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► **To cite this version:**

Ali El Zein, Adrien Beziat, Pascal Pochet, Olivier Klein, Stéphanie Vincent. What drives the changes in public transport use in the context of the Covid-19 pandemic? Highlights from Lyon metropolitan area. *Regional Science Policy and Practice*, 2022, 10.1111/rsp3.12519 . halshs-03588655

HAL Id: halshs-03588655

<https://shs.hal.science/halshs-03588655>

Submitted on 6 May 2024

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Authors' version:

El Zein A., Beziat A., Pochet P., Klein O., Vincent S. (2022), What drives the changes in public transport use in the context of the COVID-19 pandemic? Highlights from Lyon metropolitan area, *Regional Science Policy & Practice*, Vol. 14, n°1, 122-141.

<https://onlinelibrary.wiley.com/doi/abs/10.1111/rsp3.12519>

<https://doi.org/10.1111/rsp3.12519>

What drives the changes in public transport use in the context of the Covid-19 pandemic? Highlights from Lyon metropolitan area

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Abstract

This article focuses on the decline in the use of public transport in the context of the Covid-19 crisis in the Lyon metropolitan area, France. Using data from a web-based survey, supplemented by traffic counts and a qualitative survey, it explains this decline by the decrease in out of home activities such as work and the concomitant increase in teleworking, as well as by modal transfers. These explanations are tested by multiple regression models that include socio-demographic, residential, professional and attitudinal variables. It concludes with a discussion on the lasting of these changes and their implications for mobility policy.

Keywords: Covid-19, daily mobility, public transport, telework, web-based survey, logistic regression.

1. Introduction

Public transport (PT) plays a vital role in the operation of cities and meeting mobility needs. Although it is a key part of mobility policies that aim to provide an alternative to the car and assist the transition to carbon neutrality, it seems to have been badly hit by the advent of the health crisis and the introduction of lockdown measures. Ridership levels fell sharply during the lockdown periods of spring 2020. A similar drop occurred for other modes of transport such as the passenger car, although it was less marked. Moreover, in the ensuing months public transport bounced back less well.

Since the beginning of the health crisis, a number of research studies have sought to describe the reduction in the use of public transport and analyse its causes. Several explanations have been suggested, including the decline in activities, the increase in teleworking and teleactivities, the implementation of strategies for avoiding public transport networks due to fear of being infected, and a transfer towards personal modes of transport. This article aims to help explain this shift away from public transport in the Lyon metropolitan area in France.

The article begins with a literature review that presents the changes in public transport use in several cities in industrialised countries since the beginning of the health crisis, and the reasons for these changes. Next, the context of the study as well as the data and methodology are described. There follows an analysis of the data to reveal how public transport use has changed. Multivariate analyses have then been conducted to identify the main explanatory factors that underlie these changes. Finally, the conclusion discusses these findings and describes the issues and challenges they raise for mobility policy.

2. Literature review

The analysed documents seek to measure the changes in the use of different transport modes, including public transport, compared to the pre-Covid period, in order to identify the factors responsible for them. The decline in public transport use has varied according to the state of spread of the virus in the area and country in question and the health measures in place. To take one example, in March 2020 - a period of population lockdown - public transport use fell by more than 70% in some UK cities, and by 80-90% in some major cities in China and the United States (Batsas, 2020), Italy and Spain (Aloi et al., 2020) and by more than 90% at national level in the Netherlands (de Haas et al., 2020). With the gradual easing of lockdown, public transport use seems to have bounced back much less well than that of other modes such as the passenger

car (Das et al., 2021; Eisenmann et al., 2021; Labonté-LeMoynes et al., 2020), the bicycle (Beck & Hensher, 2020; Molloy et al., 2021; Schaefer et al., 2021), walking (Beck & Hensher, 2020; Wang & Noland, 2021) and the e-scooter (Campisi et al., 2020). A number of factors hampered the recovery of public transport ridership levels.

Firstly, the decrease in PT use is explained by the general decline in activities. Research carried out on the period in question shows a sharp decline in activities of all types, whether related to work, leisure or consumption (Beck & Hensher, 2020; Parady et al., 2020). The massive reduction in the number of work or study related trips had a particularly strong impact on PT use (Awad-Núñez et al., 2021).

To some extent, these unmade trips have been replaced by remote activities. Thus, the reduction in work and study related trips is due to the considerable increase in teleworking that has accompanied the pandemic, as shown by studies conducted in the United States (Mohammadian et al., 2020; Shamshiripour et al., 2020), the Netherlands (de Haas et al., 2020) and Greece (Mouratidis & Papagiannakis, 2021). In addition to teleworking, there has been an increase in other remote activities such as e-shopping and distance learning, for example (Macharis et al., 2021; Mouratidis & Papagiannakis, 2021; Shamshiripour et al., 2020). Such remote activities have to some extent replaced activities that require trips, on a short-term basis in response to government-imposed restrictions on activities. However, a Swedish research suggests that more structural changes are taking place in the habits of pre-Covid public transport users and that they are abandoning the mode altogether or using it more occasionally (Jenelius & Cebecauer, 2020).

A second part of the explanation for the fall in public transport use is to be found in modal transfer. The literature shows that some of the trips that were made on PT before the Covid crisis have been transferred to personal modes such as the passenger car, bicycle or walking (Barbieri et al., 2021; Basu & Ferreira, 2021; Bucsky, 2020; Schaefer et al., 2021; Zhang et al., 2021). An increase in monomodality in daily trip-making has also been observed, to the benefit of personal modes (Eisenmann et al., 2021). Bicycle use, which was already increasing in some cities prior to the health crisis, benefited from a deadweight loss effect (Jenelius & Cebecauer, 2020) and was assisted by specific road design measures, particularly in Europe (Adam & Ortár, 2022; Barbarossa, 2020). The use of self-service bicycles also increased, and they have proved to be more resilient than other shared mobility systems (Teixeira & Lopes, 2020; Wang & Noland, 2021).

Users have implemented PT avoidance strategies due to fear of infection (Basu & Ferreira, 2021; Beck et al., 2021; Eisenmann et al., 2021; Schaefer et al., 2021). According to an on-line survey conducted in Hungary, Japan, Germany, Bulgaria and Austria, between 70 and 80% of the public transport users who have abandoned it say that this is due to PT avoidance (Shibayama et al., 2021). Users are afraid of overcrowding in PT (Basu & Ferreira, 2021) and see public transport, in particular the Metro, as presenting a health risk (Abdullah et al., 2020; Beck & Hensher, 2020; Shibayama et al., 2021; Vickerman, 2021). Nevertheless, public health measures such as cleaning, hand sanitizing and compulsory mask wearing, tend to reassure users and have led to a partial return to public transport use (Labonté-LeMoyne et al., 2020).

