Will COVID-19 hinder or aid the transition to sustainable urban mobility? Spotlight on Portugal's largest urban agglomeration

Patrícia C. Melo

ISEG-Lisbon School of Economics and Management, University of Lisbon and REM/UECE, Lisbon, Portugal

Correspondence
Patrícia C. Melo, ISEG-Lisbon School of Economics and Management, University of Lisbon and REM/UECE, Lisbon, Portugal. Email: pmelo@iseg.ulisboa.pt

Funding information
Fundaç~\~ao para a Ciência e a Tecnologia, Grant/Award Numbers: PTDC/EGEECO/28805/2017, PTDC/GES-GCE/4046/2021, UIDB/05069/2020

Abstract
This study discusses the possible effects of two major COVID-19 disruptions – that is, the widespread adoption of working from home and the ‘bio-security’ fear affecting public transport – on travel patterns in Lisbon urban agglomeration. Drawing on evidence from the literature on the effects of teleworking on travel demand and the determinants of public transport, together with the analysis of travel data before and during the pandemic, the study concludes that the pandemic may hinder, more than aid, the transition to a sustainable mobility paradigm in Lisbon and its metropolitan area. The analysis of monthly travel demand shows that car use has recovered at a faster rate than public transport use, reaching pre-pandemic levels in some of the main arterial roads serving Lisbon. There appears to be a substitution of public transport trips by both driving and active micromobility. The main losers so far are public transport operators: the pandemic increased operating deficits and the need for additional public subsidies, putting at risk the future financial sustainability of public transport. Without serious commitment by local and national governments, the pandemic is likely to be another missed opportunity to transition to a better, more sustainable, urban mobility system.
1 | INTRODUCTION

The coronavirus disease 2019 (COVID-19) pandemic has caused major disruptions to the way we live, work and travel. Some of these disruptions may accelerate processes that were already taking place, but their outcomes remain uncertain and difficult to predict, such as their possible effects on urban mobility patterns. During the earlier phases of the pandemic, there was a sense that cities (and societies more generally) would use this crisis as an opportunity to speed up the transition to more sustainable living and travel. The sudden improvement in the quality of the urban environment resulting from the reduction in road congestion, noise and air pollution brought to light the unresolved conflict between ecology and the economy. As the crisis progressed, and its negative impacts on the economy deepened, the urge for recovery, strongly assisted by rising vaccination levels, revealed a rather familiar reality, with mobility patterns heavily based on car use as well as road congestion and pollution increasing to pre-pandemic levels.

The capability of cities (and countries) to shift travel mobility paradigms is influenced by many factors, notably the ways in which land use and transport systems interact with each other and how their design determines the possibility to travel using different transport modes. Portugal provides an interesting case study for over-investment in road infrastructure, particularly motorways, and disinvestment in public transport, notably railways. According to EUROSTAT data, in 2017 Portugal had the third-highest endowment of motorways relative to gross domestic product (GDP) and the fifth-highest endowment of motorways relative to population in the European Union (EU). Motorway construction was particularly generous in the two metropolitan areas; for example, Lisbon metropolitan area is the NUTSII region in Europe with the second-highest density of motorways per square kilometre (sixth highest per person) (Padeiro, 2018). Recent evidence for Portugal suggests that the expansion of the motorway network between the mid-1990s and late 2000s contributed to suburbanization (Rocha et al., 2021), promoting further car dependency and lack of improvement of public transport systems.

This paper contributes to the debate on the challenges and opportunities created by the COVID-19 pandemic regarding the transition to more sustainable travel mobility, with a special spotlight on Portugal’s largest urban agglomeration, which accounts for approximately one-third of the total population and employment in the country. I focus the discussion on the potential effects of two of the major disruptions caused by the pandemic, notably the large-scale change in working practices (i.e., working from home and flexible working practices) and the health-related penalty imposed on public transport systems owing to the fear of virus contamination. The impact of these disruptions on travel behaviour in the short and longer term is not necessarily the same because people adjust their decisions to new circumstances over time and in response to public policy. Consequently, the fate of urban mobility is likely to differ according to city-specific measures, notably local governments’ efforts to prevent the substitution of public transport by driving.

The analysis suggests that there is a ‘mobility paradox’ in Lisbon, consisting of a strong substitution of public transport trips by both solo driving and active micromobility. I use the evidence from the literature on teleworking and travel demand, and the determinants of public transport demand, to discuss how the COVID-19 pandemic may hinder, rather than aid, the transition from the current car-based mobility paradigm to a more sustainable urban travel mobility paradigm. The discussion is supported by monthly travel data for different transport modes before and during the pandemic, which shows that public transport demand remains substantially below pre-pandemic levels.
levels whereas traffic has essentially recovered to pre-pandemic levels. In addition, the prospects for sustainable urban mobility worsened further after the local elections in September 2021, with the new, centre-right, elected mayor promising cheaper car parking for residents and putting at risk some of the major routes of the planned cycle network, which may now face additional hindrances to its full implementation.

The paper is organized as follows. Section 2 gives a brief overview of the two studies directly relevant to this study. Section 3 describes the data collected and their respective sources, whereas Section 4 analyses travel patterns in Lisbon and the wider metropolitan region before and during the COVID-19 pandemic. Section 5 discusses the implications of the disruptions in working practices and public transport for the future of sustainability of urban mobility in Lisbon. Section 6 provides concluding remarks.

2 | WORKING FROM HOME, ‘BIO-SECURITY’ FEAR, AND PUBLIC TRANSPORT DEMAND: WHAT CAN WE LEARN FROM EXISTING RELATED LITERATURE?

2.1 | Teleworking and travel demand

Existing research on the effects of teleworking on travel demand spans back to the early 1990s and increased substantially as the adoption of information and communication technology (ICT) became more widespread. The initial view was that teleworking could be used as a travel demand management strategy to reduce the number of trips and distances travelled (e.g., Choo et al., 2005; Hamer et al., 1991; Helminen & Ristimäki, 2007; Henderson et al., 1996; Kitamura et al., 1991; Mokhtarian et al., 1995; Nilles, 1991; Pendyala et al., 1991), but more recent studies tend to conclude that teleworking can actually induce more travel or, at best, permits only minor travel reductions (e.g., de Abreu e Silva & Melo, 2018a; de Abreu e Silva & Melo, 2018b; He & Hu, 2015; Hjorthol & Nossum, 2007; Kim et al., 2015; Melo & de Abreu e Silva, 2017; Nelson et al., 2007; Zhu, 2012; Zhu & Mason, 2014).

The mechanisms underlying the relation between teleworking and travel behaviour are multiple and complex, including factors relating to individual and household preferences, demographic and socioeconomic circumstances, and the land use characteristics of the residential and workplace locations. Besides the direct effects of teleworking on commuting trips, there can also be indirect effects on non-work travel, travel mode choice and residential location, all of which affect the overall net effect of teleworking on travel demand (e.g., de Abreu e Silva & Melo, 2018a; de Abreu e Silva & Melo, 2018b).

The effects of working from home on travel demand can also differ over time. In the shorter term, teleworking can reduce the scope of trip chaining, increasing the number of non-work trips on teleworking days (Pendyala et al., 1991). There can also be longer-term effects on travel demand through residential relocation away from workplace locations. The increased disposable income due to savings in commuting cost and travel time may facilitate residential relocation to peripheral urban areas, contributing to sprawl and longer commutes (Mokhtarian, 2009; Nilles, 1991). Since the quality of public transport is generally inferior in suburban areas, teleworking may increase car use levels in the longer term through residential relocation. Consequently, although the total number of commuting trips of teleworkers may be smaller compared with non-teleworkers, the total distance travelled by car may be greater. The overall net outcome is difficult to predict and is likely to be specific to both the household and the local context.

The COVID-19 pandemic led to the adoption of working from home by the large majority of (non-essential) workers, as well as the elimination of most out-of-home activities due to lockdown restrictions. The result was a sudden fall in mobility levels and travel demand by both private and public transport. Although working from home may become a widely accepted practice in post-COVID-19 vaccinated economies, at least for some occupations and industries, its circumstances will be very different owing to the elimination of constraints on travel and social life.
Evidence from pre-pandemic teleworking studies may be helpful in predicting the effects of working from home on travel demand patterns, but only to some extent. People’s perceptions about the value of their time, the value of their local residential environment and the safety of different modes of transport, amongst other factors, have been affected by the pandemic and are likely to influence travel behaviour in uncertain ways. The simplest scenario would be an overall reduction in the number of trips due to less commuting. This effect may be more attractive for workers living further away from their workplace, in which case there would also be a more than proportional reduction in distance travelled and air pollution levels. Reality is more complex, though, and people are likely to use the saved travel time and money to do other activities they like, which may require travel. They may also decide to use the increased disposable income to relocate for greener pastures and put up with longer, even if fewer, commutes. Changes in household location are likely to affect not only home-to-work commute distances, but also travel mode choice. In particular, moving out of urban areas tends to be associated with an increase in car ownership levels, so the overall effect depends on households’ residential preferences and the extent to which the pandemic may alter them.

