Working from Home Final Report

Working from Home (WFH) and Implications for Revision of Metropolitan Strategic Transport Models

iMOVE Projects 1-031 and 1-034 (2020-2022)

‘Flexibility is here to stay’ and ‘employers who offer a balance of WFH and in office will attract more high-quality employees’

The Future of Office Space Summit, 17 February 2021

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Transport and Main Roads Qld (“TMR”)

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Executive Summary

The world has changed in ways we would not have expected prior to early 2020. While the interest continues unabated with themes such as integrated transport and land use, the promotion of sustainable transport (public transport and active transport modes in particular), and a refocus on place and movement linked to 'vision and validate' in contrast to 'predict and provide', the context has changed in a non-marginal way as a result of coping strategies in response to the COVID-19 pandemic. Whereas coping strategies are often immediate and short term, we now see evidence of such strategies developing into more permanent and long-term structural responses that have deepened a commitment to a number of new experiences that we often describe as positive unintended consequences of COVID-19.

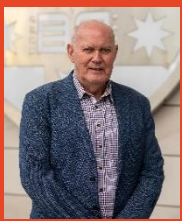
March 2020 will forever be etched in our minds as the beginning of what has become the most concerning health pandemic faced by all generations of the living population. Almost two-and-three quarter years on, we are starting to see a number of signs for what the future might evolve into through structural change brought about by many events, and no more so than the burgeoning growth in working from home (WFH). No longer associated with negative stigma, working from home, or remote working more generally, has become almost folklore with all elements of society slowly recognising that it is to some extent here to stay, and we should start rethinking how this non-marginal change in the way we live, and work will be used to restructure the fabric of society. In this report, we draw on the research we have undertaken as part of an ongoing project on WFH and its relationship to travel and work since March 2020 to speculate on what we think are likely to be the big changes in the land transport sector and society more broadly that would not have been considered, at least to the same extent, pre-COVID-19.

At the centre of this structural response is working from home (WFH), which to the surprise of most has received significant support from both employees and employers in many countries, largely linked to evidence of increased productivity, whether perceived or real. WFH to some extent is here to stay and looks like 'stabilising' as one to two days a week depending on employee occupation and the essential nature of in-office or customer-facing requirements. While it may be some time until we are able to indicate, with some confidence, the impact that WFH will have on traffic congestion on the roads and crowding on public transport, there is a sense already that it is a game changer, and indeed is one of the most effective policy levers that the transport sector has had for many years in 'managing' the performance of the transport network.

This report summarises the main findings and policy implications of a three-year project carried out in Australia to understand the impacts of COVID-19 and particularly, WFH, in the transport network. Data collection began at the beginning of the pandemic in early 2020 up until the end of 2022, with a total of seven data waves. This research is part of iMOVE Cooperative Research Centre (CRC) research projects 1-031 and 1-034 with Transport and Main Roads, Queensland (TMR), Transport for News South Wales (TfNSW) and West Australian Department of Transport (WADoT). The report presents evidence on the incidence of WFH and how it has been received by employees and employers from the height of restrictions up to a period when restrictions were relaxed, followed by further lockdowns throughout Australia. We show what this might mean for work productivity, lifestyle, and the changing preferences for passenger modes. We also analyse the impact of WFH in non-commuting travel behaviour and its implications in businesses' decisions on their main office space. With a growing preference, within some occupation classes, to WFH 1 to 2 days a week, and a good spread through the weekdays, we discuss what this means for the way we analyse the impact of transport initiatives on the performance of the transport network with a particular emphasis on the growth in suburbanisation of transport improvements, less costly service and infrastructure improvements, and the changing role of public transport.

The proportion of working days that are from home have decreased since the start of the pandemic in early 2020, but have remained relatively similar since the end of 2021, with over 30% for the Greater Sydney Metropolitan Area (GSMA) and over 20% for South East Queensland (SEQ). It seems that as we move forward towards a COVID-normal scenario, respondents want to work around 2 days a week from home (2.17 for GSMA and 1.87 for SEQ in September 2022) with lower incidence rates in regional locations. The majority of employers and employees perceive their productivity levels to be the same or even better than their pre-COVID levels when working from home, and the same when working outside home. Evidence suggests that workers are reallocating the saved commuting time in doing unpaid work for their main job from home (25-28%), doing home-based leisure activities (18-23%), and household tasks (17-25%). In terms of mobility patterns, our findings suggest that, as the proportion of days WFH increases, the number of non-commuting travel increases, particularly trips with purpose of shopping, personal business or social recreation. The appendices provide all of the papers prepared during the course of the project.

ITLS Team



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1 Introduction

COVID-19 has resulted in a seismic change in the way we all work and travel. A notable change has been remote working away from the main office with much of this occurring from home. Recognising that not all jobs can support working from home (WFH), the ability to do so to some extent is now seen as a legitimate alternative to commuting to the traditional workplace for many workers, with much of the prior stigma evaporating as a result of the relatively productive experience. Since March 2020 when the pandemic took hold and Australia went into lockdown, initially for an unknown period, we recognised a need to start tracking the changes that were expected to unfold as many individuals as possible and households entered an unexplored option to WFH. As a forced measure, it gave us a real-world experiment of the impacts of an extreme event on the way we go about our business and live our lives.

The journey to track changes in WFH and all of the consequent positive and negative impacts began with a first survey in March/April 2020 and has continued to this day with seven surveys undertaken. In Figure 1 and 2 we show the course of data collection from the start of the pandemic to September 2022. Over this period of time, we have witnessed strict lockdowns, easing of restrictions, back into strict lockdowns in the presence of the Delta variant, and then once widespread levels of vaccination were achieved, the removal of most restrictions. In Figure 2, noting the sizeable change in the size of the units on the y-axis, we see the dramatic change in COVID-19 cases after the Christmas period of 2021 and beyond, of course in a context of over 95% of the population now having at least two COVID-19 vaccination injections.

A timeline of events is summarised in the Appendix, noting that there have been significant differences between each State in Australia. The most significant differences relate to a total border closure in Western Australia for most of the time (opening up in March 2022), significant periods of lockdown in Victoria throughout the entire period (Melbourne totalling 263 days, more than any other city globally), and a notable 106-day lockdown in Sydney and the Region of NSW from July to October 2021. These variations have provided a rich opportunity to gain an understanding of the impact of restrictions with different degrees of severity on the propensity to WFH and a range of ancillary impacts such as unexpected positive support from employers to WFH, significant reductions in the use of modes that involve sharing, notably public transport and ride sharing services, with a return to the use of the private car where travel had to take place.

With reduced commuting in all jurisdictions accompanied by increased WFH, our interest focussed on what this might mean for future use of all the passenger modes, including active modes of walking and cycling, and whether the accumulating evidence over three years signals a ‘new normal’ as we learn to live with COVID-19 under an increasingly vaccinated population. Our research focusses on three streams: a descriptive overview of what changes are occurring as a result of WFH; a consideration of how the spatial incidence of WFH can be embedded in a new suite of travel choice models to account for changes in commuting modal activity and the spill-over to non-commuting travel with greater flexibility in where and when individuals work, opening up new temporal and spatial opportunities for travel; and what all of this might mean for a broader structural change agenda linked to transport investment in the future, businesses’ office space, growing levels of car use and congestion with continued nervousness in using public transport and other modes associated with sustainability goals, the suburbanisation of activity (linked to a 15-minute city), a rethink of the value proposition of the Central Business District (renamed as a Downtown Activity Precinct), and implications for wellbeing and social exclusion.

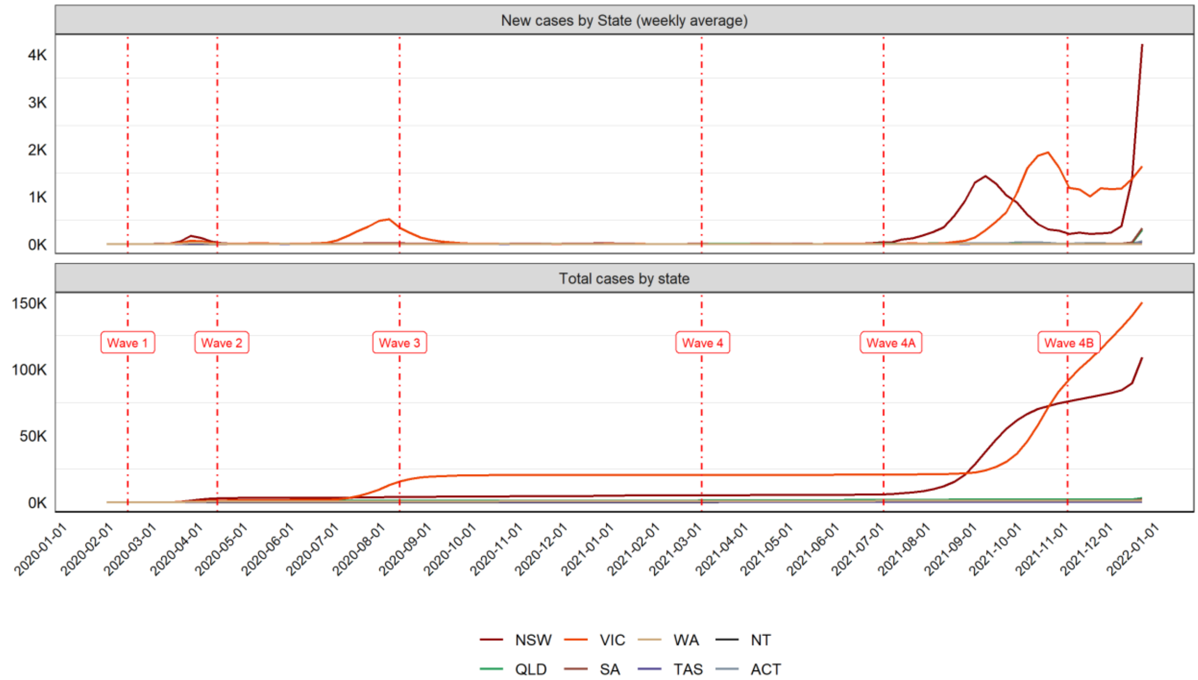

Figure 1: Timeline of surveys versus daily COVID-19 cases – 2020-2021 only

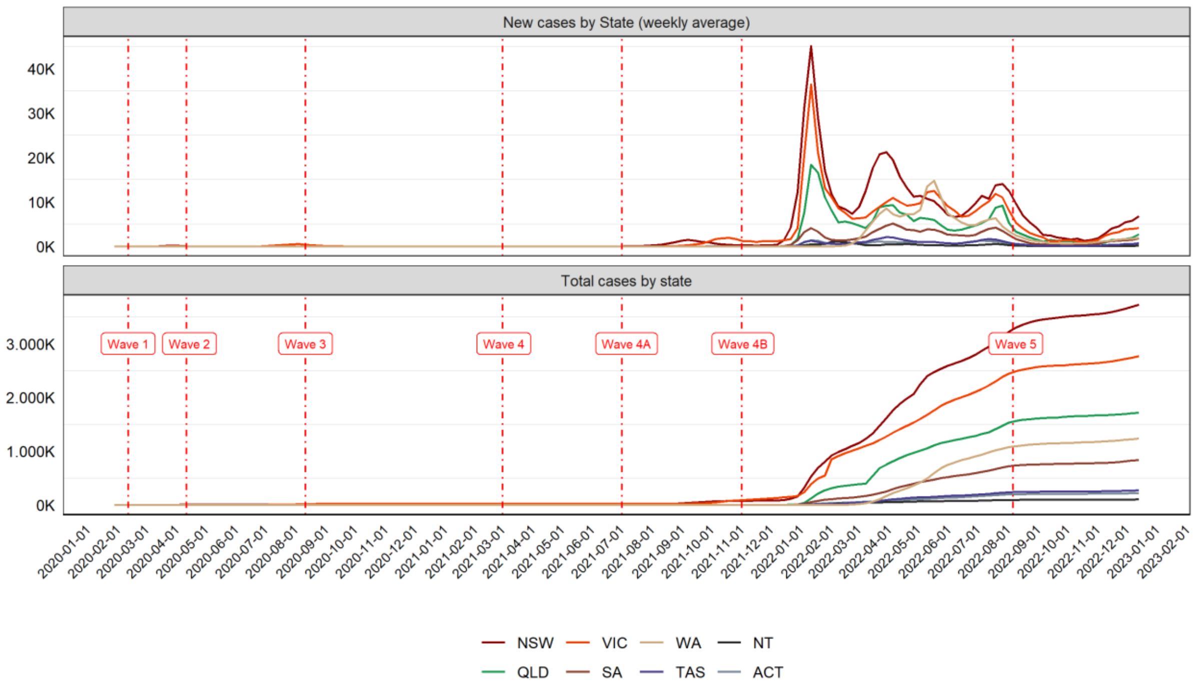

Figure 2: Timeline of surveys versus daily COVID-19 cases by State to date

The report is structured as follows. We begin with an overview of the surveys undertaken over the first 30 months of pandemic, followed by a descriptive synthesis of some of the most interesting findings in terms of the changing incidence of WFH and the accompanying views on employee productivity as perceived by employees and employers, the ways in which travel time 'savings' from reduced commuting is reallocated to other work and leisure activities, and what this means for wellbeing and general satisfaction with life. The following sections focus on the impact of WFH in non-commuting travel behaviour, and its implications on businesses' office space decisions. The final section offers a high level strategic and policy-focussed view on what all the findings mean for future transport and land use planning and investment. A large number of papers have been published by the authors as part of this project, which are included in the Appendices. The document presents the main policy implications of the project and outlines some of the key insights as societies slowly gain an understanding of what the 'next normal' may indeed deliver.

2 A journey through the last three years

The sample size, date, location, and key socioeconomic characteristics are summarised in Table 1. All surveys were conducted online using the Pure Profile customer panel. The data was cleaned using widely accepted methods (extreme outliers, speed of completion, non-sensical responses) and the resulting sampling lines up well with the Australian Bureaus of Statistics (ABS) census in 2021.

The primary focus of our research has been on the States of New South Wales (NSW) and Queensland since the funding support came primarily from transport authorities in these two States, with a small amount of additional funding provided by Western Australia Department of Transport as a way to keep apprised of what was occurring in Eastern States. In this report we will focus on the metropolitan areas of NSW and Queensland, referred to as the Greater Sydney Metropolitan Area (GSMA) and Southeast Queensland (SEQ), respectively. The GSMA includes Newcastle in the north through to Sydney and Nowra/Illawarra in the South; SEQ stretches from the Sunshine Coast in the north through Brisbane to the Gold Coast in the south. Although some preliminary modelling of commuter mode choice and the probability of WFH was undertaken using Waves 1 (Beck et al., 2020) and Wave 2 (Hensher, Beck, et al., 2021), the main development of a mode choice model incorporating WFH that can be integrated into strategic transport models for the GSMA and SEQ occurred in Wave 3 (Hensher, Balbontin, et al., 2022), Wave 4 (Hensher, Wei, et al., 2021) and Wave 5 (Hensher, Beck, et al., 2023). We ensured we had enough workers in Waves 3 to 5 to be able to estimate discrete choice models of the mixed logit form.