Thus, research on the subject focuses on two main types of explanation for the move away from public transport: on the one hand, the reduction in activities that require travel and, on the other, the transfer to other modes of transport, mainly due to public transport avoidance strategies. However, the specific effect of each of these principal types of explanatory factors is not easy to determine from the literature. This article aims to propose a measure of the effect on PT demand of changes in travel-generating activities on the one hand, and of modal transfers on the other. It is based on surveys conducted in the Lyon metropolitan area.

3. The context: The Lyon metropolitan area during Covid-19

a- The Lyon area

This research deals with the Lyon metropolitan area and its nearby municipalities which make up the Rhône *Département* (Figure 1). In 2018, this *Département* had a population of 1.86 million, 1.4 million of whom lived in the Lyon metropolitan area (INSEE, 2021c). The central municipalities of Lyon and Villeurbanne account for almost half (48%) of the population in the metropolis (INSEE, 2021b) and 36% of the *Département's* entire population. The population density is 527 persons/km² in the Rhône *Département* and 2,606 in the Lyon metropolitan area. It is markedly higher in Lyon (10,834 persons/km²) (INSEE, 2021a) and Villeurbanne (10,376 persons/km²) (INSEE, 2021b) than in the outskirts. Tertiary sector jobs (business services and the public sector) are highly concentrated in the central zone of Lyon and Villeurbanne, while the outskirts of the metropolis are home to a high proportion of its industrial jobs (INSEE, 2016, 2017).

The local authority of the metropolitan area and Sytral (its public transport authority) have adopted proactive transport policies during the last 25 years. These include restrictive measures

with regard to passenger car traffic and parking in the center, the expansion of the public transport network and, in recent years, the provision of more cycle paths and infrastructure¹. As a result, the services provided by the public transport system in the Lyon metropolitan area are very good. The network is organised around four metro lines, seven tramway lines and 26 high-capacity bus routes, as well as 100 conventional bus routes. On the other hand, public transport provision is much more limited outside the Lyon metropolis, and is essentially limited to bus services² and regional train. In addition, in France, employers reimburse half the cost of their employees' season tickets, on condition they travel to work by public transport, which has also helped to increase its use among the working population.

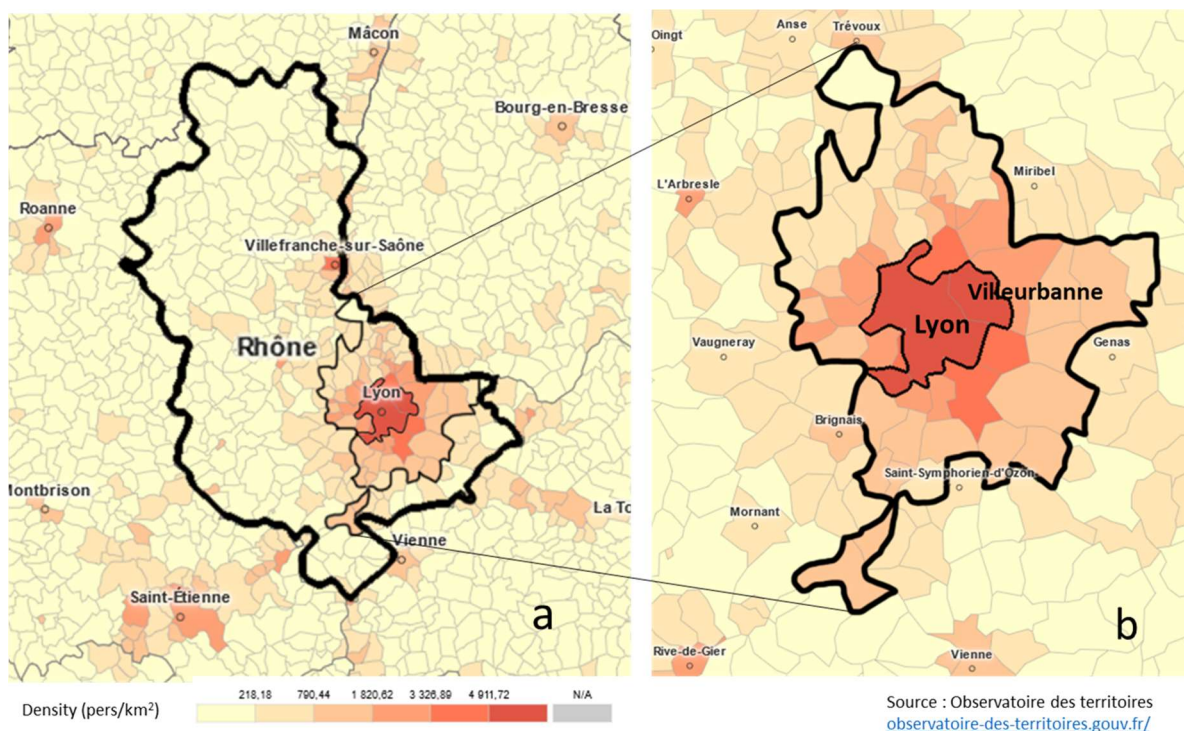


Figure 1. The Rhône Département (a) and the Lyon metropolitan area and the central area (Lyon-Villeurbanne) (b)

The 2015 Household Travel Survey revealed that modal split for residents of the Lyon metropolitan area was as follows: public transport 19%, walking 35%, bicycle 2%, passenger car 42%, with the remaining 2% being on other modes. Compared to the previous survey (2006), public transport had gained 4 percentage points (15% in 2006) and walking 2 percentage

¹ See the Lyon metropolitan area authority website: https://www.grandlyon.com/fileadmin/user_upload/media/pdf/voirie/20190621_guide-amenagement-cyclable.pdf

² See the Sytral (Syndicat Mixte des transports pour le Rhône et l'agglomération lyonnaise) website: <https://www.sytral.fr/413-les-reseaux-de-transport.htm>

points, while the car had declined significantly (by 6 percentage points). Prior to the health crisis, the share of public transport was thus the highest of any French city, outside the Île-de-France region³.

b- The chronology of Covid-19 and public health measures

The first cases of Covid-19 in France were confirmed at the end of January 2020, before the number of people infected increased rapidly in February and March. In this context, strong public health measures were introduced to slow the spread of the virus. Thus, from 17 March, strict confinement was imposed. It severely limited face-to-face activities and travel which were reserved for essential sectors of activity. Apart from a few exceptions, only very short outings were allowed in the area around the home and for specific reasons (for example individual exercise). Non-food shops and businesses considered "non-essential", restaurants, bars and cafés, cinemas and places of entertainment were required to close. Lockdown was gradually eased from 11 May 2020⁴. According to the "Covid-19 Stringency Index", on a scale of 0 to 100, the stringency of restrictions in France was rated at 88 throughout the period of lockdown (17 March to 11 May 2020). It then dropped to 77 the day after the end of lockdown, and stood at 52 at the time of our surveys⁵.

