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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

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ABSTRACT

This paper estimates the short-term reduction in money and time costs associated with a reduction in car and public transport commuting activity in the Greater Sydney Metropolitan Area (GSMA) during a period of the COVID-19 pandemic in which Australia started to see an easing of restrictions (see Beck and Hensher 2020a). As of late May 2020, three months after COVID-19 resulted in restrictions in Australia, we saw an annual travel time reduction for car and public transport commuters in the GSMA of $5.58 billion, representing a 54.02% reduction in the Pre-COVID-19 total time costs, much of which we would suggest can be associated with reductions in congestions costs. Adjusting further for reduced employment volumes relative to pre-COVID-19 levels, to take into account reduced commuting activity due, in part, to a lower volume of work associated with a loss of employment or lower employment hours, the annual time cost reduction for all commuters who still have regular pre-COVID-19 levels of employment are estimated as $4.4 billion. Hence there is $1.17 billion worth of reduced time costs associated with significantly reduced employment hours, including a loss of employment. The implications for road investment linked to congestion in particular is profound, and shows how much of an increase in benefit to society, through congestion busting, can be obtained by more flexible work arrangements, even allowing for some switching into car out of public transport. Whether the current decrease in travel costs will be long-lasting is unknown, but it does support the appeal of working from home, if it is sustainable, as a policy lever to reduce levels of congestion on the roads and crowding in public transport.

1. Introduction

Since the widespread transmission of COVID-19 in early 2020, we have seen perhaps the greatest ever change in the quantum of travel activity occur, with the pace of adjustment almost instantaneous as governments have moved to impose varying levels of restrictions. Fig. 1 shows the number of daily new cases of COVID-19 in Australia, with the two waves of a survey carried to date as part of an ongoing research program to monitor and assess the changing patterns of travel during COVID-19 as we move into a 'new normal' at an unknown future date. These surveys asked respondents to reflect on travel and activities during the height of the initial spike in new cases, and in Wave 2 during a period of relatively low new infections, when discussion was turning towards a staged relaxation of restrictions. The pandemic clearly has had an impact of commuting activity as more people work from home either by choice or by compulsion, and has delivered a policy lever that previously had never been taken seriously as a way of containing growing traffic congestion on the roads and crowding on public transport. This translates into a potentially significant decrease in the time and monetary costs of commuting, which is not only a benefit to individuals but also to society as whole which pre-COVID-19 was seen as a major welfare loss, including a productivity loss. We are able to quantify what this cost is, and to see how much of a reduction has been achieved in the short term associated with COVID-19.[1]

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[1] Although socioeconomic segmentation is of interest, we have not undertaken this herein since we wanted to focus on the aggregate changes in time and monetary commuting costs. We do know, from unpublished preliminary research, that differences associated with occupation are far more relevant than age, income and gender.

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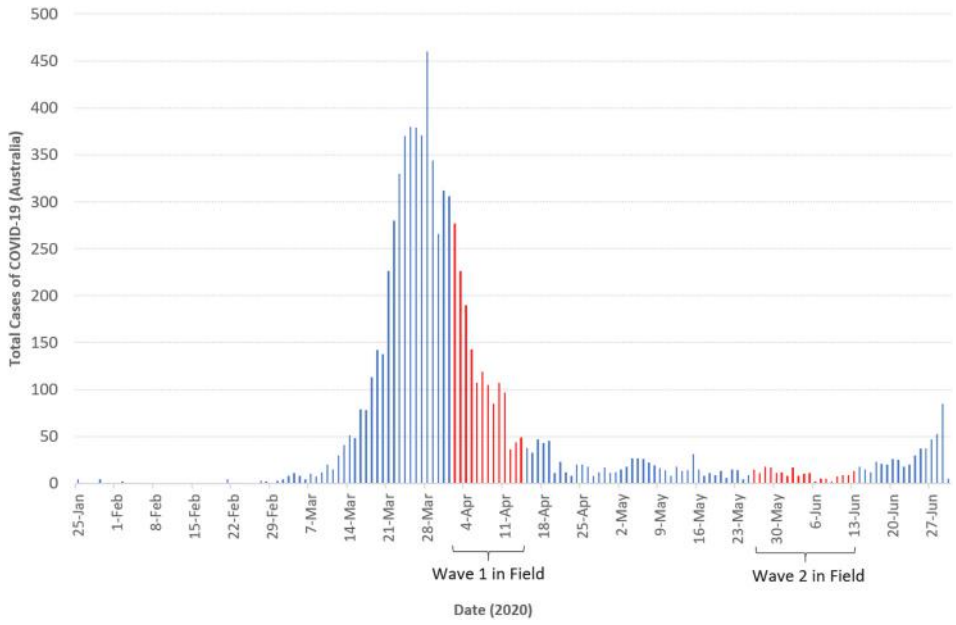

Fig. 1. Daily new cases of COVID-19 in Australia (Beck and Hensher 2020)
Source: https://www.health.gov.au/news/health-alerts/novel-coronavirus-2019-ncov-health-alert.

Globally the number of studies that investigate the impact of COVID-19 on transport networks continue to grow. One of the first, the MOBIS-COVID-19 study, that follows respndents from a pre-COVID-19 survey in September 2019 and January 2020 using GPS tracking and shows the nature of change in activities and travel patterns with Switzerland (MOBIS 2020). Others have looked at the role that the transport network plays in the propagation of COVID-19 globally (Chinazzi et al., 2020), and others with particular reference to Wuhan (Zhang et al., 2020). There has been examination of the impact on aviation networks (Abu-Rayash and Dincer 2020), and how COVID-19 has impacted in air pollution due to changes in activity and travel (Berman and Ebisu 2020). With regards to the policy implications on transport, authors have explored the way in which social distancing might impact on travel behaviour and the policy implications therein (De Vos 2020), how the external costs of COVID-19 infection risk might result in the need for "activity pricing" where a monetary penalty exists for violations of travel restrictions (Oum and Wang 2020), or propose a framework for policy making and evaluation (Zhang 2020).