### 2.2 Determinants of the demand for public transport

Fear of virus contamination, despite increasing levels of vaccination, makes public transport a less attractive travel mode choice. People might avoid using public transport because they perceive it as being unsafe, compared with private transport, because of having to share a confined and often crowded space, where keeping a minimum social distancing can be difficult (e.g., De Vos, 2020; Dong et al., 2021). The resulting reduction in passenger numbers, and thus in operating revenues, exacerbates the need for public subsidies, compromising the maintenance and investment in services, as well as the financial sustainability of public transport systems. The unusual circumstances created by the COVID-19 pandemic may also limit the efficacy of the standard measures used in the past by operators and municipalities to promote the use of public transport, notably pricing policies, which may now be substantially less effective.

In this section, I draw on the conclusions from review studies of the determinants of public transport demand (e.g., Holmgren, 2007; Litman, 2004; Paulley et al., 2006) to discuss some of the possible implications of the pandemic for the future of public transport in post-COVID-19 vaccinated economies. The price of travelling by public transport is one of the main factors influencing the demand for public transport. Existing evidence suggests that price elasticity ranges between $-0.2$ and $-0.5$ in the short term and between $-0.6$ and $-0.9$ in the longer term (e.g., Holmgren, 2007; Litman, 2004; Paulley et al., 2006). This means that an increase of 10% in the price of travel cards is associated with a reduction in patronage of 2–5% and 6–9% in the short and longer term, respectively. The precise value of the elasticity, however, can differ with the geographical context (e.g., built environment and land uses), the type of user (e.g., income level, economic status) and journey purpose (e.g., commuting, shopping) (Litman, 2004). Importantly, the fact that demand for public transport is usually relatively inelastic means that increasing prices can also increase net revenues, ceteris paribus. This relation may be fundamentally altered by the fear of virus contagion created by the pandemic, which may make people more responsive to rises in price levels, especially for higher-income users with more alternative travel options available, making the negative impact on operating revenues more severe.

The quality of service, notably the frequency level, is another major determinant of public transport demand. Changes in frequency levels (e.g., trains per hour) can have a relatively stronger impact on patronage, compared with changes in pricing. In other words, the demand–supply elasticity estimates can often exceed (in absolute value) the demand–price elasticity estimates (e.g., Melo & Ramli, 2014). The ‘bio-security’ threat created by the COVID-19 pandemic may further emphasize this pattern owing to the now even greater importance of providing more frequent, faster and safer journeys to users. Compared with pre-COVID-19 times, both travel times and waiting times are now perceived as being relatively more valuable than the monetary cost of a trip. To ensure
minimum social distancing, public transport operators had to provide service levels that were higher than pre-pandemic for demand levels that were lower than pre-pandemic, increasing the gap between operating revenues and operating costs.

The price of alternative travel modes, namely driving, is another important factor affecting the demand for public transport. Cross-price elasticities between demand for public transport and fuel prices (i.e., the main indicator for the cost of driving) reveal there is a clear substitution between public transport and driving. Furthermore, this effect becomes stronger in the medium and longer term as people adjust their behaviour to the new relative prices. Accessibility to free or under-priced parking is also a major predictor of driving.

3 | DATA AND METHODOLOGY

This section provides a description of the variables, and respective data sources, collected to analyse travel patterns in Lisbon and its metropolitan area in the recent past. Describing travel patterns in Lisbon, and more generally in Portugal, is challenging owing to the lack of regular measurement tools. Travel surveys are carried out occasionally, ruling out the possibility of developing longitudinal studies. Consequently, the majority of travel-related analyses rely on the population censuses, which collect data on commuting distances, commuting times and main transport modes every 10 years.

The most recent travel survey was carried out in 2017 by Portugal’s Statistics Office (INE) and covered the municipalities of Lisbon and Porto metropolitan areas: Inquérito à Mobilidade nas Áreas Metropolitanas do Porto e de Lisboa, IMob 2017 (INE, 2018). The IMob travel survey contains information for different types of statistical units, namely households, individuals, vehicles and trips. The survey is organized into different sections, collecting information on residential location, household size and characterization of its members (e.g., age, gender, education, occupation), household income, characterization of individual travel mobility (e.g., travel distance, travel time, mode of transport), characterization of vehicles available, daily trips (e.g., destination, mode of transport, purpose), expenditures with transport (e.g., fuel, parking, tolls, public transport) and individual opinions about/motivations for using the car or public transport in regard to comfort, safety, accessibility, travel time, cost, etc.1 The IMob is the best, most recent and detailed data on travel behaviour and mobility patterns in Lisbon and its metropolitan area before the pandemic. To analyse travel demand during the pandemic, it was necessary to collect data from a range of sources, including public transport operators, Statistics Portugal, Lisbon municipality and the Institute for Transport and Mobility (IMT). Table 1 provides a summary of the data used in the empirical analyses.

The collection of data from different sources to obtain repeated time series data for local travel has some limitations. One limitation is that we cannot say anything about the evolution of modal split in the period studied, despite having time series data for public transport operators, traffic counts and cyclist counts. Another limitation is that the data do not permit identifying modal shift between transport modes due to specific events such as COVID-19. This is unfortunate given its importance for policy-making. Consequently, it is very difficult to unveil the underlying causes of changes in travel mobility patterns, notably the distinction between size effects (i.e., a genuine reduction in mobility) and composition effects (i.e., a shift in mobility between travel modes). This distinction is fundamental for public policy.

The methodology consists of two sets of empirical analyses. The first analysis describes travel patterns in Lisbon before the pandemic using data from the aforementioned IMob 2017 travel survey (i.e., Section 4.2). The second analysis describes travel demand after and during the pandemic using monthly data between 2018 and 2021 on the (i) number of passengers using the main public transport modes; (ii) traffic counts for the main urban motorways and

1The reference day for the description of travel mobility corresponds to the day before the date of responding to the survey. The number of responding households and individuals for the metropolitan area (Lisbon) was 27911 and 62712 (6306 and 12890), respectively. Households were sample from 49 zones, which were defined using clustering analysis methods based on indicators relating census-based information on mobility patterns, and the availability and proximity to the transport network, notably motorway access nodes, public transport terminals and stations.
| Variables | Data source | Data type | Data provider |
|-----------|-------------|-----------|---------------|
| **2017**  | Car ownership, modal split, mean distances and travel times | Inquérito à Mobilidade nas Áreas Metropolitanas do Porto e de Lisboa, IMob 2017. | Cross-sectional | Statistics Portugal (INE) |
| **2018, 2019, 2020, 2021** | Average daily traffic in main urban motorways and arterial roads connecting Lisbon to the rest of the metropolitan area | Relatório de Tráfego na Rede Nacional de Autoestradas. | Time series, monthly | Instituto da Mobilidade e dos Transportes (IMT) |
| Metro passengers – Metro de Lisboa | Inquérito ao Transporte por Metropolitano (IMTM). | Time series, monthly | Statistics Portugal (INE) |
| Bus passengers – CARRIS | Inquérito ao Transporte Rodoviário de Passageiros (ITRP); direct inquiry. | Time series, monthly | Statistics Portugal (INE); CARRIS |
| Ferry passengers – Soflusa & Transtejo | Inquérito ao Transporte fluvial (ITF). | Time series, monthly | Statistics Portugal (INE) |
| Rail passengers – Fertagus | Inquérito ao Transporte por Caminho de Ferro; Fertagus train operator. Direct inquiry. | Time series, monthly | Statistics Portugal (INE); Fertagus |
| Rail passengers – CP | | | |
| Average number of cyclists per hour | Moura et al. (2021) | Repeated cross-sectional | Lisbon municipality |

*https://www.imt-ip.pt/sites/IMTT/Portugues/InfraestruturasRodoviarias/RedeRodoviaria/Paginas/Relatorios.aspx.
arterial roads serving Lisbon; and (iii) the number of cyclists based on bi-annual cycle counting campaigns (i.e., Section 4.3).

Figure 1 shows a map of public transport systems serving Lisbon and the other municipalities of the metropolitan area. Appendix B shows a map of the metropolitan area and its 18 municipalities. There is one municipal bus operator in Lisbon (i.e., CARRIS), operating essentially within the borders of the municipality, whereas bus services in the other municipalities of the metropolitan areas are provided by ten private operators. There are two railway operators, the state-owned Comboios de Portugal (CP), which is the main rail operator in the country, and the private rail operator Fertagus, which connects the north and south banks of the metropolitan area. There are also two metro operators: the state-owned Lisbon metro (ML), which functions mostly within its borders, and the privately owned light rail system MST in Almada connecting to the Fertagus railway corridor (MSL and Fertagus are owned by the same private group). There are also ferry connections between Lisbon and Almada operated by the state-owned operator Transtejo & Softusa. Figure 2 shows the main trunk roads in the metropolitan area, that is, principal itineraries (IP), secondary itineraries (IC), national roads (EN) and regional roads (ER). The main motorways

![Figure 1: Public transport services in Lisbon metropolitan area. Source: www.aml.pt](image-url)
connecting Lisbon to the other parts of the metropolitan area include the northbound A1/IC2 corridor, the southbound IP7-A2 corridor, the westbound A5 corridor, the northwest-bound IC19, IC17/A36 and A8 corridors, and the eastbound IP7 corridor.

