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Transport mode use during the COVID-19 lockdown period in Germany: The car became more important, public transport lost ground

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ABSTRACT

As a result of the coronavirus pandemic, in spring 2020 numerous protective measures were taken in Germany and all over the world. This has changed our everyday life and our mobility considerably. It is in question whether and how the pandemic and the lockdown have impacted transport mode use, attitudes towards transport modes and the ownership of individual mobility options during the lockdown period. In order to shed light on these essential aspects of transport policy, we carried out a representative travel survey in Germany during the strictest period of lockdown in the beginning of April. We have analysed overall and individual changes in transport mode usage and attitudes towards transport modes, focussing on the bicycle, the car and public transport. Also, the changes in the perception of individual mobility options with a focus on car-free households were investigated. Our results indicate that public transport lost ground during the particularly restricted period of lockdown while individual modes of transport, especially the private car, became more important. Our findings are highly relevant for transport policy when developing measures for expanding the possibilities for sustainable individual transport and developing concepts that strengthen public transport. These aspects are key for achieving a sustainable transport system in the medium- and long-term despite the coronavirus pandemic.

1. Introduction

The global coronavirus (COVID-19) pandemic is having a great impact on all areas of the everyday life of people worldwide. In Germany, we had the 100th case of COVID-19 by the February 28, 2020 and the first fatality by the March 9, 2020. In response to the COVID-19 pandemic, German federal and state governments took numerous protective measures to slow the spread of the virus down. These measures have significantly changed everyday life and travel behaviour of the German population. Most essential measures in Germany from a transport policy perspective are listed hereafter: kindergartens, schools and universities started closing by the 16th of March, the German Federal Foreign Office issued a worldwide travel alert, warned against unnecessary travel abroad, and a nationwide contact ban was announced a few days later. Besides that, various leisure facilities such as restaurants, bars, discotheques, fitness studios and churches were temporarily closed and many employers sent their employees into home-office, if possible. The period when all those measures took effect is named the strictest period of lockdown.

Analyses of mobile phone data show that trip rates decreased significantly during the lockdown, by up to 39% during its strictest period between end of March and beginning of April 2020 (Schlosser et al., 2020a). Mobile phone data, however, do not provide information on how and why people adapted their travel behaviour and transport mode usage. Because of the novelty of the situation still little is known about adaptations of travel behaviour and mode usage by different user groups. Also, the reasons behind mode usage adaptations, and the potential implications for travel patterns after the COVID-19 pandemic need to be understood.

The effects of the virus spread on activity and travel behaviour patterns, mode choice and activities were addressed in early studies in different countries around the world (e.g. Axhausen, 2020; Circella, 2020; Mohammadian et al., 2020; Askitas et al., 2020; Kraemer et al., 2020; De Vos, 2020; de Haas et al., 2020; Abdullah et al., 2020; Parady et al., 2020; Shamshripour et al., 2020). Most of the studies looked at travel pattern changes as well as changes in working and shopping behaviours (including working from home and ecommerce, i.e. online shopping). Various methods were applied, e.g. online surveys (e.g. Circella, 2020; de Haas et al., 2020), stated preference surveys (e.g. Shamshripour et al., 2020) and objective data measures via GPS Logger

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and Travel Diary App (e.g. Axhausen, 2020). For Germany, there are to our best knowledge no results published so far from representative travel behaviour studies which focus explicitly on the shifts of travel behaviour and transport mode usage during the strictest period of lockdown in spring 2020.

In order to shed light on these aspects that are essential for transport policy, we carried out a travel survey in Germany in April 2020, i.e. during the most restrictive period of the first lockdown in Germany in spring 2020. By means of these unique data, we aim to answer the following research questions: (1) How has transport mode use changed during the strictest period of lockdown? (2) How has the population at an individual level adapted its travel behaviour and attitudes towards the bicycle, the car and public transport? (3) How has the perception of car-free households toward the car changed during the strictest period of lockdown? (4) What are first conclusions and new challenges for transport policy?

The remainder of the article is structured as follows: Firstly, the travel survey we carried out and the survey data preparation is described. Then, results are presented on behavioural changes in transport mode use, followed by a description of attitudes towards transport modes and towards vehicle ownership and mobility options during the lockdown period are described. Afterwards our findings are discussed. The paper closes by a conclusion and outlook.

2. Materials and methods

2.1. Data sources

We carried out a survey in order to investigate the effects of the first lockdown in spring 2020 due to COVID-19 on mobility and travel behaviour in Germany. The contents of the survey were: travel to work, shopping, leisure and long-distance travel, use of transport modes before and during the lockdown as well as strategies and attitudes on the current situation.