Of course, mechanisms to better control travel activity with respect to congestion have also been examined prior to COVID-19. For example, rationing the ownership of private vehicles (Li et al., 2019), congestion tolling (Proost and Van Dender 2008), road pricing (Hensher and Bliemer 2014), and fuel taxation (Proost 2017), to name a few. Similarly, working from home was also explored in the literature prior to COVID-19 with the concept of telecommuting, being first formed in 1973, as a substitute for commuting (Nilles 1973) and a relatively inexpensive way to overcome several problems associated with congestion (Mokhtarian 1991). Recent studies that have explored the relationship between the choice and frequency of telecommuting and characteristics of the individual, household, job type and built environment include Sener and Bhat (2011) and Paleti and Vukovic (2017). Zhu (2012) explored the dynamic between working from home and trip generation finding a significant complementary effect of telecommuting on personal travel. However, unlike previous studies on travel activity moderation and working from home, the COVID-19 pandemic represents a widespread and longlasting shock to activity, travel and the nature of work.

The focus of this paper is on the period that is three months out from the beginning of the pandemic in Australia, which is linked to Wave 2 of the data collection program. Although the Wave 2 data is a national sample of over 1000 respondents, we focus herein on the sub-sample of 200 commuters associated with the Greater Sydney Metropolitan Area (GSMA) given that we have all the data items required to obtain annual total estimates of time and money cost changes, as detailed Section 3. The estimated percentage changes are, however, very likely to apply to at least most other Australian capital cities.

Beck et al. (2020) [2] provide a descriptive assessment of both Waves 1 and 2 for the full sample, finding a growth in the number of days people are working from home. Prior to COVID-19, 71% of respondents in employment, did not engage in any work from home. However, at the time of Wave 1 data collection in March 2020, the number not working from home dropped to 39%, with those working 5 days at home rising from 7% to 30%. In the more recent data collected in Wave 2 in May 2020, just over half the sample (54%) working no days from home, and approximately one in five (21%) working 5 days a week from home. With respect to the number of days worked from home across the three time periods, prior to COVID-19 the overall average was 0.86 days per week, during Wave 1 the average rose to 2.4 days, and in Wave 2 this average fell to 1.7 days.

Given the volatility of the topic, we add a caveat; namely, that the findings are very likely to represent a high point in the cessation of commuting activity and a significant increase in working for home, especially given the request of government for all employees to work from home unless it is essential to go to their office or other work location. The findings, nevertheless are a first effort to provide estimates of the reductions in commuting travel time costs and money costs associated with COVID-19, which can be used as a reference point to compare estimates as we move through the pandemic cycle into a future with uncertainty. While we do not think the cost reductions reported below will be as high in future months (unless there is a new spike and lockdown, as in Victoria in July 2020) we anticipate there still be a sizeable number of days of working from home. The evidence on this is mounting (see Beck and Hensher 2020a) and the conclusions in this paper, which suggest that working from home will hold some amount of appeal, even if it is one day a week which we know will have a

[2] There is an extensive literature review in Beck and Hensher (2020, 2020a) and Beck et al. (2020) on working from home, telecommuting, which we do not repeat in the current paper.

Table 1
GSMA sample compared to census data.

	GSMA(ABS)	Wave 2
Demographics		
Female	51%	50%
Age	44.7 (those 18+)	44.0
Income	$105,300	$125,000
Children (for those with)	1.9	1.8
Occupation		
Manager	9%	3%
Professional	39%	48%
Technician & Trade	11%	6%
Community & Personal Services	15%	6%
Clerical & Administration	9%	5%
Sales	2%	15%
Machine Operators & Drivers	6%	3%
Labourers	9%	1%

significant impact on the performance of the transport network, especially if the one day can be distributed equally across a week and staggered throughout a day. The findings also offer a number of interesting possibilities to start thinking about the implications this might have on the reprioritisation of investment in transport infrastructure and service reforms.

The paper is organised as follows. We begin with outlining the changing nature of work within the sample of commuters from the GSMA region analysed in this paper, which provides the context within which we are seeing a significant change in commuting activity. This is followed by a discussion of data sources used in calculating estimates of monetary and time costs, presenting the per passenger commuting trip costs for car and public transport before COVID-19 and after three months into the pandemic. We have not allowed for walking and cycling which is a very small amount of commuting activity in the GSMA. The next section takes this evidence and together with data on annual travel by car and public transport obtains an annual estimate of monetary and time costs for each mode. The results are presented under two scenarios – the first assuming that all pre-COVID-19 commuters retained their employment status and the second accounting for the change in employments status. We briefly comment on the cost reductions in Wave 1 compared to Wave 2 as a way of highlighting the extent of a return to commuting and some amount of continuing to work from home as restrictions were eased. We conclude the paper with comments on what we see as growing support for working from home to varying degrees and what this might mean for commuting activity in terms of cost savings to commuters if this continues to be observed and the broader implications on investment in transport infrastructure when levels of congestion and crowding may be less than anticipated post-COVID-19.

2. COVID-19 and work in the greater Sydney Metro Area

Data was collected in late May 2020 after an approximate two month period of stability in the identification of new COVID-19 cases, at a time when many restrictions around travel and activities were easing. Table 1 provides a comparison of the GSMA sub-sample of data analysed herein compared to selected Australian Bureau of Statistics census data. The sample compares favourably to the census data, with two caveats; namely that we have potentially a sample with higher average incomes, and that the occupations of those in the sub-sample also exhibit differences. It should be noted, however, that the Wave 2 survey provided an open field for respondents to type in their occupation, which was coded by the research team using the Australia and New Zealand Standard Classification of Occupations. There may be inconsistencies in how a stated occupation was coded.

While Fig. 2 shows the change to the volume of work, Fig. 3 highlights the shock as to where work is completed. Prior to COVID-19, 58% of respondents in the GSMA did not complete any work from home (over the sub-sample the average was 0.8 days per week from home). In Wave 2 however, we see a rise in the number of days worked from home in a week (an average of 2.5), and interestingly we see preliminary evidence that increased levels of work from home would be preferred in the future (average of 2 days per week) compared to before COVID-19.