At the same time, local authorities also introduced measures. Sytral boosted the cleaning and disinfection procedures for vehicles and required compliance with barrier measures (masks, distances between seated passengers, boarding solely by the rear doors, etc.). By the end of March, ridership on Lyon's public transport had dropped by 90%⁶. Services were adapted (with a 50% reduction on the metro and tramway) by halting services at 11 pm⁶. The lower level of supply was continued until the end of lockdown (11 May 2020) when the supply was increased to over 85%⁷, of pre-lockdown levels, before returning to 100% of pre-lockdown levels on 9 June 2020⁸.

³ See the Lyon urban area planning agency website:

<https://www.urbalyon.org/sites/default/files/productions/publications/imports/2019-11/m-cmd-agglo.pdf>

⁴ See the French Government website: <https://www.gouvernement.fr/info-coronavirus/les-actions-du-gouvernement>

⁵ See Ourworldindata website: <https://ourworldindata.org/grapher/covid-stringency-index>

⁶ See the Sytral press release of March 27, 2020: https://www.sytral.fr/uploads/Externe/66/411_044_cp.pdf

⁷ See the Sytral website:

https://www.sytral.fr/TPL_CODE/TPL_ACTUALITE/PAR_TPL_IDENTIFIANT/5146/20-actualites.htm

⁸ See the Sytral website:

https://www.sytral.fr/TPL_CODE/TPL_ACTUALITE/PAR_TPL_IDENTIFIANT/5209/87-reseau-tcl.htm

4. Data and method

This research employs a mixed method research approach (Hesse-Biber, 2010), combining quantitative and qualitative data (Beziat et al., 2021)⁹. The quantitative data were derived from two different sources: a web-based questionnaire survey and count data. In this article we draw mainly on the questionnaire survey, which is supplemented by insights provided by qualitative data from interviews and count data.

a- The web-based survey

The quantitative survey was conducted between 16 June and 5 July 2020 by means of a web-based questionnaire which was distributed *via* the following main channels:

- Facebook *via* paid advertising, disseminated within predetermined perimeters (Lyon, the metropolitan area including Lyon, the Rhône *Département* without the metropolitan area...)
- networks of a more institutional nature: Sytral's information stream and website, the OnlyMoov multimodal route search and traffic information application, municipal authorities in the Rhône *Département*, outside the metropolitan area.

When the survey was disseminated *via* the local public transport authority's information stream, public transport users were obviously over-represented in the sample. The results cannot therefore be applied to the population as a whole. However, this over-representation provides a sufficiently large sample of public transport users before the Covid-19 crisis to enable us to assess how their mobility changed during it, and to investigate the causes of the changes.

The survey mainly addressed mobility practices between the period prior to lockdown (i.e. before March 2020) and the period immediately after it (June 2020). The questions related to the period prior to lockdown concerned a typical working week without precising a particular week. Concerning the period immediately after lockdown, the questions concerned the last week prior the day of answering the questionnaire. The survey also included questions about the socio-demographic and occupational characteristics of the respondents and the characteristics of their households, home-to-work and home-to-education mobility as well as

⁹ This research is a part of CoviMob project (The Health Crisis and Daily Mobility) is funded by the Lyon metropolitan authority, the public transport authority Sytral, IDEX Lyon and the CNRS. The flow data presented in Figure 3 were obtained from the observatory set up by the Arcadis consultancy, a partner of the project partners. The dissemination as well as the weighting of the web survey benefited from the collaboration of the Mobil'homme consultancy, another partner of the project. See CoviMob website: <https://web.msh-lse.fr/covimob/>

mobility for other purposes (shopping, leisure, visits, etc.), the use of different modes of transport with a particular focus on public transport (purposes, frequency, reduction, etc.), and whether or not the respondents engaged in teleworking, and if so under what practical terms.

This web-based survey was administered to 2,298 persons aged 18 and over living in the Rhône *Département* including the Lyon metropolitan area. As a survey medium, the internet can lead to representativeness biases, because of unequal ease of access and self-selection biases (Bayart & Bonnel, 2012; Bethlehem, 2010). Such biases were apparent in our sample. The raw sample was characterised by the over-representation of women, 18-34 year olds, residents of the municipalities of Lyon and Villeurbanne, working persons and those with higher education qualifications. Conversely, the over 60s and non-working persons were under-represented, as were the residents of the areas furthest from the center. The data were weighted using INSEE population census¹⁰ figures by the level of urbanisation of the municipality of residence (or of a group of municipalities, when located in the outskirts and more rural zones of the survey perimeter), age, and sex. For working people, an additional weighting was carried out, in order to correct the over-representation of higher education workers in the sample. This additional weighting factor straightens the structure of professions, without eliminating completely this bias in favor of “higher intellectual and managerial professions” (Beziat et al., 2021). The survey thus allowed us to provide descriptive analyses of the changes that took place (based on weighted data), and to relate changes in public transport use to various explanatory factors, such as socio-demographic variables, place of residence, economic activity status, changes in teleworking practices, changes in the frequency individuals perform various types of activity, household car ownership, etc.

b- Data on mode-by-mode changes in flows

The flow data were obtained from permanent automatic hourly counts in the Lyon metropolitan area which have been available since January 2019. They were analysed by the CoviMob Observatory (see note 9). The database was obtained from 2,200 traffic counting stations, 70 bicycle counting stations, and ticket validation data in the case of public transport use. Once

¹⁰ INSEE is the National Institute of Statistics and Economic Studies. The most recent census data available at the time of the analysis, as of 2017, were used.

processed and aggregated, the count data provide a week-by-week description of changes in car¹¹, bicycle and public transport flows from before the onset of the crisis.

c- Qualitative survey

The qualitative investigations were conducted by means of 20 interviews with residents of the metropolitan area, conducted between the beginning of June and mid-July 2020, as well as 5 interviews in September and October with residents of municipalities in the Rhône *Département*, outside the Lyon metropolitan area. During the recruitment process, we sought to obtain a diverse group of respondents, according to location, gender, age category, educational attainment and family situation. The interviews focused in particular on changes in mobility and transport mode use, changes in activities such as work, day-to-day living, consumption, leisure practices and their locations as well as respondent's residential aspirations.