When selecting the survey design, it was of utmost importance to cover both, overall (i.e., inter-individual) and intra-individual changes in travel behaviour due to the COVID-19 pandemic. The variations in travel behaviour of individuals can be considered from two perspectives: as an overall variation or as an intra-individual variation. The overall variation describes the variation of travel behaviour between (different) groups of people in two periods of time. The intra-individual variation on the other hand, considers variations in a person's behaviour over a given period of time (Kunert, 1994). Therefore, we created a survey design for self-assessment of travel behaviour before and during the lockdown. Hence, the information is not collected via trip diary, which is a common method for travel surveys, as it would have been realistically impossible for respondents to fill in trip diaries for days that are dated back several weeks. As a substitute we used the respondents' self-assessment on their travel behaviour before and during the lockdown, and thus accepted the loss of not having exact trip information to calculate modal shares or kilometres travelled per day (Chlond and Eisenmann, 2018).

The survey was conducted from 6th to April 10, 2020 and covered the respondents' travel behaviour during the seven days prior to the survey (i.e. 30th of March to 10th of April). This period fell into the strictest lockdown in Germany. The respondents were also queried on their mobility and travel behaviour before the advent of COVID-19 in Germany, i.e. before end of February/beginning of March.

The survey was implemented as an online survey. The sample includes 1000 respondents aged 18 and above, and is representative for Germany. Table 1 gives an overview on the target distribution of the German population, exemplarily differentiated by age group, gender, and spatial category of place of residence as well as the unweighted and weighted sample distribution. Only the unweighted sample fits well to the target distribution for Germany. Small deviations were compensated by a weighting factor, which is controlled for age, gender, spatial category of place of residence, level of education and territorial status (West German and East German federal states). The fieldwork was conducted by KANTAR GmbH and the respondents were drawn from the KANTAR access panel. Since the KANTAR access panel was used, the determination of a "classical response rate" is not possible. Hence, the conversion rate, i.e. the probability that panelists will participate in the survey after being invited to do so, may serve as a proxy. For our survey, the conversion rate was 88% and therefore twice as high as for other surveys with the KANTAR access panel. This shows the great interest of people in the topic amongst respondents in April 2020.

Table 1
Structure of the population living in Germany (aged 18 and above), compared to the structure of unweighted and weighted sample, by age group, gender and spatial category of place of residence (Destatis, 2019, 2020).

	German population		Unweighted sample		Weighted sample
	[Mio.]	[%]	[#]	[%]	[%]
Total population	69	100	1.000	100	100
Age group					
18–24 years	5	8	135	14	12
25–34 year	10	15	170	17	14
35–44 years	10	15	191	19	15
45–54 years	12	17	171	17	16
55–64 years	12	18	134	13	18
65+ years	19	27	199	20	25
Gender					
Female	42	51	500	50	51
Male	41	49	500	50	49
Spatial category of place of residence					
Urban region – metropolis	15	18	213	21	18
Urban region – regio-polis and major city	12	14	154	15	15
Urban region – medium-sized city, urban area	21	25	253	25	24
Urban region – small-town area, village area	5	6	51	5	6
Rural region – central city	5	6	54	5	6
Rural region – medium-sized city, urban area	11	14	142	14	16
Rural region – small-town area, village area	13	16	133	13	15

2.2. Data preparation

We divided respondents into modal groups, following the methodology proposed by Nobis (2015). The essential criterion for the group classification is which modes of transport (car, public transport and bicycle) respondents used in the course of one week. Hence, we found three monomodal groups, each of which used only one of the modes of transport examined, and four multimodal groups, reflecting the various possibilities for combining modes. As the respondents reported their transport mode usage for two periods of time (before the advent of COVID-19 in Germany and during the period of strictest lockdown) each survey participant was assigned to two modal groups according to their transport mode usage before and during the strictest period of lockdown. This allows for analyses on mode-use changes from both the overall and the intra-individual perspective.

Respondents for whom the determination of modal groups in both periods was not possible were excluded from the subsequent analyses. The resulting sample comprises 804 respondents (80% of the gross sample), i.e. 196 respondents (20% of the gross sample) could not be assigned to a modal group. There were two reasons for this:

1. During the particularly restricted period of lockdown, people stayed at home and reduced their out-of-home activities to a minimum. As a result, modal groups for the lockdown period could not be identified for some respondents because they did not take any trips at all in the seven days prior to the survey (n = 46 respondents).

2. There were respondents who did not travel either by bicycle, car or public transport before the lockdown (n = 52 respondents) or during the lockdown (n = 98 respondents). Walking trips were not considered in the modal groups.