4 | MOBILITY PATTERNS BEFORE AND DURING THE COVID-19 PANDEMIC

4.1 | Overview of COVID-19 phases and the impact on public transport operators

So far, there have been two major lockdown periods in Portugal. The first lockdown state of emergency was declared on 19 March 2020 and lasted until 2 May 2020, after which the country moved into a calamity status until 30 June. Between 1 July and 14 September 2020, the country lived in a general alert status, although some areas of Lisbon metropolitan area remained in a contingency status with more stringent lockdown restrictions on travel mobility. From 15 September until 14 October 2020, there was a new general contingency status with specific teleworking arrangements in the metropolitan areas. From 15 October to 8 November 2020, the country moved into a calamity status with limited cross-municipality mobility. From 9 November 2020 until 7 January 2021, the country re-entered a state of emergency, but there was an exceptional easing of restrictions on mobility during the Christmas period.
The state of emergency was continually renewed until 15 March 2021, after which the government rolled out a plan for the re-opening of the economy, in tandem with a cohort-based vaccination plan for the population. As of 15 November 2021, approximately 87% of the population had been vaccinated and domestic travel mobility conditions were essentially the same as in pre-pandemic times. Appendix A provides a diagrammatic overview of the pandemic phases in terms of the severity of constraints on travel mobility and social meetings.

Public transport operators responded to the decline in travel demand by reducing the level of services provided while maintaining designated minimum service levels (i.e., 50% of usual pre-pandemic winter frequency level) for essential workers and travel. Passenger levels were limited to either one-third or two-thirds of the maximum capacity, depending on the severity of the pandemic and lockdown status, a limitation which was abolished only in August 2021. According to a report produced by the transport authority for Lisbon metropolitan area (TML, 2021), whilst the level of services provided by public transport operators had resumed to pre-pandemic levels in September 2020, demand remained well below pre-pandemic levels. The number of monthly travel cards sold by all public transport operators in the metropolitan area between April and December 2020, compared with the same period in 2019, varied between 12% (April) and 65% (October). In addition, passenger numbers in 2020 were only about 57% of the passengers transported in 2019. Although comprehensive comparable data for 2021 are not yet available, the statistics reported by the different public transport operators suggest that passenger numbers are still considerably below pre-pandemic levels, whilst service levels are at least as high as before the pandemic. The widening gap between operating revenues and costs has worsened the deficits faced by public transport operators, putting at risk their financial sustainability. To compensate public transport operators for the increasing operating deficits, the national government created bespoke legislation allowing for the allocation of pre-existing funds to COVID-19 financial support (i.e., PART,3 PROTransP4 and funding for discounted travel cards for children, students and the elderly).

4.2 | Mobility patterns in Lisbon and the metropolitan before the COVID-19 pandemic

Mobility patterns in Lisbon and its metropolitan area are strongly car dependent. According to data from the decennial censuses and the recent IMob travel survey, car use increased drastically over the past 40 years: from 13% of total commuting trips in 1981 to 22% in 1991, 43% in 2001, 54% in 2011 and 59% in 2017. In contrast, commuting by public transport decreased from 62% in 1981 to 47% in 1991, 34% in 2001, 28% in 2011 and 16% in 2017 (INE, 1992; INE, 2002; INE, 2003; INE, 2012; INE, 2018). If we consider trips for all purposes, walking and cycling accounted for 23% and 0.5% of trips, respectively, according to the IMob travel survey carried out in 2017. There are no data referring specifically to cycling in the decennial censuses.

In this section, I provide a brief characterization of travel patterns in Lisbon and the metropolitan area, based on the recent IMob travel survey, in terms of car ownership, travel distance and travel time by transport mode for intra- and cross-municipality travel. Where possible, I focus specifically on commuting data and their characteristics because of the direct effects of working from home on this type of trip. I also distinguish between municipalities according to data availability (see Appendix B for a map of the 18 municipalities in the metropolitan area).

Level of car ownership varies across municipalities, with lower values observed for municipalities with higher population density (Table 2). This is a well-known regularity in travel demand: denser areas tend to have shorter journeys and can sustain better public transport systems, ceteris paribus, contributing to lower levels of car use.

---

1For detailed information about vaccination levels in Portugal see: https://www.vacinacaocovid19.pt.
2Programa de Apoio à Redução Tarifária (PART). PART is a national programme aiming to reduce the negative externalities resulting from car-based mobility, notably road congestion, the emission of greenhouse gases, atmospheric pollution, noise, energy consumption and social exclusion.
3Programa de Apoio à Densificação e Reforço da Oferta de Transporte Público (PROTransP). PROTransP is a national programme providing financial support to the inter-municipal communities, which correspond to NUTS3 regions in Portugal, for the development of policies and measures that increase the provision of public transport services in areas where car-dependency levels are higher and public transport use is lower, revealing a great potential for modal shift in favour of public transport.
Car ownership also increases with income level, which tends to be higher in denser urban areas owing to agglomeration economies (e.g., D’Costa & Overman, 2014; Melo & Graham, 2009). On average, across the metropolitan area, 61% of households have one car, 29% of households have two cars and 6% of households have three or more cars. The mean number of cars per household, considering only households with at least one car, is 1.44 for the whole metropolitan area and ranges between 1.30 for Amadora and 1.55 cars for Alcochete and Cascais. The share of households owning at least one car is very high, exceeding 90% in all municipalities; the share of households with three or more cars is also considerable, ranging between 4% for Almada and Amadora and 8% for Alcochete, Barreiro and Palmela.

Given the high levels of car ownership, it is not surprising to observe, in Table 3, that the car is the main travel mode, accounting for 59% of all trips in the metropolitan area and ranging between 45% of all trips in Lisbon and 78% of all trips in Mafra. In 7 out of the 18 municipalities, at least two-thirds of all trips are made using the car. Public transport (i.e., bus, metro, train, ferry) accounts for a maximum of 21% of total trips in Lisbon, followed by Almada and Odivelas with 19% each, Amadora, Barreiro and Loures with 18% each, and Seixal and Sintra with 15% each. The remaining municipalities have substantially lower levels of public transport use. Compared with other European capital cities, Lisbon has relatively worse performance in terms of public transport use, even when compared with its

### Table 2: Car ownership by municipality

| Municipality      | Population | Share population (%) | Population density (people per km²) | Percentage of households with 0, 1, 2 or 3+ cars | Mean number of cars |
|-------------------|------------|-----------------------|-------------------------------------|-----------------------------------------------|--------------------|
|                   |            |                       |                                     | 0    | 1    | 2    | 3+   |                   |                    |
| Alcochete         | 19,020     | 0.67                  | 148                                 | 3.2  | 52.5 | 36.0 | 8.4  | 1.55              |                    |
| Almada            | 169,330    | 6.00                  | 2,419                               | 5.3  | 62.4 | 28.2 | 4.2  | 1.39              |                    |
| Amadora           | 178,169    | 6.32                  | 7,492                               | 5.4  | 70.2 | 20.2 | 4.2  | 1.30              |                    |
| Barreiro          | 75,978     | 2.69                  | 2,088                               | 2.1  | 61.3 | 28.4 | 8.1  | 1.48              |                    |
| Cascais           | 210,889    | 7.47                  | 2,165                               | 3.5  | 52.9 | 36.3 | 7.3  | 1.55              |                    |
| Lisboa            | 504,964    | 17.90                 | 5,047                               | 4.4  | 66.1 | 24.9 | 4.5  | 1.36              |                    |
| Loures            | 207,567    | 7.36                  | 1,241                               | 4.9  | 57.7 | 32.2 | 5.1  | 1.45              |                    |
| Mafra             | 82,581     | 2.93                  | 283                                 | 4.8  | 54.0 | 34.7 | 6.4  | 1.51              |                    |
| Moita             | 64,767     | 2.30                  | 1,172                               | 4.7  | 61.9 | 26.0 | 7.4  | 1.44              |                    |
| Montijo           | 55,742     | 1.98                  | 160                                 | 3.8  | 57.4 | 31.3 | 7.5  | 1.49              |                    |
| Odivelas          | 156,083    | 5.53                  | 5,881                               | 1.6  | 66.5 | 25.5 | 6.3  | 1.40              |                    |
| Oeiras            | 174,249    | 6.18                  | 3,798                               | 2.9  | 57.3 | 32.8 | 6.9  | 1.50              |                    |
| Palmela           | 64,146     | 2.27                  | 138                                 | 5.8  | 54.0 | 32.1 | 8.1  | 1.53              |                    |
| Seixal            | 165,123    | 5.85                  | 1,730                               | 2.2  | 65.0 | 28.2 | 4.6  | 1.39              |                    |
| Sesimbra          | 50,972     | 1.81                  | 260                                 | 5.6  | 56.5 | 30.8 | 7.1  | 1.49              |                    |
| Setúbal           | 116,979    | 4.15                  | 508                                 | 3.8  | 57.5 | 32.1 | 6.6  | 1.48              |                    |
| Sintra            | 383,946    | 13.61                 | 1,203                               | 2.0  | 62.4 | 29.4 | 6.2  | 1.44              |                    |
| Vila Franca de Xira | 140,844   | 4.99                  | 443                                 | 3.3  | 57.5 | 34.1 | 5.2  | 1.47              |                    |
| AML               | 282,1349   | 100                   | 936                                 | 3.7  | 61.2 | 29.3 | 5.8  | 1.44              |                    |

Notes: 1Considering households with at least one car. The figures reported were estimated using sampling weights for households.

