Case study and data collection

Washington D.C. is capital of the United States, with a land area of 177 sq km and a population of approximately 690,000 people, making it the 20th largest city in America (QuickFacts 2021). Bike-sharing in Washington, D.C., was established in May 2013, and has enjoyed rapid growth since then. Capital Bikeshare operates the largest shared bike system in the Washington region. The system includes 627 stations and around 5,400 bicycles as of May 2021. We used data from Capital Bike share to explore the travel behavior of Washington D.C. residents in this research. The original data contains the journeys time of each order as well as the start and finish stations' locations, as well as basic ride order information, such as the user type. However, it does not include any personal information.

3.2. User behaviour pattern analysis

In this study, we plan to use novel complex networks predicated on the creation of a feasible transport system and journeys data from bike sharing journeys to analyse the transition of usage patterns for bike sharing in Washington D.C. during the unparalleled COVID-19 pandemic. Complex networks are used in the literature to analyse the user behaviour of the bike-sharing systems and fit the aim of this study well (Wu & Kim, 2020; Ferreira et al, 2016). The strength of the network nodes indicates the frequency of the bike sharing usage and the path length in the network illustrates how different users in the bike sharing network are connected. We employ topographic indices derived from graph theory: strength and strength allocation will be used to quantify such transition. To create the network, we split the study region into tiny lattices of 1 km by 1 km; these lattices are then designated as the network's nodes. If the contribution bike order appears between two nodes, then the link has meaning. The number of trips in the grid is set as the weight of the link. The strength of each node s_i may be estimated using this unique complex network:

We use b_{ij} to indicate that there is a link between two nodes i and j. Assuming that node i and node j are connected, then a_{ij} is set to 1. On the contrary, if there is no link, it is 0. The number of grid nodes is N, and the weight between the two nodes is set to w_{ij}.

$$s_i = \sum_{j=1}^{N} w_{ij} \cdot a_{ij} \tag{1}$$

$P(s)$ denotes the relationship between the amount of nodes and their intensity. We indicate s_i

as the average value of all node strength. $P_{(s)}$ is cumulative probability distribution with intensity s, that is, calculate the probability value that the intensity of the car is greater than s. We investigate the cyclist's riding path and behaviour using the formula's average intensity and node distribution.

$$P(s) = \sum_{s \doteq s}^{\infty} p(s') \tag{2}$$

$$P(S \geq s) = e^{ks+b} \tag{3}$$

The average route length L is the average number of steps along the shortest path for all pairs of nodes in the whole network.

$$L = \frac{1}{n(n-1)} \sum_{i \neq j} d_{ij} \tag{4}$$

In general, it is assumed that a node i has k_i edges linking it to other nodes in a complex network, which means that the node i has k_i neighbors. Clearly, there can be no more than k_i $(k_i\text{-}1)/2$ edges connecting k_i nodes. And the ratio of the number of the actual edges between the node i and its neighbors, E_i, to the total potential edges, $k_i (k_i\text{-}1) /2$, is defined as the node i's clustering coefficients CC_i.

$$CC_i = \frac{2E_i}{k_i \times (k_i - 1)} \tag{5}$$

The clustering coefficient CC of a complex network are the average of the clustering coefficients of all nodes i in the complex network. N is the total number of nodes in the complex network.

$$CC = \frac{\sum_{i=1}^{N} CC_i}{N} \tag{6}$$

4. Results and Discussions

4.1. COVID-19 bike-sharing trips

The cycling time in this study covers the time of the outbreak in the Washington D.C. area, ranging from January 1 to December 31, 2020. We investigate the travel behaviours of passengers who use the shared bicycle mode of transportation during the first year of the pandemic. The first incidence of illness was discovered in the region in March 2020, yet

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individuals continued to live and work as usual. Initially, the disease did not pose a significant problem for tourists. Although authorities in America were slower to act than elsewhere, by April most Americans were prioritizing protecting public health over concerns about the economy (Ballew et al, 2020). After the initial lockdowns, formal announcement of the end of the acute phase signified an attempt to resume work. These events were all well-known to the general public and widely publicised in the media, allowing researchers to distinguish between the various phases of the COVID-19 pandemic.