To assess the underlying reasons for altered transport mode choice sets, we analysed the attitudes towards different modes of transport. Therefore, survey participants were asked the question "How do you feel when using the following modes of transport, respectively how would you feel if you used the following modes of transport? Please compare your current perception with your perception before the spread of COVID-19." The respondents could choose between five answer categories: "much more convenient than before", "more convenient than before", "no change", "more inconvenient than before", "much more inconvenient than before". The modes of transport considered in the grid question were: bicycle, car, carsharing, local public transport, long distance train and airplane. For this study, we focussed on the bicycle, the car and local public transport.

Furthermore, we carried out a binary logistic regression model to better understand which population groups wished they had owned a car during the particularly restricted period of lockdown. We asked respondents from car-free households: "Do you wish you had owned a car of your own in the current situation?" This information served as an independent variable in our regression model. For the regression model estimate, we used the statistical computing software R. As the question was restricted to respondents from car-free households, the sample for the regression analysis was reduced to 188 respondents (19% of the sample).

3. Results

Our results provide comprehensive insights into the changes in transport mode use, attitudes towards transport modes and towards individual vehicle ownership during the lockdown period.

3.1. Transport mode use changes on an overall perspective

For the analysis of transport mode changes, we compare the distribution of the population in the modal groups for the two time periods considered in the survey (Fig. 1).

Analyses on the overall perspective show that more people used only *one* mode of transport (monomodal) during the lockdown in spring 2020 than before: before the advent of COVID-19 in Germany 68% of the adult population in Germany was restricted to one mode of transport. During the strictest period of lockdown this share increased to 83%. This fact results in particular from the increase of monomodal car users from 53% to 66%. The share of monomodal bicycle users increased from 6% to 9% whereas the share of monomodal public transport users decreased slightly by 1 percentage point.

In turn, all four multimodal modal groups decreased. For the three multimodal groups with public transport usage, the shares halved. The share of multimodal transport users with bicycle and car usage decreased from 18% to 12%.

Fig. 1 also indicates how many respondents used the bicycle, car or public transport before and during the lockdown period respectively. Therefore, we summed up all modal groups with a specific mode of transport. For example, to estimate how many people had the bicycle in their choice set before COVID-19 (32% of respondents), we summed up the share of monomodal cyclists (6%) with the multimodal groups of car & bicycle (18%), public transport & bicycle (4%) and car & public transport & bicycle (4%). Please note that bicycle users, car users and public transport users together add up to more than 100%, as multimodal respondents are part of more than one of these three groups. Table 2 shows the share of the adult population living in Germany with bicycle, car and public transport in their mode choice set differentiated by sociodemographic characteristics.

The overall share of people who used the bicycle decreased from 32% to 24% during the particularly restricted period of lockdown. However, these shares slightly increased for young adults (18–24 years) from 43% to 44%, but decreased for all other age groups. Bicycle usage decreased more sharply for men (minus 10 percentage points) than for women (minus 5 percentage points). The share of bicycle users in metropolises was stable, while it decreased in other spatial categories. The steepest drop can be found amongst inhabitants from small town areas (from 38% to 16%).

The share of respondents who used the car remained fairly stable. This holds true for all age classes, genders and spatial categories.

Only 13% of the adult population used public transport during the lockdown compared to 23% before the advent of COVID-19 in Germany. This can be seen amongst all age groups; the drop seems to be strongest amongst young adults (from 47% to 19%). Public transport usage dropped more significantly amongst men (from 22% to 10%) than amongst women (from 24% to 15%). Considering the spatial category of place of residence, we see the steepest drop of public transport users amongst inhabitants of metropolises (from 47% to 32%) and major cities (from 35% to 21%) during the strictest period of lockdown.

3.2. Transport mode use changes on an intra-individual perspective

Due to the nature of our travel survey, not only overall analyses (section 3.1), but also intra-individual analyses can be displayed. The intra-individual perspective is crucial to better understand individual transport mode use changes and adaptations.

Fig. 2 displays the share of bicycle users, car users and public

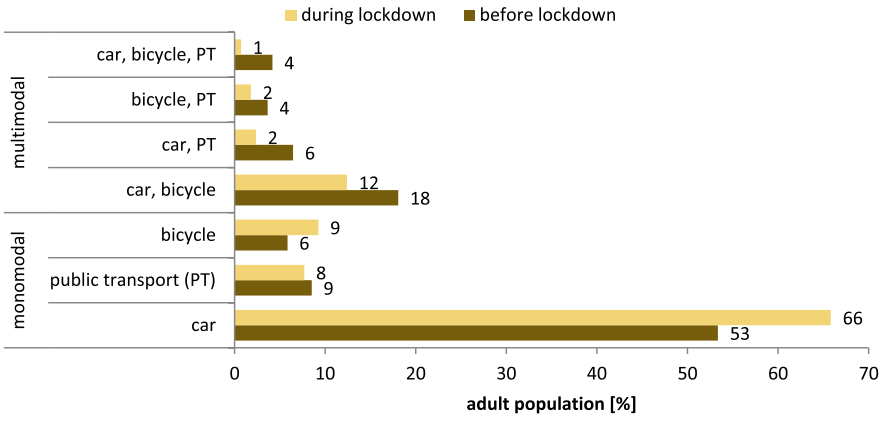

Fig. 1. Multi- and monomodal groups before and during the particularly restricted period of lockdown in Germany in spring 2020.