In addition to these five waves, we recognised a need to get into the field during the significant lockdown (in Sydney in particular) from July 2021 to October 2021, and to also get back into the field soon after the main lockdowns were eased or totally relaxed. This results in Waves 4A and 4B where the focus was on the suite of questions related not to the requirements of a re-estimated modal choice model, but to capture the WFH responses and other associated impacts that were also identified through Waves 1 to 4. Wave 4A focussed only on the GSMA (387 individuals) and SEQ (329 individuals) and Wave 4B had 2,189 observations spread throughout four locations (GSMA=573, SEQ=721, Victoria=437, and Western Australia=224). Wave 4A and 4B data descriptives are detailed in Section 2.6. In addition, we undertook a separate survey in the GSMA on the impact of COVID-19 and WFH on the capacity needs at the main office location and the growth anticipated in the use of satellite of third offices, which is detailed in Section 2.8. We further highlight that the Wave 5 data collection was significantly delayed due to ongoing flooding in QLD and NSW (the primary states for data collection), along with industrial disrupts that further disrupted transport networks. We anticipate that disruption will only become increasingly more prevalent, bringing the location of work into even sharper focus.

Table 1: Overview of Survey Samples

	Wave 1	Wave 2	Wave 3	Wave 4	Wave 5[1]	ABS*
Total sample	1,074	1,457	2,500	2,019	3,759	n/a
Survey period	March-April 2020	May-June 2020	August-October 2020	April-May 2021	August-September 2022	2021
Number of workers	714	916	1,696	1,149	2,575	
Female	52%	58%	64%	59%	62%	51%
Age	46.3 (σ = 17.5)	48.2 (σ = 16.2)	44.7 (σ = 16.7)	48.3 (σ = 17.6)	44.1 (σ = 16.4)	48.2
Median Income[2]	Household $92,826 (σ = $58,896)	Household $92,891 (σ = $59,320)	Personal $60,646 (σ =$49,897)	Personal $61,410 (σ =$47,500)	Personal $72,054 (σ =$56,981)	Personal = $60,320 Household = $74,776
Have children[3]	32%	35%	35%	32%	39%	25%
Number of children	1.8 (σ = 0.8)	1.7 (σ = 0.9)	1.7 (σ = 1.04)	1.8 (σ = 1.0)	1.9 (σ = 1.0)	1.8
Occupation for those working						
Manager	1%	2%	14%	16%	15%	13%
Professional	38%	35%	29%	27%	30%	22%
Technician & Trade	5%	6%	5%	5%	5%	13%
Community & Personal Services	8%	10%	9%	10%	11%	11%
Clerical and Administration	17%	17%	21%	20%	22%	14%
Sales	23%	22%	10%	10%	10%	9%
Machine Operators / Drivers	2%	2%	3%	5%	2%	6%
Labourers	5%	5%	6%	6%	5%	10%
State						
New South Wales	22%	32%	46%	44%	51%	32%
Aust. Capital Territory	2%	2%	1%	1%	0.1%	2%
Victoria	28%	24%	9%	2%	0.6%	26%
Queensland	22%	18%	35%	43%	47%	20%
South Australia	11%	11%	4%	4%	0.8%	7%
Western Australia	11%	10%	4%	4%	0.9%	10%
Northern Territory	1%	1%	0.3%	0%	0.03%	2%
Tasmania	2%	3%	1%	1%	0.1%	1%

*Source: Australian Bureau of Statistics Annual Key Figures

[1] Wave 5 had a significantly larger sample size than previous waves targeting workers in New South Wales and Queensland, which explains the higher average income in this wave and the state's proportion of the sample.
[2] ABS reported income is for all individuals 15 years or older, whereas we sample 18 years or older, this may explain some of the discrepancy in personal income.
[3] Our survey reports whether a household has children or not, whereas the ABS only provides a definition of a family and includes households without children in that composition.

2.1 How has the incidence of WFH changed?

Figure 3 summarises the number of days working from home over the survey period, and Figure 4 the proportion of working days that are WFH. Waves 1 and 2 represent a period during the initial lockdown period (see Appendix timeline) when the Federal and State governments mandated working from home unless a person's job was defined as essential and required being out of the home. The highest incidence of WFH, with a proportion of 0.697 of the working days for the GSMA, is observed in the first month of the pandemic, significantly higher than Australia as a whole (0.598) and SEQ (0.542). In part this is explained by the occupation mix of residents (Beck & Hensher, 2020a). At this time the nature of the COVID-19 virus was still unknown, and no vaccine existed.

As the first lockdown period progressed into its third month (June 2020), a reduction in the incidence of WFH starts, but still well above 0.5 for the GSMA and SEQ (Beck & Hensher, 2020b). As lockdown was eased and generally relaxed except for a few conditions such as social distancing in public venues and mask wearing on public transport and other close contact venues outside the home, the proportion of days WFH reduced to an average of 0.502 for the GSMA and 0.400 for SEQ (Wave 3, Beck & Hensher, 2020a, 2020b). These are still relatively high suggesting an average of 2 to 3 days a week WFH across the working population in metropolitan areas, which translates into higher averages for occupations such as professional, manager and clerical workers.

Wave 4 began a period of significant easing of most restrictions but maintaining social distancing and mask wearing on public transport. The vaccine rollout had begun, though less than 1 in 5 people in Australia were vaccinated. A considerable drop in the incidence of WFH at an average of 0.280 for SEQ and 0.284 for the GSMA is observed, closer to an average of 1 day per week. The question at the time was whether this is going to be indicative of what the 'next normal' might look like. This was soon dispelled with a major lockdown when the Delta strain took hold and Australia's view on minimising the number of individuals with the disease (in contrast to the hospitalisation rate) resulted in a lockdown similar to the earlier period at the beginning of 2020. The proportion of working days WFH sky-rocketed (Wave 4A) to 0.524 for SEQ and 0.503 for the GSMA, back to the levels in mid-2020 but not to the levels in the first months of the pandemic. As the Delta virus became contained to what was described as acceptable levels, with the 80% vaccination rate achieved for two jabs, by Mid-October the GSMA opened up, with SEQ already opened up early August after only a very short lockdown (but with border closures since the 80% full vaccination rate was not yet achieved as a condition for border to be re-opened). Again, there is a significant drop in the incidence of WFH (Wave 4B) down to 0.246 for SEQ and 0.389 for the GSMA. The SEQ figure is interesting in that it is a return to the Wave 4 mean estimate before the lockdowns in SEQ although the GSMA average remains relatively high suggesting greater reticence to get out and about. This can in part be explained by the explosion of the Omicron variant that had begun in mid-December 2021 and grew at an exponential rate in NSW in particular (Figure 2). Although residents were not restricted during the Omicron outbreak, there was significant nervousness about interacting with other people, which we have described as voluntary lockdown (officially referred to as shadow lockdown by State government).

Early 2022 data was collected only in the GSMA, which suggested a slight decrease in the proportion of working days that are WFH to 0.355. Wave 5 conducted in August and September 2022 provided an opportunity to establish the extent to which the average level of WFH may be stabilising in the GSMA and SEQ. Whereas the GSMA has an average proportion of WFH close to what was observed in the SEQ almost 12 months prior (Wave 4B) of 0.270, the SEQ is the lowest since COVID-19 began with a proportion of 0.180, and we are now starting to see a position of likely future WFH rates. This is unclear, but the view is that such an equilibrium is getting close (or has even arrived) at a rate associated with a future hybrid work model. Table 2 summarises some important spatial differences in the mean estimates of WFH only and at some point during the day where, as expected, there are higher rates for Central business districts than other residential locations in the metropolitan areas and also quite different lower estimates for rural/regional contexts in NSW and Qld.

Figure 5 presents the average number of days individuals reported to prefer to WFH only (i.e., not go to the office) moving forward in Waves 3, 4 and 5. Interestingly, results show than in June 2021, individuals wanted to WFH less days of the week, probably linked to a prolonged period of restrictions and fatigue. In September 2022, the average number of days people want to WFH only went back up, reaching levels similar to those reported in August 2020. The preferred number of days WFH is consistently lower in rural areas than metropolitan areas, both in NSW and Qld.

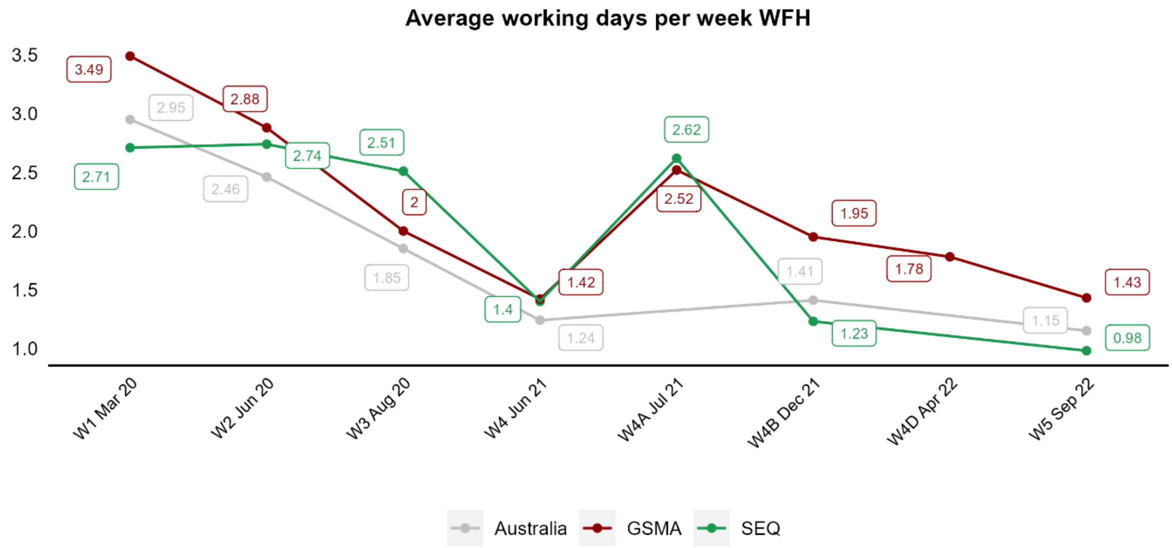

Figure 3: The number of working days that are working from home at some point[4]

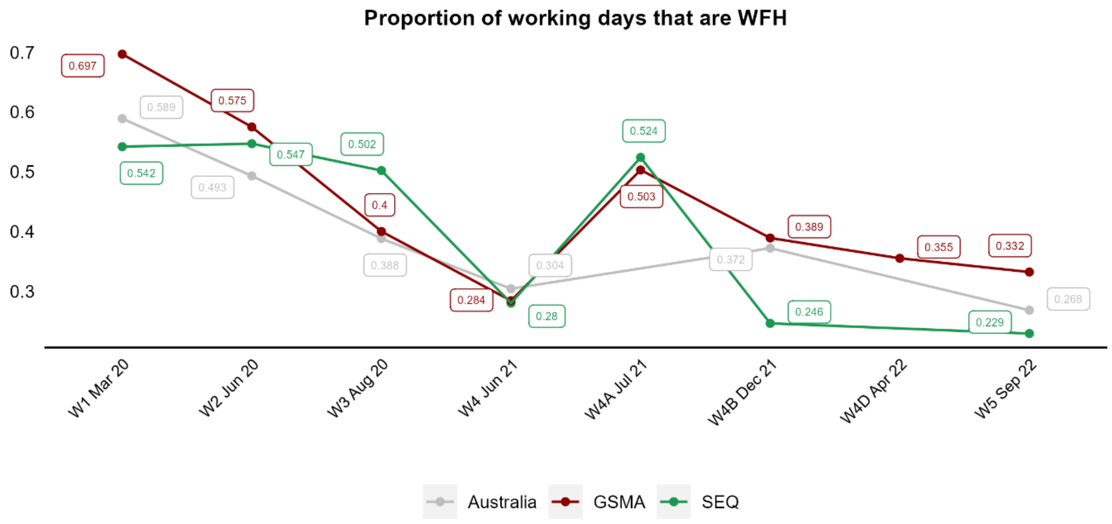

Figure 4: The proportion of working days that are working from home at some point[4]

[4] Australia includes all states including NSW and QLD, which represents the majority of the sample for Waves 3 to 5

Table 2: A summary of key WFH indicators in Wave 5

	GSMA	Rural NSW	Sydney CBD	SEQ	Rural QLD	BNE CBD
Average days worked	4.30 (1.34)	4.45 (1.53)	4.39 (1.32)	4.44 (1.23)	4.69 (1.24)	4.55 (1.30)
Weekdays	4.02 (1.42)	3.94 (1.43)	4.24 (1.37)	4.07 (1.31)	4.29 (1.19)	4.27 (1.29)
Weekends	0.27 (0.60)	0.50 (0.81)	0.16 (0.50)	0.37 (0.69)	0.40 (0.70)	0.28 (0.61)
Average days WFH at some point	1.43 (1.86)	0.82 (1.65)	2.20 (1.91)	0.98 (1.66)	0.86 (1.70)	1.62 (1.90)
Weekdays	1.36 (1.82)	0.73 (1.47)	2.16 (1.87)	0.92 (1.57)	0.80 (1.57)	1.55 (1.84)
Weekends	0.06 (0.32)	0.09 (0.37)	0.03 (0.23)	0.06 (0.31)	0.06 (0.32)	0.07 (0.32)
Average days WFH only	1.21 (1.76)	0.62 (1.49)	2.00 (1.90)	0.77 (1.44)	0.66 (1.54)	1.40 (1.75)
Weekdays	1.17 (1.72)	0.55 (1.33)	1.96 (1.86)	0.72 (1.39)	0.62 (1.41)	1.35 (1.73)
Weekends	0.05 (0.28)	0.06 (0.32)	0.03 (0.23)	0.05 (0.27)	0.04 (0.28)	0.06 (0.28)
Proportion of days WFH only	0.27 (0.38)	0.14 (0.31)	0.43 (0.39)	0.18 (0.32)	0.14 (0.31)	0.32 (0.38)
Weekdays	0.27 (0.38)	0.14 (0.31)	0.43 (0.39)	0.17 (0.32)	0.14 (0.31)	0.31 (0.38)
Weekends	0.03 (0.17)	0.04 (0.19)	0.02 (0.15)	0.03 (0.17)	0.03 (0.16)	0.04 (0.19)
Sample size	**1135**	**232**	**231**	**874**	**270**	**163**

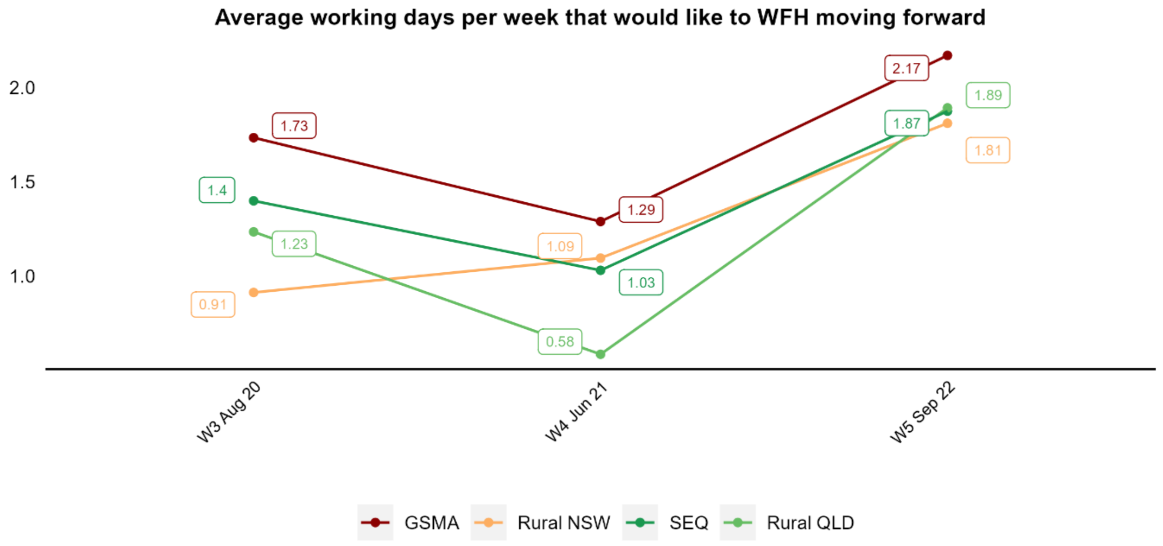

Figure 5: Number of working days that individuals prefer to work from home only

The main mode distribution for commuters is presented in Figure 6 for Waves 3, 4 and 5. It is encouraging to see that the private vehicle use has decreased significantly since the start of the pandemic, reaching a 77% for SEQ and 65% for GSMA, while public transport and active mode use has increased reaching a 16% and 7%, respectively for SEQ, and 30% and 5% for GSMA.

