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# Cycling during and after the COVID-19 pandemic

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## Abstract

Since the outbreak of the COVID-19 pandemic at the beginning of 2020, there have been significant changes in mobility worldwide. This chapter gives a short overview of general mobility behavior changes and a detailed summary of changes in relation to cycling and bicycle-related reactions of municipalities in urban planning to address and cater to those changes.

Overall, there was a decrease in general mobility due to travel restrictions, school closures, or people working from home. Additionally, similar changes in the transport modes used could be observed in many different countries, with the significantly decreased number of trips with public transport while at the same time private car usage increased. This chapter focuses on cycling trips, which have increased since they offer a socially distanced way of traveling, especially compared to non-individual travel modes. These changes in mobility subsequently influenced accident numbers and emissions. Many cities worldwide reacted to the different circumstances and adopted new, often temporary, infrastructure measures that encouraged people to cycle and walk more. Measures taken include tactical urbanism, pop-up bike lanes and

expansion of the bicycle network, the closures of streets and intersections for cars, the adjustment of speed limits, and the encouragement to use bike-sharing.

The chapter also reflects on the potential of the pandemic and the urban planning interventions put in place as a catalyst for sustainable mobility behavior. The pandemic has opened the way for further mobility transition toward both active travel modes and environmental friendliness in general. Many changes that were observed will persist and may change the way we move and fulfill our mobility needs in the long-term, as the increase of mobile working or the shift toward virtual meetings continue. In the end, the changed circumstances due to the pandemic worked as a catalyst for implementing such measures, and the cities should further make use of this opportunity.

**Keywords:** Cycling, Sustainable mobility behavior, Mobility transition, Tactical urbanism, Pop-up bike lanes, Transport mode choice



## 1. Introduction

With the beginning of the COVID-19 outbreak and the restrictions put in place to prevent an uncontrolled spread of the virus, the circumstances for daily activities changed. In this time, people were suddenly asked to deal with an unprecedented societal transition in the form of travel restrictions, school closures, loss of employment, and new, often imperfect, digital solutions for product delivery and working from home. These new conditions resulted in changed mobility patterns. In general, COVID-19 hotspots shifted from one region to another, resulting in different restrictions. As a result, mobility behavior developed very differently in the course of the COVID-19 pandemic.

The reduction of overall mobility was reported in many cities and countries, with numbers reaching pre-pandemic times once the restrictions were removed. In most areas, the mobility behavior pattern showed these ups and downs, and it is difficult to compare the number and phases of lockdowns, restrictions in place and reduced and the measures put in place on a global level. While the effects could be observed worldwide, the focus of the following chapters will be to summarize the findings and give examples from mainly Europe, the Americas, and some Asian studies.

A remarkable shift in the modal split distribution was observed. Cycling was seen as a reliable and resilient option in pandemic times as it enabled social distancing and a low risk of contagiousness. Additionally, it combined further advantages like being outside, staying physically active, and strengthening the immune system. [Knie et al. \(2021\)](#) state that 11% of those surveyed specified that they had “*acquired a first, further or better bicycle due to corona*”

(p. 22). There are detailed studies on the effect of the pandemic on cycling traffic all over the globe which used different data sources, like app data, counters or surveys (e.g., [Anke et al., 2021](#); [Hong et al., 2020](#)). [Buehler and Pucher \(2021\)](#) give a first compact review of those cycling studies.

The increase in cycling is also reflected in the higher demand for bicycles and its sales figures. According to the NPD Group, sales of bicycles between April 2020 and April 2021 were up by 57% in the United States ([Sorenson, 2021](#)). In France, the total number of bikes sold increased by 1.7% to 2.68 million in 2020, and e-bike sales increased even by 31% ([Beckendorff, 2021](#)). In the United Kingdom, a report sales in the cycling market grew by up to 60% at the start of the pandemic, and e-bikes sales more than doubled ([Bicycle Association \(2020\)](#)). Data from the first half of 2021 show that sales increased (+52%) compared to pre-pandemic levels ([Bicycle Association, 2021](#)). The report also suggests that the demand for bikes could not be fully satisfied because of a lack of bike availability. In Germany, bike sales (including e-bikes) increased by 17%. E-bikes sales alone increased even more (44%). Total revenue from bike sales was 6.44 billion euros, an increase of 61% ([Zweirad-Industrie-Verband \(ZIV\), 2021](#)).

Besides the behavioral side as a response to the corona pandemic, the municipalities also put up interventions that were meant to support a shift to cycling-based movements in cities. Those urban planning measures were often temporarily and quickly installed, like the famous pop-up bike lanes, street closures, or tactical urbanism interventions. In sum, the focus of this article is to show and discuss which measures were taken and which mobility and especially cycling behavior were observed on a general level in the prominent global lockdown waves. This article additionally aims to study the opportunity the COVID-19 pandemic has on the increase of cycling and potential long-term effects. The question to discuss is what changes will be permanent and which changed circumstances lead to a long-term change of mobility pattern.



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## **2. General mobility and cycling trends during the COVID-19 pandemic**

The pandemic had a substantial impact on individual routines and mobility behavior. There have been several studies of COVID-19 impacts on mobility which mostly report similar results with trips by motorized transport as well as active mobility options increasing and public transport trips decreasing (e.g., [Abdullah et al., 2020](#); [Ahangari et al., 2020](#);

[Anke et al., 2021](#); [Knie et al., 2021](#); [Nobis et al., 2021](#)). In [Table 1](#), the trends are summarized in general and for cycling as well as specific for urban and non-urban areas.

## 2.1 Mobility behavior

Mobility data in the United Kingdom shows a mobility reduction by approx. 65% during the first lockdown period. During the summer of 2020, overall mobility increased, but not to pre-pandemic levels, and then decreased again in November 2020 due to rising cases and new restrictions ([Enders et al., 2020](#)). In Germany, the [Covid-19 Mobility Project \(2021\)](#) shows that daily mobility decreased by up to 35–40% during lockdown periods in spring and winter 2020, but mobility numbers quickly went back to their normal levels with fewer restrictions. In Switzerland, [Molloy et al. \(2020\)](#) found a 50–60% reduction in the average traveled kilometers per day. A study with respondents coming from South and South-East Asian countries stated that the majority of the respondents (57%) did not go to work or school and the primary purpose of trips shifted significantly from work or study trips to shopping trips and travel distances were reduced ([Abdullah et al., 2020](#)). There was a significant shift in mode choice from public transport to private transport (cars, motorbikes) and non-motorized modes. About 87% of Indonesian respondents stated that they reduced their traveling (very) significantly and the lower frequency of travel correlates with a decrease in participation in out-of-home-activities ([Irawan et al., 2021](#)).

[Teixeira and Lopes \(2020\)](#) show that the ridership drop in New York City due to the pandemic was considerably smaller for bike-sharing (drop by 71%) than for subway ridership (90%). Additionally, the authors found evidence that a modal shift from public transport to bike-sharing occurred and therefore consider the bike-sharing system is a more resilient option than the subway system. Similarly, [Heydari et al. \(2021\)](#) view the bike-sharing system in London as a resilient part of the urban transportation system as shared bicycle usage did not decrease significantly. However, the authors show that usage times increased during lockdown periods, indicating changes in people's mobility behavior and the usage of bike-sharing systems as a substitution for public transport.