Table 2
Share of the adult population living in Germany, who used bicycle, car or public transport before COVID-19 and during the lockdown period in spring 2020, by age group, gender and spatial category of place of residence.

	Bicycle		Car		Public transport	
	Before lockdown	During lockdown	Before lockdown	During lockdown	Before lockdown	During lockdown
Total population	32%	24%	82%	81%	23%	13%
Age group						
18–24 years	43%	44%	70%	70%	47%	19%
25–34 years	37%	26%	75%	78%	31%	18%
35–44 years	30%	23%	88%	85%	14%	11%
45–54 years	31%	29%	79%	79%	27%	14%
55–64 years	28%	13%	83%	82%	22%	14%
65+ years	27%	19%	90%	87%	9%	5%
Gender						
Female	28%	23%	80%	80%	24%	15%
Male	35%	25%	84%	82%	22%	10%
Spatial category of place of residence						
Urban region – metropolis	30%	29%	69%	64%	46%	32%
Urban region – regio-polis and major city	36%	27%	69%	67%	35%	21%
Urban region – medium-sized city, urban area	36%	27%	81%	82%	21%	10%
Urban region – small-town area, village area	38%	16%	95%	97%	10%	3%
Rural region – central city	25%	19%	79%	82%	23%	13%
Rural region – medium-sized city, urban area	32%	23%	90%	91%	11%	4%
Rural region – small-town area, village area	23%	19%	95%	92%	8%	2%

Transport mode use changes on an intra-individual perspective.

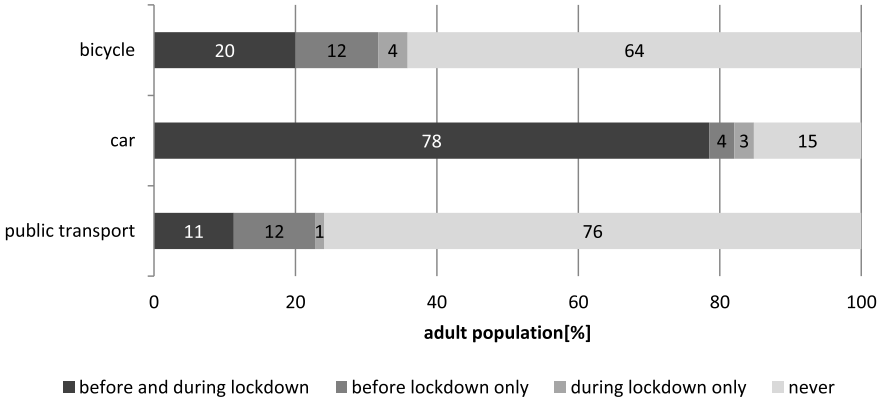

Fig. 2. Bicycle users, car users and public transport users from an intra-individual perspective (before and during the particularly restricted period of lockdown in spring 2020).

transport users from an intra-individual perspective. For each mode of transport, we split the sample into four groups: (i) people that used the transport mode before and during the lockdown, (ii) people that used the transport mode before the lockdown only, (iii) people that used the transport mode during the lockdown only and (iv) people that used the transport mode neither before nor during the lockdown. The findings shown in Fig. 2 correspond directly to the values from Table 2. Let's take bicycle users as an example. Adding the share of people that cycled before and during the period of lockdown (20%) to the share of people that used the bicycle only before the period of lockdown (12%), we can conclude that in total 32% of the adult population used the bicycle before the pandemic. This result is in line with the overall display on bicycle usage before COVID-19, shown in Table 2 (see percentage total population).

Intra-individual analyses indicate that car users were fairly stable in their vehicle preferences: 77% of respondents had the car in their mode choice set before and during the pandemic. The share of people with changed preferences towards car usage is small: 4% only used a car before and 3% only used the car during the lockdown.

The share of people with changed preferences in public transport and bicycle use has increased. 12% of the respondents who used the bicycle stopped doing so during the strictest period of lockdown. Meanwhile, 4% of the population started using the bicycle during the lockdown. For public transport, more than half of its former regular users stopped using public transport in the particularly restricted period of lockdown (12% of the adult population).

3.3. Changed attitudes towards various modes of transport

Shifts in attitudes towards different modes of transport might be one reason for the observed modal shift during the period of lockdown. To gain a better understanding of this, we analysed the attitudes towards the bicycle, the car and local public transport (Fig. 3) for transport mode use groups shown in Fig. 2. Due to the low sample sizes of some of the intra-individual modal groups, some groups are disregarded in the subsequent analyses.