Figure 2 situates the dates of the surveys with respect to the public health measures taken to limit the spread of the coronavirus. The web-based survey and the qualitative survey thus relate to a period when face-to-face activities resumed, although only partially, in particular because of the large proportion of working persons who were still teleworking in June 2020 (Chausse & Malard, 2020).

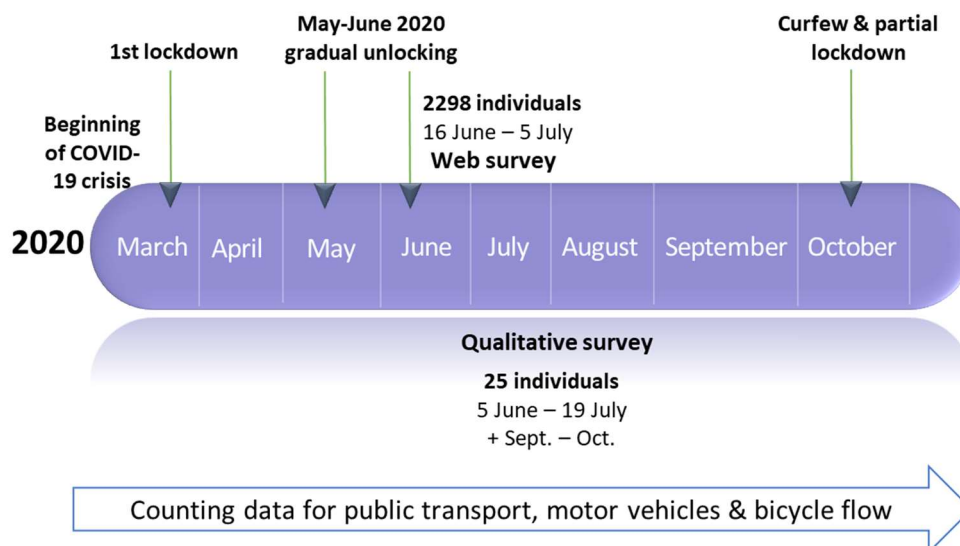


Figure 2. The timing of the different surveys in relation to the public health measures

¹¹ The counting stations report all motor vehicles (passenger cars, bus, vans and trucks) without distinction. However, the part of bus and trucks is marginal in the total and passenger cars account for most of the traffic in the Lyon metropolitan area.

5. Changes in PT use

a- A brief description of the period

Count data were available for public transport, passenger car and bicycle flows for all 2019 and 2020 and until November 2021 (Figure 3). As the scales of the three graphs are not the same, only the relative changes can be compared. The reduction in use of the three modes was very marked during the first period of lockdown, especially in the case of public transport (a 90% reduction between 13 March and 11 May 2020). The web-based and qualitative surveys were conducted at a time when public transport use was considerably lower (by 33%) than at the same time of the year in 2019. In contrast, over the same period, car flows were down by 7% and cycle flows were up by 30%.

The second striking feature, compared to that observed for bicycle and passenger car use, is the less marked bounce back of public transport ridership with the gradual easing of lockdown in May 2020. At that date, in contrast to cycling and car use, public transport had still not regained its 2019 ridership level.

The figures for the most recent period confirm this situation. In November 2021, when the public health measures were less restrictive than in June 2020, public transport use was 13% lower than in November 2019 (compared with a 5% drop in car use and a 41% increase in bicycle use). The results of the surveys and counts are substantiated by the local press, which has reported the return of traffic jams (Girardon, 2021¹²) and an increase in bicycle use (Le Progrès, 2021¹³).

¹² <https://www.20minutes.fr/lyon/3120403-20210911-lyon-plus-embouteillee-avant-epidemie-covid-19-niveaux-extremes>

¹³ <https://www.leprogres.fr/transport/2021/11/19/39-de-deplacements-a-velo-a-lyon-entre-2019-et-2021-c-est-la-hausse-enregistree-par-strava-metro>