The subjective well-being has also changed differently for the different transport modes throughout the pandemic. For example, in April 2020 in Germany, 9% of respondents said they would feel more comfortable or

**Table 1** Overview of trends in mobility behavior in reaction to the corona pandemic.

	<b>Mobility trends during the COVID-19 pandemic</b>	<b>Details of the cycling trends</b>
Key trends in general	Shift in the modal split distribution All transport modes decreased absolutely, except cycling Primary purpose of trips shifted from work or study trips to shopping/leisure trips Household income influences direction of mobility behavior change Changes most prominent for age 65 and under Emissions decreased, especially during hard lockdown times	Preference of individual transport modes, like cycling, because of possible social distancing Number of accidents decreased during lockdown periods, especially the amount of fatally injured cyclists
Key trends in urban areas	Increase in walking Increase in cycling Increase in private car use Decrease in public transport use	Average daily kilometers cycled increased Times of cycling trips and trip purposes changed (more leisure, more midday) Length of cycling trips changed (longer trips for leisure purpose) Cycling increased in more transit-oriented cities while it decreased in more bicycle-oriented university cities
Key trends in non-urban areas	Decrease in public transport use but to a lesser extent than in urban areas Change in car use	More bicycle activities in rural areas for recreational purpose

From Aloi, A., Alonso, B., Benavente, J., Cordera, R., Echániz, E., González, F., Ladisa, C., Lezama-Romanelli, R., López-Parra, Á., Mazzei, V., Perrucci, L., Prieto-Quintana, D., Rodríguez, A., Sañudo, R., 2020. Effects of the COVID-19 lockdown on urban mobility: empirical evidence from the City of Santander (Spain). *Sustainability* 2020, 12, 3870. <https://doi.org/10.3390/su12093870>;

Follmer, R., Schelewsky, M., 2020. *Mobilitätsreport 02, Ergebnisse aus Beobachtungen per repräsentativer Befragung und ergänzendem Mobilitätstracking bis Ende Juni*. Ausgabe 31.07.2020, Bonn, Berlin, mit Förderung des BMBF.; Möllers, A., Specht, S., Wessel, J., 2021. *The Impact of the Covid-19 Pandemic and Government Interventions on Active Mobility (Working Paper No. 34)*. University of Münster, Germany, Institute for Transport Economics.; Molloy, J., Schatzmann, T., Schoeman, B., Tchervenkov, C., Hintermann, B., Axhausen, K.W., 2020. Observed impacts of the Covid-19 first wave on travel behavior in Switzerland based on a large GPS panel. *Transport Policy*. Volume 104, 2021, 43–51. <https://doi.org/10.1016/j.tranpol.2021.01.009>; Anke, J., Francke, A., Schaefer, LM., Petzold, T., 2021. Impact of SARS-CoV-2 on the mobility behavior in Germany. *Eur. Transp. Res. Rev.* 13, 10. <https://doi.org/10.1186/s12544-021-00469-3>; Maier, O., 2021. *Perspective of Cycling Industry - Cycling in Times of COVID*.

much more comfortable if they used or would use a bicycle compared to pre-pandemic times; in summer and autumn 2020, this figure was 11%, in spring 2021, it was 13%. In autumn 2021, 15% of respondents said they would feel more comfortable or much more comfortable if they used or would use a bicycle than before the spread of the coronavirus (Nobis et al., 2021). Hong et al. (2020) applied app data to different types of cycling infrastructure. While the increase in non-commuting-cycling was the highest on safe cycling infrastructure (shared off-road infrastructure, park routes) after the implementation of the lockdown, the increase was also significant on roads with no specific cycling infrastructure, implying that people were encouraged to use these roads more because of lower traffic volumes and therefore, increased safety. The authors also reported higher increases on cycling routes with attractions (i.e., rivers, parks) and good connections to essential destinations (e.g., supermarkets).

Although most studies focused on urban mobility, the initial situation concerning transport modes is different in rural areas, with car use having a much higher share of the modal split. On the other hand, all other modes have a lower share of the modal mix in rural areas than in urbanized areas. During the pandemic, the use of public transport decreased. The most noteworthy change was car usage in rural areas, with 78% of responses stating a change. About 45% state that they use the car less (versus 20% of the urban drivers), and 33% use it more (versus 23% of urban drivers) (Anke et al., 2021).

The mobility reduction was most prominent for people under the age of 65 during the beginning of the pandemic and went back to or even above their pre-pandemic levels as the pandemic continued, and new routines were established (Knie et al., 2021). In contrast, overall mobility for older people has continued to decrease. In addition, people of the older age group were more sensitive to the risks of the virus and the risk of infection on public transport (Park and Cho, 2021).

According to Parker et al. (2021), people with lower incomes did not decrease their public transport travel as much. Under normal conditions, the mobility footprint increases with income: On average, the higher the income, the higher the mobility indicators, such as time spent on the road and distance traveled. At the beginning of the pandemic in 2020, there was a brief reversal of this relationship, with people from higher income levels having lower mobility indicators due to the possibility of working remotely (Follmer, 2020). The already lower modal split share of motorized private transport in low compared to high-income households had decreased even

further from 45% to 40% from May 2017 to May 2020 but was almost returning to pre-pandemic levels in May 2021 in Germany (Knie et al., 2021). At the same time, the share of motorized private transport in the modal split of people with high household income has risen steadily from 54% in May 2017 to 58% in May 2020 to 61% in May 2021. The share of cycling in the modal split has hardly changed for low, medium, or high household income alike, suggesting that cycling use is not significantly dependent on socio-economic indicators in Germany. Schaefer et al. (2021) found that in the choice of changing transport modes, eco-consciousness played an essential role in using the bicycle instead of the car.

## 2.2 Trip purpose

As gyms were closed and curfews implemented, cycling was suitable for some people to keep physically active. In Germany, the reduction in mobility was most significant for work and educational purposes and smaller for recreational and leisure purposes (Knie et al., 2021). Meanwhile, the number of trips for shopping and errands was roughly the same in May 2020 compared to pre-pandemic times. Hong et al. (2020) used crowdsourced cycling data from the activity app Strava which correlated with automatic bicycle counters, to analyze changes in cycling activity in Glasgow, Scotland, UK. With the pandemic beginning in March 2020, commuting trips decreased significantly. However, the number of non-commuting trips started to increase, indicating that people used cycling more as a form of exercise.

People did not necessarily perceive the removal of their daily trips as enrichment. In a study from the Netherlands, 69% of the respondents stated they miss at least some facets of commuting, where the main aspects include the activity of commuting itself (53%), the ability to spend some time alone (25%), and feeling independent (24%). These specifications have varied greatly depending on the transport mode. For example, 55% of car commuters did not miss their commute, while 91% of bicycle and e-bike commuters missed at least one aspect of their commute. The study also shows that the longer the commute, the less it was missed (Rubin et al., 2020).

## 2.3 Accident numbers and emissions

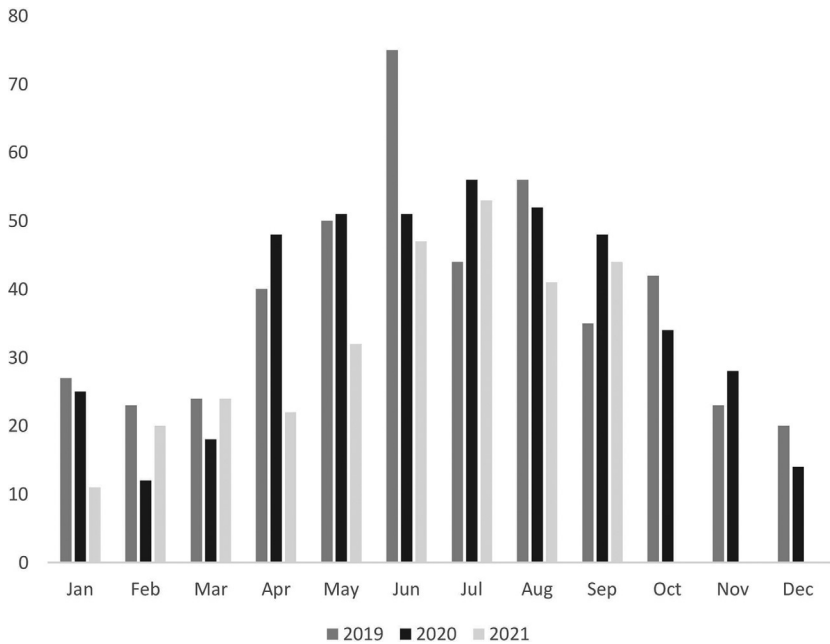
The changes in mobility during the COVID-19 pandemic had different impacts on road traffic collisions and road deaths in different countries. While there was a reduction of both indicators in 32 out of 36 countries



in April 2020 compared to April 2019, there was an increase in the other four countries (Yasin et al., 2021). Wegman and Katrakazas (2021) also found a reduction of traffic fatalities in 23 out of 24 countries in 2020 compared to a baseline of the previous years (2017–2019), the only exception being Switzerland. There are differences in reduction rates with almost no reduction in Finland, a reduction between 15% and 25% in Mexico, New Zealand, Great Britain, Japan, Greece, Slovenia, Belgium, Sweden, and France, and a reduction of more than 35% in Argentina and Iceland. In Great Britain, a reduction of 68% in April 2020 compared to the 3-year average for 2017 to 2019 was observed (Department for Transport, 2021). In contrast, there was an increase in road deaths by 50% in Slovakia and by 9% in Denmark in April 2020 compared to April 2019 (European Transport Safety Council, 2020). One explanation for the increase could be that the reduction in traffic has created emptier roads where risky driving, such as speeding, is much more likely to occur and lead to more severe injuries in collisions.