We performed data cleaning to remove a small number of erroneous data points, e.g. if the trip had no beginning or ending point, or the riding time is only a few seconds. This might be due to an equipment malfunction or a mistake in the traveller's operation. Fig. 1 depicts the amount of bike sharing system (BSS) rides taken during COVID-19 after invalid orders have been removed. It is clear that the general number of bike-sharing rides declined dramatically following March 17th, which was most likely due to the public response to rising infection rates. During the initial lockdown, the number of bike-sharing rides remained low. The number of trips progressively increased following the lockdown, however continued to be lower than before the lockdown, indicating that the COVID-19 pandemic had a sharply negative effect on bike sharing use.
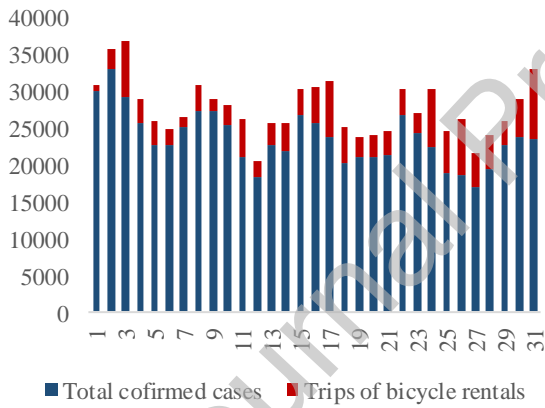
Fig. 1 shows the total number of confirmed cases and the number of shared bicycle trips in our data set since the initial outbreak. This makes it straightforward to see the rise in orders during the pandemic. Furthermore, we compared