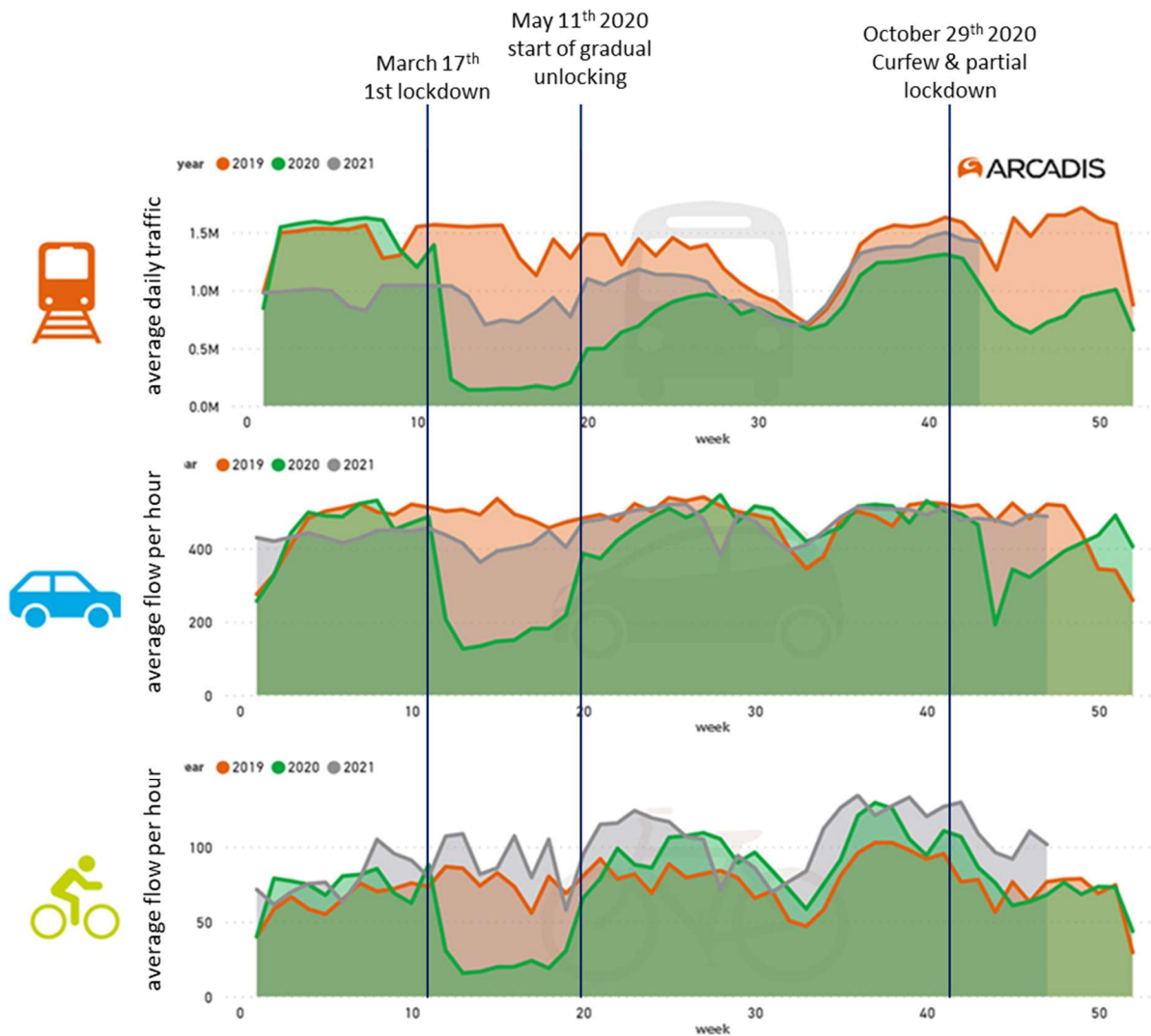


Figure 3. Bicycle, passenger car and public transport use

b- Home-to-work trips and public transport use: what has become of the individuals who used public transport before the Covid crisis?

The web-based survey informs us about the usual mode of transport used for home-to-work trips before March 2020 for those who were in employment before the health crisis as well as that of those who were not teleworking every day of the week in June 2020. For both periods, we also know the number of days worked per week and the number of teleworking days. There has been a considerable growth in teleworking since the onset of the health crisis (Klein et al., 2020a).

The interviews show a fairly strong desire for teleworking among respondents living far from their place of work who are reluctant to return to public transport for their commuting trips which are often very long.

We can therefore make the hypothesis that the mobility of working persons by public transport has been considerably modified (Klein et al., 2020b). By weighting PT use for home-to-work trips by the number of days that working persons commute to work, we can see how public transport use for home-to-work trips changed between the period before March 2020 and June 2020. Sankey diagrams (Figures 4 to 6) reveal how public transport use changed between the two periods. These diagrams also show, for the purposes of comparison, the minute proportion of home-to-work trips on other modes that had switched to public transport in June 2020.

The only modes involved were the passenger car and the bicycle, and the transfer involved just 2% and 1% of home-to-work trips by car and bicycle respectively before March 2020. Only 49% of the working persons who travelled to work on PT before lockdown still did so in June 2020 (Figure 4). This halving of the volume of home-to-work trips made on public transport can be broken down into two parts, depending on the reasons behind it:

- The reduction in the overall volume of home-to-work trips is the main factor responsible for the fall in home-to-work trips made by PT. More than two-thirds (70%) of the decline in these trips is explained by the decrease in the total number of commutes. Three quarters (76%) of this reduction is due to teleworking, and one quarter is due to reduced activity levels (partial “unemployment”, complete “unemployment”, and cessations of activity).
- Modal transfers account for 30% of the total. The passenger car has benefited most from this change, followed by the bicycle and walking. Modal transfers in the opposite direction - working persons who were cyclists or motorists before the crisis who changed to public transport - are extremely marginal.

Many of the respondents to the qualitative survey cited preventive attitudes regarding infection as an explanation for this modal shift. The comfort and efficiency of each mode of transport were also mentioned, due to the reduced frequency of public transport services and the absence of road congestion. However, car use was not very popular with the respondents, partly because of parking constraints at the workplace, and partly because commuting by car is financially expensive and sometimes tiring.

The interviews also showed that some regular users of public transport returned to it from June 2020, partly reassured by the hygiene and social distancing measures introduced in vehicles and at stations and stops.

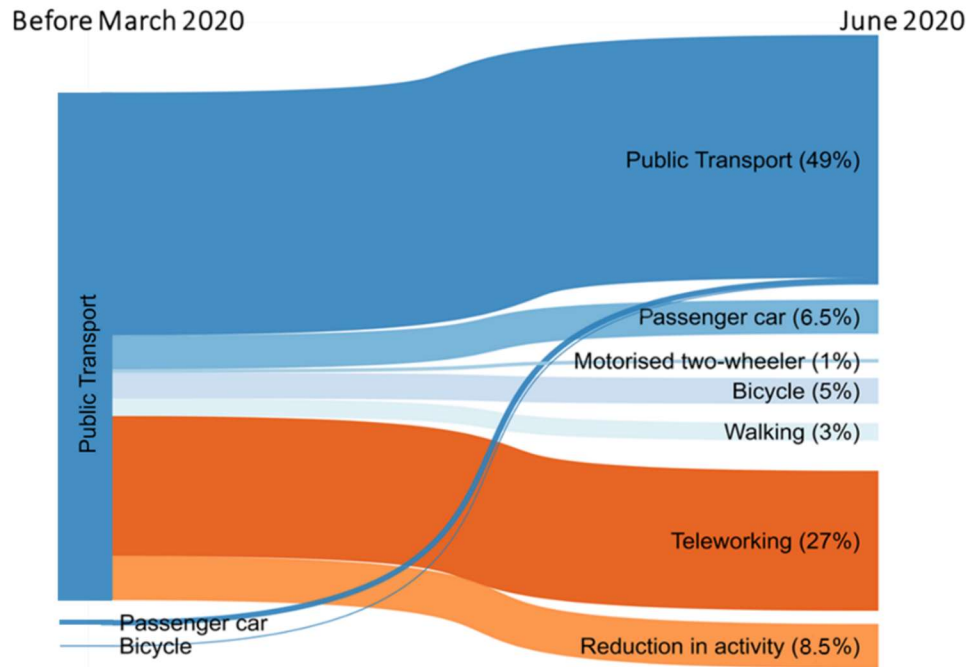


Figure 4. Change in PT use for home-to-work between the time before March 2020 and June 2020, for the population in work in June 2020 residing in the entire study area

Sankey diagrams can also be plotted by either focusing on working persons residing in the central zone of the metropolitan area or on those residing in its outlying areas (Figures 5 and 6). In both cases the reduction in the number of home-to-work trips by PT was of the same order of magnitude. However, for working persons residing in the outskirts, the decrease in the overall volume of home-to-work trips (due to teleworking and the reduction in activity) was particularly marked (74% of the total, compared to 26% for modal transfers), compared to working persons residing in Lyon and Villeurbanne (67% and 33% respectively). The contribution of teleworking to this reduction in the volume of home-to-work trips was also higher in the outskirts (80%) than in the center (73%). In the outskirts, the modal transfer was towards the car in nearly three-quarters (73%) of cases. In comparison, in the center, cycling and walking gained most from the modal transfers: the car (and motorized two-wheelers) accounted for only one-third (34%) of the modal transfers.