However, the change in road fatalities was not the same for all transport modes. Wegman and Katrakazas (2021) show a decrease for all transport modes in the countries studied, with the largest decrease for public transport-related fatalities (68%) and the smallest for cyclists (6%), which may be related to a decrease in public transport trips made. The Department for Transport (2021) even saw a rise in pedal cyclist fatalities by 41% in Great Britain, while serious injuries fell by 1% and slight injuries fell by 10% in 2020 compared to the 3-year average for 2017–2019. In this case, the increase in pedal cyclist fatalities is in line with the increase in pedal cyclist traffic. The numbers have continued to move in very different directions in different countries in 2021. While the National Center for Statistics and Analysis (2021) estimates an increase of 18.4% in motor vehicle traffic fatalities in the United States for the first half of 2021, a new high since 2006, provisional data shows a 7% drop in road deaths in 2021 compared to 2020 in Ireland, a record low since recording began in 1959 (Road Safety Authority, 2022).

The number of accidents has decreased during lockdown periods, especially the amount of fatally injured cyclists during hard lockdown times. In Germany in March 2020, the number of total severe accidents was down to 68% compared to the average number of 2017–2019, the number of fatal cyclist accidents at 67%, and the number of accidents with personal injury at 87%. Those decreases primarily occurred during the start of the lockdown and went up to almost the same amount afterward. The numbers of fatally injured bicyclists are shown in Fig. 1. As many people switched from public transportation to individual modes of transport, less experienced or novice



**Fig. 1** Number of fatal injured bicyclists accidents in Germany, 2019–2021. Source: own analysis with data from DESTATIS, 2022. Fachserie. 8, Verkehr. 7, Verkehrsunfälle. Monatlich, [https://www.statistischebibliothek.de/mir/receive/DESerie\\_mods\\_00000096](https://www.statistischebibliothek.de/mir/receive/DESerie_mods_00000096) (accessed on 20 December 2021).

car and bicycle riders were on the road. Further, the spring season was enjoyable and additionally stimulated the use of active mobility modes.

The change in traffic volume has not only triggered a change in the number of accidents but also in traffic-related emissions. The global CO<sub>2</sub> emissions decreased by about 17% in April 2020 compared with the average 2019 levels, about half of this being due to changes in surface transport (Le Quéré et al., 2020). The global daily fossil CO<sub>2</sub> emissions only from surface transport decreased by up to 7.5 MtCO<sub>2</sub> d<sup>-1</sup> in April 2020 concerning annual mean daily emissions from this sector in 2019. As Jackson et al. (2021) expected, the global fossil CO<sub>2</sub> emissions returned to 2019 levels in 2021.



### 3. Measures to promote cycling during COVID-19

The COVID-19 pandemic has significantly affected mobility behavior. Various studies have shown the effect of the different phases of lockdown conditions on overall mobility, transport modes, trip lengths, and the relation between trip purposes. Certain factors such as gender,

age, eco-consciousness, household income, or the risk of infection influenced the behavior's direction. In many places, the municipalities responded to the new circumstances: Temporary and permanent measures in infrastructure have been implemented. Examples of these and how they, in turn, have affected mobility behavior are presented in this part of the article.

Many cities worldwide have adopted new, often temporary, infrastructure measures to deal with the changed circumstances of the pandemic. Active travel modes, i.e., walking and cycling, emerged as they offer a socially distanced way of traveling, especially when compared to public transport. Additionally, some municipalities have seen the pandemic as an opportunity to start a transformation to become healthier and more environmentally friendly cities (Nikitas et al., 2021). Cycling, in particular, is seen as a low-cost, sustainable mode of transportation with a low risk of COVID-19 transmission (Kraus and Koch, 2021). It is a central pillar of the transition toward a more sustainable mobility system and helps to reach the UN climate goals. However, these activities needed more support, including a safe space, especially in the dense urban areas. Therefore, to encourage people to cycle more and ensure that doing so is safe, both in terms of risk of infection and protection from road safety risks (Adriazola-Steil et al., 2021), changes in the cycling infrastructure were necessary. There are various measures taken which include: (a) tactical urbanism, like road painting; (b) pop-up bike lanes and the extension of the bicycle network and the number of bicycle parking racks in general, (c) traffic calming with the closures of streets and intersections for cars and the implementation of speed limits or (d) the encouragement to use or facilitate the use of bike-sharing, which are described in detail below.

In general, the measures implemented to respond to the COVID-19 pandemic helped reduce congestion and improve traffic safety. Various actors have launched datasets to catalog these measures. For example, the European Cyclists' Federation (European Cyclist' Federation (ECF), 2020) launched the COVID-19 Cycling Measures Tracker, which lists cities across Europe with their planned and implemented measures. Of 2600 km announced, just 1500 km have been implemented, and 1.7 billion € have been allocated for cycling promotion as of February 2022. 77% of the listed measures are cycle lanes/tracks, 18% are traffic calming/reduction measures, 4% are car-free sections, and 1% are wider sidewalks. The city of Rome is leading the board of announced measures with 150 km of cycling measures announced and 15.7 km implemented, while London is leading the board of implemented measures with 75% (77 km) of cycling measures implemented.

Granada has implemented 100% of the announced 60 km of traffic calming/reduction. In relation to its population, the country of Luxembourg has announced and implemented the most kilometers with 89 km. [Combs and Pardo \(2021\)](#) also started a publicly available global dataset that lists over a thousand pandemic-related mobility measures. The most common measure is curb space reallocation with 27%, while the most frequently mentioned one is the expansion of street space for walking/cycling with 43%. [NUMO, the New Urban Mobility alliance, et al. \(n.d.\)](#) also manage a dataset where over 500 mobility responses to COVID-19 from 245 cities are listed (as of February 2022). The 572 initiatives listed use different approaches like communication, financial support, or changes to public space.

Furthermore, also at the country level, actions were taken. Within the EU, many countries also adopted the approach of promoting cycling in their COVID-19 recovery plans, aiming for a more sustainable recovery. According to the analysis of the [European Cyclist' Federation \(ECF\) \(2020\)](#), within these plans, around 1.7 billion € are reserved for cycling infrastructure, safety, tourism, and promotion ([European Cyclist' Federation \(ECF\), 2021a](#)).

### 3.1 Tactical urbanism

Many cities used actions of tactical urbanism to react to the urgency of the pandemic. In contrast to long-term, strategic urban planning, tactical urbanism is seen as a quick, low-cost approach to tackle problems in the urban environment to improve life quality and sustainability. Tactical urbanism involves the participation of local communities and neighborhoods and is mainly limited to small-scale, temporary actions. However, it is also used to initiate long-term changes or experiment with new ideas before larger investments are made ([Lydon and Garcia, 2015](#)). Tactical urbanism is mainly seen as a bottom-up approach ([Graziano, 2021](#)); however, [Lydon and Garcia \(2015\)](#) argue that local governments can also adopt it in a more top-down way to react to new demands quickly. This was primarily the case during the pandemic. Citizens should be encouraged to participate in the planning process by directly testing the interventions and giving feedback. Many cities tried to find solutions for the public space as a reaction to the pandemic. These temporary changes caused by the pandemic can also test future changes toward more sustainable cities in an urban lab. [Marti and Espindola \(2020\)](#) describe how tactical urbanism can be used in this sense: “*The actions of tactical urbanism implemented these weeks (rapid, low cost, reversible*

*interventions like ground painting or using mobile urban furniture) constitute an interesting laboratory to explore and test permanent changes in the transformation of our streets in order to build more peaceful cities: cleaner and less polluted, human-centered and easily inclusive, slower and enabling new urban experiences.”* (p. 22). Because of the low cost of the measures, it is possible to implement them very quickly and change and adapt them continuously to the needs of a situation. Some of the following measures explained or parts of them can be categorized into tactical urbanism.