the cycling data from 2019 to that of 2020. The most egregious performance occurred in March, which coincided with the outbreak's start. Citizens will prioritise protection this month, which will result in an increase in the number of sick individuals and a fall in the number of people who use the shared bicycle system. In the months that followed, the number of riders increased, showing that travellers are more ready to use the shared bicycle system to maintain social distance. The obvious conclusion is that the outbreak has had an impact on the urban bike-sharing system (see Fig. 2). When compared to 2019, the number of people's trips and the travel duration reflect a downward trend.
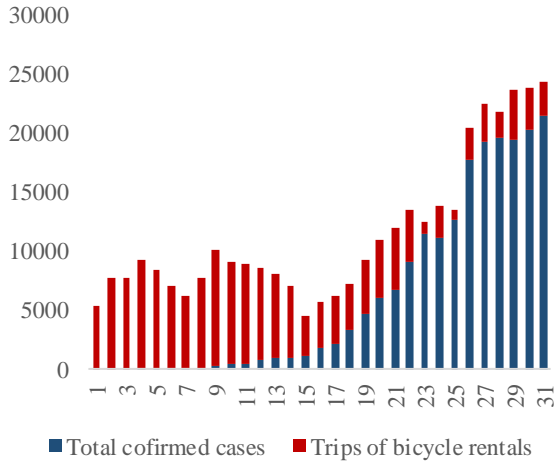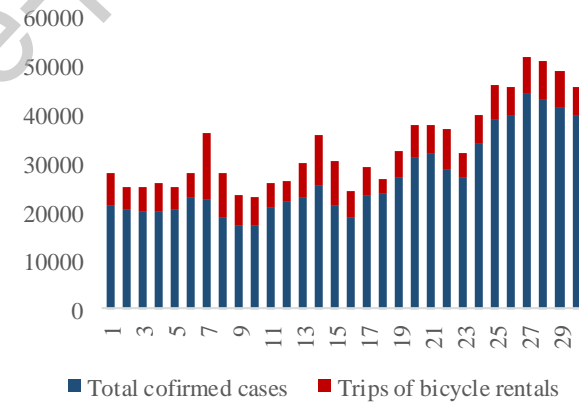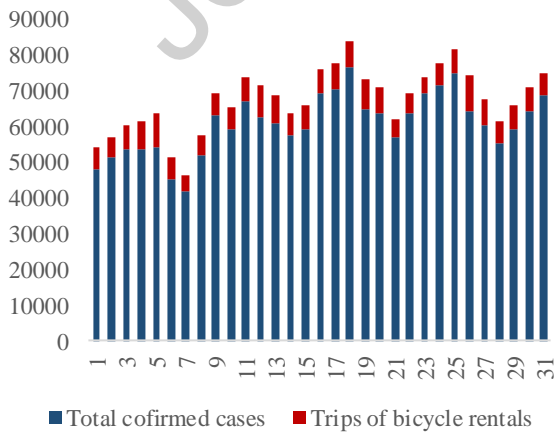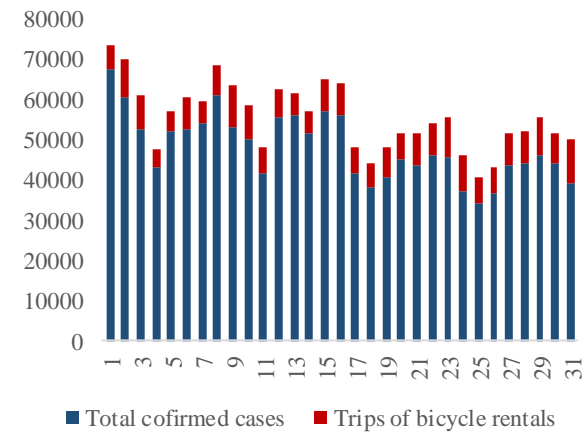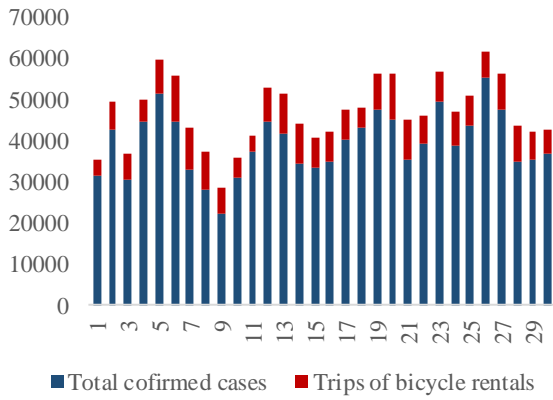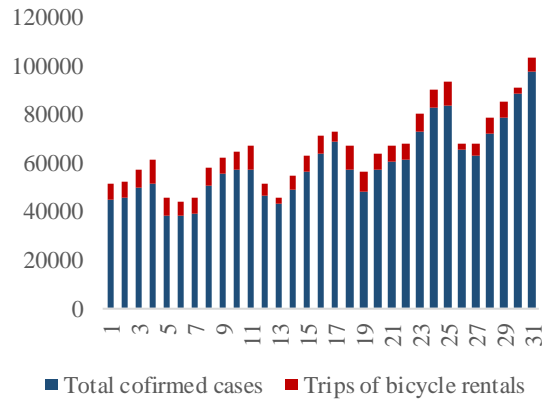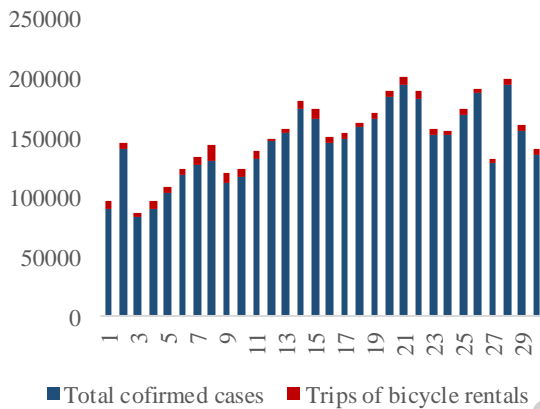
(a) March
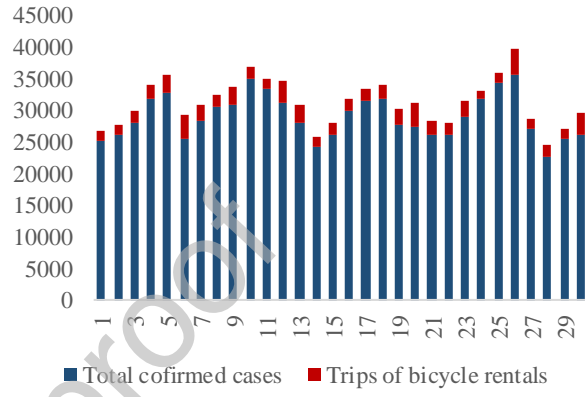
(b) April
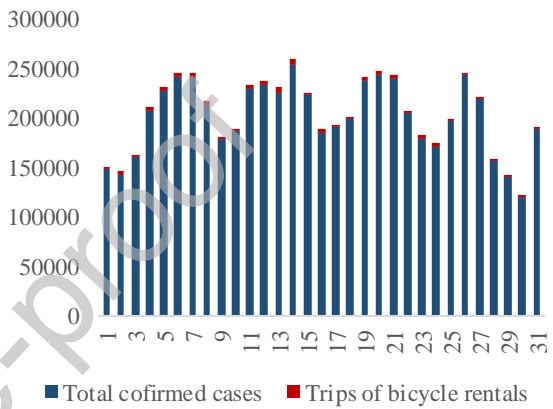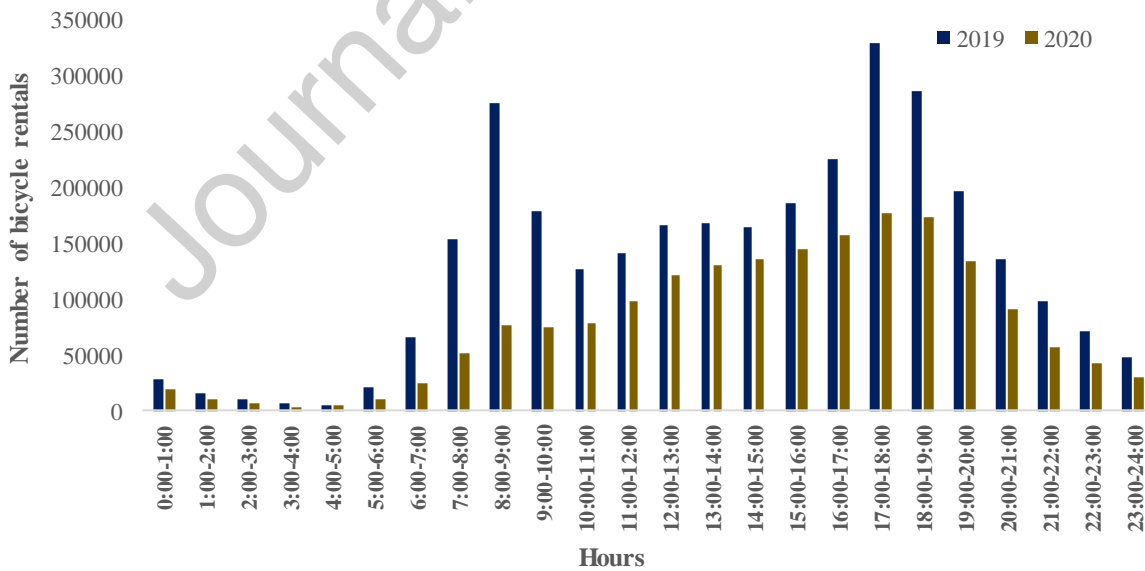
(c) May