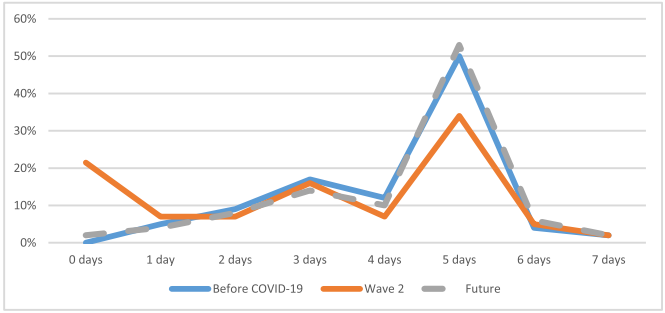

Fig. 2. Comparing the number of days worked in a week.

To further understand the experiences with working from home, we explored the benefits and barriers that may exist. Respondents who are able to work from home were asked to rank (from most to least) the benefits of working from home, chief amongst which are not having to commute and having a more flexible work schedule, as shown in Fig. 4. As shown in Fig. 5, the barriers to productive work from home are disruption from children and/or family and the ability to effectively collaborate with colleagues, though ability to concentrate is ranked second relatively frequently.

With respect to the productivity of the work from home experience, Fig. 6 shows that for respondents in the GSMA, there is little difference between perceived productivity when working from office compared to the "normal" work location, and in aggregate, productivity is marginally higher. Although not reported herein, employers in general support this view of employees and generally are more accepting of WFH. For employers, defined to included people in organisations who are in a role where they can recommend and make a decision on employers to from home, 23% indicate that productivity has increased a little (17%) or a lot (5%) with 53% suggesting no change. This compares with 66% from employees. Finally, Fig. 7 shows that overall, the work from home experience has been largely positive for these respondents. Overall, the Wave 2 survey results provide not only evidence of the impact of COVID-19 on work, but that the experience with working from home may be one that will continue moving into a post-COVID world.

Lastly, it should be noted that the impact of COVID-19 on work varies by occupation. The impact on the number of days of employment for clerical and administration, sales, and labourers has been particularly stark as can be seen in Table 2. Fig. 8 shows that managers, technicians and tradespeople and professionals are more likely to be given the choice to work from home, or have been directed to do so by their employer. These results suggest that any savings that accrued to changes in work, may be disproportionately spread.

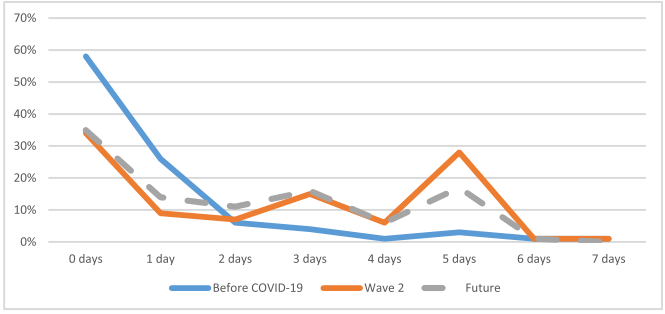

Fig. 3. Comparing the number of days worked from home in a week.

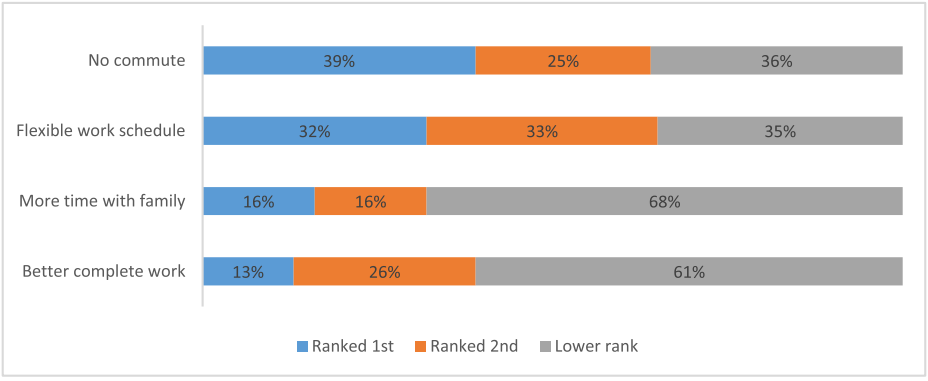

Fig. 4. The benefits of working from home.

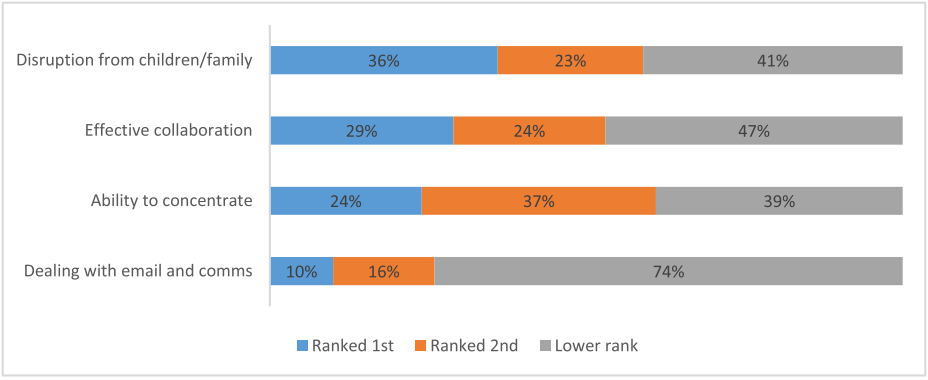

Fig. 5. The barriers to working from home.

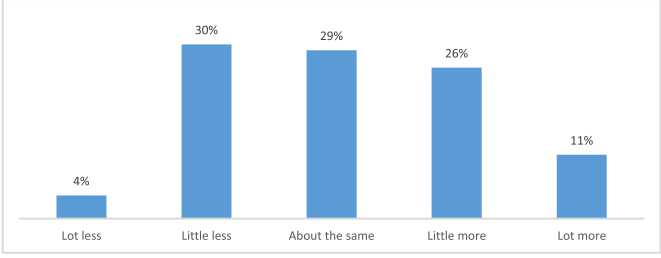

Fig. 6. Productivity when working from home (employee perception).