A key influence on the ability to WFH is an individual's occupation. As seen in Figure 7, the proportion of working days that are WFH and in Figure 8 the number of days WFH for Waves 3, 4 and 5. Results show that employees in the categories of manager, professional and clerical/administration are more likely to WFH, which aligns well with the nature of work and the ability to work from any location, in contrast to many workers in other categories such as machine operators and drivers who cannot do their job unless they are on-site. The last two categories show the difference between white-collar and blue-collar occupations, which have significant differences as expected across all waves and areas. In a number of papers such as (Hensher, Balbontin, et al., 2022), we have developed a mapping equation to obtain variations in the probability of WFH depending on occupation in particular, and locational attributes as well as the commuting travel time. The probability obtained from the mixed logit model of the commuter choice between no work, WFH and, if commuting, mode of transport by time of day and day of the week over seven days. The mapping equation is used to obtain a spatial representation of the probability of WFH as shown for the GSMA and SEQ in Figure 10 for Waves 3, 4 and 5.

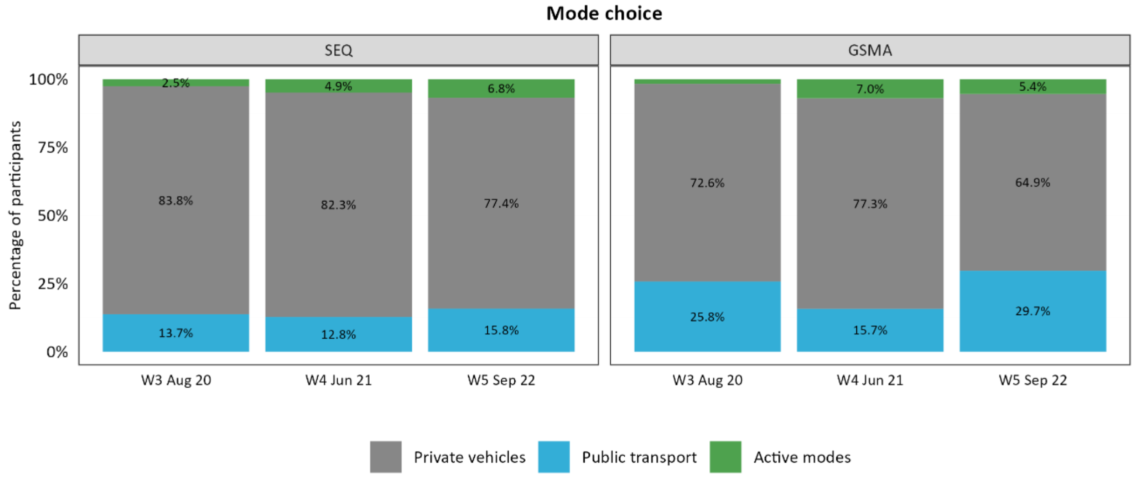

Figure 6: Mode choice for GSMA and SEQ, Waves 3,4 and 5

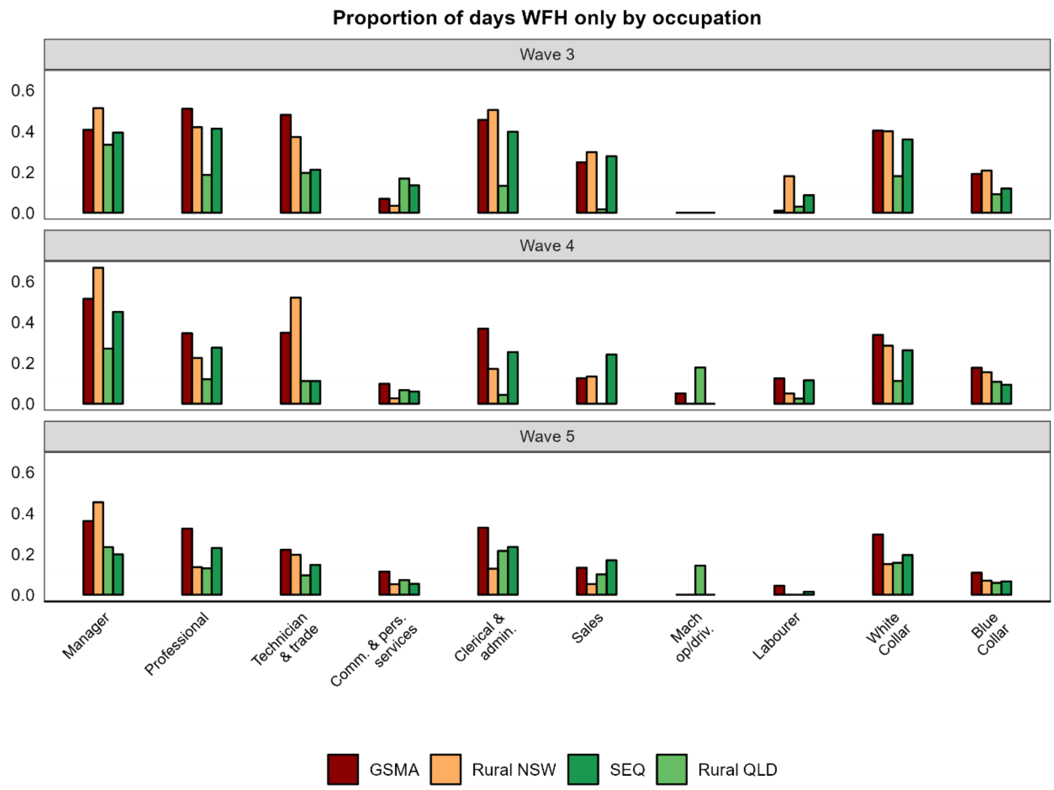

Figure 7: Percentage of working days that individuals work from home by occupation

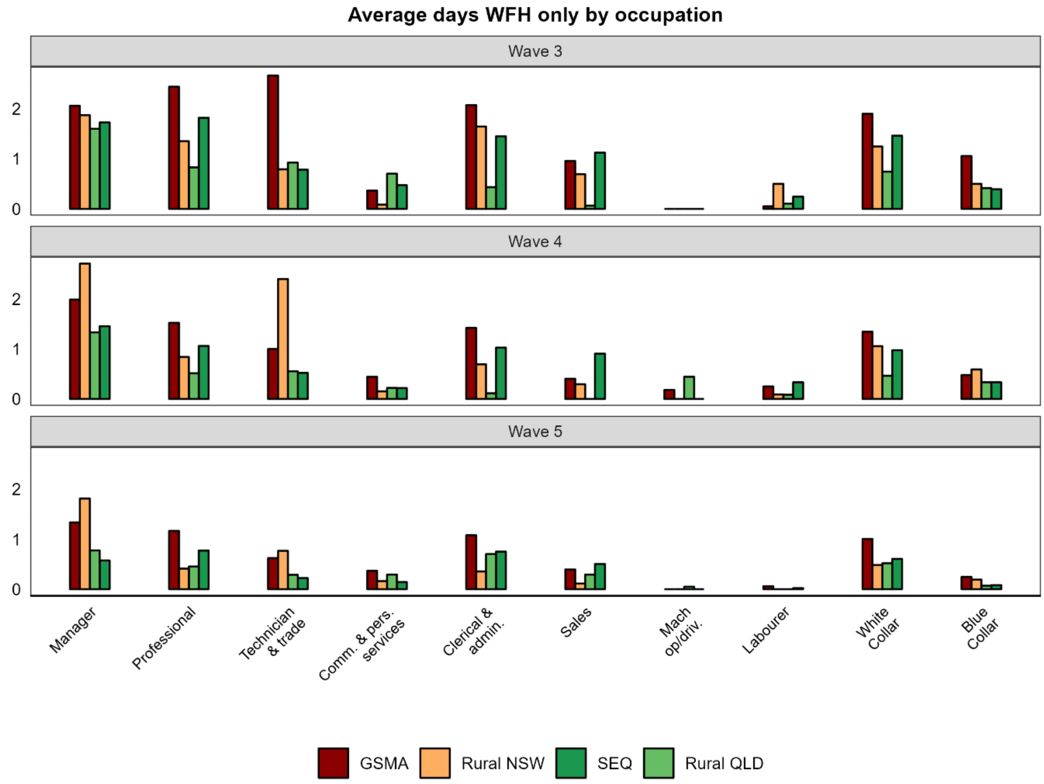

Figure 8: Number of days WFH by occupation

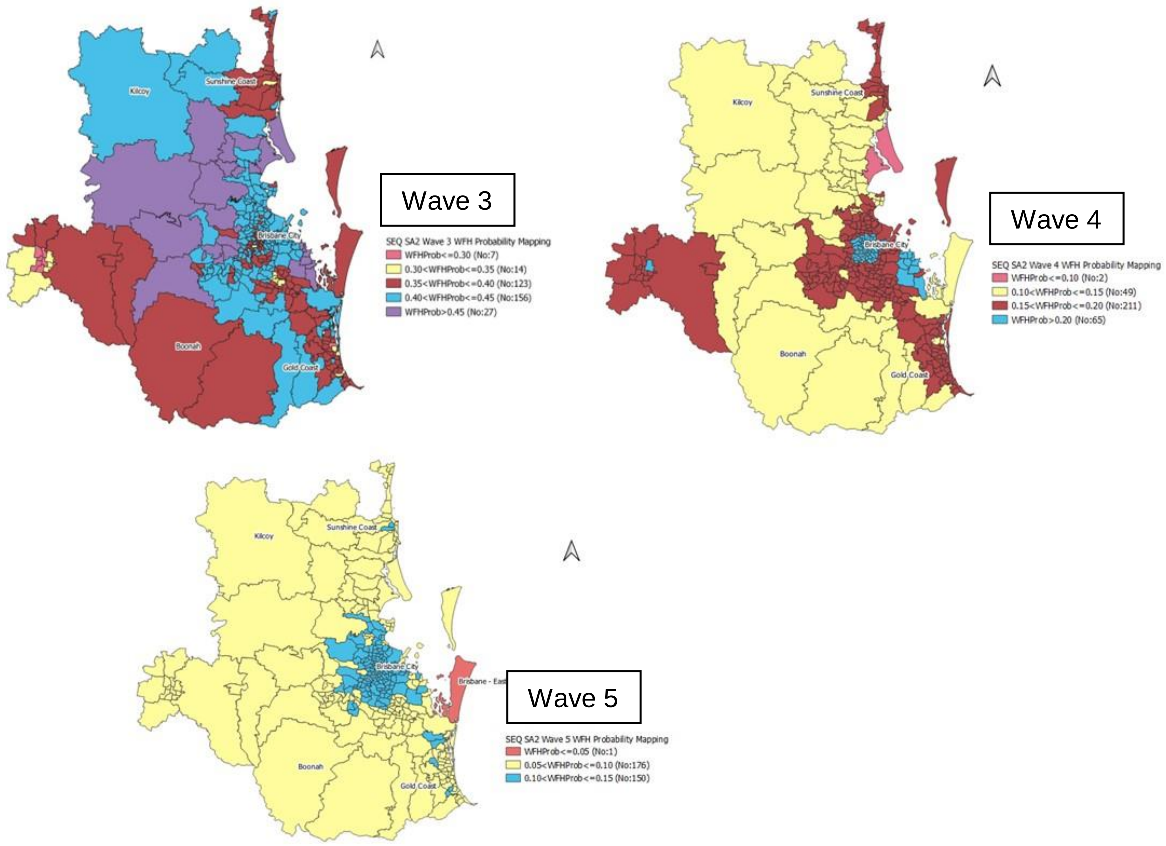

Figure 9: Probability of WFH by SA2 SEQ - Waves 3,4 and 5

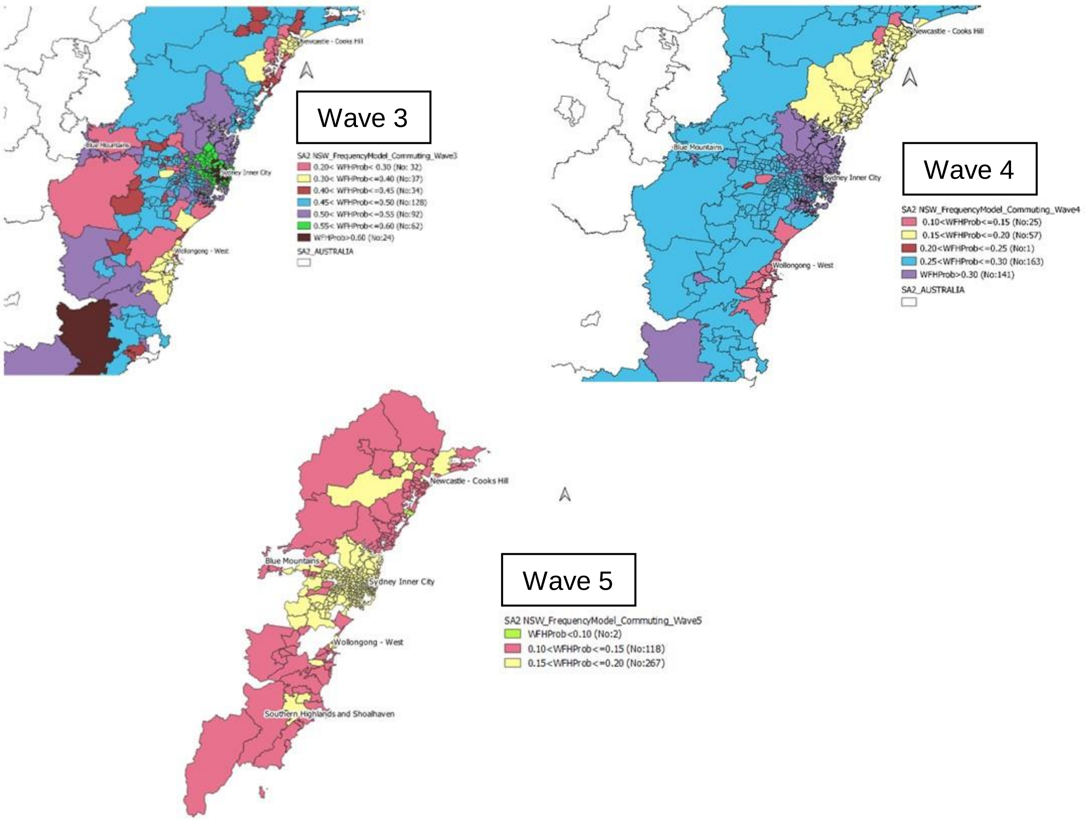

Figure 10: Probability of WFH by SA2 GSMA - Waves 3,4 and 5

An example of how rates of WFH can be estimated within various locations is presented in Figures 11 to 14. They provide another perspective on the change in the probability of WFH for each SA2 location in the SEQ and GSMA between data collected in September 2020, June 2021 and August-September 2022. These is clear evidence over this 28-month period of a reduction in the average number of days WFH, with the reduction being greater between September 2020 and June 2021 than between June 2021 and September 2022, suggesting a convergence to a level of WFH which we might describe as stabilised hybrid working.