(d) June

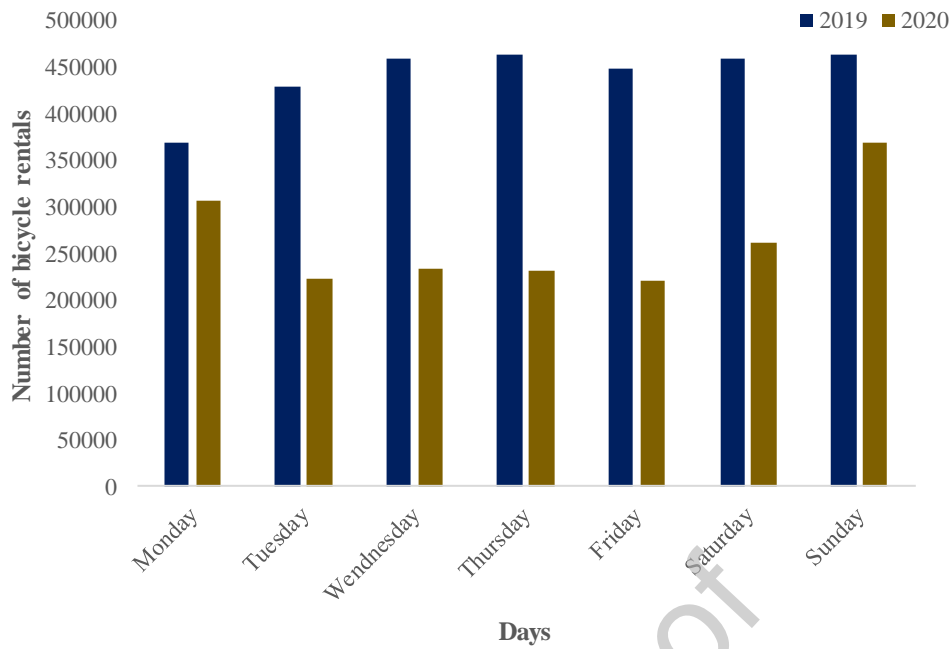(e) July

(f) August

(g) September

(h) October

(i) November

(j) December

Fig. 1. The total number of confirmed infections nationwide and the number of trips of bicycle rentals from data set.


(a) Hourly

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(b) Weekly

Fig. 2. Changes in the average day and week usage of shared bicycles.