3. The cost of commuting before and during COVID-19

In calculating estimates of the time and money costs associated with changes in commuting activity before and during COVID-19, we have used data from Wave 2 of the ongoing longitudinal study (see Beck and Hensher 2020; 2020a for details), together with Transport for NSW and the Australian Bureau of Statistics Journey to work data from the 2016 Census. The overall findings are summarised in Tables 3 and 4.

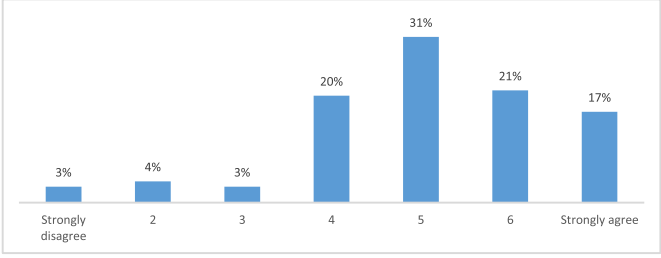

Fig. 7. Overall working from home has been a positive experience.

Table 2
Average days worked and worked from home by Occupation.

	Days Worked Before COVID-19	Days Worked Wave 2	Days WFH Wave 2
Manager	5.0	5.0	4.3
Professional	4.5	3.7	2.7
Technician & Trade	3.5	3.3	1.5
Community & Personal Services	3.6	2.7	0.1
Clerical & Administration	3.1	1.8	1.4
Sales	4.3	2.1	0.8
Machine Operators & Drivers	5.0	6.0	1.3
Labourers	3.5	2.5	2.5

We need to convert travel time into 2020 dollars. For car, we apply the values recommended by Transport for NSW (TfNSW, 2020) of $17.72 for the value of travel time savings per person hour (VTTS), and $30.12 for the value of reliability (or travel time variability (VoR). For public transport, we also applied the recommended values from TfNSW for in vehicle and out of vehicle VTTS of $17.72 and $26.28 respectively. The operating costs ($/trip) and toll cost ($/trip), as well as peak and off-peak travel times for each of the O-D pair, were obtained from the MetroScan system networks (Hensher et al., 2020).

We accounted for the peak and off-peak times using the data provided by the Traffic Volume Viewer by Roads and Maritime Services (RMS) of NSW (Traffic Volume Viewer TfNSW, https://www.rms.nsw.gov.au/about/corporate-publications/statistics/traffic-volumes/aadt-map). Given the definitions provided by RMS, the peak time includes the hours between 6am and 10am and 3pm–7pm, and the off-peak time includes all other hours outside the peak time. Based on data on the Annual Average Daily Traffic (ADDT) volumes for major roads in NSW,

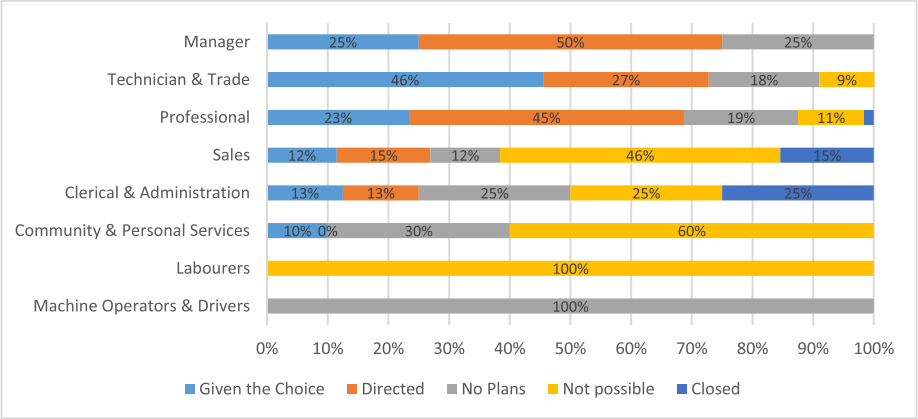

Fig. 8. Work from home policy by Occupation.

Table 3
Costs of commuting by car before and during COVID-19 in late May 2020.

Before COVID (2019)	*Per trip monetary cost ($)*	*Per trip time cost ($)*	*Per trip Generalised Cost ($)*	*Weekly Cost ($)*	*Trips per week*	*OD Distance (km)*
Median	$2.71	$15.30	$17.71	$133.46	8.00	15.3
Mean	$5.73	$16.46	$22.20	$161.83	7.09	37.8
STD	$12.46	$12.26	$20.65	$161.65	3.68	88.5
During COVID (Late May 2020)	*Per trip monetary cost ($)*	*Per trip time cost ($)*	*Per trip Generalised Cost ($)*	*Weekly Cost ($)*	*Trips per week*	*OD Distance (km)*
Median	$0.50	$9.62	$10.05	$50.24	5.00	4.5
Mean	$1.37	$12.00	$13.37	$90.81	7.07	11.7
STD	$1.75	$11.93	$13.01	$117.67	7.76	14.9
% Change During/Before COVID-19	**−76.05%**	**−27.12%**	**−39.76%**	**−43.88%**	**−0.29%**	**−69.18%**

Notes for Tables 3 and 4: (i) From 2019 to 2020 inflation was negligible (with a change of 0.3%) but we made this small change so that all $ estimates are directly comparable in current dollars (ii) all data items are calculated from individual observations and then summed to calculate the three moments (median, mean, standard deviation) (iii) the increase in the median and mean distances is due to a greater incidence of shorter commuting trips not being undertaken compared to longer commutes.

Table 4
Costs of commuting by public transport before and during COVID-19 in late May 2020.