### 3.2 Pop-up bike lanes

One solution that has been widely adopted is the so-called pop-up bike lane. Pop-up bike lanes are created by the reallocation of road space from car traffic to bike traffic, transforming former car lanes, which are not as busy as a result of reduced mobility during the pandemic, into new, temporary cycleways (Lovelace et al., 2020). These bike lanes are marked by paint and cones or bollards, which create a physical separation from motor traffic, as shown in Fig. 2. The separation with standard equipment and paint from road construction sites were the most popular forms at the early stages of the pandemic. However, design guidelines for pop-up bike lanes were quickly developed



**Fig. 2** A pop-up bike lane in Berlin Friederichshain-Kreuzberg. *Source: Peter Boytman Creative Commons CC0 1.0.*

that recommend a width of around 3 m to ensure safe passing while respecting social distancing measures (Adriazola-Steil et al., 2021; Mobycon, 2020).

This movement was a global one, and new pop-up bike infrastructure has also been implemented in many cities in North America, South America, and Australia, briefly described below. In Europe, approximately 2000 km of pop-up bike lanes have been announced (European Cyclist Federation (ECF), 2021b). A leading example, which made headlines worldwide, is Bogota, Colombia. Among one of the first metropolises, they instantly added 84 km of temporary bike lanes to its already existing cycling network of 550 km (World Health Organization (WHO), 2020). This measure had the effect of doubling the number of cyclists while also increasing the interest of citizens in cycling in general.

Further major examples can be found in Brussels, Belgium, where about 25 km of cycle lanes were added; Berlin, Germany, with about 24 km of new lanes; or London, UK, with about 25 km of pop-up bike lanes. Paris, France, implemented around 80 km of cycling infrastructure, primarily as pop-up bike lanes. Most notably, Rue de Rivoli, a major thoroughfare in the city center, has been completely closed to private car traffic, and a wide cycle lane has been created. Paris also implemented several accompanying measures and accelerated its already existing plan to become cycling-friendly by 2024. In Vienna, Austria, temporary bike lanes of only 2.5 km were implemented, which were generally well used, but they were discontinued, despite the findings of great potential for adding even more bike lanes in Vienna (Frey et al., 2020). Barcelona, Spain, added 21 km of temporary bike lanes with plans to make these changes permanent (Medina et al., 2020). They also announced plans to create about 33 km of bike lanes until 2023, using the pop-up infrastructure to start a long-term transformation into more cycling-friendly (de Barcelona, 2021).

As a good example of how cycling is promoted in a smaller municipality, the COVID-19 transport recovery plan of Leicester City Council (2020) is described. Leicester, UK, based their plan on three essential principles: first, the need for more safe travel options in terms of the health of residents; second, the general need for sustainable mobility due to the climate crisis; and third, social equity. As a result, they announced in their plan in May 2020 the production of one mile of pop-up cycle track every week for 10 weeks alongside several other measures, including free maintenance through local bike shops and rental bicycles for employees. They also launched a new bike-sharing scheme in spring 2021 to provide additional safe and sustainable mobility options with reduced fees and even e-bikes for rent.

Overall, pop-up bike lanes have been a success story getting more people to cycle. Kraus and Koch (2021) calculate an average increase in cycling of about 42% triggered by pop-up bike lane programs compared to control cities. The increased numbers of cyclists also come from new cyclists who were not able or who did not dare to cycle before. With a reduced car traffic volume and a separation from the motorized traffic, the new cyclists were confident enough to both try to cycle and also to cycle longer routes. A survey from Berlin states several major advantages of the new pop-up bike lanes: greater distance from motorized traffic and pedestrians, more space for keeping distance and for overtaking, and more direct routes. These result in safer, faster, and more comfortable journeys (Götting and Becker, 2020).

In Berlin, Germany, the city government initiated the implementation of pop-up bike lanes in cooperation with the local council administration (Bezirksamt Friedrichshain-Kreuzberg, 2020). As a result, most people supported the project, with 94% of respondents stating their support (Götting and Becker, 2020). However, the project was also the focus of discussions about the legality of pop-up infrastructure (Berlin.de, 2021); in October 2020, a court decided that the implementation of pop-up bike lanes was legal and justified under the circumstances of the pandemic (Oberverwaltungsgericht Berlin-Brandenburg, 2020). Therefore, at the end of 2021, it was announced that the great majority of pop-up bike lanes in the district of Friedrichshain-Kreuzberg would be converted into permanent cycling infrastructure (Bezirksamt Friedrichshain-Kreuzberg, 2021). The local government states increased equity and safety for vulnerable road users as the main factors for the conversion of the infrastructure.

The installation of pop-up bike lanes also brought further long-term changes, as an investigation report about a pop-up bike lane in Berlin shows (Deutsche Umwelthilfe e.V., 2021). The bike lanes at Kantstraße and Neue Kantstraße were quantitatively observed from the first lockdown in April 2020 in Germany. Before the installation, the traffic volume on Kantstraße averaged 20,982 motor vehicles per day. From April 2020, i.e., after the installation of the pop-up cycle track, until the end of October 2021, there were only 16,387 motor vehicles per day. The number of motor vehicles has therefore reduced by 22%. On the other hand, the number of cycling movements has increased by 232% in the same period, from 1542 to 5125 cycling movements per day. With the reduced number of motor vehicles, the  $\text{NO}_2$  pollution at Kantstraße has decreased from  $33 \mu\text{g}/\text{m}^3$  in 2019 to  $26 \mu\text{g}/\text{m}^3$  in 2020. The change exceeds the average reduction as an effect of the COVID-19 pandemic of about  $2 \mu\text{g}/\text{m}^3$ . This pop-up cycle track will be converted into a regular cycle track (Latz, 2021).

Apart from the pop-up bike lanes, the public network was also extended for cycling and walking. [Buehler and Pucher \(2021\)](#) compiled a survey on the overall expansion of the bicycle network and found that in 32 of 42 European and 102 of 200 North-American cities, new bike lanes were built. For example, in London, the network expanded by 100 km, in Paris by 80 km, in New York City by 102 km, and in Montreal by 88 km.

### 3.3 Open streets

Another measure implemented by many cities was so-called open streets or slow streets ([Lydon, 2021](#)). A primary example of tactical urbanism is that these streets have been opened for use by cyclists and pedestrians and are partially closed for cars. If cars are allowed, pedestrians and cyclists have priority, and there are often traffic calming measures as well as speed limits in place to ensure that people can move safely and socially distanced in the road space. For example, in Brussels, a “slow street”-zone was created, spanning the entire city center, with priority for pedestrians and cyclists and a speed limit of 20 km/h ([International Transport Forum \(ITF\), 2020](#)). In addition, a citywide speed limit of 30 km/h was implemented, except for a few major roads. In Vienna, 25 temporary “encounter zones” were created, which allowed pedestrians to use the road space ([Frey et al., 2020](#)). However, due to the lack of additional structural design measures, pedestrians’ usage of these zones was generally low, and the program was discontinued.

In the city of Oakland, USA, an extensive “slow streets” program was initiated by the Oakland Department of Transportation at the beginning of the pandemic in April 202 and designated around 119 km of its street network as potential slow streets with priority for cyclists and pedestrians, and only local motorized traffic allowed ([City of Oakland, 2020](#)). Using a tactical urbanism approach, the program was rolled out by using temporary measures like barricades, cones, and signs and relying on community feedback to choose new locations and improve implementation ([OakDOT, 2020](#)). An interim findings report showed that vehicle traffic dropped significantly on slow streets, no fatal or severe crashes involving cyclists or pedestrians occurred, and 77% of participants of an online survey stated that they support the program ([OakDOT, 2020](#)). Additionally, a new program called “Essential places” was launched to improve traffic safety in critical locations based on community feedback. In order to evaluate the program, the city used an online survey, which was available in multiple languages, to reach as many people as possible, as well weekly meetings with community organizations and local transportation advocate organizations ([OakDOT, 2020](#)).



In October 2020, the city began to replace temporary infrastructure elements that required high maintenance, such as cones and barricades, with more durable materials in specific locations (City of Oakland, 2022). It is also planned to implement permanent “slow streets” following long-term plans to convert existing neighborhood bike routes (OakDOT, 2022).