To study the behaviours of users, the first step is to explore the travel trajectories of travellers. Data were processed and location-allocation models were applied using a geographic information system (GIS) network analysis module. We use applied trajectory analysis using information about the street network (from the Washington Regional Bureau of Statistics, 2019). Geospatial data and geographic information system (GIS) are vital to the development of a smart city in the basic concept of mapping the actual world to the virtual environment as a reference frame, and can provide city perception and visualisation of the city's transportation network (Tao et al., 2013). As a result, we can obtain information about the road network in the Washington D.C metropolitan area through this website, as well as information about the city's rivers. This geographic network may be used to calculate cyclists' journeys mobility. Among them, the location of the station and the number of users are the key factors. There is a positive correlation between the number of people participating in the program and the number of resident population, activity area and public transportation network. Additionally, the network can examine locations with a large volume of bicycle journeys. As shown in Fig 3, the concentrated site locations are the most densely populated (red represents the most users). By identifying the stations, as well as the number of users and driving trajectories, the potential development of the entire network can be clearly assessed.
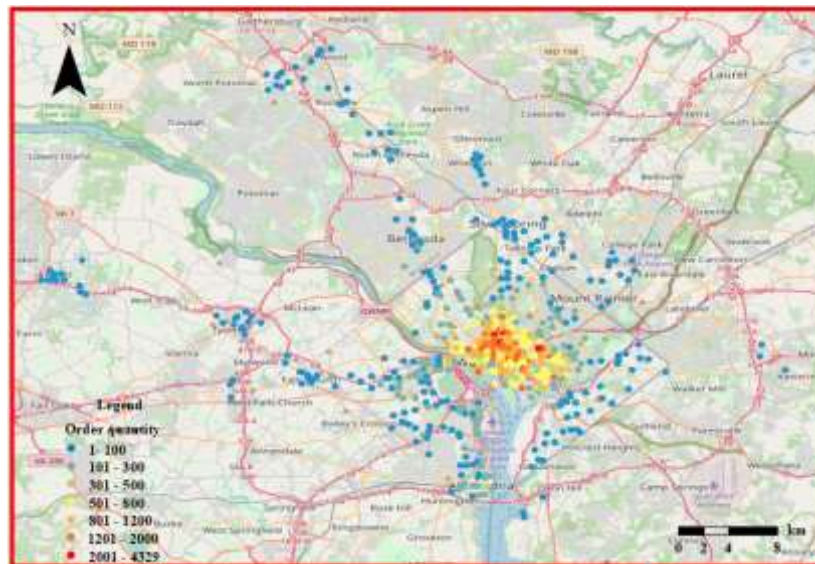
(a) bike sharing distribution in January
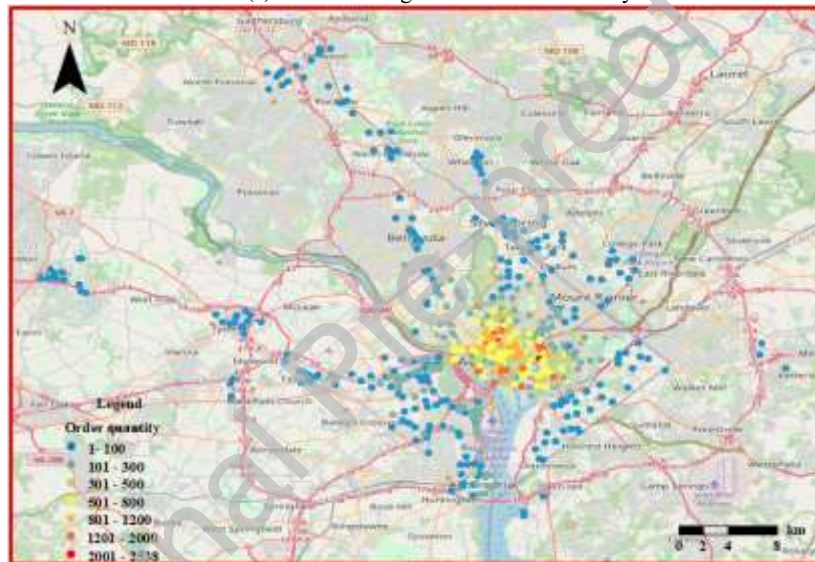
(b) bike sharing distribution in March
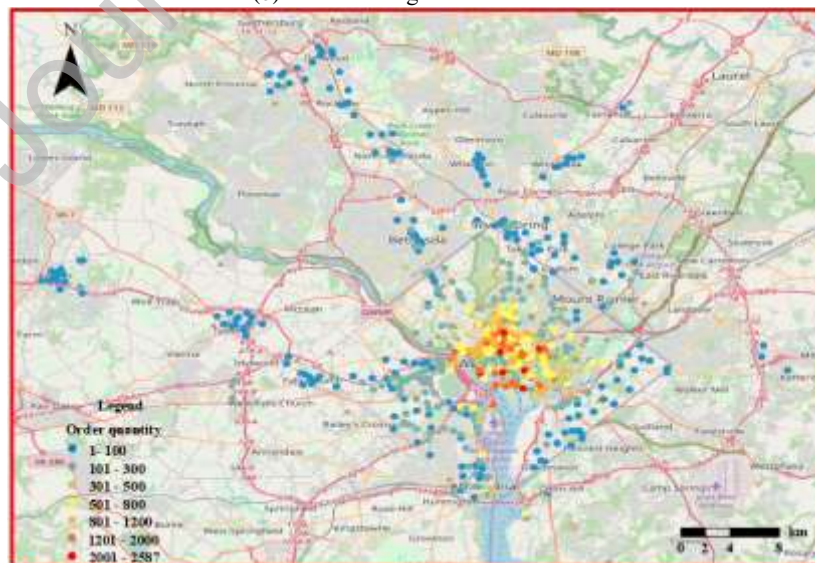
(c) bike sharing distribution in June

Fig. 3. The starting point and ending point distribution of bike sharing cyclists.