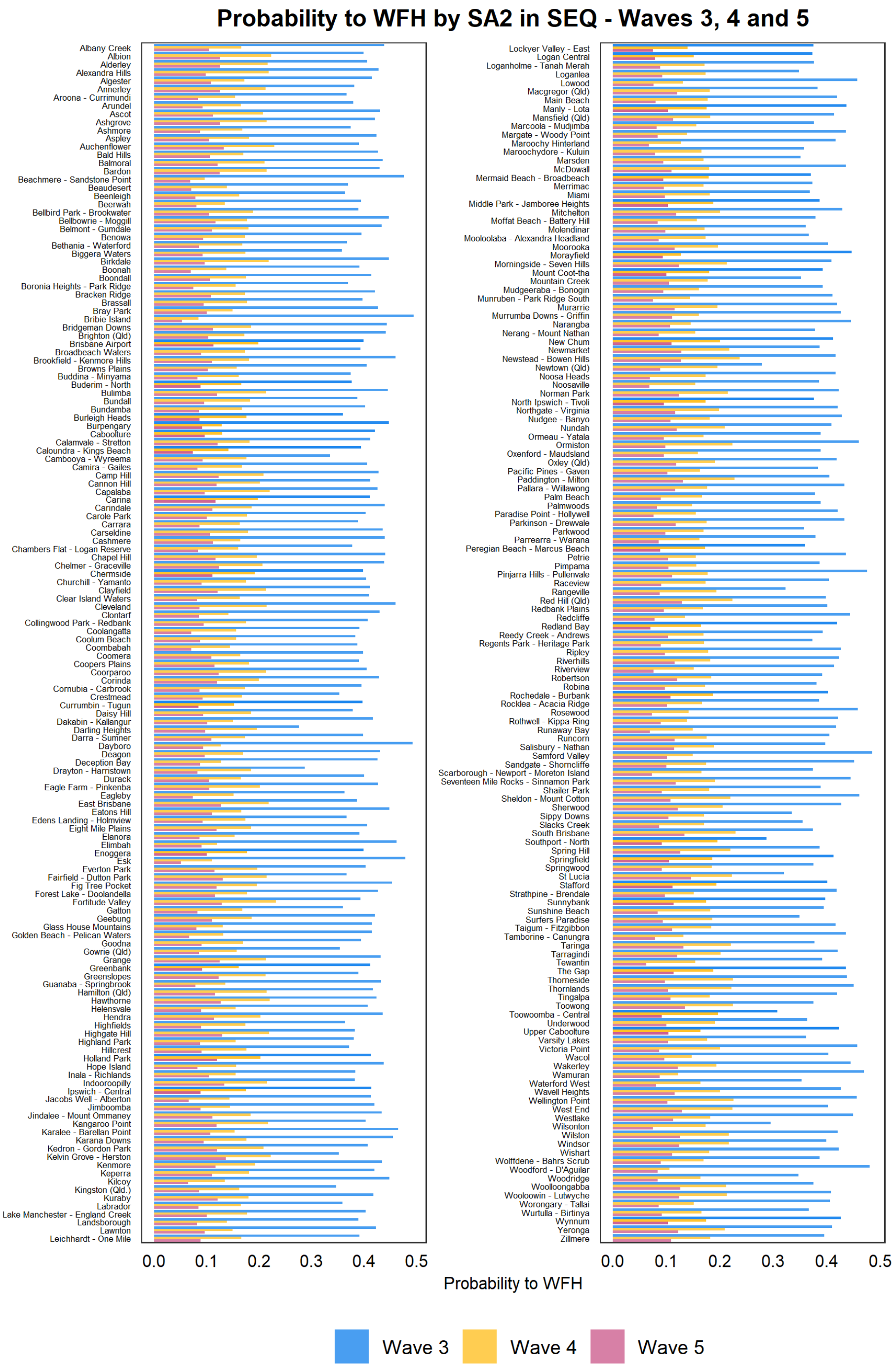

Figure 11: Probability to WFH SEQ by SA2 – Waves 3, 4 and 5

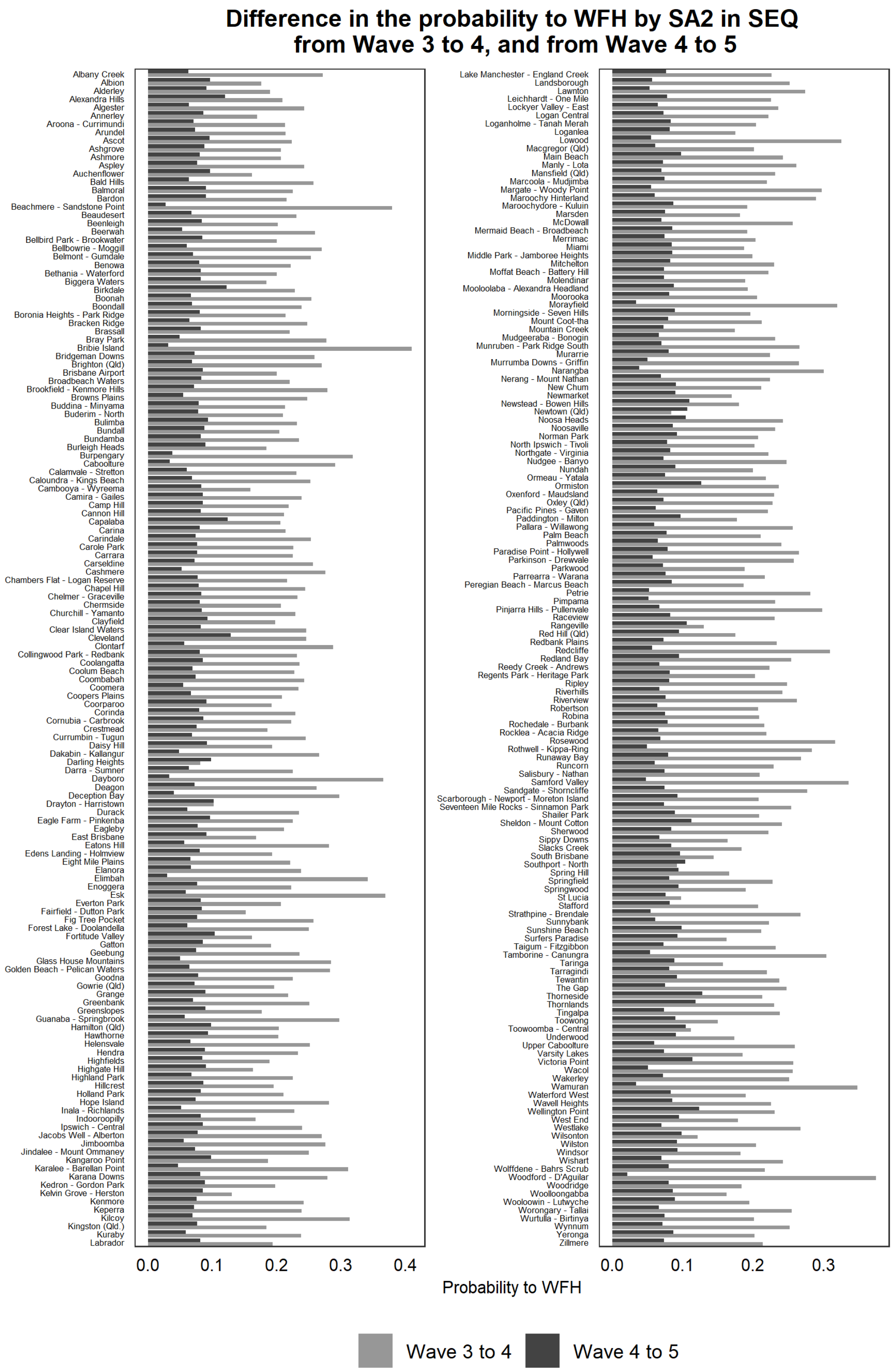

Figure 12: Changes in the probability to WFH SEQ by SA2, from Wave 3 to 4 and Wave 4 to 5