The bicycle was perceived diversely. Amongst the stable cyclists, 13% felt more convenient and 3% even much more convenient than before the period of lockdown. 8% of stable cyclists perceived the bicycle as more inconvenient. Amongst respondents, who stopped using the bicycle, almost a quarter stated that they felt more or much more inconvenient riding a bicycle.

The car showed a considerable "feel-good" factor and gained the highest share of respondents that felt more or much more convenient

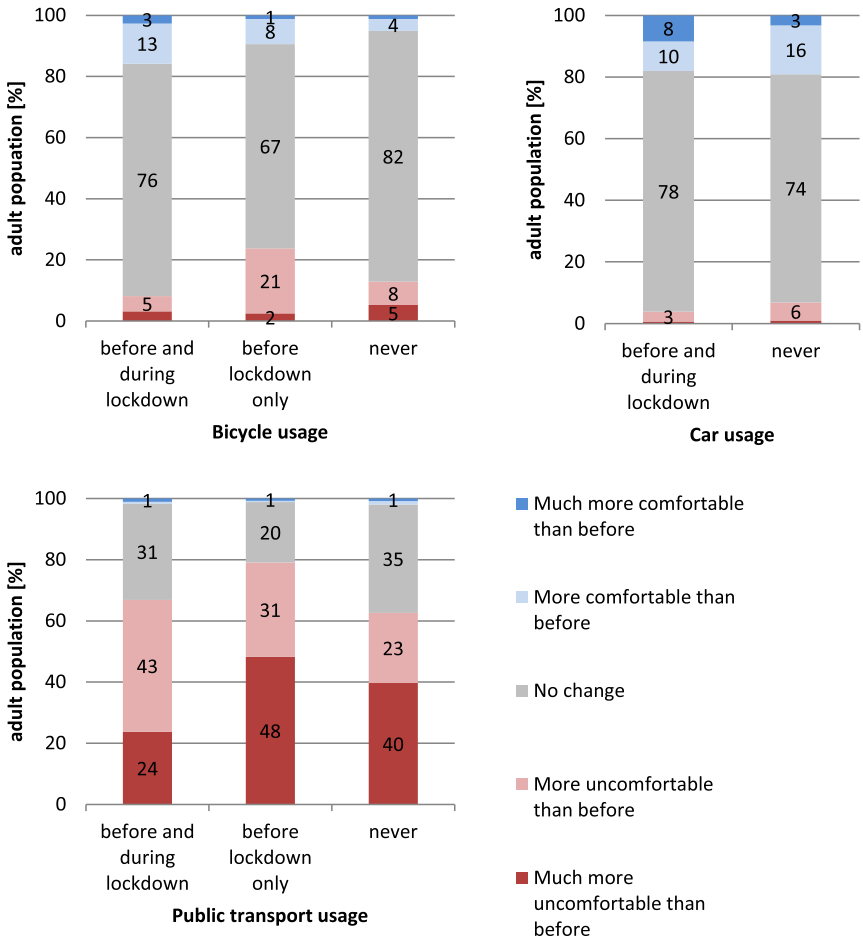

Fig. 3. Changed attitudes towards the bicycle (a), the car (b) and local public transport (c) in accordance with mode usage before and during the particularly restricted period of lockdown in Germany.

using the car than before the lockdown period. The approval rates are 18% amongst stable car users and 19% amongst stable non-car users. Hence, more than three quarter of respondents did not change their attitudes towards the car during the lockdown period. On the other hand, 7% of stable non-car users stated that they would feel more or much more inconvenient than before using a car.

Public transport, in contrast, suffered greatly in the perception of transport users. Many respondents in all modal groups perceived public transport as less convenient. 43% of stable public transport users felt more inconvenient and 24% much more inconvenient using public transport than before the lockdown period. These numbers are even worse for constant non-users of public transport and amongst individuals that stopped using public transport during the lockdown period. Amongst this group 31% declared feeling more inconvenient and even 48% much more inconvenient than before the strictest period of lockdown. These changes in attitudes may partly explain the significant decline of public transport use during the period of lockdown.

3.4. Changed perception towards individual mobility options

The previous analyses show that individual modes of transport, namely the bicycle and the car, came off better in terms of their use and attitudes towards them than public transport during the strictest period of lockdown. Next, we analyse whether this had also an impact on the perception of individual mobility options. Therefore, we asked all respondents whether they were currently planning to buy a bicycle or an e-bike. Further analyses focus on car-free households and their perceptions towards private cars.

The COVID-19 pandemic had slight effects on bicycle purchase decisions: 5% of respondents stated that they were planning to buy a bicycle or an e-bike in response to the COVID-19 pandemic. Amongst car-free households, the share is slightly higher: 7% were considering a bicycle purchase.