As mentioned above, first case of COVID-19 in Washington D.C. was confirmed in March of 2020, and the number of patients progressively climbed thereafter. As a result, the local government enacted strict social distance restrictions, the social distancing plan was adjusted, and traffic and passengers on public transit plummeted at this time. As shown in Figs 3 (a), before the pandemic, especially during the busy Christmas holiday season, the majority of journeys starting places and destinations are in the central region of Washington D.C., particularly around shopping malls and transit terminals where there was a high volume of orders. Trip patterns remained similar until the outbreak discovered. We picked all the March distributions to highlight the fall in bicycle sharing orders in Washington and a considerable reduction in travel in the city centre during the pandemic's progress, as shown in Figs. 3 (b). In comparison to the prospective trips and attracted trips created during the epidemic's early stages in March. Due to the density of employment in the city centre, attracting tourists generates more travel. Figs. 3 (c) depicts the distribution of traveller density in June, as well as the variation in activity location. In other words, tourists increased their utilisation in June. The demand density for lands in the city centre, in particular, has surged. In comparison to March utilisation, a June network study reveals that passengers' preference for shared bikes has progressively regained.

4.2. Travellers' cycling habits during the pandemic

The general reduction in use is visible from the clear intensity distribution curve in Fig. 4, and this obvious slope can directly indicate the frequency of node-sharing bicycle use. There was only a minor slope between the detection of the pandemic, that is, at the beginning of March. This suggests that the fraction of nodes with fewer trips is lower, while the proportion of nodes with higher intensity is greater. In mid-March, the slope of the intensity distribution grew decreased following the news of human-to-human transmission. By June, an objective phenomenon arose. According to the intensity distribution of nodes, individuals were eager to commute on shared bicycles. Participation in the shared bicycle plan steadily improved, although it was still far from normal. There was also a notable change in the time of day that people used shared bicycles. Table 2 summarizes the fitted intensity distribution data in order to quantify this trend shift. It should be noted that when the P value is less than 0.01, a satisfactory match is established.

Table 2

Strength distribution type of bike-sharing trips.

Year	2019				2020				2021			
Month	3	6	11	12	3	6	11	12	3	6	11	12
k	-0.0009	-0.0007	-0.0011	-0.0015	-0.0017	-0.0013	-0.0018	-0.0028	-0.0017	-0.0011	-0.0012	-0.0016
b	0.159	0.145	0.167	0.165	0.183	0.146	0.185	0.204	0.146	0.151	0.180	0.188
R^2	0.947	0.959	0.94	0.94	0.962	0.972	0.939	0.948	0.977	0.958	0.922	0.931
F	6567.01	9792.76	591.416	5246.8	9032.75	13488.7	5368.23	5174.36	14477.5	9182.17	4486.03	4822.16
Residual	0.02	0.014	0.023	0.024	0.016	0.011	0.025	0.023	0.009	0.016	0.032	0.029
Strength_ start	477.987	627.498	392.126	283.499	281.681	357.167	251.187	155.369	249.938	397.537	336.685	261.04
Strength_end	477.088	627.498	393.507	283.003	281.194	354.216	251.187	153.898	246.214	393.867	337.704	261.04

Note: k and b are the parameters in Eq.3. R^2 represents the proportion of the variance explained by the equation. *F* is the *F* statistic. All p values for 2019, 2020 & 2021 are zero.