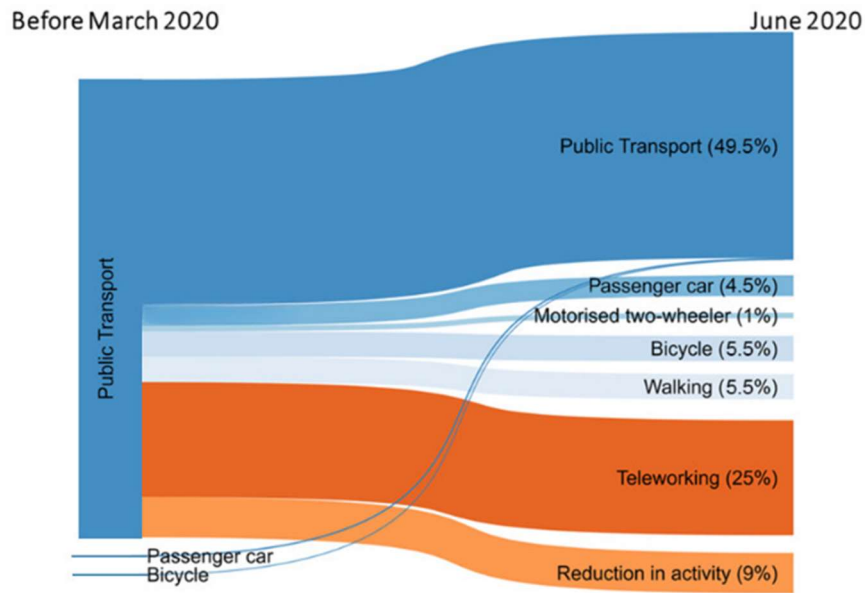


Figure 5. Change in PT use for home-to-work between the time before March 2020 and June 2020, for the population in work in June 2020 residing in the central zone of the Lyon metropolitan area

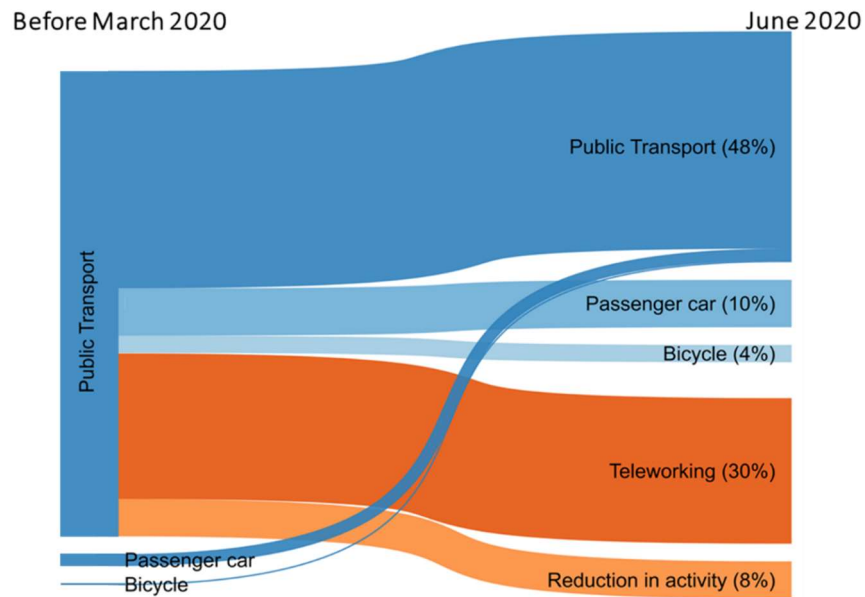


Figure 6. Change in PT use for home-to-work trips between the time before March 2020 and June 2020, for the population in work in June 2020 residing in the outskirts of the Lyon metropolitan area and in zones outside it

The changes reported in this section relate to home-to-work trips. The shift away from public transport use was due, primarily, to an overall decrease in the volume of home-to-work trips on a given day, resulting essentially from the scale of the increase in teleworking since the

introduction of public health restrictions. In addition, the findings highlight changes in the transport modes used for home-to-work trips, which are to the disadvantage of public transport.

In the following section, we shall present multivariate analyses of the changes in the use of public transport by differentiating between working and non-working persons.

c- The effect of the various explanatory factors on the reduction in public transport use

In order to estimate the effects of the relevant variables we have identified, we used logistic regression models with, as the dependent variable, lower PT use in June 2020 than before March 2020. Logistic regression allows us to model the relationships between a vector of explanatory variables and a binary variable of interest. The "glm" function in the R "Stats" package was used to fit the models and estimate the value of the coefficients for the different explanatory variables. A negative coefficient, for the modality studied, means that the probability of lower use of PT decreases, all other things being equal, compared to the reference modality. Conversely, a positive coefficient means that the probability of a decrease in the use of public transport increases, all other things being equal, relative to the reference mode.

We ran the "glm" function on two subsamples of our panel: working persons and non-working persons (students, retirees, house persons, etc.). The reason for this was that working persons are characterised by specific work-related variables. The choice was also based on the assumption that changes in the behavior of respondents who are working persons and those who are non-working persons are to some extent due to different variables.

In order to illustrate the relationships between the binomial dependent variable and the explanatory variables, we categorised the independent variables as follows:

- socio-demographic characteristics (for both subsamples : in the "Working persons" models as well as the "Non-working persons" models, see Table 1);
- attitudes towards managing the health crisis on public transport networks (for both subsamples);
- additional days of teleworking and unemployment compared to the time before lockdown (only for respondents who were working in June 2020 - see the "Working persons" models);

- changes in mobility levels apart from work-related mobility, compared to before lockdown (for both subsamples);
- frequency of PT use before lockdown (for both subsamples);
- changes in the use of other transport modes compared to before lockdown (for both subsamples).

The variables and their frequency for each subsample are presented in Table 2 in the Appendix.

For each of the subsamples we have presented the results of two variants of the model, one with all the variables, the second with all the variables except the variables that describe the changes in the use of other transport modes, in view of the important and specific role of these mode change variables (Table 1).