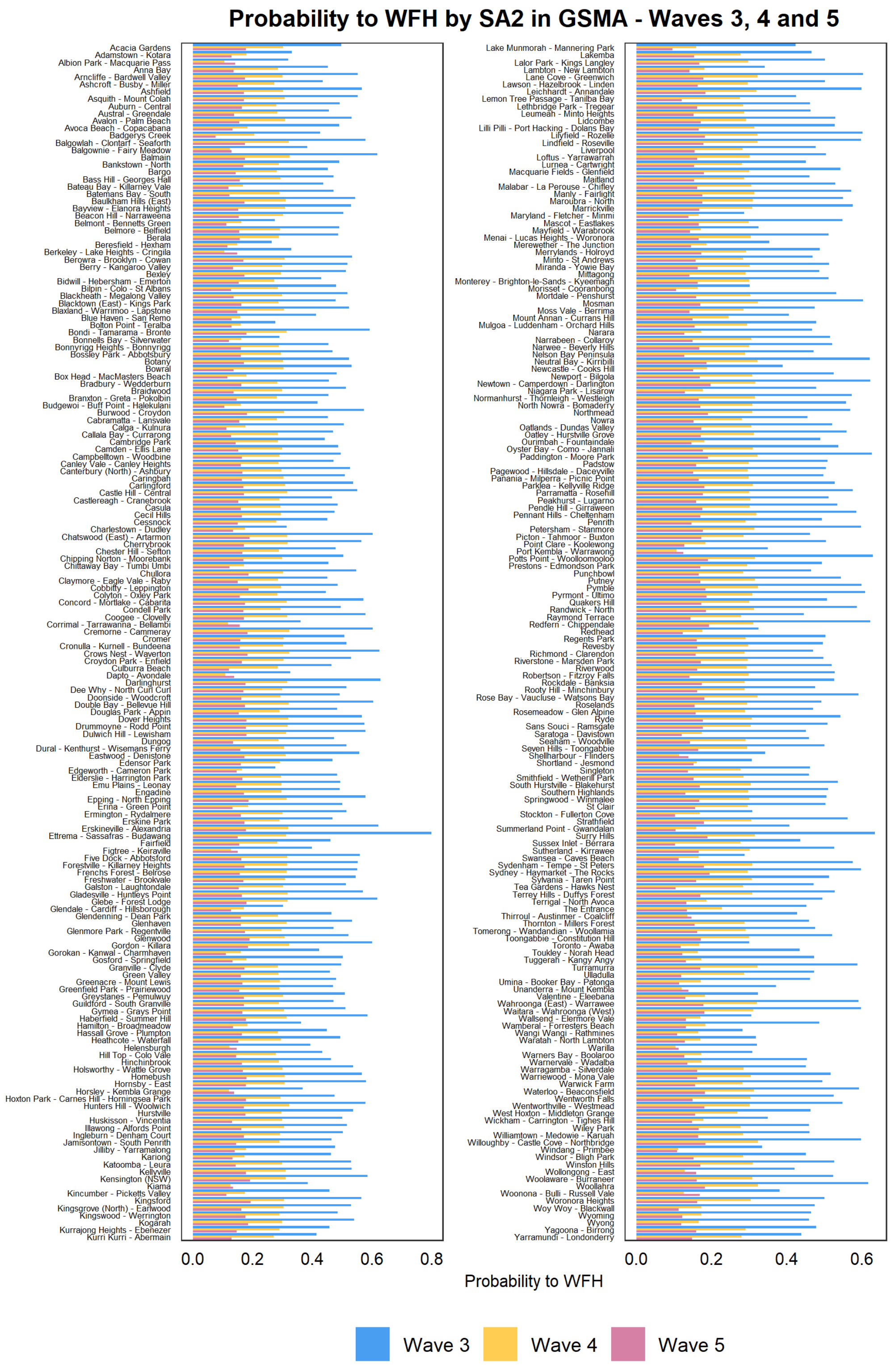

Figure 13: Probability to WFH GSMA by SA2 – Waves 3, 4 and 5

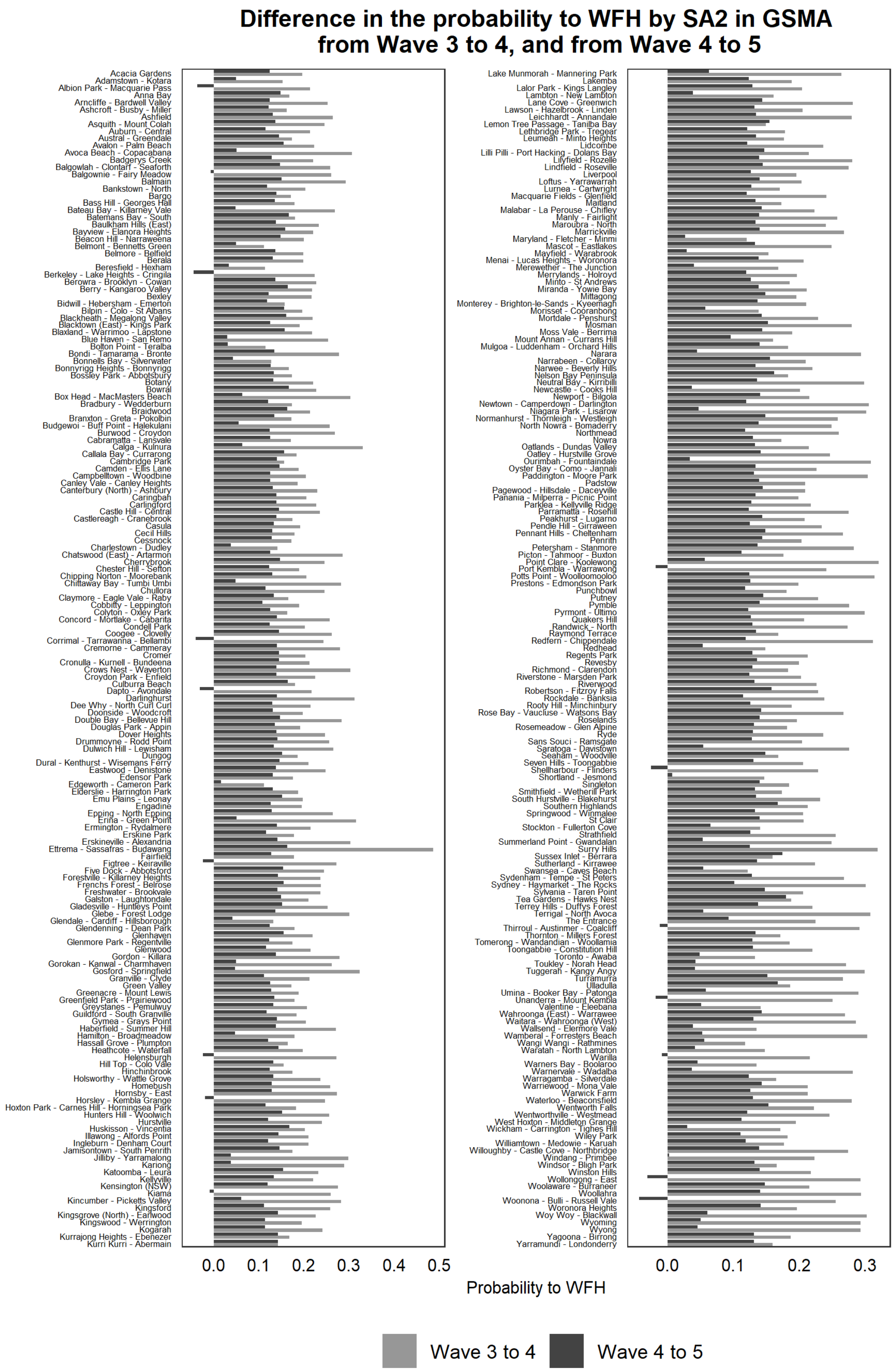

Figure 14: Changes in the probability to WFH GSMA by SA2, from Wave 3 to 4 and Wave 4 to 5

2.2 What do commuters do with the time saved from reduced commuting?

A particular interest is what happens to any travel time reallocated away from commuting to other activity classes as a result of increased working from home. This is a test of the extent to which the theoretical trade-offs between travel and work, and travel and leisure, and work and leisure occur under the new era of a greater incidence of working from home. Our research offers new evidence on the way in which 'saved' commuting time over a period (i.e., a week) is allocated to three main activity classes, namely paid work, unpaid work and leisure, and furthermore what are some of the statistically significant influences on this re-allocation. Details are provided in (Hensher, Beck, et al., 2022). Table 3 shows that on average for those who save time from commuting, 60 mins per day is saved in Wave 4, with this saving being allocated on average as 45.9-52.8% to leisure, 32.1-23.9% to paid work and 22-23.3% to unpaid work for GSMA-SEQ, respectively. The findings are important in obtaining estimated time benefits from reduced commuting activity with such travel time being traded against work and against leisure, and what this might mean for the future travel, activity location, and lifestyle landscape.

Table 3: Descriptive Profile of the Incidence of Commuting Time Re-allocation throughout a week – Wave 4

	GSMA	SEQ
Commuting time saved (mins per day)	63.2 (116.8)	58.5 (101.1)
Time spent doing additional work that I receive pay for (%)	32.1 (33.4)	23.9 (31.2)
Time spent doing additional work for which I receive no extra pay (%)	22.0 (25.4)	23.3 (30.6)
Time spent on leisure or family (%)	45.9 (33.9)	52.8 (38.3)
Days per week WFH only	2.8 (1.8)	2.4 (1.8)
Days per week WFH at some point	3.2 (1.6)	2.8 (1.6)
Days per week Work (from any location)	4.3 (1.6)	4.2 (1.5)

Hensher et al. (2022) undertook a simulation of the relationship between the probability of allocating saved commuting time to each activity class as age and commuting time varies. It is found that as the amount of time saved from reduced commuting increases, *ceteris paribus*, the probability of allocating a higher quantum of time to leisure and unpaid work increases and decreases for paid work. The rate of change is similar for leisure and unpaid work as the amount of commuting time saved increases, although the latter has a lower probability, suggesting that the main substitution is between paid work and both unpaid work and leisure. The simulation results in our sample suggest that, *ceteris paribus*, if a respondent saves less than 100 minutes as a result of less commuting, then they will allocate more of this time to paid work relative to unpaid; but this will be opposite for a respondent saving more than 100 minutes as a result of less commuting. In the case of an individual's age, as age increases, *ceteris paribus*, the probability of allocating a higher quantum of time to leisure increases significantly, while it decreases for both paid and unpaid work at a similar rate, suggesting approximately equal substitution between all work and leisure activities. The results show that, *ceteris paribus*, a respondent who is 50 years old tends to allocate half of their saved time from not commuting to leisure, around 30% to paid work and 20% to unpaid work.

The Wave 4 finding does not provide enough evidence on the extent to which the reallocation of commuting time to leisure, paid and unpaid work is associated with specific activities that occur inside or outside of the home. This is important to know since any outside activity is associated with increased travel, which can add to the quantum on non-commuting travel on the road network or elsewhere depending on whether active modes or public transport is used. In subsequent waves (beginning with 4B) this issue was explored more, and Figure 15 summarises the allocation time to activities associated with leisure and paid/unpaid work. For SEQ, 23-21% of all time saved is associated with leisure activities undertaken in the home, 17-25% household tasks (i.e., chores), and 8-9% is associated to leisure outside of the home, i.e., a total of 48-55% of the saved time is allocated to leisure activities plus household tasks for Wave 4b-Wave 5, respectively. The equivalent percentages for GSMA are 18-19% for leisure activities in home, 20-23% for household tasks, and 12-7% for leisure activities outside home, i.e., 50-49% of all saved time is allocated to leisure plus household tasks for Wave 4b-Wave 5, respectively.

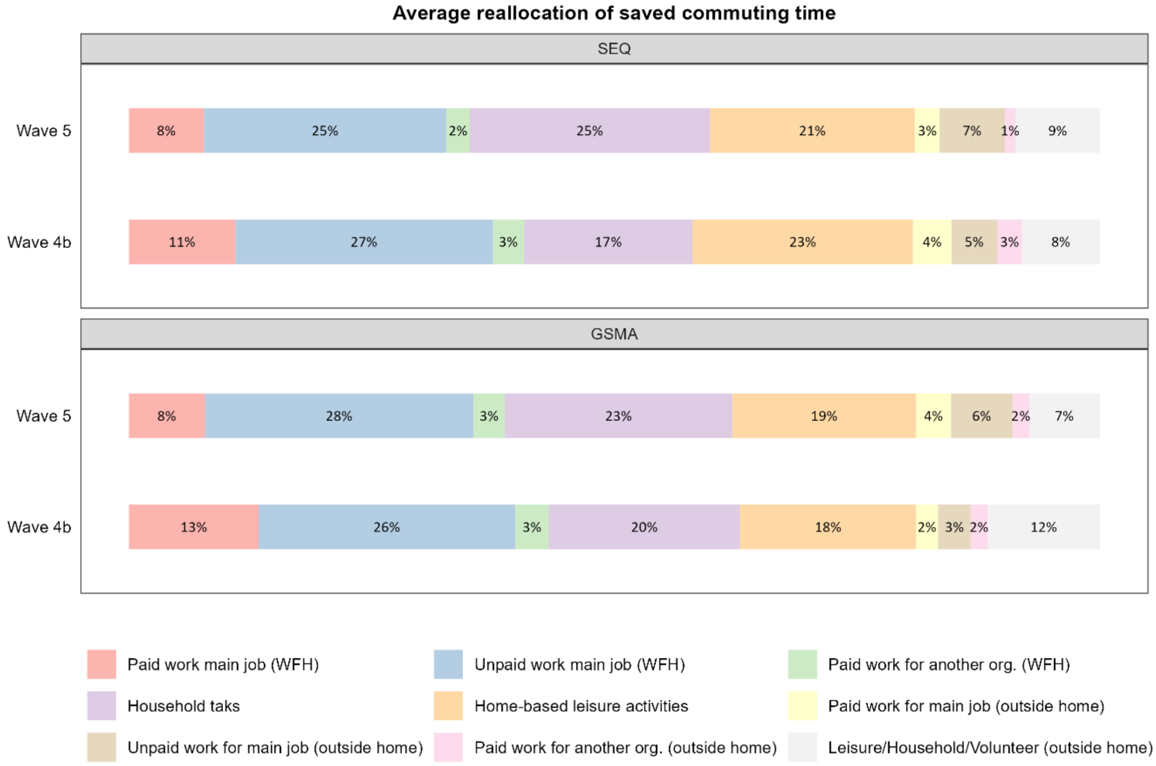

Figure 15: The breakdown of the allocation of saved commuting time within leisure and work – Waves 4B and 5

The results for the total daily and weekly saved time by not commuting is presented in Figure 16. In SEQ, respondents saved an average of 68 daily minutes and 8.2 hours in the last week by not commuting, those in GSMA saved an average of 74 daily minutes and 9.4 hours in the last week.

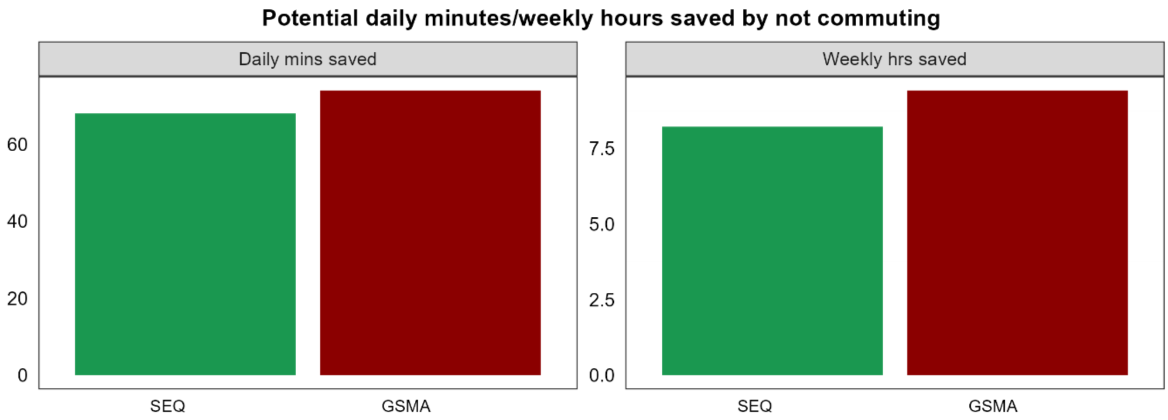

Figure 16: Saved commuting time by not commuting – Wave 5

2.3 Does WFH and reduced commuting have a positive benefit on wellbeing?

While we would have preferred that the virus had not taken hold, we must look forward to use this 'extreme event experience' to obtain positive benefits to individuals, households and society more broadly. This position must recognise that mental health and well-being, including social exclusion has not gone away (see Stanley et al., 2022) and that it remains a high priority for governments as well as for business more generally.

Included in Waves 3, 4 and 5 were a series of well-being questions identical to those used in the UK Office of National Statistics Annual Population Survey (ONS, 2021), as part of their quarterly estimates of life satisfaction. The four questions used asked respondents to indicate: (i) how satisfied they are with life nowadays, (ii) how worthwhile they think things done in life are, (iii) how happy they felt yesterday, and (iv) how anxious they felt yesterday. The four well-being questions are reported on a scale from 0 representing 'not at all' to 10 representing 'completely'. Given concerns often raised about the mental health risks associated with extensive periods of WFH, the extent to which experiences with working from home, and associated impacts such as reduced stressful commuting has resulted in improved well-being or not was investigated.

Looking at 'how worthwhile are the things you do in life' which is highly correlated with all except the anxiety scale. In the distribution presented in Figure 17, shows a right-skewed distribution with rating scores of 7 and 8 dominating. This already hints at evidence that satisfaction with life, in particular as people moved away from the initial peak of COVID-19 infections, was returning to some greater degree of positive 'normality' and was robust for those people who were still working during this period.

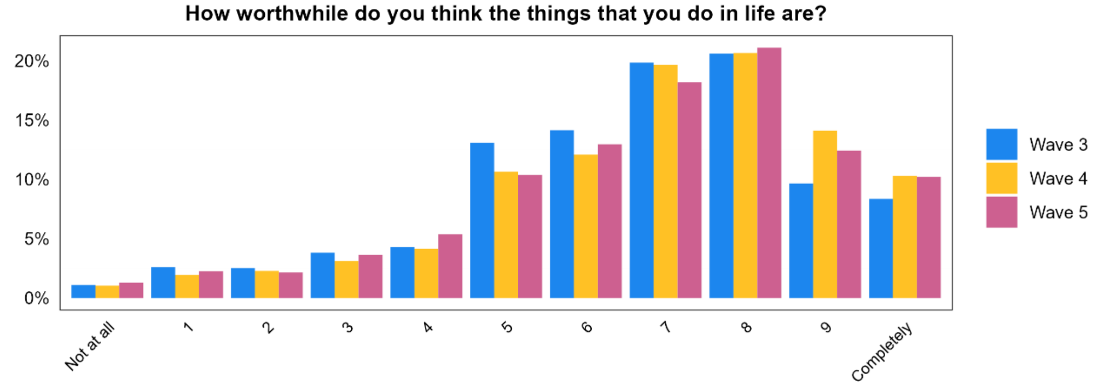

Figure 17: Distribution of the "how worthwhile are the things you do in life" statement – Waves 3, 4 and 5

The detailed analysis is set out in (Hensher & Beck, 2022) using Waves 3 and 4 data and herein provide a summary of the main findings as to whether there is a systematic behavioural link between well-being, with working from home, reduced commuting linked to distance to work, balancing work with non-work activities, and various socio-economic characteristics. An ordered logit choice model was implemented on the 11-point scale to investigate the presence or otherwise of such a relationship. The evidence suggests that the opportunity to have reduced commuting activity linked to working from home, increased work-related productivity and an improved balance between time spent on work and time spent not working, have all contributed in a positive way to improving the worth status of life, offsetting some of the negative consequences of the pandemic. Thus, the empirical evidence suggests that some good has come out of the pandemic and the policy implication is very clear; namely, to continue to ensure that people feel trusted and supported to work from home successfully, and know they are making a contribution while doing so. Meaningful work provides meaning to life.