Although these four ranges all match the exponential distribution effectively, the inclinations are varied, which can indicate the change of bike-sharing user behaviour to a certain degree, as given in Table 2. The term "strength begins" and "strength ends" refers to the riding strength. It is obvious that the values of these two components eventually grow. This demonstrates that the number of individuals using shared bikes is increasing and has a tendency to stabilise. Individuals are less inclined to take shared bikes to travel to locations where bike-sharing consumers used to go, suggesting a lagged return to commuting, which might also be related to the large number of government employees in the capitol who were able to continue to work from home.
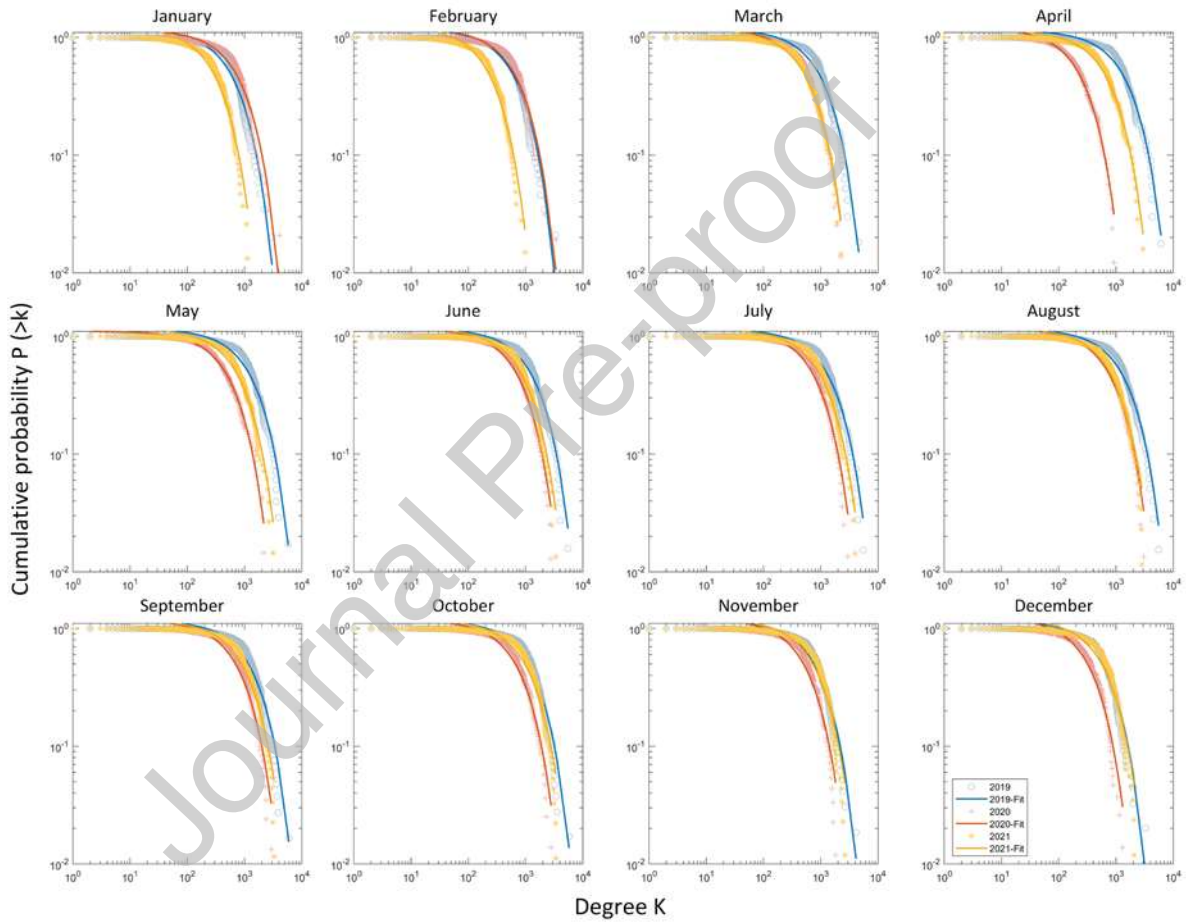
Fig. 4. Comparison of cumulative intensity distribution in different months in 2019, 2020 and 2021. Degree k means the node strength $s_i = k$.

Table 3

Average path and clustering coefficient.

Year/Month	2019				2020				2021	
	3	6	11	12	3	6	11	12	3	6
Average path length	2.68 3	2.49 2	2.92 3	3.21 3	2.83 6	2.5 3	2.79 1	2.86	2.78 9	2.65 6
Maximum path network	12	9	12	13	12	9	16	14	14	12

diameter										
Clustering coefficient	0.551	0.571	0.535	0.504	0.493	0.408	0.462	0.395	0.451	0.506

Comparison of cumulative intensity distribution in different months in 2020 and 2021 is given below (see Fig. 4). March 2020 was the beginning of the pandemic. In March 2021, the USA had just recovered from the peak in December of the previous year and was about to enter the next wave of the pandemic where the Delta variant became dominant. The daily increase in cases is the same order of magnitude (slightly higher) as in 2020. The overall travel demand had not returned to the level before the pandemic. In June 2020, the pandemic was about to enter the next peak, and in June 2021, it had just recovered from the peak in May. Judged by mortality rates, the pandemic was more serious than in June 2020. However, the use of shared bicycles in June 2021 exceeded 2020, indicating that with the development of the pandemic, shared bicycles have played a more important role over time in meeting travel needs. This can also be seen by the average path length and maximum path network diameter. The values of the average path length in June 2020 and 2021 are 2.53 and 2.65, respectively, and the values of maximum path network diameter are 9 and 12, respectively. The larger values of the two indicators in 2021 demonstrate that the scale of the network is enlarged, and the users are more dispersed. This indicates that people in more diversified areas tend to use shared bikes with the trends of the pandemic. As the overall travel demand is about the same or lower than in June 2020, the proportion of shared bicycles grew larger but took longer to do so than in other case studies we have cited. In the year 2021, the noticeable variations in the intensity analysis occur in November and December. The cycling patterns in these two months are almost identical to the trends in November and December of last year, and the two curves are quite close to one another. Table 2 presents that this is the case. Having said that, by the winter of 2021, the number of individuals who use shared bikes will have returned to normal.