Before COVID (2019)	*Per trip monetary cost ($)*	*Per trip time cost ($)*	*Per trip Generalised Cost ($)*	*Weekly Cost ($)*	*Trips per week*	*OD Distance (km)*
Median	$6.61	$14.76	$21.37	$170.97	8.00	12.7
Mean	$6.20	$16.05	$22.25	$189.13	8.34	18.0
STD	$1.82	$11.84	$13.35	$150.41	4.68	22.5
During COVID (Late May 2020)	*Per trip monetary cost ($)*	*Per trip time cost ($)*	*Per trip Generalised Cost ($)*	*Weekly Cost ($)*	*Trips per week*	*OD Distance (km)*
Median	$4.55	$7.28	$11.84	$59.84	4.00	4.4
Mean	$4.83	$8.83	$13.66	$72.70	5.36	18.5
STD	$1.51	$8.01	$9.43	$65.02	4.94	46.8
% Change During/Before COVID-19	**−22.06%**	**−45.00%**	**−38.60%**	**−61.56%**	**−35.67%**	**3.20%**

we calculated the drop in the traffic flow/traffic volume during the AM and PM peak times in the GSMA to be 17.63% in 2020 (from January 2020 up to mid-August)[3] compared to all of 2019, and the drop of AADT volumes during the off-peak period to be 18.28% in 2020. In calculating the generalised cost (GC) for each period, we adjusted the in-vehicle time and buffer time accordingly for GCs during the COVID-19 period. We erred on the side of caution in adjusting down the operating cost per kilometre by 20% given reduced traffic congestion.

The generalised cost per person trip per for car (GCpersT) and generalised cost per person trip for public transport (GCPubT) are given as follows:

GCpersT = VTTS*in-vehicle time + VoR*buffer time + operating cost ($/trip) + tollcost ($/trip) for all purpose of trips (peak/offpeak)
GCPubT = invt VTTS *invehicle travel time + out-of-vehicle VTTS *out of vehicle travel time + PT fare ($/trip) for all purpose of trips (peak/offpeak)

In calculating the public transport time, we adjusted the proportion of train and bus trips based on the incidence rates observed in Wave 2 before and during the COVID-19 period, with train trips representing 68% (pre-COVID) and 55.6% (during COVID) of all trips among the entire public transport (PT) trips (Hensher et al., 2020). The public transport fare per trip remains the same during the COVID-19 period.[4]

The monthly patronage figures for public transport for train and bus

[3] RMS does not provide monthly estimates of average daily volumes. During the restriction period in April and May 2020, we could have assumed that the volume decrease would be more than 17.63%, but we have adopted a conservative estimate of 17.63%.

[4] Although TfNSW lowered fares for the off-peak period to encourage some travel to be shifted out of the peak, the off-peak discount commenced on 6 July which is after the Wave 2 data collection period.

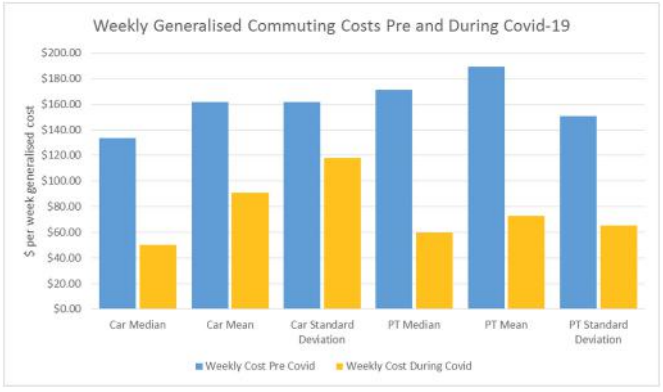

Fig. 9. Comparison of commuter time and cost outlays in 2019 (Before COVID-19) and in late May 2020 (During COVID-19).

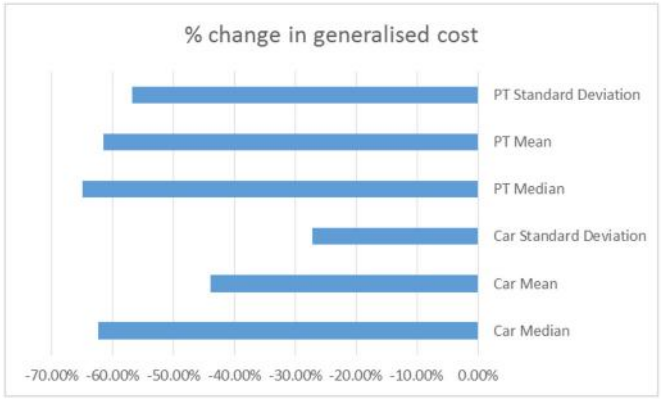

Fig. 10. Comparison of percentage change in commuter time and cost outlays in 2019 (Before COVID-19) and in late May 2020 (During COVID-19).

provided by TfNSW (TfNSW, https://www.transport.nsw.gov.au/data-and-research/passenger-travel/public-transport-patronage/public-transport-patronage-monthly), indicate that the number of one-way train and bus trips in May 2020 during severe restrictions under Stage 3 were 69% and 66% less than the numbers in February 2020 before such restrictions. We have also included data on ferry and light rail usage (which is a small component of the overall public transport task). We have conservatively assumed that fewer passengers on PT would reduce both in-vehicle and out-of-vehicle time by at least 10%, taking into account such factors like less delay for boarding trains during peak hours and less delay due to reduced traffic congestion for buses. We made this adjustment in calculating the generalised cost for public transport. Figs. 9 and 10 summarise the findings from Tables 3 and 4

4. What does this mean for annual reductions in time and money cost outlays?

The annual cost reductions for commuting by car and public transport given in Tables 5 and 6 are calculated from the findings in Tables 3 and 4 and the listed assumptions on the amount of travel over a year. According to the data released by the Australian Bureau of Statistics in May 2018 (ABS 2018), there were approximately 516 thousand commuters taking public transport and 1.252 million commuters using a vehicle (i.e., as driver or passenger) in the GSMA each day. Taking these bases into account, the results are summarised in Tables 5 and 6 The average annual reduction in time costs for car travel is $2312 equivalent to $48.16 per week or $9.63 per weekday. The average annual reduction in time costs for public transport is $5,203, equivalent to $108.39 per week, based on 48 annual working weeks, or $21.68 per weekday. This is substantial reduction in commuting costs, with the overall average

Table 5
Annual cost reduction for car and public transport commuting trips per passenger.