A similar program was implemented in Seattle, USA: approximately 40 km of neighborhood streets were converted to so-called Stay Healthy Streets. They were implemented to give people safe space for walking, cycling, or other activities while being closed through traffic (Seattle Department of Transportation, 2021). The program was focused on areas where a higher percentage of people of color, people with disabilities, and children live to increase equity of access to safe mobility and public space (Firth et al., 2021). The city has also used an online survey to assess whether these efforts have been successful and if the changes should be made permanent (Seattle Department of Transportation, 2021). This is, as mentioned, an essential part of those measures as they allow reaching a more diverse user group and receiving feedback from those users. This is the precondition for assessing and implementing measures that suit the needs of all groups of users.

### 3.4 Changes in bike sharing systems

With the increased demand for cycling during the pandemic, bike-sharing systems have played an essential role in meeting this need as they increase the accessibility of cycling. While in some cities, e.g., in Santander, Spain, the bike-sharing systems were suspended because of concerns of increased COVID-19 transmission risks (Aloi et al., 2020), most cities expanded their systems or implemented special offers to give people, who needed to travel, a safe option to do so. According to Teixeira et al. (2021), using bike-sharing to avoid public transport and maintain social distance were more relevant motivations for users. In contrast to the city of Leicester introducing a new bike-sharing scheme, other cities and bike-sharing operators implemented different measures. In Glasgow and Edinburgh, the UK, the first 30 min of every ride were made available free of charge (POLIS, 2020). Additionally, free memberships for the bike-sharing system were offered to healthcare workers (Wilson, 2020). In Berlin, 30-min rides on its system Nextbike were offered free. In Boston and Chicago, the USA, Lyft has introduced free and reduced-fare programs for essential workers and discounts for other users (Miketa and Sun, 2020). In New York City, a program that provided free trips

to the city's "critical workforce" was implemented (Teixeira and Lopes, 2020). Some systems also implemented additional health measures, such as more frequent cleaning of the bike fleet and station facilities, to decrease the risk of COVID-19 transmission (Jobe and Griffin, 2021). However, it is also essential to highlight the need to communicate better these efforts to increase the perceived safety of the systems and attract more users.



#### **4. Potential long-term changes in mobility behavior**

Some impact of the pandemic changes may turn into long-term behavior. Of particular importance here is the extent to which the pandemic situation offers opportunities for promoting sustainable mobility. The pandemic and its measures can be understood as a disruptive event (Anke et al., 2021). Because of the perceived disruption, a so-called window of opportunity opened to change behavior as the set outside conditions had changed. The behavior had to adapt to that, and new mobility routines could develop.

Many people started to increase the use of their individual motorized transport. This has adverse side effects on the environment. Particularly problematic in this context is the permanence of these changed mobility patterns. The potential change in mobility behavior toward a more environmentally friendly one needs supporting factors to make maintaining it as easy as possible. The pandemic showed that many people changed from public transport to an individual transportation form. Since many people who used public transport before the pandemic have changed their mobility behavior so that it now no longer plays a role, awareness of it as a mobility option must again be fostered. This problem can be avoided or mitigated by implementing further investments and efforts to attract environmentally-friendly mobility options and the redesigning of places and infrastructure to encourage active mobility. This was their first, or greatest extent of, active mobility experience for many people. Fuller et al. (2021) show that improved cycling skills and confidence due to the national lockdown are relevant for continuous cycling after lockdown relaxations. Slightly more than 50% of respondents who were new to cycling or started again during the pandemic stated that they would rate improving their skills and confidence as an extremely or fundamental reason for continuing cycling after loosening the lockdown restrictions compared to 27% of those who had continuously cycled. Increased confidence was cited as extremely or very important by a similar number of respondents: 59% of those new to or restarted cycling and 25% of those who had cycled before and

during the pandemic. For women, in particular, improved confidence and cycling skills were very or extremely important (42–49%) compared to male respondents (28–29%).

In general, the usage of digital services has become more popular. As routes were cut where possible during the COVID-19 pandemic and parts of the retail sector were forced to close temporarily, online retailing increased in importance. Instead of face-to-face meetings, the majority of people also reported that they, during and immediately after the first lockdown, preferred to hold online meetings (50%) or to make phone calls (83%) instead of face-to-face meetings with family and friends (Follmer and Schelewsky, 2020). An important influencing factor is also the increased work in the home office, which results in the reduction of numerous commutes and, at the same time, changes in leisure and errand routes. Before the COVID-19 pandemic, approximately 10–15% of the workforce in Germany worked at least partially from home (Follmer, 2020). In spring 2020—during the first lockdown—25% to 35% of the employees worked from home (Nobis et al., 2020), and around 40% were estimated at the EU level (European Union, 2020). In high-income groups, the opportunity to work from home is more frequent than average, and the numbers were even higher. The changes in transport modes already described—the avoidance of public transport and the switch to private cars—were particularly evident for high-income individuals and became more pronounced as the pandemic progressed. The fact that there will probably not be a (complete) return to “normal times” concerning the home office is shown by the continuation of this form of work in the course of the pandemic.

Although the home office was nothing new, the COVID-19 pandemic presented many companies and employees with new challenges. Each person’s living situation is different, and the conditions for working from home vary in different factors like place of work, ergonomics, and care responsibilities (Bilge et al., 2020; Bockstahler et al., 2020). About 44% of people with care responsibilities without support work outside of typical working hours, 38% of people with care responsibilities with support work late into the night and on weekends (Bockstahler et al., 2020). This also impacts the daily traffic pattern, with bike traffic shifting more to midday and afternoon. Female respondents scored significantly higher on remote working stressors than male and diverse respondents (Bilge et al., 2020; Demmelhuber et al., 2020). Despite the possible risks of remote working, many people see advantages; almost half of the respondents would like to work from home as often after the pandemic as during it (Hans Böckler Stiftung, 2020). The study also shows that the more the respondents earn, the greater their desire to work from home is.

The increase in working remotely and virtual substitutes of real traffic will persist beyond the pandemic, even if in a reduced volume. An essential prerequisite for this is the promotion of digitalization, especially to further encourage digital alternatives that stimulate environmentally friendly mobility behavior and provide mixed land use to facilitate working from home. On the other hand, more digitalization will likely increase the distance to facilities, and the drop in requirement to be at work every day will reduce commuting travel. Both may increase distances and thus the ability to cycle for transport. The changed environmental conditions and thus the changed mobility behavior will also have long-term effects on traffic planning. Long-term, this might also lead to a relocation of homes which has further effects on the transport system. So far, these effects, especially the increased use of digital services, have not yet been sufficiently considered in the simulations and models. There is also a social dimension as not everyone can work from home and no safe public transport means no option to travel and therefore, possibly no income. The major challenge here is to increase the attractiveness of sustainable transport for all user groups and include this in the planner's perspective. It takes a tremendous effort to change mobility behavior again after one has become accustomed to a different mode of transport. The beginning of the lockdowns was clearly defined, acting as a robust signal for many that there was a genuine need to adjust their behavior, including mobility behavior substantially. However, the end of the pandemic still seems a bit amorphous and so lacks the decisive impulse that was present at the start. Another behavioral change would be more difficult in this situation, requiring additional education and communication measures.

To prevent contagion and enable physical activity, space in public areas is necessary, even in dense urban areas. It is necessary to reallocate space for cyclists and create areas for recreation and pedestrians. Specific measures proved to be very successful in promoting active mobility and reducing air pollution, like CO<sub>2</sub> and NO<sub>2</sub>. These gains should not be squandered by a lack of further funding or research.



## **5. Summary and outlook on mobility after COVID-19**

The different stages of the pandemic revealed how changeable mobility and cities are. Different studies have illustrated how pandemic-induced changes in mobility led to significant reductions in traffic accidents leading to personal injury or fatality and reduced congestion and CO<sub>2</sub> emissions. The new hygiene and social distances requirements and the changes in mobility,

including increased need and willingness for both walking and cycling, had governments and municipalities all over the world respond with numerous temporary and permanent infrastructure measures. Many of these pandemic measures have brought to light the possibility of major changes being accomplished in a concise time frame when the political will (and the urgency) is there.

A significant number of cities have demonstrated that temporary traffic experiments, such as pop-up bike lanes or open streets, can be used to try out new structures and public space layouts. The cities used the opportunity to implement measures and evaluate these measures, which can be made permanent if successful and well-received. One's own – preferably positive – experience helps with the acceptance of measures. With users' feedback, the COVID-19 measures can be improved continuously and increase acceptance from all user groups. The pandemic has shown what is possible and how willing people are to change their mode of transport. The mere reduction of cars on the road at the beginning of the first lockdown in 2020 has been enough to alter the safety perception of some people sufficiently enough for them to see cycling as a viable option. The implementation of new bicycle infrastructure also supported this.