5. Policy implications

First, we describe the bike routes and the intensity with which they are used in the outcome analysis section. Thus, the owners of the shared bicycle system may get precise user preferences, allowing them to distribute the appropriate quantity of bicycles and station locations. Second, urban developers may utilise the study findings to influence their assessments of user demands, system financing, and urban bicycle route building. Finally, the results of this study may aid operators and urban transportation planners in developing a

better understanding of bike-sharing systems, particularly their ability to add resilience during pandemics, using techniques developed for analysing the capacities of BSS to add resilience in the face of poor weather. Finally, our findings can be used to advocate for everyday mobility and greater awareness of the social effect of the city's shared bicycle system, as well as to increase public knowledge of the system.

6. Conclusion

Exploring how the COVID-19 affects public travel behaviours can assist planners and policymakers to understand how the pandemic affects people's commuting lives and consumer choices, as well as give some hints on how to adapt to this pandemic. Widespread lockdowns and limits to international travel grab the headlines, but more subtle changes in travel patterns have occurred locally. Many studies have revealed that during a pandemic, travellers can choose or change means of transportation, away from common carriers and in favour of autonomous transport choices. The number of people who use public transit to travel during this special season has decreased because to the heightened risk of virus transmission in enclosed areas. However, after a period where usage fell, more users than ever are eager to engage in the shared bicycle scheme. This demonstrates that when the urban transportation system is experiencing difficulties, the shared bicycle system may be employed as a sustainable and resilient method of transportation.

COVID-19 is largely airborne, and keeping a safe distance from others is an effective means to avoid infection. Since the outbreak, more people are ready to utilize shared bikes for their whole commutes rather than just the final few miles. We found that many passengers are willing to use communal bicycles to finish the full journeys rather than the last mile option. In March, most individuals were forced to work from home to safeguard their safety. As a result, it is plausible that individuals may bike sharing as a form of exercise that not only ensures social distance but also fulfils exercise needs. The purpose of this research is to analyze the intensity and behavior of bike-sharing travel during a pandemic phase in order to determine if it may help disease transmission while also preserving appropriate social distance. As a result, this study examined the intensity and behavior of bike-sharing travel throughout the pandemic period and in doing so makes two significant contributions. To begin, we developed a new complex network based on shared bicycle travel and road network architecture, and then examined user behaviour patterns using complex network theory, topological indicators of intensity and distribution, and statistical features. Second, we examine and explain the user's riding intensity using three years of riding data. The changes

in user riding patterns between normal and epidemic years were examined. Furthermore, it is plausible that the reason for people's travel has shifted, such as being near a hospital or clinic. In comparison to 2019, shared bicycle stations have been established in the proximity of parks and dense residential areas, according to data collected. If bike sharing enterprises recognize that users need bicycles for an ever-growing range of uses and provide stations accordingly, more passengers use shared bicycles, and the number of shared bicycles will grow as a result. City planners may also recognize that during a pandemic, public bicycles could be utilized for both amusement and commuting and thus could be worthy targets of subsidisation. Two limitations apply to this investigation. First, we are unable to immediately collect data support for passenger travel tools due to the privacy of other public transportation data. As a result, we made no comparisons between bike-sharing programmes and other modes of transportation.

In follow-up studies, we will gather data on travel modes and intensity, such as buses, subways, and private automobiles, and assess and debate other forms and intensities of travel. Second, many riders are not anticipated to take the quickest route between two points on the network, since many bikers will choose the safest or more enjoyable route. We calculated the straight-line distance rather than the actual distance in order to examine the user's actual driving route in future study through surveys. Bicycle schemes could be an excellent option that protects public health while also contributing to a more sustainable transportation system. To make bicycle programs more practical and resilient, public bike use should be encouraged and incentivized, and bicycle infrastructure should be better constructed. While the number of participants and frequency of use will differ from one site to the next, the logic and method used in this study may be extended to the intensity of shared bicycle use in other locations or countries. For example, when alternative modes of transportation are not available or when variables beyond human temporarily out of control (epidemic/communicable disease) exist, this approach may be used to examine and explore the elasticity of demand for shared bicycles. We hope that the findings of this study will aid in the sustainable development of cities and human health.
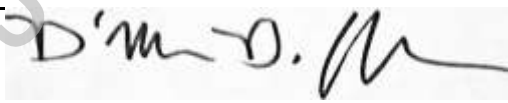
Conflict of Interest Declaration

We the undersigned declare that this manuscript is original, has not been published before and is not currently being considered for publication elsewhere.

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

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Sincerely,

NAME	SIGNATURE	DATE	CONLICT OF INTEREST (State NONE if there is no conflict of interest)
Yan Chen	*Yan Chen*	2/3/2021	I declare that there is no known conflicts of interest that could have influenced the research outcome.
Xinlu Sun	Xinlu Sun (signed)	2/3/2021	I declare that there is no known conflicts of interest that could have influenced the research outcome.
Muhammet Deveci		2/3/2021	I declare that there is no known conflicts of interest that could have influenced the research outcome.
D'Maris Coffman	*D'm D. M*	2/3/2021	I declare that there is no known conflicts of interest that could have influenced the research outcome.

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