Base: average per *passenger before COVID-19*	Car	Public Transport	Weighted average for both modes
Annual monetary costs before COVID-19	$1950	$2482	$2105
Annual monetary costs during COVID-19	$376	$668	$461
Annual monetary costs reduction	80.70%	73.09%	78.08%
Annual time costs before COVID-19	$5601.76	$6421.93	$5841
Annual time costs during COVID-19	$3289.93	$1219.24	$2686
Annual time costs reduction	41.27%	81.01%	54.02%
Annual generalised costs before COVID-19	$7551.70	$8903.54	$7946
Annual generalised costs during COVID-19	$3666.36	$1886.94	$3147
Annual generalised costs reduction	51.45%	78.81%	60.40%

Note: The values shown consider all the car and public transport passengers before COVID-19. The cost reduction reflect the decrease in the number of trips. Monetary costs include only running costs. The weighted average is based on the number of one-way commuting trips by each mode.

monetary cost of $34.24 per week being of particular interest in terms of additional gross income available for spending on other items and activities.

The annual cost reduction for all car commuters in the GSMA is estimated as $1.97 billion for monetary costs, **$2.894 billion for time costs**, and $4.864 billion for total generalised cost. The annual cost reduction for all public transport commuters in the GSMA are estimated to be $0.936 billion for monetary costs, **$2.685 billion for time costs**, and $3.621 billion for total generalised cost.

The $5.579 billion of reduction in travel time costs represents a 54.02% reduction in the Pre-COVID-19 total time costs of $10.3 billion, much of which we would suggest can be associated with congestions costs.[5] During May 2020 we observed a significant reduction in commuting activity (Beck and Hensher 2020). This is equivalent to a $8.485 billion reduction in overall generalised cost.

The estimates in the previous paragraphs assume that all pre-COVID-19 commuters retained their employment status fully and for those who did not, that their working from home profile was similar to those commuters who retained their jobs. This is only correct if we want to obtain an estimate of the impact of COVID-19 of commuting costs as if COVID-19 had no impact on employment. However, understanding that some reduction in commuting is due to changes in the levels of employment as a result of restrictions, another way of looking at the commuting cost impact is to calculate the annual reduction in time and monetary commuting costs by recognising that the average "volume" of work lost (volume = (number of days before-number of days during)/

[5] The Infrastructure Australia (2019) Table 11 titled 'Sydney's most congested roads (user experience), 2016′ suggests that the share of journey time dues to congestion in the GSMA major road network is around 69%; however, their analysis accounts for traffic on the entire network, and so the congestion percent is lower for the overall network, which we assume is around 40% for other roads. The 2016 congestion cost estimate of $8 billion translates into a total time cost for the congested part of the network of $11.59 billion. In our study the majority of travel occurs on the main network. The results are similar and we think vary mainly due to the assumption made by the consultants to Infrastructure Australia of the number on one-way weekly commuting trips by car. For Sydney, the cost of congestion alone was expected to double to $15.7 billion annually over the next 12 years up to 2031 (Infrastructure Australia 2019). For those using public transport, the cost of crowding on trains and buses was expected to reach $223 million compared to $68 million today.

Table 6
Overall cost reductions assuming everyone retained their hours of work.

	Car	Public Transport	Total
Annual monetary costs before Covid-19	$2,441,332,498	$1,280,506,591	$3,721,839,088
Annual monetary costs after Covid-19	$471,295,090	$344,533,563	$815,828,652
Annual monetary costs reduction	***$1,970,037,408***	***$935,973,028***	***$2,906,010,436***
Annual time costs before Covid-19	$7,013,398,312	$3,313,717,547	$10,327,115,859
Annual time costs after Covid-19	$4,118,988,731	$629,128,276	$4,748,117,007
Annual time costs reduction	***$2,894,409,581***	***$2,684,589,271***	***$5,578,998,852***
Annual generalised costs before Covid-19	$9,454,730,809	$4,594,224,138	$14,048,954,947
Annual generalised costs after Covid-19	$4,590,283,820	$973,661,839	$5,563,945,659
Annual generalised cost reduction	***$4,864,446,989***	***$3,620,562,299***	***$8,485,009,288***

number of days before). This calculation reveals that there was a 34% reduction in the volume of work in April 2020 (Wave 1 of the survey), and with some level of employment returning in that figure was 21% in May 2020 (Wave 2).[6] A simple linear projection to early September (Wave 3) suggests an estimate of 10%, but this on-going, albeit relatively small levels of commuting transfer in Sydney may impact on this gradual return to pre-COVID-19 levels.

Taking into account the volume of work reduction for May 2020, Table 7 summarises the annual cost reduction for car commuters *assuming to still have regular pre-COVID-19 levels of employment* in the GSMA; estimated as $1.556 billion for monetary costs, **$2.287 billion for time costs**, and $3.843 billion for total generalised cost. The annual cost reduction for all public transport commuters in the GSMA are estimated to be $0.739 billion for monetary costs, **$2.121 billion for time costs**, and $2.86 billion for total generalised cost. Total annual time cost reductions are hence $4.407 billion.

In concluding the commentary of the evidence, we also comment on the findings in early April from Wave 1 to show the progression of commuting as restrictions were eased in late May. The full details for early April are given in Appendix Tables A1 to A5. As of early April 2020, we saw an annual travel time reduction for all commuters in the GSMA of $6.96 billion. This represents a 67.6% reduction in the Pre-COVID-19 total time costs of $10.3 billion, compared to 54.02% in late May. Adjusting further for reduced employment volumes relative to pre-COVID-19 levels, the annual time cost reduction for all commuters who still have regular pre-COVID-19 levels of employment are estimated as $5.5 billion, compared to $4.407 billion in late May. The average annual reduction in time costs in early April for car travel is $3447 equivalent to $71.80 per week or $14.36 per weekday. The average annual reduction in time costs for public transport is $5,134, equivalent to $106.95 per week, based on 48 annual working weeks, or $21.39 per weekday. This is substantial reduction in commuting costs, with the overall average monetary cost of $27.45 per week compared to $34.24 in early April. As expected, we are starting to see a progressive move back to commuting activity, with average commuting time costs

[6] It should be noted that the volume of work calculation encompasses the impact of JobKeeper, a $1500 per fortnight income support from the Federal Government to employees in order to keep employees working or at least not being classified as unemployed (regardless of actual hours worked). JobKeeper, however, can result in people still not working (if the business is closed they still retain the payment), or working less days/hours.

Table 7
Overall annual reductions after adjusting for changes in volume of work hours in May 2020.