Source: Author, based on IMob 2017 microdata.

(e.g., Cervero & Kockelman, 1997). Car ownership also increases with income level, which tends to be higher in denser urban areas owing to agglomeration economies (e.g., D’Costa & Overman, 2014; Melo & Graham, 2009). On average, across the metropolitan area, 61% of households have one car, 29% of households have two cars and 6% of households have three or more cars. The mean number of cars per household, considering only households with at least one car, is 1.44 for the whole metropolitan area and ranges between 1.30 for Amadora and 1.55 cars for Alcochete and Cascais. The share of households owning at least one car is very high, exceeding 90% in all municipalities; the share of households with three or more cars is also considerable, ranging between 4% for Almada and Amadora and 8% for Alcochete, Barreiro and Palmela.

Given the high levels of car ownership, it is not surprising to observe, in Table 3, that the car is the main travel mode, accounting for 59% of all trips in the metropolitan area and ranging between 45% of all trips in Lisbon and 78% of all trips in Mafra. In 7 out of the 18 municipalities, at least two-thirds of all trips are made using the car. Public transport (i.e., bus, metro, train, ferry) accounts for a maximum of 21% of total trips in Lisbon, followed by Almada and Odivelas with 19% each, Amadora, Barreiro and Loures with 18% each, and Seixal and Sintra with 15% each. The remaining municipalities have substantially lower levels of public transport use. Compared with other European capital cities, Lisbon has relatively worse performance in terms of public transport use, even when compared with its
main Iberian neighbours Madrid and Barcelona, which have a share of public transport use of circa 40% and 30%, respectively (Urban Audit, 2011).

With regard to trip distance and travel time by travel mode and purpose, Table 4 shows that, for work-related journeys, people using the car spend, on average, 25 min (15 km) travelling, in contrast to 41 min for bus (18 km) and metro (9 km), and 51 min (19 km) for train. The respondents using the bicycle for work-related trips spend, on average, 32 min (8 km) travelling. These figures provide further evidence of low public transport performance in relation to other modes of travel.

Table 5 and Figure 3 reveal interesting differences in travel patterns and modes across municipalities. Despite the mean distances and travel times of intra-municipal trips being substantially shorter compared with inter-municipal trips, they are nonetheless heavily based on car use. Amadora and Lisboa have the lowest levels of car use, each with 39% of all intra-municipal trips compared with the metropolitan-wide value of 53%. In contrast, Mafra and Cascais have the highest levels of car use, with nearly 75% and 68% of all intra-municipal trips done by car, respectively. Lisbon has the highest public transport use for intra-municipal trips, with 25% of all trips. Despite the short distances travelled – the mean travel distance of intra-municipal trips in the metropolitan area is 3.7 km – mobility is still heavily dependent on private motorized vehicles, which is further evidence of an inefficient and unsustainable mobility system in the metropolitan area. Considering inter-municipal trips, the lowest shares of car use are recorded again for Lisbon and Amadora with 62% and 68%, respectively, whereas the highest shares are reported for Mafra (95%), Montijo (85%), Setúbal (85%) and Cascais (84%).
To gain a better understanding of the effects of the pandemic on travel mobility in Lisbon, I collected monthly data between 2018 and 2021 for the number of passengers transported by the main public transport operators and mean daily traffic on the main arterial roads serving the city. It is difficult to separate the effect of COVID-19 from the ‘natural trend’ in travel patterns before the pandemic, especially because the implementation of the PART programme in April 2019 changed the structure and pricing of public transport in Lisbon metropolitan area in a drastic way. Programa de Apoio à Redução Tarifária (PART) is a national programme introduced in 2019 by the Portuguese government with the objectives of increasing public transport use, mitigating the effect of the negative externalities of car use and promoting greater territorial cohesion. It provides financial support to transport authorities to reduce the price of travel cards and to coordinate public transport services with the aim of improving service levels; most of the financial support was used to reduce the price of travel cards. In the case of Lisbon metropolitan area, the myriad of existing travel cards was replaced with a single travel card for the municipality and the metropolitan area, costing 30€ and 40€, respectively. Before PART, the price of travel cards varied with distance to Lisbon, with values over 100€ for the more peripheral municipalities. PART represented savings of more than 60% for five municipalities and between 50% and 60% for four municipalities (Figure 4). According to the evaluation report published by the Institute for Transport and Mobility (IMT, 2020), there was an immediate increase in public transport demand: between May and December 2019, passenger numbers and travel card sales rose by 18% and 25%, respectively, together with a reduction in the sales of occasional tickets. Consequently, the analysis carried out in the paper cannot assess the effect of the pandemic, and home working, on the change in travel demand levels in 2020 and 2021, compared with 2019 (after PART) and 2018 (before PART). Nevertheless, it can provide indicative evidence on the overall effect of the full and partial lockdowns due to the pandemic (including the effects of teleworking, teleshopping, psychological effect of fear of virus spreading in public transport, etc.), as well as other factors relating to public transport operators’ decisions on service levels, schedule and safety measures.

Figures 5 and 6 show the monthly change in passenger number by public transport operator and mean daily traffic count between 2018 and 2021, respectively. The values are reported as a monthly fixed base index for 2018, measuring the percentage change in relation to the respective month in 2018. The figures for the absolute number of passenger and traffic counts are reported in Appendix C.
### Table 5: Inter- and intra-municipal trips by transport mode, mean distance and travel time, by municipality

| Metropolitan area | Intra-municipal trips | Inter-municipal trips |
|-------------------|-----------------------|-----------------------|
|                   | % intra-municipal trips\(^1\,^2\) | Mean distance\(^3\) | Mean travel time\(^4\) | % trips by car\(^5\) | % trips by public transport\(^5\) | Mean distance\(^6\) | Mean travel time\(^7\) | % trips by car\(^8\) | % trips by public transport\(^8\) |
| Metropolitan      | 65.4                  | 3.7                   | 16.6                   | 53.2                  | 11.2                  | 16.4                   | 35.0                   | 70.8                  | 25.0                  |
| area              |                       |                       |                       |                       |                       |                       |                       |                       |                       |
| Alcochete         | 56.3                  | 2.3                   | 10.3                   | 61.1                  | 4.1                   | 19.3                   | 30.8                   | 79.3                  | 18.0                  |
| Almada            | 68.5                  | 4.4                   | 16.7                   | 55.4                  | 14.1                  | 15.0                   | 33.3                   | 72.5                  | 20.9                  |
| Amadora           | 57.1                  | 2.6                   | 12.2                   | 38.7                  | 7.3                   | 11.1                   | 30.8                   | 67.8                  | 25.5                  |
| Barreiro          | 65.7                  | 3.1                   | 12.9                   | 56.0                  | 7.3                   | 18.8                   | 31.6                   | 69.9                  | 23.7                  |
| Cascais           | 71.3                  | 4.2                   | 14.7                   | 67.7                  | 6.6                   | 20.1                   | 35.8                   | 83.5                  | 14.7                  |
| Lisboa            | 63.4                  | 4.2                   | 23.1                   | 39.3                  | 24.6                  | 16.8                   | 40.0                   | 61.9                  | 34.9                  |
| Loures            | 58.1                  | 3.5                   | 14.8                   | 54.6                  | 9.5                   | 13.9                   | 31.3                   | 73.2                  | 22.1                  |
| Mafra             | 80.4                  | 5.0                   | 13.0                   | 73.4                  | 6.3                   | 29.2                   | 36.3                   | 94.9                  | 4.6                   |
| Moita             | 66.2                  | 2.0                   | 10.6                   | 41.2                  | 5.5                   | 17.0                   | 29.3                   | 68.2                  | 21.5                  |
| Montijo           | 68.5                  | 3.3                   | 12.3                   | 59.3                  | 2.5                   | 20.3                   | 30.3                   | 85.4                  | 13.1                  |
| Odivelas          | 58.6                  | 2.4                   | 13.8                   | 50.0                  | 7.1                   | 11.4                   | 32.3                   | 69.1                  | 26.8                  |
| Oeiras            | 54.4                  | 2.9                   | 13.9                   | 59.6                  | 6.4                   | 13.3                   | 32.0                   | 77.5                  | 18.8                  |
| Palmela           | 62.3                  | 3.7                   | 13.0                   | 63.5                  | 7.0                   | 19.3                   | 30.0                   | 79.5                  | 18.3                  |
| Seixal            | 68.3                  | 3.7                   | 18.2                   | 57.0                  | 5.0                   | 16.5                   | 33.4                   | 69.9                  | 24.2                  |
| Sesimbra          | 68.9                  | 4.0                   | 15.0                   | 64.8                  | 1.3                   | 19.6                   | 33.9                   | 85.4                  | 10.0                  |
| Setúbal           | 79.9                  | 3.4                   | 13.9                   | 64.4                  | 3.7                   | 23.8                   | 37.4                   | 73.6                  | 18.6                  |
| Sintra            | 69.3                  | 4.1                   | 15.0                   | 61.2                  | 6.3                   | 17.0                   | 35.8                   | 72.4                  | 24.2                  |
| Vila Franca de Xira | 74.9              | 3.5                   | 14.3                   | 51.3                  | 4.9                   | 22.0                   | 38.8                   | 69.2                  | 26.2                  |