2.4 What is the evidence on productivity implications of WFH?

“The five-day office week is dead, long live the hybrid model”, says Productivity Commission’s chair, Michael Brennan (July 12, 2021, SMH)

One of the risk factors in WFH was whether it would have a negative impact on the productivity of employees. This study, , like many others, found that productivity as perceived by both the employee and the employer has remained unchanged and may even have increased on balance, as presented in Figure 18. Encouragingly, employers have been surprised, with the ability of employees to remain productive and even often increase their productivity, which has links to reduced stress associated commuting, increased flexibility in when to work, and the general improvement in lifestyle. Some of the productivity gains may also be attributable to people working more (see allocation data in Section 2.2) either because they feel they have to, or because they have nothing else to do in lockdown. The implication being that it should not be the expectation that people work longer (particularly unpaid) while WFH, otherwise that could potentially degrade the experience.

Clearly the support from employees and employers for WFH is not uniform as shown in Figure 19, with a higher percentage of employees and employers perceiving a little more and a lot more productivity in Wave 4 and 5 compared to Wave 3, possibly partly linked to being better organised and began to see a continuing employer support for WFH. This translates into a sizeable percentage of employees having the choice to WFH with a balanced plan (or hybrid model) of office and home as presented in Figure 19. In general, that the results show that perceptions of productivity while WFH have remained constant throughout the pandemic, and even at the latest data collection period (Wave 5), workers feel they are just as productive as in their regular workplace before COVID-19.

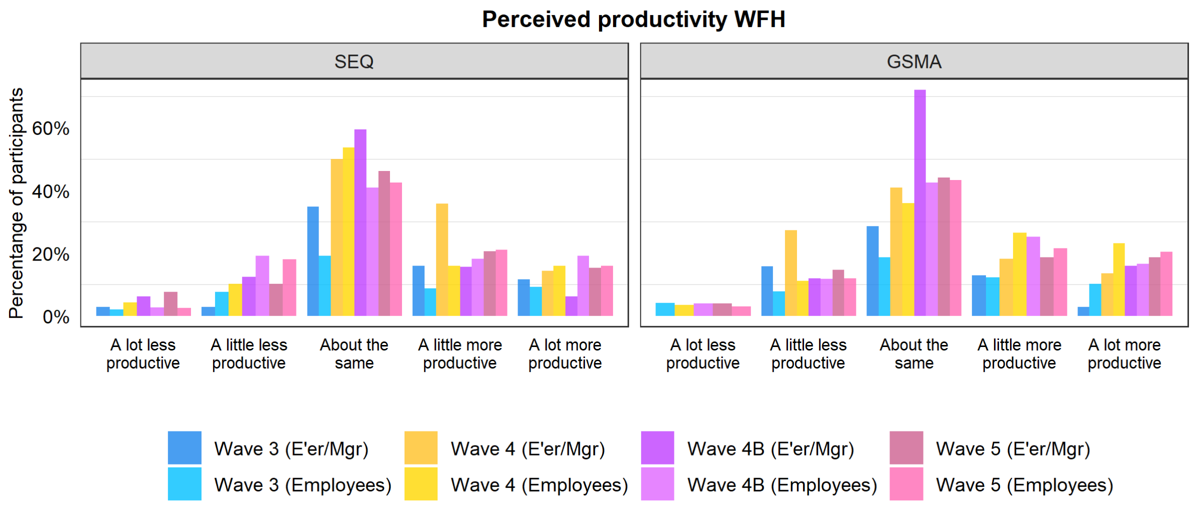

Figure 18: Perceived productivity of WFH by employees and employers - Waves 3, 4, 4B and 5

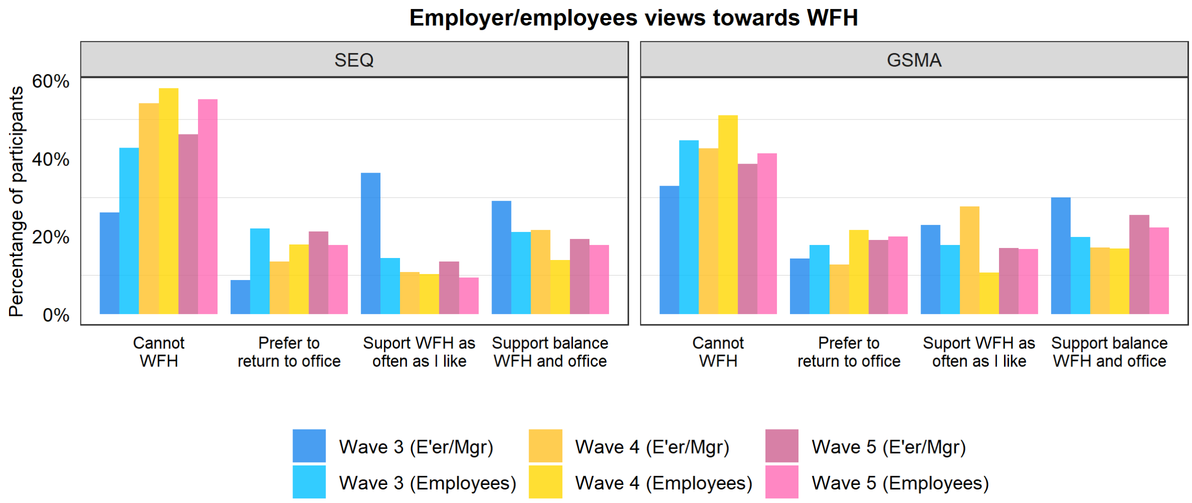

Figure 19: Employees and employers views towards WFH - Waves 3, 4 and 5

Beginning in Wave 4B, respondents were also asked to determine their perceived level of productivity when working outside home compared to pre-COVID-19 levels. The results are presented in Figure 20. More than half of the respondents said to have the same level of productivity as pre-COVID when working outside home, and a similar percentage feel less and more productive.

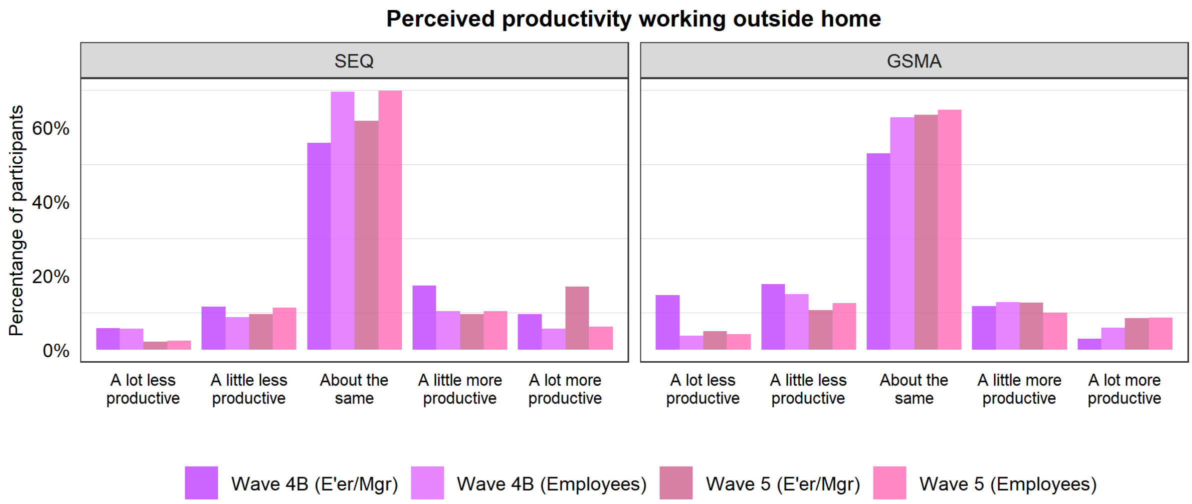

Figure 20: Perceived productivity impact working outside home - Waves 4B and 5

2.5 How might WFH impact on the days of the week commuting?

Knowing the incidence of WFH is important; however also identifying what days of the week WFH occurs is important for transport planning since capacity needs are typically determined by the peak periods. Figure 21 summarises the percentage of workers who WFH on each of the 7 days of the week. In general, for each metropolitan area and wave of data, the distribution is remarkably flat across the weekdays, with a range in the latest period of Wave 5 being 20% to 26% for the GSMA and 14% to 16% for SEQ. What this suggests is that the WFH impact has spread evenly through the weekdays, which is a very encouraging sign for peak period planning; however, it is necessary to look at the evidence at an origin-destination level in order to see the extent to which this flatness is spatially widespread or not.

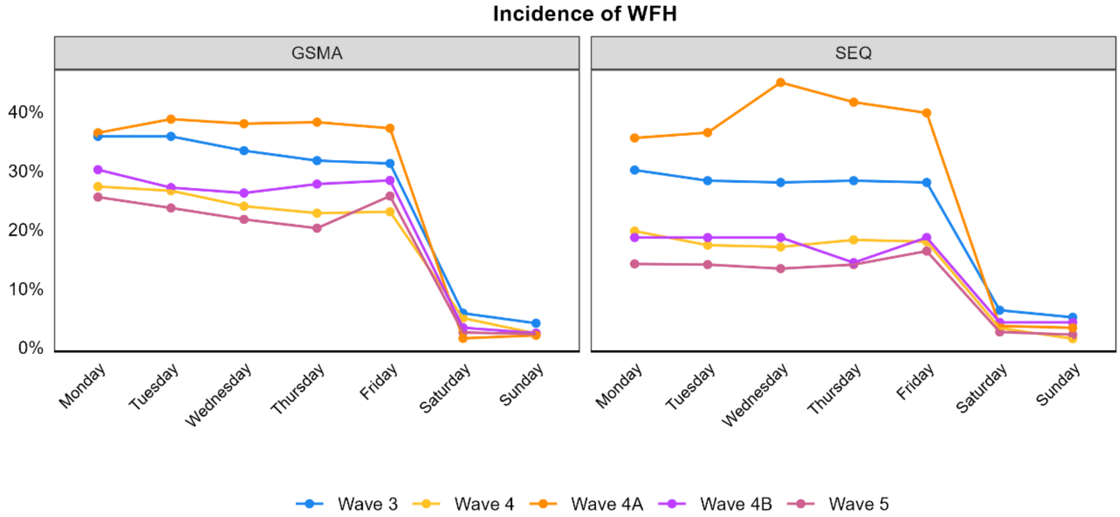

Figure 21: The incidence of WFH only by day of the week across the waves for the GSMA and SEQ

The proportion of workers who WFH, commute or not work for each day of the week across all waves is presented in Figure 22 for SEQ and GSMA.

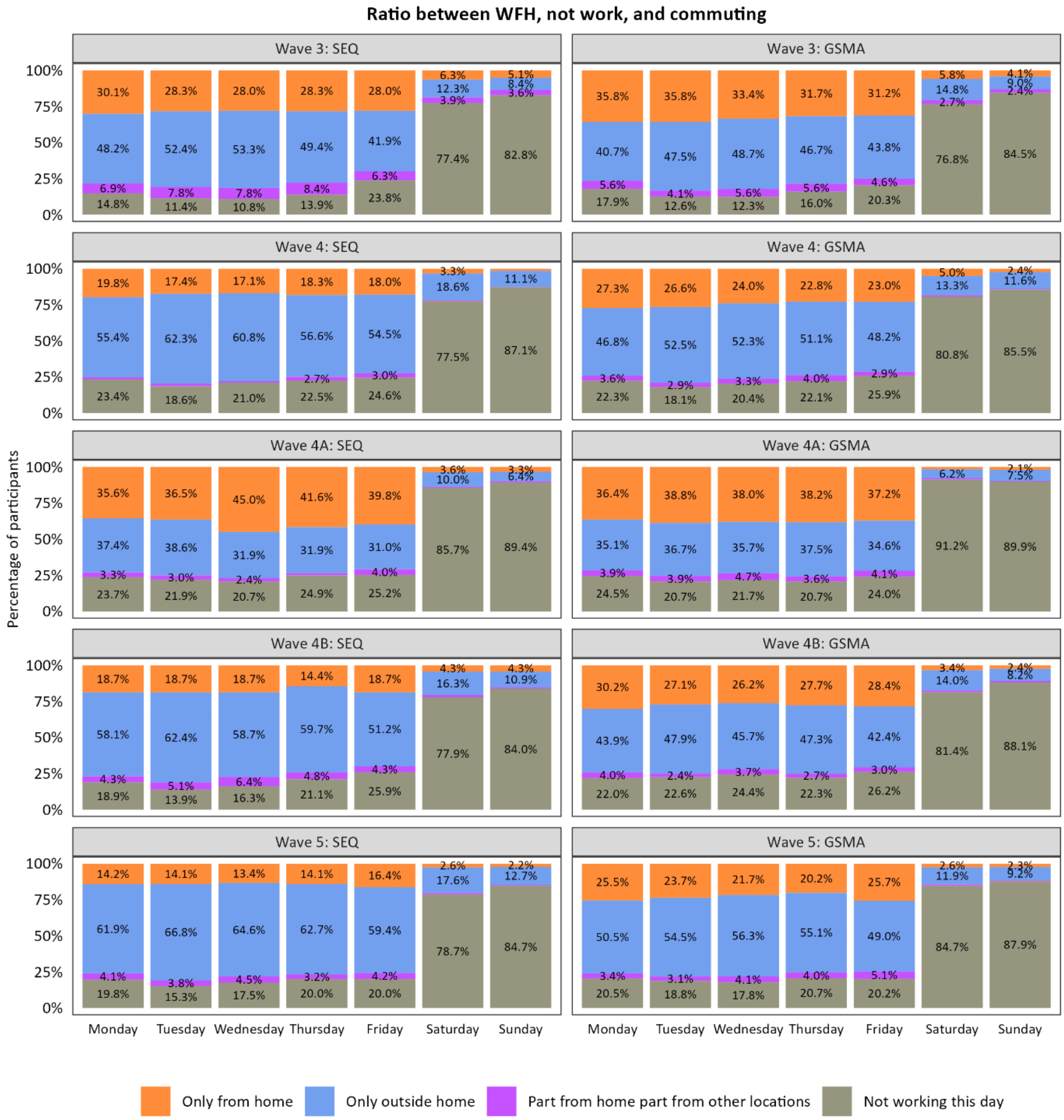

Figure 22: Not work, WFH or commute by day of the week across the waves for the GSMA and SEQ

2.6 The impact of the pandemic on public transport use by commuters: Waves 4A and 4B

Public transport patronage has taken a deep dive during the pandemic and remains at levels significantly lower than those before COVID-19. In Australian capital cities, levels have struggled to go beyond 70% of the pre-COVID-levels with patronage being as low as 45% during some periods of lockdown. Beck et al. (2022) have looked into the barriers to public transport use and actions required to restore confidence. This section provides an overview of the main findings.