Total reduction	Car	Public Transport	Total Reduction
Annual monetary costs reduction	$1,556,329,552	$739,418,692	$2,295,748,245
Annual time costs reduction	$2,286,583,569	$2,120,825,524	$4,407,409,093
Annual generalised costs reduction	$3,842,913,121	$2,860,244,216	$6,703,157,338

increasing by 19.9%. We will continue to monitor the adjustments through continuing Waves of data collection, focussing on not only adjustments in commuting activity but also the role that working from home plays in a resulting new equilibrium.

5. Conclusions

The evidence presented in this paper, while related to the short-term impact of a pandemic, has important implications for road investment linked to congestion in particular if it translates into a long-lasting outcome, and clearly it shows how much of a benefit to society, through congestion busting, could be obtained by more flexible work arrangements, even allowing for some switching into car out of public transport. While we do not expect such significant drops in commuting activity as we progress through and out of the COVID-19 pandemic, we might still expect some amount of reduced commuting and a propensity to work from home to some degree. As we collect more data on a regular basis over the next year, we should be able to adjust the May 2002 evidence. The plan includes extending the evidence to all of Australia and each State of Australia.

We do not, however, anticipate a full return to pre-COVID-19 commuting activity. An increasing number of studies including our ongoing monitoring of working from home, are suggesting that both employees and employers are supportive of some rearrangement of working activity centred on working from home (Beck and Hensher 2020a). The results discussed in Section 2 suggest that the work from home experience will likely translate into change dynamics of work moving forward.[7] This is also backed by a range of wider studies; for example a survey of 6000 Australian workers in the public sector has found 39 per cent of those surveyed would be happy to continue working from home some of the time - even when the coronavirus pandemic ends (Community and Public Sector Union 2020). Only 11 per cent of those surveyed wanted to work from home all the time, 39 per cent some of the time, 30 per cent most of the time, and 14 per cent only on occasion. A University of Sydney survey (June 10, 2020, unpublished) found the following positives in rank order for staff: no commute, less distractions, balance work/life - access to family/exercise, and flexible hours; however the greatest challenges are not switching off/working longer hours, loss of collaboration/social connections, reduced workstation quality and reduced physical activity.

The Business for Clean Air Taskforce[8] in June 2020, a consortium that includes electronics giant Philips, ride sharing platform Uber and French utility firm Engie, with the backing of the U.K. government

[7] A referee suggested that if people are giving the chance, or encouraged to work from home, this may open doors for more employments and thus attract more people into the labour markets, presumably people who are interested in part-time employment. We agree that some people might be more interested in being in the workforce if they can work from home since it opens greater flexibility in the actual hours of the day worked and aligns better with child care and other supporting tasks that often are too constraining for some people.

[8] https://www.globalactionplan.org.uk/clean-air/business-for-clean-air-taskforce.

concluded that "Perhaps unsurprisingly, some 87% of those currently working from home said they would like to continue to do so "to some degree". Should they get their wish, some 17 million people will continue flexible, remote work—an increase of some 58% over the pre-lockdown figure of 10.8 million who worked from home." An unpublished Webinar discussion at the Committee for Sydney on August 19, 2020, had several members reporting that they are finding that it is hard to get people back to the office, with particular resistance from younger employees.

Overall, COVID-19 has clearly had a significant impact on work and travel. While acknowledging that there is still likely volatility in behaviour as the impact of the pandemic continues to vary and play out, and that more data will need to be collected over time, our research to date demonstrates that the changed behaviour leads to significant changes in generalised cost and the associated monetary and time costs, which in turn may have important ramifications on how transport investment decisions are made moving forward. In particular, any investment in maintaining working from home, or at least encouraging increased working from home relative to pre-COVID levels, can lead to very large improvements in travel networks and overall cost savings.

In summary, while we suggest that there is likely to be further adjustments in response as we slowly move out of COVID-19 restrictions and beyond, we can only speculate at this stage that there will be a change in the reduction in time and money costs (and hence generalised cost), but that it is unlikely to return to the pre-COVID-19 levels. As part of an ongoing study, we are tracking behavioural responses in terms of working from home and quantum of commuting by each mode (allowing for substitution between modes, with a likely greater use of car and reduced public transport use). We have repeated the survey in early September, 2.25 months after the survey that the current paper is based on. Preliminary evidence suggests that public transport commuting has not increased and car commuting has increased slightly. We do, however, suggest that within the Australian context with almost no local transmission of COVID19 as of mid-November 2020, that we will be in a better position in February 2020 to gain confidence in the settling down of the quantum of WFH and hence the extent of commuting, if the current negligible transmission rate continues and the messaging that it is safe to use public transport is reinforced (Nelson 2020). However the popularity of working from home to some extent is now confirmed, with support from both employees and employers (notably is some specific occupations), and hence this suggests that the pre-COVID-19 levels of commuting will not return, certainly not in the foreseeable future. We discuss some of the medium to longer term implications of COVID-19 in Beck and Hensher (2020b).

In terms of what recommendations can be given to policy-makers and employers, we would suggest that the following should be top of mind based on the Australian experience to date, but that many might resonate at a more global level.

- While we are likely to see a recovery of office workers back to the Central Business District (CBD) of the cities on any given day, it could be at a reduced level, which will not only support reduced road traffic congestion but also manageable crowding on public transport compared to pre-COVID-19.
- Local suburbanisation can take on a new and appealing meaning which opens up opportunities for revitalisation of suburbia.
- These locational adjustments of WFH align well with promoting the 20 or 30 min city.
- All of these locational responses will present challenges for property developers and property agents who manage office space.
- Rents, relative to the average trend, may decline in the CBD as large enterprises rethink their priorities.
- There is another way to reduce the burden on WFH while avoiding the need for the stressful commutes and loss of flexibility in working hours, namely the local shared or satellite office, often referred to as the 'third office' or neighbourhood business hub.
- With fewer days commuting, we can expect to see a greater use of the private car in general, but specifically for commuting, since commuters who were previously public transport users might be more prepared to put up with traffic congestion and parking costs for two to three days a week, but not necessarily for five days.
- This has important implications for public transport patronage, and indeed may require a rethink of the structure of fares (beyond a peak and off-peak differentiation) and local on-demand services.
- It also raises the issue of road pricing reform or incentive–based loyalty rewards programs to manage and contain congestion.