33% of individuals in car-free households missed an own car during the lockdown and 6% even considered buying one. We conducted a regression analysis concerning the changed perception towards the car during the particularly restricted period of lockdown amongst members from car-free households. As the sample of respondents who plan buying their own car is low, the regression analysis served to better understand who missed having a car of their own (Table 2).

The regression model indicates that women are more likely than men to miss a car of their own. Also, the age of an individual from a car-free household is an explanatory factor: Young adults between 18 and 24 years had a higher tendency to miss owning a car than older persons. Interestingly, people between 35 and 44 tended to miss owning a car slightly more than people between 25 and 34 year. The employment status in combination with the commuting situation also impacts the perception towards having a car: employed people that were not commuting during the lockdown were more likely to miss a car of their own. Interestingly no effect was found for employed individuals that commuted to work during the lockdown. People that live in metropolises and major cities in urbanized regions were less likely to miss a car of their own than people from other and less urbanized spatial categories. Also, public transport usage during lockdown and the attitudes towards

public transport interact with whether people miss owning a car: individuals that used public transport during the particularly restricted period of lockdown and individuals, who feel (much) more inconvenient using public transport than before the advent of the COVID-19 pandemic tend to miss owning a car more than other members of car-free households. Respondents that stated that either themselves or someone in their families belonged to the COVID-19 risk group, tended to miss owning a car. Also, respondents with a strong locus of control seem to miss owing a car of their own more. Therefore, the item "I am directly responsible for the improvement or impairment of my health" serves as explanatory variable. Table 3.

Other variables were tested in the regression model and turned out to be not significant: bicycle usage and walking during the particularly restricted period of lockdown, employment status: full time and part time working (without link to commute during the lockdown), having children in the household and COVID-19 infection.

4. Discussion

Our results indicate that public transport lost ground in Germany during the particularly restricted period of lockdown while individual modes of transport, especially the private car, became more important.

Public transport was hit hardest by the COVID-19 pandemic. This pattern was found also during earlier virus pandemics in other parts of the world: During the severe acute respiratory syndrome (SARS) epidemic in Hong Kong in 2003 the use of public transport decreased initially (Lau et al., 2003). Also, the studies on the likely responses to a hypothetical Ebola virus outbreak in New Zealand (Petrie et al., 2016) and in the United States (Kelly et al., 2015) indicate that avoiding public transportation would be a well-accepted protective measure in both countries. In Germany, the share of the adult population that had public transport in their mode choice set dropped by almost half during the strictest period of COVID-19 induced lockdown in spring 2020. The steepest declines were seen among men, young adults and inhabitants of metropolises. These results are in line with travel survey studies conducted in the Netherlands and in King County, Washington, US, which also showed a sharp drop in public transport use (de Haas et al., 2020; Brough et al., 2020). In fact, about two third of the respondents stated that they felt/would have felt (much) more inconvenient using public transport at that time than they did before the lockdown. Amongst people that used public transport in their everyday life, but stopped doing so during the particularly restricted period of lockdown (12% of the adult population), the shares are highest: four out of five respondents stated they would have felt more or much more inconvenient using public transport. Our findings for Germany align with the findings of de Haas et al. (2020) for the Netherlands: about two thirds of the Dutch population perceived local public transport as negative or very negative compared to one sixth before the advent of the COVID-19 pandemic. Abdullah et al. (2020) come in their travel survey study with respondents from multiple countries to similar result: they explain the drop of public transport usage with the fact that respondents placed a higher priority to the pandemic related concerns in their mode choice. We suggest that the change in attitude may have played a big role in their altered mode choices. Our survey did not go any deeper into the reasons for this change in attitude towards public transport. We assume that those population groups might be afraid of being infected with COVID-19 on public transport via respiratory droplets and aerosols (i.e. if they are unable to keep a sufficient distance from fellow travellers) or via contaminated surfaces (i.e. if they touch for example handrails or door handles).

Table 3
Probability that survey participants from car-free households missed owning a car during the lockdown period in spring 2020. Estimation results (and the corresponding levels of significance) of a binary logistic regression model.

Parameters	Miss owning a car: yes
Intercept	−0.260**
Gender: female	0.121*
Age group: 18–24 years	0.284***
Age group: 25–34 years	0.188**
Age group: 35–44 years	0.224**
Employment status: employed & not commuting during the lockdown	0.232***
Place of living: metropolises, regiopolises and major cities in urban regions	−0.113*
Public transport usage during the lockdown: yes	0.186***
Changed attitudes: feeling (much) more inconvenient using public transport than before the COVID-19 pandemic	0.186***
Statement „Me and/or persons in my family belong to the COVID-19 risk group": agree or highly agree	0.117*
Statement "I am directly responsible for the improvement or impairment of my health": agree or highly agree	0.123*
Number of observations	*188*
Log-likelihood with constants only	*−121.2172*
Log-likelihood at convergence	*−101.5043*
McFadden R^2 (constants-only base)	*0.163*

Significance levels: *** 1% level ** 5% level * 10% level.