Cycling can be one of the environmentally-friendly alternatives to motorized private transport for individual transportation. Bicycles are an ideal mode of transportation to enable a resilient mobility system in a city. Some cities have shown creativity in encouraging citizens to be actively mobile, with free bicycle maintenance and repair measures. People who have switched to active mobility because of the pandemic need to be supported to stay there (e.g., via incentives from the employer or health insurance). It has been common for measures promoting active mobility to focus on urban areas usually. However, it is necessary to pay attention to rural areas as well, since the dependence on cars is still much higher there. Infrastructure and alternative, attractive solutions must first be implemented in these areas.

Even with cities' implementation of active mobility policies and infrastructure and the increased interest in cycling as a viable mobility option, there can be additional challenges. For example, sales of bicycles had already been rising before the pandemic, but the surge in demand caused them to increase at an even higher rate. The more considerable demand understandably led to supply bottlenecks, resulting in some would-be cyclists being unable to access bicycles. The further expansion of bike-sharing systems can be a solution here. Further, it is attractive for municipalities to encourage first-time cyclists to continue to use the bicycle post-pandemic.

The changed traffic situation forced by the COVID-19 pandemic opened a window of opportunity for behavioral change, i.e., the quiet streets or the opportunities for active mobility is a shared long-term memory in the collective mind. In this sense, the benefits and opportunities for changing mobility and its role as a catalyst in the mobility revolution have been a positive side effect of the pandemic that has affected humanity for the past years. This changed mobility system and this shared experience gave a glimpse of what the transport revolution can look like and what is possible—that is an opportunity. All the tactical urbanism measures showed that the greatest challenges of the transport transition are not technical and, in many aspects, do not require innovations. The political will to change is sufficient in most cases to implement lasting, substantial change in a concise time frame. Sustainable, safe mobility and a better quality of life can be created with relatively simple means; people just need to be enabled to gain new experiences in order to break with habitual behavior. So far, the pandemic period has provided many examples of getting started. What is done during such a situation to cope with the pandemic can prepare us better when a similar situation happens again in the future. The best practices and innovations have been and continue to be developed; cities and governments just need to start the transition.

## References

- Abdullah, M., Dias, C., Muley, D., Shahin, M., 2020. Exploring the impacts of COVID-19 on travel behavior and mode preferences. *Transp. Res. Interdiscip. Perspect.* 8, 100255. <https://doi.org/10.1016/j.trip.2020.100255>.
- Adriazola-Steil, C., Pérez-Barbosa, D., Batista, B., Luke, N., Li, W., Sharpin, A., 2021. Safe Bicycle Lane Design Principles: Responding to Cycling Needs in Cities during COVID and beyond. World Resources Institute. <http://doi.org/10.46830/wrigb.20.00063>.
- Ahangari, S., Chavis, C., Jeyhani, M., 2020. Public Transit Ridership Analysis during the COVID-19 Pandemic. <https://doi.org/10.1101/2020.10.25.20219105>.
- Ajuntament de Barcelona., 2021. Cyclable Network Set to Grow with an Additional 32.6 Kilometres of Bike Lanes. [https://www.barcelona.cat/infobarcelona/en/tema/mobility-and-transport/cyclable-network-set-to-grow-with-an-additional-32-6-kilometres-of-bike-lanes-2\\_1108633.html](https://www.barcelona.cat/infobarcelona/en/tema/mobility-and-transport/cyclable-network-set-to-grow-with-an-additional-32-6-kilometres-of-bike-lanes-2_1108633.html). (accessed on 03 January 2022).
- Aloi, A., Alonso, B., Benavente, J., Cordera, R., Echániz, E., González, F., Ladisa, C., Lezama-Romanelli, R., López-Parra, Á., Mazzei, V., Perrucci, L., Prieto-Quintana, D., Rodríguez, A., Sañudo, R., 2020. Effects of the COVID-19 lockdown on urban mobility: empirical evidence from the City of Santander (Spain). *Sustainability* 2020 (12), 3870. <https://doi.org/10.3390/su12093870>.
- Anke, J., Francke, A., Schaefer, L.M., Petzold, T., 2021. Impact of SARS-CoV-2 on the mobility behavior in Germany. *Eur. Transp. Res. Rev.* 13, 10. <https://doi.org/10.1186/s12544-021-00469-3>.

- Beckendorff, J., 2021. Frankreich 2020: E-Bikes lassen Fahrradbranche jubeln. RadMarkt – Das Branchenmagazin. <https://radmarkt.de/nachrichten/frankreich-2020-e-bikes-lassen-brasanche-jubeln>.
- Berlin.de, 2021. Rechtsstreit um Berliner Pop-up-Radwege in Berlin beendet. <https://www.berlin.de/tourismus/infos/verkehr/verkehr/6450506-4357821-rechtsstreit-um-berliner-popupradwege-in.html>.
- Bicycle Association, 2020. Official Industry Stats Reveal Record Extent of Covid Cycling Sales Growth. Press release December 4, 2020. <https://www.bicycleassociation.org.uk/news-press/official-industry-stats-reveal-record-extent-of-covid-cycling-sales-growth/>.
- Bicycle Association, 2021. BA MDS Reports Continued Surge: Sales Up 52%. Press release August 2, 2021. <https://www.bicycleassociation.org.uk/news-press/mds-reports-continued-surge-bikes-up-56/>.
- Bilge, P., Alkan, A., Ağanoglu, R., 2020. Managing work-life balance during the COVID-19 crisis. (<https://www.dpg-physik.de/vereinigungen/fachuebergreifend/ak/akc>).
- Bockstahler, M., Jurecic, M., Rief, S., 2020. Working from Home Experience. An Empirical Study from the User Perspective during the Corona Pandemic. (<http://publica.fraunhofer.de/dokumente/N-605596.html>).
- Buehler, R., Pucher, J., 2021. COVID-19 impacts on cycling, 2019–2020. *Trans. Rev.* 41 (4), 393–400. <https://doi.org/10.1080/01441647.2021.1914900>.
- City of Oakland, 2020. City of Oakland Announces “Oakland Slow Streets” Program Starting Saturday to Enable Safer Walking, Cycling. <https://www.oaklandca.gov/news/2020/city-of-oakland-announces-oakland-slow-streets-program-starting-saturday-to-enable-safer-walking-cycling> (accessed on 03 January 2022).
- City of Oakland, 2022. Oakland Slow Streets – Essential Places. (<https://www.oaklandca.gov/projects/oakland-slow-streets>).
- Combs, T., Pardo, C., 2021. Shifting streets COVID-19 mobility data: findings from a global dataset and a research agenda for transport planning and policy. *Transp. Res. Interdiscip. Perspect.* 9. <https://doi.org/10.1016/j.trip.2021.100322>.
- Covid-19 Mobility Project, 2021. Covid-19 Mobility Project. <https://www.covid-19-mobility.org/de/> (accessed on 16 December 2021).
- Demmelhuber, K., Englmaier, F., Leiss, F., Möhrle, S., Peichl, A., Schröter, T., 2020. Working from Home before and After the Coronavirus: Effects and Gender Issues. *ifo Schnelldienst digital 1* (No. 14), 01–04. <https://www.ifo.de/en/publikationen/2020/article-journal/working-home-and-after-coronavirus-effects-and-gender-issues>.
- Department for Transport, 2021. National statistics. The impact of lockdown on reported road casualties Great Britain, final results: 2020. <https://www.gov.uk/government/statistics/reported-road-casualties-great-britain-annual-report-2020/the-impact-of-lockdown-on-reported-road-casualties-great-britain-final-results-2020>.
- Deutsche Umwelthilfe e.V., 2021. Untersuchungsergebnisse: Verkehrliche Auswirkung Pop-up Radweg Kantstraße. <https://www.duh.de/presse/pressemitteilungen/pressemitteilung-sensationserfolg-pop-up-radweg-kantstrasse-in-berlin-untersuchung-der-deutschen-umwelthilfe-belegt-v/> (accessed on 20 December 2021).
- Enders, A., Pickthall, A., Nicoletti, L., Cullinan, C., 2020. COVID-19 and Mobility. <https://www.endersanalysis.com/reports/covid-19-and-mobility> (accessed on 20 December 2021).
- European Cyclist’ Federation (ECF), 2020. COVID-19 Cycling Measures Tracker. <https://ecf.com/dashboard>.
- European Cyclist’ Federation (ECF), 2021a. Final analysis: Cycling becomes mainstream in EU member states’ COVID-19 recovery plans. <https://ecf.com/news-and-events/news/final-analysis-cycling-becomes-mainstream-eu-member-states-covid-19-recovery> (accessed on 22 December 2021).
- European Cyclist’ Federation (ECF), 2021b. COVID-19 Cycling Measures Tracker. (<https://ecf.com/dashboard> (accessed on 20 December 2021)).