Notes: \(^1\)The share of incoming trips only considers trips within the metropolitan area. \(^2\)Based on Table V.1 of the dataset containing the results for Lisbon metropolitan area. \(^3\)Based on Table V.6 of the dataset containing the results for Lisbon metropolitan area. \(^4\)Based on Table V.7 of the dataset containing the results for Lisbon metropolitan area. \(^5\)Based on Table V.8 of the dataset containing the results for Lisbon metropolitan area. \(^6\)Based on Table VI.10 of the dataset containing the results for Lisbon metropolitan area. \(^7\)Based on Table VI.11 of the dataset containing the results for Lisbon metropolitan area. \(^8\)Based on Table V.12 of the dataset containing the results for Lisbon metropolitan area.

Source: Author, based on municipal-level tables from IMob 2017.
Figure 5 shows a continuous year-on-year increase in public transport demand until February 2020, after which there is a sudden drop in passenger numbers due to the implementation of the first full lockdown to reduce the spread of COVID-19. Public transport demand between April 2019 and February 2020 shows relatively stronger growth rates, which might partially reflect the reduction in the user cost of travel cards following the introduction of the PART programme in April 2019. Interestingly, Figure 6 shows that traffic demand between April 2019 and February 2020, compared with the same period in 2018, decreased in some parts of the trunk road network, notably traffic crossing the bridge 25 de Abril (which is also served by the Fertagus rail operator). These travel trends are in line with the conclusions of the aforementioned study of the impact of PART carried out by IMT (2020).

After March 2020, following the introduction of the first lockdown period due to the COVID-19 pandemic, we observe a drastic and immediate drop in car traffic and public transport demand. In the case of public transport, the reduction in monthly passengers in relation to March 2019 ranged between 50% (CARRIS) and 74% (Fertagus). Traffic volumes in March 2020 dropped to about two-thirds the values recorded in March 2019. April 2020 was
the first full month of lockdown and compulsory home working, recording the lowest values of travel mobility since the start of the pandemic. Travel mobility recovered gradually from May to August/September 2020, after which it reduced again because of the new constraints imposed on travel owing to the increase in the number of COVID-19 infections and deaths. The declaration of the second lockdown state of emergency in November 2020, lasting until mid-March 2021, led to another fall in travel demand, with monthly figures typically below 50% of 2019 pre-pandemic values. The first 3 months of 2021 registered the lowest values of travel mobility, but since then we can observe a steady recovery. The recovery is especially notable for car use, with traffic figures recorded across the main urban motorways and arterial roads serving Lisbon in the third quarter of 2021 at nearly the level of 2018 and 2019 (Figure 6). The recovery is more heterogeneous for public transport (Figure 5): whereas passenger numbers for rail and bus services exceeded 70% (80–90%) of 2019 (2018) pre-pandemic levels by August–September 2021, metro demand remained below 60% of 2018 and 2019 pre-pandemic levels for the same period.

Although it is not possible to make any causal claims about the effect of home working on travel demand, the limited information on home working available for Portugal is indicative of a large effect. Data from EUROSTAT’s Labour Force Survey shows that the percentage of employed persons working from home in Portugal jumped from 6% to 7% between 2011 and 2019, and to 14% in 2020, which can only be explained by the COVID-19 lockdowns. The only other source of information on home working, particularly during the pandemic, is the bespoke rapid survey Inquérito Rápido e Excepcional às Empresas COVID-19 (COVID-IREE), carried out jointly by the Bank of Portugal and Statistics Portugal to assess the effects of the pandemic on the economy. The COVID-IREE collects information on various economic dimensions of private sector businesses (excluding the financial sector), asking specific questions about home working. It was implemented between the second half of April 2020 and July 2020, after which it was suspended given the positive evolution of the pandemic situation. The worsening of the COVID-19 pandemic in the fourth quarter of 2020 led to the implementation of additional, occasional, editions (i.e., November 2020 and February 2021). According to the COVID-IREE, the percentage of firms with more than 75%, 50% and 25% of the workforce on teleworking ranged between 10% (July 2020) and 16% (April 2020), 12% (July 2020) and 20% (April 2020), and 16% (July 2020) and 26% (April 2020), respectively. It is difficult to predict future trends in teleworking.

5https://ec.europa.eu/eurostat/databrowser/view/lfsa_ehomp/default/table?lang=en.
6https://webinq.ine.pt/public/pages/queryinfo.aspx?id=COVID-IREE.
7There have been recent changes to the country’s teleworking legal framework, with effect from 1 January 2022, which may facilitate the wider adoption of teleworking. For more information on Law Nr. 83/2021, see: https://www.pgdlisboa.pt/leis/lei_mostra_articulado.php?nid=3483&tabela=leis.
for Portugal, but the recent advances in its legal framework, with effect from 1 January 2022, may facilitate its adoption.8

The discussion of Figures 5 and 6 suggests the following tentative conclusions. The first conclusion is that driving has recovered faster than public transport, and in some cases already reached (or even surpassed) pre-pandemic traffic and congestion levels.9 The second conclusion is that the increase in traffic levels is likely to result partly from the substitution of public transport trips. In fact, given that teleworking is still a recommended practice adopted by many employers, the nearly full recovery of driving can only be understood in the presence of modal shifting from public transport to driving.

8See Law Nr. 83/2021: https://www.pgdlisboa.pt/leis/lei_mostra_articulado.php?nid=3483&tabela=leis.
9For more details, see Lisbon Traffic Report: https://www.tomtom.com/en_gb/traffic-index/lisbon-traffic/.

FIGURE 5  Public transport demand in Lisbon, suburban rail & ferry connections (2018 = 100). Source: Author, based on data collected from INE and directly obtained from public transport operators. Note: Passenger numbers for the rail operator CP refer to the three main urban agglomerations in Portugal: Lisbon, Porto and Coimbra
Although there is no information on which public transport trips are being substituted for, the low(er) patronage levels for the metro operator suggest that these journeys may be particularly affected. Metro journeys are mostly limited to Lisbon municipality (there are only a few stations outside Lisbon) and tend to be shorter than other public transport journeys (Table 4). This means that shorter, urban, trips previously done by metro may now be done using the car or active travel. The observed rise in micromobility systems in Lisbon, including personal and shared e-bikes

**FIGURE 6** Mean daily traffic in urban motorways and arterial roads serving Lisbon (2018 = 100). Source: Author, based on data collected from IMT quarterly traffic reports
and shared e-scooters (e.g., Félix et al., 2020; Moura et al., 2021), may account for part of the substitution of metro trips (and public transport more generally).

The implementation of temporary cycling infrastructure during the pandemic may also help explain the rise in the use of active travel in the city (e.g., Moura et al., 2021). The best comparable data available consist of manual counting campaigns carried out in May and October since 2017 in the same locations and over the same time periods, summarized in the CML-Ativos report by Moura et al. (2021), which shows that the number of cyclists observed on the same 19 spots and over the same time periods increased by 87% between 2017 and 2018, 10% between 2018 and 2019, and 30% between 2019 and 2020, whilst decreasing by 5% between 2020 and 2021. However, the data for 2021 refer only to the May campaign, preventing any definite conclusions for that year. Furthermore, the observed reduction is not likely to be representative of total cycling in Lisbon in 2021 because the expansion of the cycling network created alternative routes, increasing cycling on new parts of the cycling and road networks, many of which were not in the original 19 spots (see Figure 1 of Moura et al., 2021). Moreover, some new segments of active travel increased considerably, notably e-bikers and e-scooters (Moura et al., 2021). The creation of a financial ‘mobility fund’ in June 2020 by the municipality, in addition to the national mobility fund, to support the acquisition of conventional and electric bicycles by residents, also increased the demand for new bicycles. The increase in bicycle sales registered by sports and/or bike shops may partly result from the public financial support provided by the local and national governments, and is also indicative of a strong increase in cycling in Lisbon. Both trends – that is, increase in bicycle sales and use during the pandemic – have been observed in other cities worldwide in tandem with the provision of temporary cycle lanes (Moreno et al., 2021).