The impacts on the use and perception of the bicycle as a mode of transport were diverse. On the one hand, the share of adults with the bicycle in their mode choice set dropped from 32% before the advent of the COVID-19 pandemic to 24% during the strictest period of lockdown and about one in ten respondents felt (much) more inconvenient riding a bicycle during the lockdown period. On the other hand, about 4% of transport users started using the bicycle during the lockdown period, i.e. the bicycle may have attracted new user groups. Also a certain share of the population stated that the bicycle gained a "feel-good" factor, however the consent rates are not as high as for the car. Moreover, 5% of respondents stated that they were planning to buy a bicycle or an e-bike. In March and April 2020 bicycle sales actually increased significantly (Beneke, 2020), indicating that the popularity of bicycles has further augmented in Germany during spring and summer of 2020. When interpreting our results on bicycle usage, one may keep in mind that the survey was conducted at the beginning of April when weather conditions were unstable in Germany, while bicycle use normally depends on favourable weather conditions (Nobis, 2019). De Vos (2020) underlines the importance of bicycle usage in a period of social distancing and deduces that walking and cycling might be relevant to maintain satisfactory health levels in society.

The car became more important during the strictest period of lockdown in spring. The share of people with car used remained stable at a high level despite decreased overall travel demand during the lockdown period: about four out of five adults in Germany used the car, both in their typical travel behaviour and during the strictest period of lockdown. Moreover, the share of monomodal car users even increased by 13 percentage points during the lockdown period. Also studies from other countries showed a relative rise of car usage during the first COVID-19 lockdown in spring 2020 (e.g. Axhausen et al., 2020; De Vos, 2020; de Haas et al., 2020; Abdullah et al., 2020; Shamshripour et al., 2020). In comparison to other modes of transport, the car gained the highest share of respondents that felt more or much more convenient using it: about one out of six respondents stated that the individual car had gained a "feel-good" factor in the COVID-19 lockdown period. Our results align with findings from the Netherlands, where positive attitudes towards the car have increased noticeably as well (de Haas et al., 2020). A great advantage of the car as a mode of individual transport during the pandemic might be that it provides a protected space for the occupants, and there is no need to fear virus infection from unwanted interaction with other people. Car-free households are of special interest in this regard as they are used to managing their everyday life without access to a car of their own. Our survey results show that one third of individuals in car-free households missed owning a car during the lockdown and 6% even considered buying one. Individuals, who missed a car of their own are more often female, between 18 and 44 years, used public transport

during the lockdown period and felt inconvenient while using public transport. Furthermore, they tend to live in suburban and rural regions.

The increased positive perception of the car and its firm embeddedness in the mode choice set of the majority of the population needs to be regarded as critical against the background of the need for a sustainable transformation – or "Verkehrswende" – of the transport system. While transport related CO_2 emissions dropped considerably worldwide during the lockdown period (Le Quéré et al., 2020), this is mainly explained by the fact that the lockdown resulted in decreased daily activities and transport demand (i.e. less trips).

People might adopt these newly experienced perceptions and mode use behaviours in the medium run. If so, we may see higher shares of car usage and car mileage and consequently higher greenhouse gas emissions from transport after the pandemic than before the advent of COVID-19 in Germany. In order to overcome the impact that the pandemic has had in particular on augmented car use, we recommend expanding the possibilities for sustainable individual transport and developing concepts that strengthen public transport.

When developing concepts to strengthen the public transport system during the pandemic, the reduction of unwanted, close and unsecured contact to fellow travellers should be the main goal. In Germany, public transport users have been required to wear face masks in public transport vehicles since late April. Moreover, maintaining the same or an even higher level of service despite the decline in passenger numbers made for more individual space in the vehicles. However, a level of service improvement despite dropped passenger numbers is costly for public transport providers and in part not possible for capacity reasons. Several measures were taken by the public transport providers to get back their customers' trust:

- Technology-based measures, such as actual information on occupancy rates of busses, subways and trains, should give public transport users the possibility to alter their travel plans and use less frequented vehicles, but may also lead them to stand back from public transport use.
- Personnel in vehicles and stations, who ensure the compliance with the COVID-19 based measures, should guarantee a situation in public transport that significantly reduces health risks.
- Vehicle cabins were cleaned and disinfected (in particular handrails and control knobs) several times a day.