Commuters were asked to indicate what their main barriers were to using public transport at the present moment. The evidence for the GSMA and SEQ is provided in

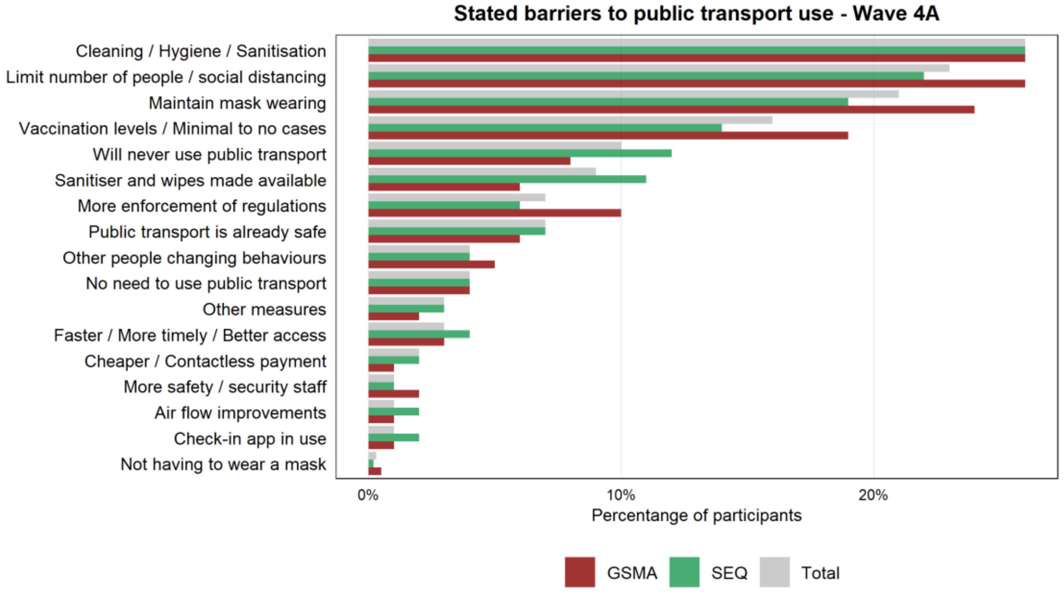

Figure 23. For those that are concerned, there were 14 themes emerging. The inability to social distance, and the number of other public transport users not doing so, was a concern, as was the cleanliness and hygiene status of public transport. With regards to cleanliness, reference was commonly made to the lack of overt sanitising services on-board and the large number of touch points that are required while using public transport (notwithstanding contactless ticketing). While the lack of enforcement of COVID regulations was explicitly mentioned by a small number of respondents, implicit concerns about social distancing and mask wearing are concerns about others not following the rules or being made to follow them. Concerns about the behaviour of other passengers mainly comprised of not being sure of where other people are from or where they have been, general distrust of the hygiene status of other people, and a very clear theme that many feel that people still use public transport when they should otherwise stay home because they are sick (coughing and sneezing, general germs and/or illness not just specific to COVID-19). This category could be described as a distrust of other people and generally thinking of other public transport users as inconsiderate of others.

Respondents were then asked what measures would need to be taken in order to make them feel more confident about using public transport. The most important measure is ongoing cleanliness. Many respondents stated that they had to be able to see that it was being done (either having continuing cleaning being conducted, scented cleaning materials, even an information sheet in the vestibule that informed passengers of when the carriage or bus was last cleaned). Limits on people using public transport and/or social distancing measures combined with ongoing use of masks were also a commonly stated measures that would increase confidence. Several respondents stated that more services were required to allow for distancing to occur. A smaller number of respondents explicitly stated they wanted more enforcement of regulations. Vaccination and/or low to no case numbers would be needed for some to return to using public transport. In responses, some suggested that vaccination be mandatory for travel on public transport, and others suggested that there be vaccinated-only carriages made available. Respondents in SEQ state that having sanitiser stations or antibacterial wipes available for passengers would make them feel more confident, many stating they would be happy to wipe down their own seat if they had wipes.

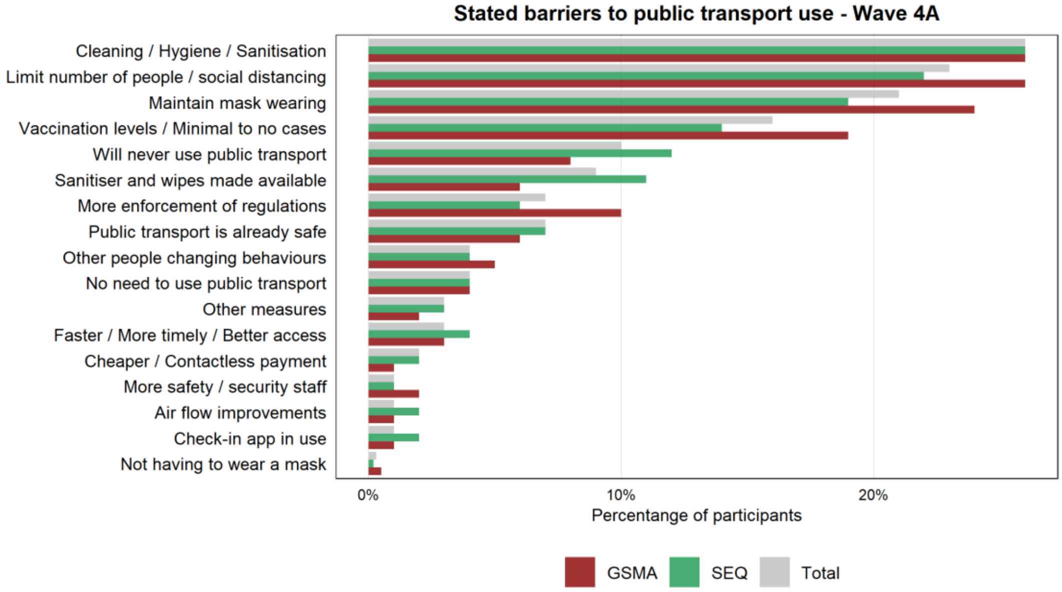

Figure 23: Commonly stated barriers to public transport use - Wave 4A

In the December 2021 survey (Wave 4B), all those sampled (commuters and non-commuters) were asked when they felt that public transport will be safe to use. As summarised in Figure 24, 15-55% felt it was safe now with the lower percentage being in Victoria (VIC) and the highest in Western Australia (WA), this not being surprising given the duration and degree of exposure to COVID-19. Also, around 10% believing it will take 12 months, with 12-20% suggesting that they are not confident about returning to public transport. These estimates align amazingly close to what many pundits are suggesting will be the longer term (10 year) return to public transport of around 80%.

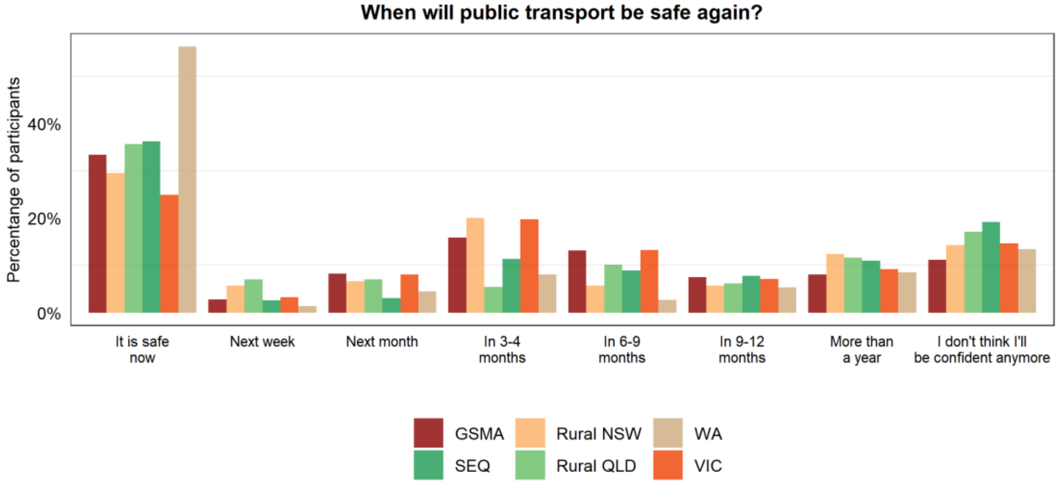

Figure 24: When will public transport be safe to use? - Wave 4B

2.7 How might WFH impact on non-commuting travel activity?

After more than two years, with WFH continuing to some extent as a non-stigmatised alternative to going to the regular office, non-commuting travel is also likely to change as workers and their families have greater flexibility in how they schedule that other travel activity. While there has been a significant amount of research on how the COVID-19 pandemic has impacted on the incidence of commuting activity, especially by mode, in large measure due to increased working from home, the translation of this impact to all trip purposes and modes has been somewhat neglected. Given a finite amount of weekly time available, it is useful to know the extent to which increased WFH and consequent reduced commuting trips has resulted in changes in the incidence of travel by other trip purposes and associated modes.

Non-commuting travel behaviour associated with different purposes, such as work-related trips, education, shopping, or personal business/recreation trips, and different modes (i.e., car, public transport and active modes), was analysed in relation to individuals' work from home weekly behaviour (Balbontin et al., 2022). The results for GSMA and SEQ are presented in Figure 25, which suggest across all waves and jurisdictions, respondents that WFH more often are more likely to undertake shopping trips and personal business/social recreation trips, and less likely to make commuting trips. It is interesting to note that in SEQ in Wave 4b, the increment in shopping trips seems to be higher as the frequency of WFH increases compared to other waves.

Prior to the pandemic there has been limited attempt to examine the relationship between WFH and other trip making behaviour; some literature finding it to be a complement for non-commuting trips (Mokhtarian et al., 1995, 2004; Choo et al., 2005) and others finding reduced commuting trips being substituted for non-commuting trips (Zhu, 2012; Kim et al., 2015). Our findings suggest that those who WFH at a higher rate also have relatively more non-commuting trip activity. This is likely to have spatial implications as this non-commuting activity is likely to be occurring in more local suburban areas in and around the homes where those WFH live. We are seeing strong signs that this 'next normal' is almost certainly resulting in a longer-term growth in local trips for all trip purposes with modal substitution occurring between car, public transport and active modes (the latter growing fast in terms of walking, bicycles and e-scooters).

By identifying some of the key influences on patterns of change in mobility, an improved behavioural understanding on the switching patterns of travel is gained. The evidence found in the analysis of trip making changes during the ongoing pandemic suggests that increased WFH and reduced commuting is associated with varying rates of change in one-way non-commuting trip making behaviour which varies by trip purpose and mode. Failure to recognise this behavioural response across all trip-making activity, if the focus is only on commuting changes, will result in misinformed advice on how the pandemic has changed the overall amount of travel activity.

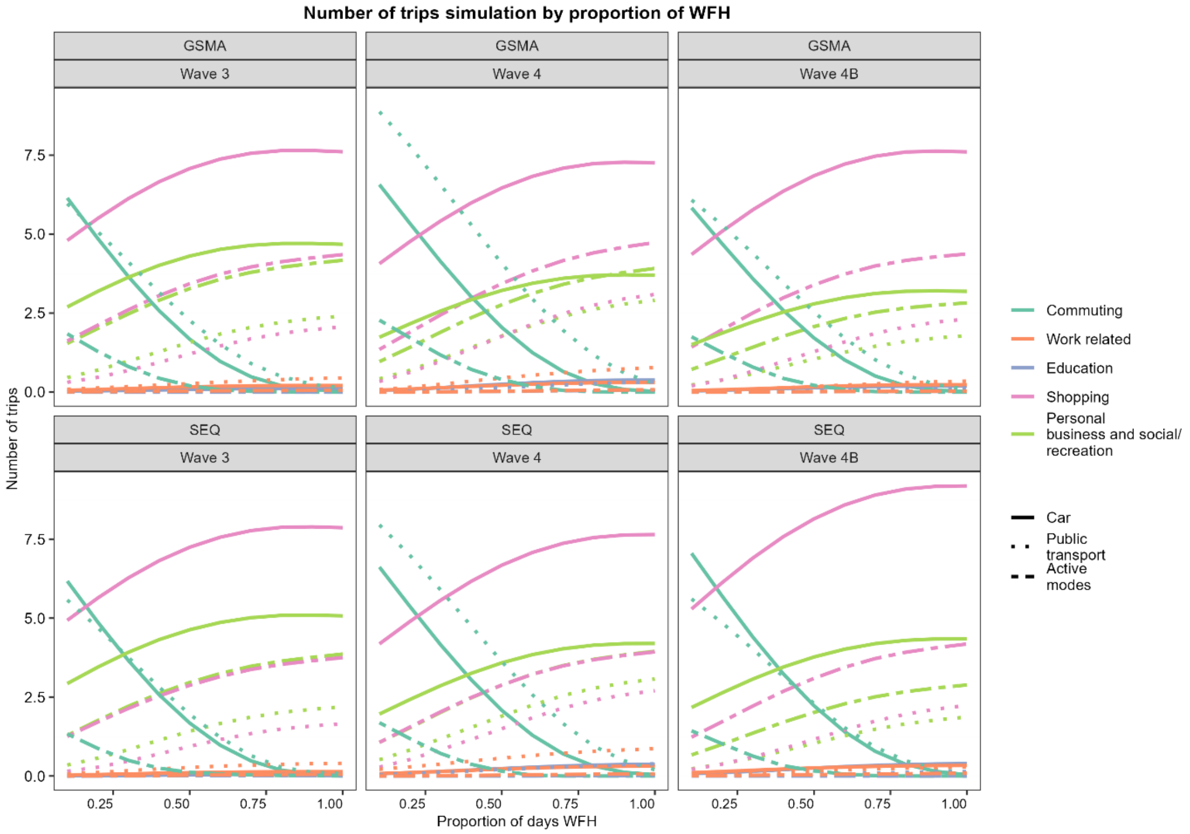

Figure 25: Simulated number of one-way trips by proportion of WFH – Waves 3, 4 and 4B

2.8 Has the pandemic and WFH had an influence in office space?

There are the beginnings of a growing number of structural changes in the workplace that look like becoming key features of a 'next normal'. While we will live with a quantum of uncertainty on what is increasingly referred to as 'a return to the office', the evidence is mounting almost daily to suggest that the pre-COVID-19 work environment has changed forever, and for many good reasons supported by a significant number of employers and employees.

Businesses are starting to review their workspace requirements at their main office location (linked in part to WFH), with some being closed temporarily, while other organisations have downsized their space or planning on doing so when leases are renewed. Complementing this space review is a consideration of the role that other office space associated with renting at a satellite office[5] (by the hour or day, for example) might play, which is likely to be closer to where employees live, enabling some amount of working from home and/or return to the main office to be transferred to this alternative location, which we refer to increasingly as working near home (WNH). The satellite office offers a respite to both the long commute and being at home for extended periods, especially where work-related facilities at home are somewhat limited.

To examine this more closely, a random sample of 500 organisations in the GSMA with a quota sample of 100 businesses in the Sydney CBD was taken (Hensher, Wei, et al., 2022). There was no quota sampling of organisation size. The data source was an online panel provided by Pure Profile and respondents were screened such that those who have relevant knowledge of their organisation's office location and sizing plans were sampled. A screening question was used to ensure that a respondent was working in the same organisation pre-COVID-19 and today, and that they had awareness (and ideally decision-making capacity) in sharing with us information on the organisation's workspace plans, actual and anticipated, as well as the WFH and WNH activity. The survey took around 10 mins to complete. The final useable sample was 459, with the balance of data deemed unreliable for a number of key reasons including outlier responses to key questions. A descriptive profile of the data over the three periods is summarised in Table 4.