- European Transport Safety Council, 2020. The impact of COVID-19 lockdowns on road deaths in April 2020 (PIN briefing). (<https://etsc.eu/pin-briefing-the-impact-of-covid-19-lockdowns-on-road-deaths-in-april-2020/>).
- European Union, 2020. Telework in the EU before and after the COVID-19: where we were, where we head to. [https://ec.europa.eu/jrc/sites/default/files/jrc120945\\_policy\\_brief\\_-\\_covid\\_and\\_telework\\_final.pdf](https://ec.europa.eu/jrc/sites/default/files/jrc120945_policy_brief_-_covid_and_telework_final.pdf) (accessed on 6 January 2022).
- Firth, C., Baquero, B., Berney, R., Hoerster, K., Mooney, S., Winters, M., 2021. Not quite a block party: COVID-19 street reallocation programs in Seattle, WA and Vancouver, BC. *SSM - Popul. Health.* 14, 100769.
- Follmer, R., 2020. Mobilitätsreport 01, Ergebnisse aus Beobachtungen per repräsentativer Befragung und ergänzendem Mobilitätstracking bis Ende Mai. Ausgabe 29.05.2020, Bonn, Berlin, mit Förderung des BMBF.
- Follmer, R., Schelewsky, M., 2020. Mobilitätsreport 02, Ergebnisse aus Beobachtungen per repräsentativer Befragung und ergänzendem Mobilitätstracking bis Ende Juni. Ausgabe 31.07.2020, Bonn, Berlin, mit Förderung des BMBF.
- Frey, H., Laa, B., Leth, U., Kratochwil, F., Scober, P., 2020. Mobilität in Wien unter COVID19 - Begleituntersuchung Temporäre Begegnungszonen und Pop-Up Radinfrastruktur. Technische Universität Wien.
- Bezirksamt Friedrichshain-Kreuzberg, 2020. Temporäre Einrichtung und Erweiterung von Radverkehrsanlagen während der Pandemie-Krise. Pressemitteilung Nr.53. (<https://www.berlin.de/ba-friedrichshain-kreuzberg/aktuelles/pressemitteilungen/2020/pressemitteilung.911780.php>).
- Bezirksamt Friedrichshain-Kreuzberg, 2021. Konsequente Verstetigung der Pop-Up-Radwege. Pressemitteilung Nr. 238. <https://www.berlin.de/ba-friedrichshain-kreuzberg/aktuelles/pressemitteilungen/2021/pressemitteilung.1158571.php>.
- Fuller, G., McGuinness, K., Waitt, G., Buchanan, I., Lea, T., 2021. The reactivated bike: self-reported cycling activity during the 2020 COVID-19 pandemic in Australia. *Transp. Res. Interdiscip. Perspect.* 10, 100377. <https://doi.org/10.1016/j.trip.2021.100377>.
- Götting, K., Becker, S., 2020. Reaktionen auf die Pop-Up-Radwege in Berlin. Ergebnisse einer explorativen Umfrage zur temporären Radinfrastruktur im Kontext der Covid-19 Pandemie. IASS Study. <https://doi.org/10.2312/iass.2020.019>.
- Graziano, T., 2021. Smart technologies, Back-To-The-Village rhetoric, and tactical urbanism: post-COVID planning scenarios in Italy. *Int. J. E-Plan. Res.* 10 (2), 80–93. <https://doi.org/10.4018/IJEPR.20210401.0a7>.
- Hans Böckler Stiftung, 2020. HOMEOFFICE: BESSER KLAR GEREGETLT. Arbeitswelt. 15. <https://www.boeckler.de/de/boeckler-impuls-homeoffice-besser-klar-geregetlt-27643.htm>.
- Heydari, S., Konstantinoudis, G., Behsoodi, A.W., 2021. Effect of the COVID-19 pandemic on bike-sharing demand and hire time: evidence from Santander Cycles in London. *PLoS ONE* 16 (12). <https://doi.org/10.1371/journal.pone.0260969>.
- Hong, J., McArthur, D., Raturi, V., 2020. Did safe cycling infrastructure still matter during a COVID-19 lockdown? *Sustainability* 12, 8672. <https://doi.org/10.3390/su12208672>.
- International Transport Forum (ITF), 2020. Re-spacing our cities for resilience. In: COVID-19 Transport Brief: Analysis, Facts and Figures for Transport's Response to the Coronavirus.
- Irawan, M., Belgiawan, P., Joewono, T., Bastianto, F., Rizki, M., Ilahi, A., 2021. Exploring activity-travel behavior changes during the beginning of COVID-19 pandemic in Indonesia. *Transportation*. <https://doi.org/10.1007/s11116-021-10185-5>.
- Jackson, R.B., Friedlingstein, P., Le Quere, C., Abernethy, S., Andrew, R.M., Canadell, J.G., Ciais, P., Davis, S.J., Deng, Z., Liu, Z., Peters, G.P., 2021. Global fossil carbon emissions rebound near pre-COVID-19 levels. *Environ. Res. Lett.* 17.



- Jobe, J., Griffin, G.P., 2021. Bike share responses to COVID-19. *Transp. Res. Interdiscip. Perspect.* 10. <https://doi.org/10.1016/j.trip.2021.100353>.
- Knie, A., Zehl, F., Schelewsky, M., 2021. Mobilitätsreport 05, Ergebnisse aus Beobachtungen per repräsentativer Befragung und ergänzendem Mobilitätstracking bis Ende Juli. Ausgabe 16.08.2021, Bonn, Berlin, mit Förderung des BMBF.
- Kraus, S., Koch, N., 2021. Provisional COVID-19 infrastructure induces large, rapid increases in cycling. *PNAS* 13, 2021. <https://doi.org/10.1073/pnas.2024399118>.
- Latz, C., 2021. Pop-Up-Radweg an Kantstraße soll dauerhaft umgesetzt werden. <https://www.tagesspiegel.de/berlin/finanzierung-zugesagt-pop-up-radweg-an-kantstrasse-soll-dauerhaft-umgesetzt-werden/27647790.html> (accessed on 29 December 2021).
- Le Quéré, C., Jackson, R.B., Jones, M.W., 2020. Temporary reduction in daily global CO<sub>2</sub> emissions during the COVID-19 forced confinement. *Nat. Clim. Chang.* 10, 647–653. <https://doi.org/10.1038/s41558-020-0797-x>.
- Leicester City Council, 2020. Leicester Covid-19 Transport Recovery Plan. (<https://news.leicester.gov.uk/news-articles/2020/may/city-s-covid-19-transport-recovery-plan-published/>) (accessed on 29 December 2021).
- Lovelace, R., Talbot, J., Morgan, M., Lucas-Smith, M., 2020. Methods to prioritise pop-up active transport infrastructure. *Transp. Findings* ([https://doi.org/\\*10.32866/\\*001c\\*.\\*13421\\*](https://doi.org/*10.32866/*001c*.*13421*)).
- Lydon, M., 2021. COVID19 Livable Streets Response Strategies [Dataset]. [https://docs.google.com/spreadsheets/d/1tjam1v0NLUWkYedIa4dVOL49pyWIP\\_IyGwRB0DOnm3Ls/edit#gid=0](https://docs.google.com/spreadsheets/d/1tjam1v0NLUWkYedIa4dVOL49pyWIP_IyGwRB0DOnm3Ls/edit#gid=0) (accessed on 20 December 2021).
- Lydon, M., Garcia, A., 2015. Tactical Urbanism: Short-Term Action for Long-Term Change. The Streets Plans Collaborative, Inc., Island Press, Washington, DC.
- Marti, M., Espindola, L., 2020. Opportunity in the time of COVID-19. *J. Public Space* 5 (3), 23–30. <https://doi.org/10.32891/jps.v5i3.1373>.
- Medina, M.A., Alvarez, C., Clemente, Y., Zarfa, M., 2020. Bike Lanes: How Cities across the World Are Responding to the Pandemic. *El Pais* (<https://english.elpais.com/society/2020-11-06/bike-lanes-how-cities-across-the-world-are-responding-to-the-pandemic.html>) (accessed on 03 January 2022).
- Miketa, D., Sun, P., 2020. As mobility patterns change, cities shift gears. *Plan. Theory* (<https://www.planning.org/planning/2020/jun/intersections-transportation/>) (accessed on 29 December 2021).
- Mobycon, 2020. Making safe space for cycling in 10 days: A guide to temporary bike lanes, from Friedrichshain-Kreuzberg, Berlin. (<https://mobycon.com/updates/a-guide-to-temporary-bike-lanes-from-berlin/>) (accessed on 20 December 2021).
- Molloy, J., Schatzmann, T., Schoeman, B., Tchervenkov, C., Hintermann, B., Axhausen, K.W., 2020. Observed impacts of the Covid-19 first wave on travel behavior in Switzerland based on a large GPS panel. *Transp. Policy* 104 (2021), 43–51. <https://doi.org/10.1016/j.tranpol.2021.01.009>.
- National Center for Statistics and Analysis, 2021. Early estimate of motor vehicle traffic fatalities for the first half (January–June) of 2021 (Crash•Stats Brief Statistical Summary. Report No. DOT HS 813 199). National High-way Traffic Safety Administration. <https://www.transportation.gov/briefing-room/usdot-releases-new-data-showing-road-fatalities-spiked-first-half-2021>.
- Nikitas, A., Tsigdinos, S., Karolemeas, C., Kourmpa, E., Bakogiannis, E., 2021. Cycling in the era of COVID-19: lessons learnt and best practice policy recommendations for a more bike-centric future. *Sustainability* 2021 (13), 4620. <https://doi.org/10.3390/su13094620>.
- Nobis, C., C. Eisenmann, V. Kolarova, Nägele, S., 2020. DLR-Befragung: Wie verändert Corona unsere Mobilität? Verkehrsmittelnutzung, Einkaufs-, Arbeits- und Reiseverhalten.