In a nutshell, travel behaviour as we move out of COVID-19 (or live with it in a vaccinated world), in the more immediate short term, appears to mean a business-as-usual scenario in terms of car use. The main reason seems to be that public transport is being substituted by solo driving and active travel. This scenario presents a real concern that congestion and pollution will return to pre-COVID-19 levels. Reversing new solo driving habits will be very difficult in the future because, once people have a car, they feel that they must justify the past investment cost even if it implies spending more money than if they opted for an alternative transport mode (i.e., sunk cost fallacy irrational decision). Although car sales fell during the lockdown periods, the effect was asymmetric in that it affected especially the sales (and imports) of new cars, whereas the sales of used cars actually increased as the economy re-opened. There are still many incentives to drive, particularly through the provision of free or under-priced parking in the municipality. According to the IMob 2017 travel survey, 41% of resident household cars in Lisbon park for free on the curbside, while 28% pay a heavily subsidized resident parking permit for up to three cars: no cost for the first car, 30€ per annum for the second car and 120€ per annum for the third car. Parking at the workplace is also heavily under-priced: 50% (27%) of workers report having free parking at their workplace (public space).

5 | FUTURE TRAVEL MOBILITIES IN POST-COVID-19 VACCINATED LISBON

The COVID-19 health crisis created two major disruptions with potential long-lasting effects on travel behaviour. The first disruption refers to the change in working practices; in particular, the mainstreaming of working from home has become an accepted practice in many occupations and industries. The second major disruption refers to the

---

10Monitoring bicycle usage in Lisbon is difficult and essentially based on manual counts which have been carried out periodically in specific points of the city. The number of counting stations increased gradually in tandem with the expansion of the cycling network and the implementation of the public bike sharing system. Despite the acquisition of 50 automatic counters in 2021, only a small number have been installed. Occasionally there are road-side surveys funded by the municipality asking cyclists basic questions about where they are travelling to/from as well as the frequency of bicycle use. These data are not publicly available.

11https://www.dn.pt/dinheiro/industria-sem-pedalada-para-ritmo-da-procura-de-bicicletas-13803550.html.

12It is worth noting that the municipality stopped charging parking fees on the curbside and public car parks during the full and partial lockdowns, making car use further attractive.
negative shock affecting public transport systems owing to the perceived ‘bio-security’ risk of virus contamination. These two disruptions have created new challenges for public transport operators and may hinder the transition to a more sustainable urban mobility system.

Homeworking and more flexible working practices may not reduce the demand for travel, especially in the medium term, as individuals and households adjust residential location, with subsequent impacts on commuting distances (even if fewer trips are made) and travel mode choice. The net effect on travel demand, including the effect on congestion and air pollution, will depend on the characteristics of the built environment of the new residential locations, notably the availability and quality of public transport. If households favour larger homes and areas with more greenery, it is possible that teleworking will favour relocation to peripheral areas that are commutable, which in turn can reinforce urban sprawl and car use. This outcome is very much in line with the evidence from the literature on teleworking and travel demand, as discussed in section 2.1.

Even in the shorter term, that is, assuming fixed residential location, people may re-allocate the saved commuting time and money due to homeworking to other activities that may also require travel. Travel patterns may become more heterogeneous – in both space and time – because on teleworking days people may centre their activities and travel around their homes, whereas on commuting days they may centre their activities around the workplace. One consequence put forward by the literature on teleworking and travel demand, as discussed in section 2.1, is that the extent of trip chaining may decrease with a resulting increase in the number of trips and distances travelled. Likewise with residential relocation, the effects on travel mode choice are difficult to predict and will depend on the characteristics of the built environment of both the residential and workplace locations.

The main message is that working from home is not going to be the panacea for shifting towards more sustainable mobility patterns. In fact, as put forward by the literature on teleworking and travel demand, it may promote an overall increase in distance travelled even if there are fewer commuting trips. The fear of virus contamination in public transport may also contribute to greater car use because travelling in crowded buses or trains has become riskier than before the pandemic. To avoid crowding, public transport operators need to provide higher service frequency and capacity to ensure comfortable levels of social distancing. The fact that patronage remains considerably below pre-pandemic levels, but a more than proportional increase in operating capacity is required, leads to widening operating deficits and increases the need for subsidies, putting at risk the financial sustainability of public transport. Mainstream vaccination has helped mitigate the negative impact of fear of infection on patronage levels, but it may be insufficient, especially as new virus variants continue to emerge. One long-lasting consequence of the pandemic may be the change in individuals’ preferences from shared transport modes – notably public transport – to personal transport modes, including solo driving but also active micromobility. To avoid going back to pre-pandemic congested and polluted urban environments, local governments need to incentivize the latter over the former.

To understand how the pandemic is affecting travel behaviour in the present, and consider the possible future trends, we need better monitoring tools. Since there are no regular travel surveys in Lisbon (nor in Portugal), it is practically impossible to measure the effect of public policies on travel demand and use the evidence to guide future policy-making. Unsurprisingly, a major limitation of this study is thus its ability to measure the effects of the pandemic on travel mobility. It is therefore helpful to consider the existing evidence for other cities. The international evidence from recently published studies using bespoke stated preference and/or revealed preference surveys to study the effects of the COVID-19 and working from home on travel behaviour seems to be mixed. This is not surprising given that cities differ not only in terms of the characteristics of their built environment and transport systems, but also in relation to the measures adopted by local governments in response to the pandemic. Some authors are optimistic and conclude that working from home can reduce congestion levels (e.g., Hensher et al., 2021), whereas other scholars suggest that future mobility patterns can include a greater use of the private car (e.g., Currie et al., 2021; Schaefer et al., 2021). For example, Currie et al. (2021) conclude that public transport demand will remain at about 80% of its pre-pandemic level. Given the uncertainty about future outcomes, most studies point to the importance of carrying out ongoing monitoring of individuals’ travel behaviour (e.g., Beck et al., 2020; Wang et al., 2021).
CONCLUSION

This study provided a discussion of the likely effects of two major COVID-19-related disruptions on travel patterns in Lisbon, namely the adoption of widespread working from home and the ‘bio-security’ fear affecting public transport. Drawing on evidence from the literature on teleworking and travel demand and the determinants of public transport, together with a descriptive empirical analysis of travel mobility data before and during the pandemic, the study concludes that the pandemic may hinder, more than aid, the transition to a sustainable urban mobility paradigm in Lisbon and its metropolitan region.

Concerning working practices, although full-week working from home is most likely not viable in the future, weekly working from home and related flexible working practices (e.g., staggered working hours) are likely to stay common practice in post-COVID-19 economies. In the short term, the increase in household income budget and time budget can be used to engage in new activities which may or may not involve travel. Furthermore, the perceived health-related ‘bio-security’ fear of virus contamination, even in extensively vaccinated economies, may contribute further to the decline of public transport use in the short term. In the longer term, households may adjust their residential location, by relocating to more peripheral areas further away from their workplaces. Since people tend to prefer more space to less space, and space is more costly in urban areas, the increased disposable income and reduced commuting frequency can facilitate residential relocation outside urban areas and city centres where the quality of public transport is weaker. Consequently, a possible outcome may be a permanent rise in car use, congestion and its associated health and environmental negative externalities.

The empirical analysis of monthly data for travel demand by transport modes in Lisbon showed that car use recovered at a faster rate than public transport demand, reaching pre-pandemic levels in parts of the road network. This increase in car use is likely to result partly from a substitution of public transport trips by solo driving, although it is not possible to test this hypothesis. Among public transport modes, the recovery has been more sluggish for Lisbon’s metro system. Since metro trips tend to be shorter (i.e., the mean travelled distance is 9 km) and are essentially limited to the city of Lisbon, they may have been replaced not only by driving but also by active travel, namely micromobility services such as shared e-bikes and e-scooters. The main takeaway is that we seem to be observing a growing polarization of travel mobility, consisting of a rise in driving and active travel and a commensurate decline in public transport. Public transport operators are facing unforeseen challenges. The pandemic increased operating deficits and the need for additional public subsidies, raising concerns about the financial sustainability of public transport in the future.

Neither technological innovation (e.g., EVs, MaaS) nor social innovation (e.g., working from home and other flexible working regimes) will be sufficient to change the current car-based mobility paradigm. Innovative proximity-based urban planning solutions implemented during the pandemic (e.g., temporary cycle lanes, provision of proximity-based services) appear to have had some success in permitting people to travel while abiding by health and safety protocols and contributing to sustainability goals by avoiding car use (Moreno et al., 2021). Urban planning policies need to be re-defined in ways that favour public transport and active travel. This can be achieved by giving more space to these modes and less space to cars (including parking), planning for denser, more mixed land uses, and for proximity-based services. In addition to rethinking urban planning, local governments also need to eliminate existing economic incentives to drive, notably the under-pricing of car parking in urban areas. Without serious commitment by local and national governments, the pandemic is likely to be another missed opportunity to transition to a better, more sustainable, mobility system.

ACKNOWLEDGMENTS

The authors acknowledge financial support from FCT – Fundação para a Ciência e Tecnologia (Portugal) and national funding through the research grants UIDB/05069/2020, PTDC/EGEE/28805/2017 – Transport Infrastructure and Urban Spatial Structure: Economic, Social and Environmental Effects (TiTuSS) and PTDC/GES-GCE/4046/2021 – Growth or Relocation? Transport Accessibility and Economic Activity Location.
REFERENCES

Beck, M. J., Hensher, D., & Wei, E. (2020). The impact of COVID-19 on cost outlays for car and public transport commuting – the case of the greater Sydney metropolitan area after three months of restrictions. Journal of Transport Geography, 88, 1–17.