Author Contributions

David Hensher: Conceptualization; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Roles/Writing - original draft; Writing - review & editing.

Matthew Beck: Conceptualization; Data curation; Writing - review & editing

Edward Wei: Formal analysis; Software; Supervision; Roles/Writing - original draft.

Camila Balbontin: Writing - review & editing

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tranpol.2020.12.003.

Appendix 1. Early April 220 (Wave 1) Comparative Evidence

Note: The change of sign between early April and late May for the percentage changes in Tables A1 and A2 compared to Tables 3 and 4 in the text, can be explained as follows. For car trips, the average distance after COVID-19 in late May is less than 1/3 of the before COVID-19 case, and in early April (Wave 1) we observe fewer commuters travelling by car but also taking longer trips (i.e., on average 51 km versus 37 km); hence the positive percentage change in Wave 1 and negative percentage change in Wave 2 for car trips on monetary cost. We also observed in late May, a higher proportion, approximately 42%, of commuters travelling to nearby suburbs (e.g., suburbs with the same postcode), indicating the people who work locally go by car, with relatively fewer people undertaking longer commuting trips, bringing down the overall monetary and time costs. For public transport, the situation is very similar. In early April, only the few individuals who commuted longer distance by public transport seemed to keep

travelling (i.e., on average 32 km versus 18 km). In late May, more commuters were taking public transport but less frequently, and they were not taking long trips compared to what they did before Covid-19. Very few travelled above 20 kms and close to a quarter only travelled within nearby suburbs.

Table A1
Costs of commuting by car before and during COVID-19 as of early April 2020

Before COVID (2019)	*Per trip monetary cost ($)*	*Per trip time cost ($)*	*Per trip Generalised Cost ($)*	*Weekly Cost ($)*	*Trips per week*	*OD Distance (km)*
Median	$2.71	$15.30	$17.71	$133.46	8.00	15.3
Mean	$5.73	$16.46	$22.20	$161.83	7.09	37.8
STD	$12.46	$12.26	$20.65	$161.65	3.68	88.5
During COVID (April 2020)	*Per trip monetary cost ($)*	*Per trip time cost ($)*	*Per trip Generalised Cost ($)*	*Weekly Cost ($)*	*Trips per week*	*OD Distance (km)*
Median	$2.00	$12.10	$14.29	$83.94	6.00	15.4
Mean	$6.03	$13.63	$19.66	$124.76	6.05	51.4
STD	$13.25	$11.38	$20.53	$146.64	3.42	71.0
% Change During/Before COVID-19	**5.22%**	**−17.21%**	**−11.42%**	**−22.91%**	**−14.6%**	**35.95%**

Table A2
Costs of commuting by public transport before and during COVID-19 as of early April 2020

Before COVID (2019)	*Per trip monetary cost ($)*	*Per trip time cost ($)*	*Per trip Generalised Cost ($)*	*Weekly Cost ($)*	*Trips per week*	*OD Distance (km)*
Median	$6.61	$14.76	$21.37	$170.97	8.00	12.7
Mean	$6.20	$16.05	$22.25	$189.13	8.34	18.0
STD	$1.82	$11.84	$13.35	$150.41	4.68	22.5
During COVID (April 2020)	*Per trip monetary cost ($)*	*Per trip time cost ($)*	*Per trip Generalised Cost ($)*	*Weekly Cost ($)*	*Trips per week*	*OD Distance (km)*
Median	$5.92	$14.60	$21.15	$146.29	6.00	14.5
Mean	$6.69	$22.45	$29.14	$186.00	6.11	32.0
STD	$1.65	$18.93	$20.20	$188.61	3.98	46.8
% Change During/Before COVID-19	**7.95%**	**39.89%**	**30.99%**	**−1.65%**	**−26.70%**	**78.10%**

Table A3
Annual cost reduction for car and public transport commuting trips per passenger, Before COVID-19 and in early April 2020

Base: average per passenger before COVID-19	Car	Public Transport	Weighted average for both modes
Annual monetary costs before COVID-19	$1950	$2482	$2105
Annual monetary costs during COVID-19	$954	$384	$788
Annual monetary costs reduction	51.10%	84.52%	62.60%
Annual time costs before COVID-19	$5602	$6422	$5841
Annual time costs during COVID-19	$2155	$1288	$1902
Annual time costs reduction	61.53%	79.94%	67.43%
Annual generalised costs before COVID-19	$7552	$8904	$7947
Annual generalised costs during COVID-19	$3109	$1673	$2690
Annual generalised costs reduction	58.83%	81.22%	66.15%

Table A4
Overall cost reductions assuming everyone retained their hours of work in early April 2020

	Car	Public Transport	Total
Annual monetary costs before Covid-19	$2,441,332,498	$1,280,506,591	$3,721,839,088
Annual monetary costs after Covid-19	$1,193,787,846	$198,238,331	$1,392,026,177
Annual monetary costs reduction	***$1,247,544,652***	***$1,082,268,260***	***$2,329,812,912***
Annual time costs before Covid-19	$7,013,398,312	$3,313,717,547	$10,327,115,859
Annual time costs after Covid-19	$2,698,291,534	$664,775,251	$3,363,066,785
Annual time costs reduction	***$4,315,106,778***	***$2,648,942,296***	***$6,964,049,074***
Annual generalised costs before Covid-19	$9,454,730,809	$4,594,224,138	$14,048,954,947
Annual generalised costs after Covid-19	$3,892,079,380	$863,013,582	$4,755,092,962
Annual generalised cost reduction	***$5,562,651,430***	***$3,731,210,556***	***$9,293,861,986***

Table A5
Overall annual reductions after adjusting for changes in volume of work hours in early April 2020

Total reduction	Car	Public Transport	Total Reduction
Annual monetary costs reduction	$985,560,275.00	$854,991,925.35	$1,840,552,200.35
Annual time costs reduction	$3,408,934,354.42	$2,092,664,414.11	$5,501,598,768.52
Annual generalised costs reduction	$4,394,494,629.41	$2,947,656,339.46	$7,342,150,968.87