Table 1. Results from the logistic regressions for the decrease in public transport use between the time before the health crisis and June 2020

Variables	Model with modal change variables		Model without modal change variables	
	Estimates		Estimates	
	Working person	Non-working person	Working person	Non-working person
Intercept	-1.7971***	-0.4308	-1.4996***	-0.222
Age – 18-34 [ref.]				
Age – 35-49	0.8213	0.5452	-0.1388	0.3715
Age – 50-64	0.3253	-0.3285	-0.0351	-0.5315
Age – > 64	0.6267	0.1623	0.176	-0.0894
Gender – M	0.0666	-0.1277	0.0406	-0.1601
Gender – F [ref.]				
Place of residence – Central area [ref.]				
Place of residence – Rest of the Metropolitan Area	-0.4937**	0.3221	-0.3792*	0.3029
Place of residence – Rest of the Rhône Dép.	-0.1921	0.2884	-0.2202	0.2963
Type of residence – apartment [ref.]				
Type of residence – Single-family home	-0.0963	-0.3114	-0.1173	-0.3726
Household car ownership – No car [ref.]				
Household car ownership – 1 car	-0.0003	0.2114	0.2523°	0.3471
Household car ownership – 2+ cars	0.2455	0.3448	0.5299**	0.4694
Household equipment – No bicycle [ref.]				
Household equipment – 1 bicycle	-0.191	0.3816	0.0823	0.3496
Household equipment – 2+ bicycles	-0.0239	0.2165	0.1595	0.3223

Household – No children under 12 [ref.]				
Household – Children under 12	0.144	0.1905	-0.04	0.023
Education – No further education [ref.]				
Education – Further education	0.0811	0.8554**	0.1395	0.8609**
Attitudes – Health risks are satisfactorily addressed in public transport [ref.]				
Attitudes – Health risks are <u>not</u> satisfactorily addressed in public transport	0.0852	0.2755**	0.0823	0.2765**
Occupation – Non-executive (employee, factory working person, etc.)	0.2737		0.0933	
Occupation – Executive [ref.]				
Type of work – Non-office worker [ref.]				
Type of work – Office worker	0.161		0.1193	
Additional – No additional teleworking days [ref.]				
1 or 2 additional teleworking day(s)	0.2573		0.2406	
3 or 4 additional teleworking days	1.1666***		1.0655***	
5+ additional teleworking days	1.6966***		1.4944***	
Partial unemployment – No partial unemployment additional days [ref.]				
1 or 2 additional unemployment day(s)	0.1967		0.2329	
3 or 4 additional unemployment days	0.1345		0.2806	
5+ additional unemployment days	0.3387		0.4634	
Recreational activities – More or same number of out of home activities [ref.]				
Recreational activities – Fewer out of home activities	0.7589***	0.7473**	0.7333***	0.6799**
Shopping – More or same number of out of home activities [ref.]				
Shopping – Fewer out of home activities	0.4092**	0.9782***	0.5689***	1.0453***
Visiting (family, friends, etc.) – More or same number of out of home activities [ref.]				
Visiting (family, friends, etc.) – Fewer out of home activities	0.5543***	0.4823*	0.4735***	0.4464*
E-shopping – Less or same level of e-shopping [ref.]				
E-shopping – More e-shopping	0.1831	0.1519	0.2752*	0.203
PT use before lockdown – Less than one day per month [ref.]				

PT use before lockdown – One day per month	-0.1127	-1.3607*	0.1651	-1.1749*
PT use before lockdown – One day per week	-0.2463	-0.9693°	0.0943	-0.7772
PT use before lockdown – Two or three days per week	-0.271	-0.9855°	0.4081	-0.7869
PT use before lockdown – Daily or almost daily	-0.8403*	-1.5296**	-0.1542	-1.3264*
Car – Less or same use [ref.]				
Car – More use	2.4735***	0.7334**		
Bicycle – Less or same use [ref.]				
Bicycle – More use	1.7690***	1.2169*		
Walking – Less or same use [ref.]				
Walking – More use	1.0255***	0.3241		
Number of observations	1413	512	1413	512
Pseudo R2 (McFadden)	0.2647	0.1788	0.1198	0.1521
The significance levels for the coefficients are as follows: *** p<0.001; ** p<0.01; * p<0.05; ° p<0.1				

After controlling for the effect of other explanatory factors, the results from the working person model confirm that teleworking significantly reduces public transport use, when it is done three days a week or more. On the other hand, teleworking just one or two days a week does not significantly reduce public transport use compared to not teleworking at all. The results also confirm that, for working persons, the decrease in PT use is significantly linked to:

- reductions in non-work activities, such as shopping, leisure and visits;
- an increase in the frequency of use of each of the other modes of transport we have considered, namely the passenger car, the bicycle and walking (car use has a greater impact than cycling and walking on the probability of using public transport less);
- when the variables that affect changes in the use of other modes are removed from the regression model, the effect of household car ownership on the decrease in PT use becomes significant. The probability that carless workers will decrease their PT use is lower than for workers with one car, and much lower than for workers with two or more cars, presumably because they have less choice to do so. The decrease of the pseudo R2 value in the variant without these mode-related variables shows the importance of these variables in explaining the decrease of PT use.
- non-daily or occasional use. Those who used public transport on a daily basis before the health crisis reduced their use significantly less than the most infrequent users.

On the other hand, socio-demographic and residential characteristics do not seem to explain much of the decrease in PT use, except in the case of working persons living in the peripheral municipalities of the metropolitan area, who seem to be significantly less affected by the decrease in PT use than working persons living in the central zone.

For non-working persons, the results of the regression show that the decline in PT use is mainly linked to:

- reductions in shopping, leisure activities, and visits;
- attitudes that aim to avoid the risk of using public transport due to fear of infection;
- an increase in the frequency of car and bicycle use;
- college education;
- occasional use of PT before the crisis;
- when the modal transfer variables are removed from the regression model, the effect of the daily frequency of public transport use before the crisis becomes significant (it leads to a smaller reduction in use). The same is true for occasional use (once a month).

On the other hand, socio-demographic characteristics and household car and bicycle ownership rates do not appear to explain the decrease in PT use, even when the modal transfer variables have been removed from the model.

6. Discussion and conclusion

The data from the questionnaire survey cannot be considered as representative of the entire population of the Lyon metropolitan area and its surrounding municipalities. However, the changes we have identified through this survey, the findings from the qualitative interviews and the count data for public transport, passenger car and bicycle flows for the area provide a number of results that are consistent with those found in the literature. A sharp decline in the frequency of public transport use has been observed since the onset of the health crisis. The main activities that drive travel - work, shopping, leisure and visits - were carried out significantly less frequently in person in June 2020 than before the crisis. Reductions in activity in the workplace and outside the home - in particular the increase in teleworking on several days of the week - all tended to reduce public transport use. The results of the multivariate

regressions also show that, all other things being equal, the frequency of public transport use was also strongly dependent on the frequency of non-work related activities carried out outside the home, such as shopping and leisure pursuits. Transfers to other transport modes took a different form in the center of the city (where they were mainly to the benefit of active modes) from in the outskirts (where they were mainly to the benefit of the passenger car). Modal transfer also seems to depend on individuals' modal use habits, affecting daily public transport users less, for example. It was all the more marked among users who had the option of using other modes of transport. These factors played a much greater role in the reduction in the use of public transport than socio-demographic or residential variables whose specific effects appear to be very limited both among working persons and among the other major groups of residents in the study area.