Cervero, R., & Kockelman, K. (1997). Travel demand and the 3ds: Density, diversity, and design. Transportation Research Part D: Transport and Environment, 2(3), 199–219. https://doi.org/10.1016/S1361-9209(97)00009-6

Choo, S., Mokhtarian, P., & Salomon, I. (2005). Does telecommuting reduce vehicle-miles traveled? An aggregate time series analysis for the U.S. Transportation, 32, 37–64. https://doi.org/10.1007/s11116-004-3046-7

Currie, G., Jain, T., & Aston, L. (2021). The impact of COVID-19 on cost outlays for car and public transport commuting – the case of the greater Sydney metropolitan area after three months of restrictions. Transportation Research Part A, 153, 218–234.

D’Costa, S., & Overman, H. G. (2014). The urban wage growth premium: Sorting or learning? Regional Science and Urban Economics, 48, 168–179. https://doi.org/10.1016/j.regsciurbeco.2014.06.006

de Abreu e Silva, J., & Melo, P. C. (2018a). Does home-based telework reduce household total travel? A path analysis using single and two worker British households. Journal of Transport Geography, 73, 148–162. https://doi.org/10.1016/j.jtrangeo.2018.10.009

de Abreu e Silva, J., & Melo, P. C. (2018b). Home telework, travel behaviour, and land use patterns: A path analysis of British single-worker households. Journal of Transport and Land Use, 11(1), 419–441. https://doi.org/10.5198/jtlu.2018.1134

De Vos, J. (2020). The effect of COVID-19 and subsequent social distancing on travel behavior. Transportation Research Interdisciplinary Perspectives, 5, 100–121. https://doi.org/10.1016/j.trip.2020.100121

Dong, H., Ma, S., Jia, N., & Tian, J. (2021). Understanding public transport satisfaction in post COVID-19 pandemic. Transport Policy, 101, 81–88. https://doi.org/10.1016/j.tranpol.2020.12.004

Félix, R., Cambra, P., & Moura, F. (2020). Build it and give’em bikes, and they will come: The effects of cycling infrastructure and bike-sharing system in Lisbon. Case Studies on Transport Policy, 8(2), 672–682. https://doi.org/10.1016/j.cstp.2020.03.002

Hamers, R., Kroes, E., & Van Oosttroom, H. G. (2014). The urban wage growth premium: Sorting or learning? Regional Science and Urban Economics, 48, 168–179. https://doi.org/10.1016/j.regsciurbeco.2014.06.006

d’Hulst, D., & Nilles, J. M., Conroy, P., & Fleming, D. M. (1991). Telecommuting as a transportation planning measure: Initial results of California pilot project. Transportation Research Record, 1285, 98–104.
Litman, T. (2004). Transit price elasticities and cross-elasticities. *Journal of Public Transportation*, 7, 37–58. https://doi.org/10.5038/2375-0901.7.2.3

Melo, P. C., & de Abreu e Silva, J. (2017). Home telework and household commuting patterns in Great Britain. *Transportation Research Part A: Policy and Practice*, 103, 1–24. https://doi.org/10.1016/j.tra.2017.05.011

Melo, P. C., & Graham, D. (2009) Agglomeration economies and labour productivity: Evidence from longitudinal worker data for GB’s travel-to-work areas. SERC/LSE discussion paper 31.

Melo, P. C., & Ramli, A. R. (2014). Estimating fuel demand elasticities to evaluate CO2 emissions: Panel data evidence for the Lisbon metropolitan area. *Transportation Research Part A: Policy and Practice*, 67, 30–46.

Mokhtarian, P. (2009). If telecommunication is such a good substitute for travel, why does congestion continue to get worse? *Transportation Letters*, 1(1), 1–17. https://doi.org/10.3328/TL.2009.01.01.1-17

Mokhtarian, P. L., Handy, S. L., & Salomon, I. (1995). Methodological issues in the estimation of the travel, energy, and air quality impacts of telecommuting. *Transportation Research Part A: Policy and Practice*, 29, 283–302.

Moreno, C., Allam, Z., Chabaud, D., Gall, C., & Pratlong, F. (2021). Introducing the “15-Minute City”: Sustainability, resilience and place identity in future post-pandemic cities. *Smart Cities*, 2021(4), 93–111. https://doi.org/10.3390/smcities4010006

Moura, F., Félix, R. & Reis, A. F. (2021). CML-Ativos: Monitorização e Avaliação do Impacte Socioeconómico de Modos Alternativos de Mobilidade. Relatório CERIS, EP n° 32/2021. CERIS, IST-Técnicos Lisboa.

Nelson, P., Safirova, E., & Walls, M. (2007). Telecommuting and environmental policy: Lessons from the e-commute program. *Transportation Research Part D: Transport and Environment*, 12(3), 195–207. https://doi.org/10.1016/j.trrd.2007.01.011

Nilles, J. M. (1991). Telecommuting and urban sprawl: Mitigator or inciter? *Transportation*, 18, 411–432. https://doi.org/10.1007/BF00186567

Padeiro, M. (2018). Dominação e reprodução da automobilidade: A rede de auto-estradas das áreas metropolitanas de Lisboa e Porto. Finisterra: Revista Portuguesa de Geografia, 53(108), 161–188. https://doi.org/10.18055/Finis12218

Paulley, N., Balcombe, R., Mackett, R., Titheridge, H., Preston, J. M., Wardman, M. R., Shires, J. D., & White, P. (2006). The demand for public transport: The effects of fares, quality of service, income and car ownership. *Transport Policy*, 13, 295–306. https://doi.org/10.1016/j.tranpol.2005.12.004

Pendyala, R. M., Goulas, K. G., & Kitamura, R. (1991). Impact of telecommuting on spatial and temporal patterns of household travel. *Transportation*, 18, 383–409. https://doi.org/10.1007/BF00186566

Rocha, B. T., Melo, P. C., Afonso, N. & de Abreu e Silva, J. (2021). Motorways, urban growth, and suburbanisation: Evidence from three decades of motorway construction in Portugal. Working Paper 0174–2021, REM Working Paper Series, May 2021.

Schaefer, K. J., Tuitjer, L., & Levin-Keitel, M. (2021). Transport disrupted – Substituting public transport by bike or car under Covid 19. *Transportation Research Part A*, 153, 202–217. https://doi.org/10.1016/j.tra.2021.09.002

TML. (2021) Relatório do desempenho sumário relativo ao Serviço Público de Transporte de Passageiros na Área Metropolitana de Lisboa de 2020 ao abrigo do Regulamento (CE) n.º 1370/2007. Relatório nr. 10/TML/2021. Transportes Metropolitanos de Lisboa, Agosto de 2021.

Urban Audit. (2011). Urban Audit Database. Data retrieved from: http://ec.europa.eu/eurostat/web/cities/data/database

Wang, D., Tayarani, M., He, B. Y., Gao, J., Chow, J. Y. J., Gao, H. O., & Ozbay, K. (2021). Mobility in post-pandemic economic reopening under social distancing guidelines: Congestion, emissions, and contact exposure in public transit. *Transportation Research Part A*, 153, 151–170. https://doi.org/10.1016/j.tra.2021.09.005

Zhu, P. (2012). Are telecommuting and personal travel complements or substitutes? *The Annals of Regional Science*, 48, 619–639. https://doi.org/10.1007/s00168-011-0460-6

Zhu, P., & Mason, S. G. (2014). The impact of telecommuting on personal vehicle usage and environmental sustainability. *International Journal of Environmental Science and Technology*, 11, 2185–2200. https://doi.org/10.1007/s13762-014-0556-5

How to cite this article: Melo, P. C. (2022). Will COVID-19 hinder or aid the transition to sustainable urban mobility? Spotlight on Portugal's largest urban agglomeration. *Regional Science Policy & Practice*, 1–27. https://doi.org/10.1111/rsp3.12518
APPENDIX A

Severity of restrictions on travel mobility and social meetings.