- Nobis, C., Eisenmann, C., Kolarova, V., Nägele, S., Winkler, C., Lenz, B., 2021. Effects of COVID on Mobility Behaviour. (<https://verkehrsforschung.dlr.de/en/projects/corotrans-effects-corona-pandemic-logistics-mobility-and-transportation-system/effects>).
- NUMO, the New Urban Mobility alliance; Polis; TNO; the Transportation Sustainability Research Center, University of California, Berkeley; Transformative Urban Mobility Initiative; the Urbanism Next Center at the University of Oregon; and the World Economic Forum's Global New Mobility Coalition (n.d.) COVID Mobility Works. <https://www.covidmobilityworks.org/>.
- OakDOT, 2020. Oakland Slow Streets Interim Findings Report. City of Oakland Department of Transportation. <https://www.oaklandca.gov/documents/oakland-slow-streets-interim-findings-report-september-2020-1> (accessed on 03 January 2022).
- OakDOT, 2022. Slow Streets - Essential Places Presentation, January 2022. Oakland Department of Transportation, Safe Streets Division.
- Obverwaltungsgericht Berlin-Brandenburg, 2020. Pop-up-Radwege dürfen vorerst bleiben 32/20. Beschluss vom 6. Oktober 2020 OVG 1 S 116/20. <https://www.berlin.de/gerichte/oberverwaltungsgericht/presse/pressemitteilungen/2020/pressemitteilung.1000806.php>.
- Park, B., Cho, J., 2021. Older Adults' avoidance of public transportation after the outbreak of COVID-19: Korean Subway evidence. *Dent. Health* 2021 (9), 448. <https://doi.org/10.3390/healthcare9040448>.
- Parker, M., Li, M., Bouzaghrane, M., Obeid, H., Hayes, D., Frick, K., Rodríguez, D., Sengupta, R., Walker, J., Chatman, D., 2021. Public transit use in the United States in the era of COVID-19: transit riders' travel behavior in the COVID-19 impact and recovery period. *Transp. Policy* 111, 53–62. <https://doi.org/10.1016/j.tranpol.2021.07.005>.
- POLIS, 2020. COVID-19: Keeping Things Moving—Glasgow and Edinburgh Launch Temporary Free Bike-Share. <https://www.polisnetwork.eu/article/glasgow-and-edinburgh-launch-temporary-free-bike-share/?id=122791> (accessed on 30 December 2021).
- Road Safety Authority, 2022. Provisional Review of Fatal Collisions. January to 31 December 2021. <https://www.rsa.ie/news-events/news/details/2022/01/01/2021-records-lowest-number-of-road-fatalities-since-recording-began-in-1959>.
- Rubin, O., Nikolaeva, A., Nello-Deakin, S., te Brömmelstroet, M., 2020. What Can we Learn from the COVID-19 Pandemic about how People Experience Working from Home and Commuting? Centre for Urban Studies, University of Amsterdam.
- Schaefer, K., Tuitjer, L., Levin-Keitel, M., 2021. Transport disrupted – substituting public transport by bike or car under covid 19. *Transp. Res. A: Policy Pract.* 153, 202–217. <https://doi.org/10.1016/j.tra.2021.09.002>.
- Seattle Department of Transportation, 2021. Stay Healthy Streets. <https://www.seattle.gov/transportation/projects-and-programs/programs/stay-healthy-streets> (accessed on 04 January 2022).
- Sorenson, D., 2021. The Cycling Market Pedals Ahead in 2021. NPD Group (<https://www.npd.com/news/blog/2021/the-cycling-market-pedals-ahead-in-2021/>).
- Teixeira, J.F., Lopes, M., 2020. The link between bike sharing and subway use during the COVID-19 pandemic: the case-study of New York's Citi bike. *Transp. Res. Interdiscip. Perspect.* 6. <https://doi.org/10.1016/j.trip.2020.100166>.
- Teixeira, J.F., Silva, C., Moura E Sá, F., 2021. The motivations for using bike sharing during the COVID-19 pandemic: insights from Lisbon. *Transp. Res. F: Traffic Psychol. Behav.* 82. <https://doi.org/10.1016/j.trf.2021.09.016>.
- Wegman, F., Katrakazas, C., 2021. Did the COVID-19 pandemic influence traffic fatalities in 2020? A presentation of first findings. *IATSS Res.* 45. <https://doi.org/10.1016/j.iatssr.2021.11.005>.

- Wilson, C., 2020. NHS staff in Glasgow offered free bike memberships. *Glasgow Times* (<https://www.glasgowtimes.co.uk/news/18341164.nhs-staff-glasgow-offered-free-bike-memberships/> (accessed on 04 January 2022)).
- World Health Organization (WHO), 2020. Ciclovías Temporales. Bogotá, Colombia (<https://www.who.int/news-room/feature-stories/detail/ciclov%C3%ADas-temporales-bogot%C3%A1-colombia> (accessed on 20 December 2021)).
- Yasin, Y.J., Grivna, M., Abu-Zidan, F.M., 2021. Global impact of COVID-19 pandemic on road traffic collisions. *World J. Emerg. Surg.* 16, 51. <https://doi.org/10.1186/s13017-021-00395-8>.
- Zweirad-Industrie-Verband (ZIV), 2021. Zahlen – Daten – Fakten zum deutschen Fahrrad- und E-Bike Markt 2020, Pressemitteilung. <https://www.ziv-zweirad.de/marktdaten/detail/article/marktdaten-2020/>.

## Further reading

- DESTATIS, 2022. Fachserie. 8, Verkehr. 7, Verkehrsunfälle. Monatlich, [https://www.statistischebibliothek.de/mir/receive/DESerie\\_mods\\_00000096](https://www.statistischebibliothek.de/mir/receive/DESerie_mods_00000096) (accessed on 20 December 2021).
- Maier, O., 2021. Perspective of Cycling Industry – Cycling in Times of COVID.
- Möllers, A., Specht, S., Wessel, J., 2021. The Impact of the Covid-19 Pandemic and Government Interventions on Active Mobility. Working Paper No. 34, University of Münster, Germany, Institute for Transport Economics.