The questions that spring to mind are, first of all, whether the effect of teleworking and modal transfers on the use of public transport will continue in the months and years to come. The changes observed and the current uncertainties also raise questions about the objectives of mobility policies, in terms of the provision and pricing of public transport or other modes. At stake is the purpose of current policies, whether they set out to encourage public transport use, cycling and walking, or to restrict the use of passenger cars.

The hypothesis that teleworking and its impacts on mobility will continue warrants further investigation. Not all jobs are suited to teleworking and it is also necessary to take into account the fact that people's experience of teleworking has revealed many challenges. However, the desire of a significant part of the workforce to engage in teleworking has been confirmed in France (Institut Montaigne, 2021) as in many other countries (World Economic Forum, 2021¹⁴). It is also apparent that property developers are adapting to the advent of teleworking in companies, and developing schemes that are appropriate in quantitative terms, as well as in terms of the design of spaces and service provision (Deloite, 2021¹⁵). To what extent will teleworking become a large scale phenomenon in the long term, and how will it transform the mobility of working persons? These questions remain open. A specific issue is the number of days per week working persons do teleworking, which we have shown to have an impact on the reduction in public transport use. Finally, it is more than likely that teleworking will have a rebound effect on the mobility of those who do it (Cerqueira et al., 2020; Greenworking &

¹⁴ <https://www.weforum.org/agenda/2021/07/back-to-office-or-work-from-home-survey/>

¹⁵ <https://www.lesechos.fr/weekend/perso/comment-le-covid-a-bouleverse-limmobilier-1346383>

Ademe, 2020). Furthermore, we can consider that easier teleworking could be accompanied by large-scale residential relocation to less dense areas (Toger et al., 2021). These residential changes can also impact the use of transport modes (de Abreu e Silva & Melo, 2018), notably to the detriment of public transport. Perhaps better understanding in this area might lead the public authorities to take a more cautious attitude towards encouraging teleworking.

Whether for work, or for shopping and leisure activities, public transport is being challenged by teleactivities and the increasing role of digital technology in urban life. As a result, its use may become less and less regular in Lyon. As in many other urban areas, public transport pricing methods, which make us of season tickets for example, are still very much designed for daily use, and will have to be altered to adapt to more irregular use.

The transfer of public transport users to other modes only partly explains the reduction in its use. However, it appears to be a long-term phenomenon, and is in direct conflict with the public policies that have been implemented for years to promote public transport and reduce the use of passenger cars in cities. The increase in cycling that has occurred since the onset of the crisis has been, at least partly, at the expense of public transport. Nevertheless, the dynamics of increasing bicycle use are in keeping with a move towards mobility policies that foster more sustainable, active modes. In this context, an interpretation of our results in terms of competition between public transport and cycling is not really appropriate. Together, the two modes create mobility solutions that reduce the need for passenger cars for certain communities and in certain areas. The dynamism of the passenger car seems to be more worrying in view of the policies announced by local authorities, in Lyon as in many cities of the world. It is still too early to know whether this change is permanent. The fatigue and wasted time associated with long car journeys on heavily congested roads, as well as rising fuel costs, are important factors that limit the growth of car use. Here again, future developments are not entirely clear. The monitoring and analysis on-going changes need to be continued, in a context where the ability of the public authorities to pursue their policies in terms of sustainable urban mobility is at stake.

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8. Appendix

Table 2: Frequency distribution of the variables used in the logistic regressions for the decrease in public transport use between the time before the health crisis and June 2020

Category	Variable	%	
		Working person	Non-working person
Binary dependent variable	Lower use of PT	0.582	0.633
Sociodemographic characteristics	Age – < 35	0.453	0.621
	Age – 35-49	0.378	0.084
	Age – 50-64	0.163	0.114
	Age – > 64	0.006	0.180
	Gender – M	0.372	0.338
	Gender – F	0.628	0.662
	Place of residence – Central area	0.668	0.480
	Place of residence – Rest of Metropolitan Area	0.258	0.375
	Place of residence – Rest of Rhône dep.	0.074	0.145
	Type of residence – Single-family home	0.161	0.211
	Type of residence – Apartment	0.839	0.789
	Household car ownership – No car	0.288	0.440
	Household car ownership – 1 car	0.515	0.359
	Household car ownership – 2+ cars	0.197	0.201
	Household equipment – No bicycle	0.399	0.499
	Household equipment – 1 bicycle	0.208	0.230
	Household equipment – 2+ bicycles	0.393	0.271
	Household – Children under 12	0.228	0.129
	Household – No children under 12	0.772	0.871
Education – College education	0.494	0.209	
Education – Non-college education	0.506	0.791	
Attitudinal variable (public transit-related) towards health crisis management	Health risks are satisfactorily addressed in public transport	0.677	0.600
	Health risks are <u>not</u> satisfactorily addressed in public transport	0.323	0.400
Teleworking conditions throughout the health crisis	Profession – Executive	0.461	-
	Profession – Non-executive (employees, factory workers, etc.)	0.539	-
	Type of work – Office worker	0.459	-
	Type of work – Non-office worker	0.541	-

	Teleworking – No teleworking	0.437	-
	Teleworking – 1 or 2 day(s)	0.185	-
	Teleworking – 3 or 4 days	0.198	-
	Teleworking – 5+ days	0.180	-
Changes in mobility behavior since the start of health restrictions	Recreational activities – Fewer out of home activities	0.754	0.689
	Recreational activities – More or same level of out of home activities	0.246	0.311
	Shopping – Fewer out of home activities	0.638	0.379
	Shopping – More or same level out of home activities	0.362	0.621
	Visiting (family, friends) – Fewer out of home activities	0.577	0.604
	Visiting (family, friends) – More or same number of out of home activities	0.423	0.396
	E-shopping – More e-shopping	0.272	0.256
	E-shopping – Less or same level	0.728	0.744
Before Covid-19 crisis public transport usage	Public transport use before health restrictions – Daily or almost daily	0.627	0.510
	Public transport use before health restrictions – two or three days per week	0.110	0.191
	Public transport use before health restrictions – one day per week	0.077	0.141
	Public transport use before health restrictions – one day per month or less	0.188	0.158
Changes in the use of other transport modes since the start of health restrictions	Car – More use	0.163	0.125
	Car – Less or same use	0.837	0.875
	Bicycle – More use	0.208	0.143
	Bicycle – Less or same use	0.792	0.857
	Walking – More use	0.295	0.385
	Walking – Less or same use	0.705	0.615