Legend
- Very high (state of emergency)
- High (state of emergency with phased re-opening plan)
- Medium (calamity status)
- Low or very low (contingency or alert status)

Notes:
- The announcement and renewal of COVID-19 status and restrictions was implemented on a fortnight or weekly basis, so the monthly summary is only indicative and may not reflect accurately changes in status conditions within the same month.
- Temporary travel mobility restrictions were implemented between Christmas and New Year.
FIGURE B1  Lisbon metropolitan area and its 18 municipalities. Source: Inquérito à Mobilidade nas Áreas Metropolitanas do Porto e de Lisboa 2017 (INE, 2018)
### TABLE C1  Monthly passengers by public transport operator

|                | CARRIS (10³) | Lisbon metro (10³) | Ferry boat |
|----------------|--------------|--------------------|------------|
|                | 2018 | 2019 | 2020 | 2021 | 2018 | 2019 | 2020 | 2021 | 2018 | 2019 | 2020 | 2021 |
| Jan            | 10,480 | 10,660 | 12,300 | 5,320 | 13,377 | 14,165 | 16,072 | 4,825 | 1,437,378 | 1,532,408 | 1,663,046 | 641,349 |
| Feb            | 9,650  | 10,410 | 11,850 | 3,750 | 12,483 | 13,691 | 15,223 | 2,900 | 1,300,320 | 1,476,127 | 1,599,214 | 451,498 |
| Mar            | 10,800 | 11,460 | 5,680 | 5,210 | 14,520 | 15,096 | 8,565 | 3,928 | 1,425,691 | 1,677,956 | 850,814 | 609,266 |
| April          | 10,560 | 11,280 | 30 | 6,530 | 14,181 | 15,076 | 2,662 | 5,423 | 1,387,130 | 1,562,287 | 306 | 739,206 |
| May            | 11,540 | 13,020 | 3,510 | 7,910 | 15,372 | 16,794 | 3,300 | 7,020 | 1,576,633 | 1,705,146 | 531,267 |
| Jun            | 10,480 | 10,880 | 5,210 | 8,320 | 13,790 | 14,550 | 4,800 | 6,823 | 1,467,059 | 1,511,525 | 741,747 |
| Jul            | 10,350 | 11,940 | 6,170 | 7,820 | 13,575 | 15,466 | 6,096 | 6,840 | 1,514,957 | 1,620,525 | 893,479 |
| Aug            | 8,790  | 10,100 | 6,000 | 7,230 | 11,959 | 12,958 | 6,080 | 6,719 | 1,434,028 | 1,573,942 | 914,023 |
| Sep            | 10,510 | 12,180 | 7,530 | 8,990 | 14,803 | 15,487 | 7,265 | 8,635 | 1,382,619 | 1,661,275 | 1,021,823 |
| Oct            | 11,880 | 13,880 | 7,930 | 9,300 | 16,520 | 18,220 | 7,852 | 9,300 | 1,675,784 | 1,823,372 | 1,022,860 |
| Nov            | 10,980 | 12,350 | 6,900 | 6,531 | 14,882 | 15,874 | 6,531 | 7,020 | 1,552,962 | 1,642,946 | 804,320 |
| Dec            | 9,650  | 11,330 | 6,180 | 6,113 | 13,706 | 15,698 | 6,113 | 6,840 | 1,481,629 | 1,575,705 | 765,108 |

|                | Train: Fertagus (10³) | Train: CP (10³) |
|----------------|----------------------|-----------------|
|                | 2018 | 2019 | 2020 | 2021 | 2018 | 2019 | 2020 | 2021 |
| Jan            | 1,803 | 1,938 | 2,521 | 961 | 10,968 | 11,634 | 14,469 | 7,429 |
| Feb            | 1,763 | 1,926 | 2,224 | 655 | 9,921 | 10,734 | 13,533 | 4,350 |
| Mar            | 1,761 | 1,846 | 1,369 | 891 | 10,629 | 10,966 | 7,559 | 5,726 |
| April          | 1,849 | 1,884 | 304 | 1,151 | 11,017 | 12,966 | 1,254 | 7,582 |
| May            | 1,860 | 2,246 | 685 | 1,433 | 11,688 | 14,015 | 4,352 | 9,240 |
| Jun            | 1,710 | 1,861 | 975 | 1,329 | 10,672 | 12,528 | 6,109 | 8,881 |

(Continues)
**TABLE C1 (Continued)**

| Train: Fertagus (10^3) | Train: CP (10^3) |
|------------------------|-----------------|
| 2018  | 2019  | 2020  | 2021  | 2018  | 2019  | 2020  | 2021  |
| Jul   | 1,506 | 2,160 | 1,127 | 1,339 | 10,942| 14,291| 8,228 | 9,566 |
| Aug   | 1,315 | 1,764 | 1,080 | 1,197 | 9,766 | 13,234| 7,703 | 9,241 |
| Sep   | 1,933 | 2,176 | 1,360 | 1,566 | 11,528| 15,221| 9,242 |
| Oct   | 1,988 | 2,690 | 1,489 |        | 12,115| 17,128| 9,676 |
| Nov   | 1,958 | 2,444 | 1,279 |        | 11,371| 14,644| 8,543 |
| Dec   | 1,686 | 2,261 | 1,151 |        | 10,660| 14,284| 7,896 |

**TABLE C2** Monthly mean daily traffic counts

| Vasco da Gama bridge (A12) | 25 de Abril bridge (A2) | VFX-Sacavem (A1) | V. Duarte Pacheco - Cascais (A5) |
|---------------------------|-------------------------|-----------------|-------------------------------|
| 2018  | 2019  | 2020  | 2021  | 2018  | 2019  | 2020  | 2021  | 2018  | 2019  | 2020  | 2021  |
| Jan   | 58,835| 62,385| 64,652| 37,254| 32,548| 129,988| 130,797| 83,488| 79,537| 80,731| 81,915| 52,732|
| Feb   | 59,677| 65,535| 65,282| 34,055| 135,770| 138,800| 135,835| 79,551| 81,534| 83,820| 84,070| 51,333|
| Mar   | 60,350| 66,862| 42,031| 42,080| 133,048| 138,324| 91,849| 92,315| 81,379| 85,472| 57,255| 61,345|
| April | 62,350| 65,522| 21,707| 50,947| 139,857| 135,896| 49,846| 116,335| 83,689| 84,781| 33,061| 71,030|
| May   | 66,164| 71,190| 37,227| 62,282| 149,030| 146,212| 94,767| 140,403| 86,635| 89,078| 53,882| 81,949|
| Jun   | 67,374| 69,723| 53,610| 62,380| 149,236| 143,386| 122,002| 137,139| 84,732| 87,323| 69,042| 78,796|
| Jul   | 71,822| 75,345| 63,043| 65,329| 157,399| 153,255| 141,708| 142,321| 85,910| 89,859| 76,800| 80,503|
| Aug   | 70,967| 71,936| 64,430| 67,407| 156,684| 148,666| 142,774| 147,795| 85,036| 86,526| 78,348| 84,538|
| Sep   | 70,774| 72,832| 64,054| 68,817| 154,719| 148,194| 141,850| 146,577| 87,773| 88,452| 80,020| 87,142|
| Oct   | 66,952| 68,901| 58,837|        | 142,590| 140,492| 127,660|        | 85,361| 87,790| 75,712|        |
| Nov   | 63,785| 65,641| 47,286|        | 131,780| 134,224| 105,699|        | 82,172| 85,265| 64,327|        |
| Dec   | 64,771| 67,789| 49,998|        | 134,645| 134,094| 104,308|        | 86,308| 86,897| 66,299|        |
|       | CRL-CREL (A8) | CRIL - V. Duarte Pacheco (IP7) | IC17 |
|-------|---------------|---------------------------------|------|
|       | 2018  | 2019  | 2020  | 2021  | 2018  | 2019  | 2020  | 2021  | 2018  | 2019  | 2020  | 2021  |
| Jan   | 61,843 | 63,688 | 65,067 | 40,803 | 75,339 | 74,359 | 75,256 | 48,324 | 71,721 | 65,179 | 68,044 | 49,273 |
| Feb   | 63,353 | 65,763 | 66,588 | 38,499 | 75,737 | 78,198 | 76,814 | 38,625 | 72,437 | 67,589 | 68,689 | 42,651 |
| Mar   | 62,511 | 66,252 | 43,078 | 45,836 | 74,804 | 75,875 | 47,550 | 51,412 | 71,414 | 67,418 | 43,990 | 49,762 |
| Apr   | 64,039 | 64,245 | 25,327 | 53,926 | 77,748 | 75,602 | 28,946 | 65,187 | 73,053 | 66,831 | 23,571 | 58,007 |
| May   | 66,781 | 69,478 | 40,277 | 62,510 | 82,229 | 82,777 | 49,688 | 71,126 | 76,806 | 70,834 | 46,386 | 63,593 |
| Jun   | 66,080 | 66,194 | 52,169 | 59,677 | 80,516 | 78,978 | 63,676 | 69,604 | 75,943 | 68,247 | 56,321 | 60,262 |
| Jul   | 67,757 | 70,432 | 58,931 | 60,491 | 81,909 | 80,461 | 67,265 | 69,919 | 77,767 | 70,148 | 56,385 | 58,238 |
| Aug   | 62,988 | 63,121 | 56,717 | 59,859 | 76,803 | 75,111 | 60,398 | 68,000 | 72,447 | 64,984 | 53,576 | 57,731 |
| Sep   | 67,405 | 68,783 | 62,371 | 66,384 | 81,932 | 79,943 | 71,263 | 75,146 | 76,380 | 67,852 | 62,885 | 61,553 |
| Oct   | 67,142 | 69,658 | 59,626 |   | 78,414 | 82,636 | 71,769 |   | 74,818 | 71,747 | 63,383 |   |
| Nov   | 65,083 | 66,470 | 51,398 |   | 75,801 | 77,659 | 61,590 |   | 72,207 | 69,445 | 57,270 |   |
| Dec   | 65,916 | 67,199 | 51,671 |   | 73,539 | 76,768 | 57,889 |   | 68,248 | 69,911 | 57,082 |  |

**TABLE C2** (Continued)