In order to strengthen bicycle travel, many European cities, such as Berlin, took the opportunity of reduced car travel during the lockdown period to install temporarily bicycle lanes, so-called pop-up bike lanes (Czeh, 2020). Those infrastructures create new spaces for cycling in the cities and ensure a safe travel as cyclists are able to keep sufficient distance from fellow cyclists and motorized vehicles in particular.

5. Conclusions and outlook

The COVID-19 pandemic has changed everyday life and caused significant impact on travel behaviour. This study reveals the reasons behind these changes looking more in-depth into individual adaptation strategies and attitudes amongst the German population. The purpose of our study was to analyse (1) changes in travel behaviour in transport use, (2) individual adaptation of travel behaviour and transport-mode related preferences, (3) shifted perceptions of car-free households towards the car and (4) to derive initial conclusions for transport policy. Therefore, we conducted a representative online survey for Germany during the strictest period of lockdown in March/April 2020. We analysed inter- and intra-individual changes in transport mode usage and attitudes towards transport modes focussing on the bicycle, the car and public transport. Moreover, the changed perceptions of car-free households on individual mobility options were investigated.

Our results indicate that public transport has significantly lost ground during the particularly restricted period of lockdown while individual modes of transport, especially the private car, became more important. This finding is underlined by our analyses from various perspectives: Firstly, the share of individuals using a car during the course of one week remained stable and the share of monomodal car users even increased. The share of people who (also) used a bicycle or public transport decreased. Secondly, intra-individual analyses indicate that car users were fairly stable in their vehicle preferences, whereas the share of people with changed – i.e. diminishing – preferences towards public transport and bicycle use increased. Thirdly, our findings on attitude shifts towards different modes of transport indicate that the car received a considerable feel-good factor during the particularly restricted period of lockdown, while the bicycle was perceived diversely and public transport was assessed negatively. Fourthly, one third of individuals in car-free households missed owning a car during the lockdown; this is particularly interesting as those people were used to managing their everyday life without their own car. Regression analyses showed that those individuals, who missed their own car were more often female, between 18 and 44 years old, used public transport during the lockdown period and felt inconvenient while using public transport. Furthermore, they tend to live in suburban and rural regions.

Considering environmental challenges and the ongoing trend toward increasing transport demand and the need to make the transport system more sustainable, suitable measures have to be implemented to support the use of active modes and public transport in particular, as it is the backbone of a sustainable (urban) transport system. At present, however, public transport in all countries (at least as it can be observed for Europe) suffers twofold from the pandemic – (i) the number of customers decreased massively in the strictest periods of the lockdown, and never regained former levels also in times of relaxation of regulations, so that revenues by ticket sales decreased as well, and (ii) extra measures to provide a high level of hygiene in the vehicles generated additional cost. Several states, as for example Germany or France, provided substantial monetary support for public transport to get through the crisis. Considering long term effects of increased reservations against public transport and new individual routines, now fully adopted to car-based mobility, it may become even more challenging for public transport not only to get back its previous customers, but to attract new ones. Most probably this will not be possible only by pull-measures that improve the supply side, but will also need significant "push actions" on the level of cities, but also in the national context, so, for instance, by infrastructure pricing or CO_2 taxation.

The strengths of the survey used for this study are that (i) it captures changes in travel patterns during the strictest COVID-19-related lockdown period in Germany, (ii) it considers, besides travel behaviour, individual strategies and attitudes related to the current situation, and (iii) a high level of representativeness of the sample for the German population is ensured due to the sampling and weighing procedure. However, our study faces some shortcomings which point towards the potential for future research: Firstly, the obtained survey only captures one short phase of the strictest period of lockdown. Given the high uncertainties regarding the duration and the characteristics of the later phases of the crisis, further and longitudinal studies which track the travel behaviour changes and the respective motivations over time are needed. Secondly, the survey design for self-assessment of travel behaviour and the lack of explicit trip reporting, e.g. in the form of a trip diary, results to limitations in the data analysis. The dataset does not allow for the production of standardized travel quantities, e.g. on modal split. It would have been favourable for a validation of our results to have GPS-based or mobile phone data available. Also, a comparison of urban and inter-urban travel was not possible due to the lack of a detailed trip diary with information of trip origin and destination (Schlosser et al., 2020b).

All in all, it is still open whether sustainable modes of transport can regain the same or even more importance in the mode choice set of the German population than before the pandemic or whether the COVID-19 pandemic is a setback for the transformation towards a more sustainable

transport system. Furthermore, which of the measures (e.g., obligations to wear face masks, vehicle disinfection) implemented by political decision-makers, public transport companies and transport planners are effective the virus spread and which are suited to increase the convenience of public transport users and which are not to prevent has not yet been studied. Therefore, it is of utmost importance that transport research monitors any developments and changes in transport mode usage in the medium and long run.

Sample credit author statement

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None.

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