There are many ongoing challenges to governments, to the broad base of employers, and even to households, as they work out how best to encapsulate the non-stigmatised WFH future. The implications for funding of infrastructure, re-prioritising land use plans, growing new office settings which include satellite offices, and what the future office environment might be are profound (Ramani & Bloom, 2021).

The impact of the change in workspace over a range of different WFH proportions, in respect of WFH (Figure 26) and use of satellite offices (Figure 27) on the quantum of main office space is examined. The range of the percentage of days working that are WFH, suggests a potential drop in the amount of office space required at the main office of between 85.2% and 62.8%. Working with what appears to be the most likely scenario of one to two days WFH per week

[5] A satellite office is a branch of a company that's physically separate from the organisation's main or primary office and can be located in a different country or on the other side of town. A satellite office can range in size from a single desk for an individual employee to a workspace housing many workers. Lately their usefulness has grown to accommodate trends around flexible working, creating convenience for a company's remote employees, help cut down on busy commutes, and reduce the number of workers in the main office at any one time. See https://www.wework.com/ideas/workspace-solutions/flexible-products/what-is-satellite-office

for many occupations, the model predicts a reduction in the percentage of office space compared to pre-COVID-19 of 79.6% for an average of one day WFH and 72.1% for an average of two days WFH. The decline of 20% to 28% in 2023 relates reasonably well to an occupancy rate in February 2022 of 18% for the Sydney metropolitan area (Williams, 2021).

Table 4: Descriptive profile of key data items across three periods

Before COVID-19	**Mean**	**σ**	**Min**	**Max**
Number of working days	4.4	1.3	0	7
Percentage of days WFH	20.5	32.5	0	100
Employer supported WFH days	1.3	1.7	0	5
Employee Numbers	847	4081	0	50000
Commuting time in minutes	35	25	0	180
April 2022	**Mean**	**σ**	**Min**	**Max**
Number of working days	4.1	1.4	0	7
Percentage of days WFH	35.5	37.5	0	100
Employer supported WFH days	2.8	1.4	0	5
Employee Numbers	711	3654	0	45000
Workspace change at main office location(s) (% compared to 100% pre-COVID-19)	72	36	0	150
Commuting time in minutes	31	23	0	150
In 2023	**Mean**	**σ**	**Min**	**Max**
Number of working days	4.1	1.4	0	7
Percentage of days WFH	35.2	35.7	0	100
Employer supported WFH days	2.5	1.5	0	5
Employee Numbers	728	3643	0	45000
Workspace change at main office location(s) (% compared to 100% pre-COVID-19)	80	32	0	200
Percent of employees will start working at satellite offices if satellite offices will be used (160 of 459 orgs)	41.8	25.3	1	100
Commuting time in minutes	31	23	0	150
Other Contextual Data	**Mean**	**σ**	**Min**	**Max**
Accommodation & food services	0.031	-	0	1
Administrative & support services	0.037	-	0	1
Arts & recreation services	0.026	-	0	1
Construction	0.057	-	0	1
Education & training	0.153	-	0	1
Electricity, gas, water & waste services	0.017	-	0	1
Financial & insurance services	0.052	-	0	1
Health care & social assistance	0.107	-	0	1
Information media & telecommunications	0.031	-	0	1
Manufacturing	0.033	-	0	1
Professional, scientific & technical services	0.137	-	0	1
Public administration & safety	0.037	-	0	1
Rental, hiring & real estate services	0.015	-	0	1
Retail trade	0.107	-	0	1
Transport, postal & warehousing	0.048	-	0	1
Wholesale	0.022	-	0	1
Main work office - Sydney CBD %	26.6		0	1
Well informed about business workspace plans *	72	-	0	0

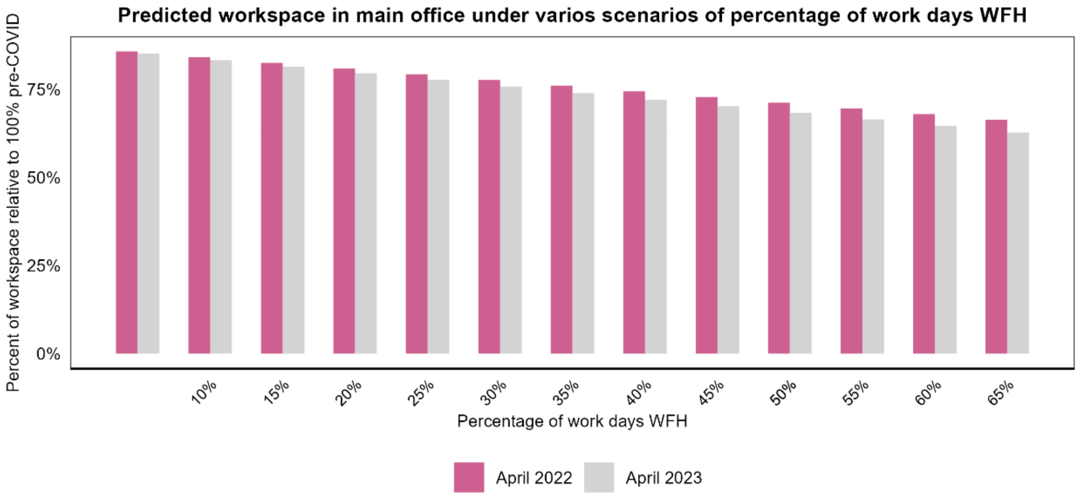

Figure 26: The expected influence of WFH levels on required office space in the main location in April 2022 and 2023

Figure 27 suggests that the growth in the use of satellite offices changes very little the quantum of main office space that is likely to be in place in 2023. The predicted impact at the mean of the likely use of satellite offices is close to 74%, which is the same range as the likely impact of WFH in Figure 26, reinforcing a view that the decrease in office space in the immediate future relative to the period just before the onset of COVID-19 is around 75%. One might speculate that some employees will use combinations of all three locations – the main office, the satellite office and WFH, adding some variety to their more flexible lifestyles. If true, to some degree, this may explain why we do not anticipate a significant change in the amount of main office workspace as satellite office use grows.

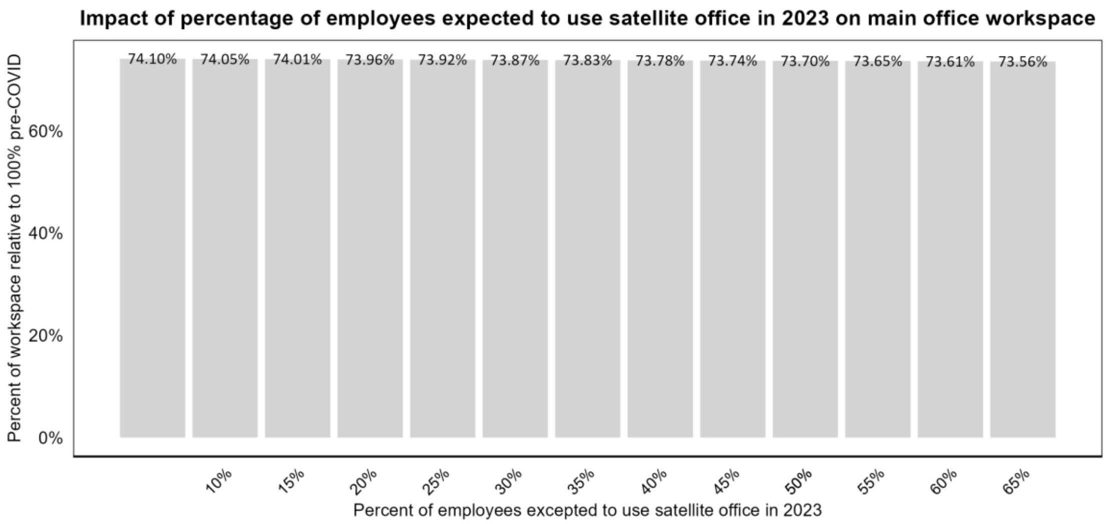

Figure 27: The expected influence of employees using a satellite office on required office space in the main location in 2023

These findings are significant in assessing policy settings that government needs to consider with respect to initiatives designed to manage changing demands on servicing various locations throughout the GSMA, especially infrastructure and ways to support businesses in delivering benefits to society as a whole. With WFH being seen as one of, if not the most, impactful transport policy instrument available for many years, the policy settings that flow from this WFH and WNH ‘next normal’ are expected to include infrastructure investments that align more with suburban investments to benefit walking and cycling and the broader agenda of the 20-minute city where reduced commuting distances become a greater priority. Importantly the changed profile of commuting may look more like reduced frequency over a week while preserving much of the longer distance commute over fewer days while either avoiding commuting at all on some days or commuting to a close by satellite office. These structural changes are evolving and look like becoming a permanent fixture of the mobility land use scape.

This is a first attempt (indeed one of the first in the academic literature) to examine the impact of COVID-19 on workspace volume decisions. It is likely that, after two years of “experimentation” with working from home, and with businesses now seeing largely unchanged productivity despite the challenges of the pandemic, decision makers are likely beginning to think more concretely about the size of main physical workplace that will be required in the future. As such, it is important that research in this area begin as it has been relatively overlooked but will also be an important determinant into future travel patterns within urban areas and indeed the composition and reimaging of many office-dense city environments.

2.9 Public transport and the importance of transport decarbonisation

The positive impact of significantly reduced mobility on the environment (such as improvements in air quality) was widely observed in the early stages of the pandemic. This has been associated with calls to exploit opportunities for the development of a greener, more resilient mobility (e.g., Budd & Ison, 2020). Fundamentally, a strong public transport sector is vital in the pursuit of decarbonisation goals. This requirement has assumed greater urgency given the weakened public transport base as a consequence of the pandemic. Beck et al. (2023) observe that the long-term implications of the pandemic on public transport seem to have so far been less investigated in the literature (a notable exception is Jenelius, 2022 who observes that the longer-term perspective is inevitably influenced by the fact that the pandemic has been more persistent than anticipated at its beginning). The significant drop in public transport patronage and the relatively slow build back to 65%-70% of pre-pandemic levels in many metropolitan areas (which may prove to be a ceiling) is contributing to concern about the impact that this will have not only on decarbonisation but also social equity.

A more positive perspective is to consider the opportunities for public transport created by the pandemic. The Transforming Public Transport Forum held in October 2021 in Victoria (PTAANZ and Aurecon, 2022) identified four challenges for future of the public transport industry, namely: the transition to zero emissions, rebuilding customer confidence post-COVID-19, embedding new mobility solutions into the broader public transport ecosystem, and optimising data to drive evidence-based planning and decision making.

Other than the need to rebuild customer confidence which has been widely documented (see for example, Beck et al., 2022) these are not new challenges. Preston (2020), for example, notes that public transport is continually evolving; for example, the influence of disruptive events such as the market entry of rideshare providers and the anticipation of greater automation and autonomy have in the past led some to speculate that the end of public transport as we know it might be in sight. There is however, particularly in the light of the pandemic, a more widespread realization that a strong public transport sector is essential to the pursuit of transport decarbonization which will not be realized by technical solutions or "fixes" (such as the move to electric or hydrogen as a fuel) alone. Additionally, government actions and economic incentives "post-COVID-19" to encourage decarbonization will likely influence the CO_2 emission pathway for decades through a 'new normal', but the decrease in emission levels experienced early in the pandemic (recalling the clear skies experienced in cities like Delhi and the growth in popularity of active modes) will only be temporary (Logan et al., 2022). Since Net Zero targets will not be met without mode shift towards public transport the need to implement strategies to recover public transport patronage while decarbonising all forms of transport has a new imperative.

These arguments are relevant both to local and longer-distance travel with the latter including implications for inter-city modal competition with a shift away from short haul flights to High-Speed Rail (in Europe at least). Beck et al. (2022) note that since public transport use lags significantly behind the rebound in private vehicle use in many jurisdictions, authorities should do everything within their power to avoid the further entrenchment of the motor vehicle as the dominant mode of transport, as this would be the fastest way to erode any gains in sustainability. If the will to tackle urban road pricing is lacking, then targeting growth in urban road traffic volumes is a second-best way to achieve more efficient travel choices. A land-use response would include substantial density increases achieved primarily through Transit Oriented Development (TOD). A transport response would include substantially improved public transport, walking and cycling opportunities, ideally as part of a package of TDM measures which can be used to reduce vehicle travel in ways that minimize costs and maximize benefits to consumers and society. Although TDM has been typically applied in large event scenarios, it is now integrated into urban transport strategies, infrastructure projects within a movement and place framework and is currently integral in the response to the COVID-19 pandemic.

2.10 The shape of cities and the Central Business District

WFH has resulted in more travel through the day, typically by car, and some flattening out of the traditional peaks and growth in off-peak travel, especially more shopping trips, and personal business/social recreation trips (Balbontin et al., 2022) which are relatively closer to home than the traditional office location. This position is reinforced by staggered working hours as offices reduce capacity leading to an increase in single-occupant car use, although it is recognised that staggered hours will not necessarily be appropriate for some types of work. Additionally, there can be effort made to ensure that the distribution of WFH is efficiently allocated over all days in the typical Monday to Friday working week, and that any staggering of commuting times across each day is similarly organised/coordinated in a smart fashion, to help provide the greatest smoothing effect on peak hour travel.

Hensher, Wei, et al. (2023) identified how working from home and a growing interest in the use of satellite offices (linked to working near home (WNH)) impacts on the amount of primary office space likely to be required (or preferred) in the near future in the Greater Sydney Metropolitan Area as we seek out evidence on what the 'next normal' may look like in the office property market. They predict a reduction in the percentage of office space compared to pre-COVID-19 of 79.6% for an average of one day WFH and 72.1% for an average of two days WFH. The decline of 20% to 28% in 2023 relates reasonably well to an occupancy rate in February 2022 of 18% for the Sydney metropolitan area (Williams, 2022). This is accompanied by an average 14.34% of staff in the future working in a satellite office or, on average, one in 6.7 employees[6].

Using data from the US Postal Service Zillow, Ramani & Bloom (2021) quantified the effect of COVID-19 on migration patterns and real estate markets within and across US cities. They find that within large US cities, households, businesses, and real estate demand have moved from dense central business districts towards lower density suburban zip-codes, and they label this the "Donut Effect" reflecting the movement of activity out of city centres to the suburban ring. While this observed reallocation occurs within cities, they did not see major reallocation across cities, suggesting less evidence for large-scale movement of activity from large US cities to smaller regional cities or towns. They rationalised these findings by noting that working patterns post pandemic will frequently be hybrid, with workers commuting to their business premises typically three days per week. This level of commuting is less than pre-pandemic, making suburbs relatively more popular, but too frequent to allow employees to leave the cities containing their employer.

These findings are significant in assessing policy settings that government needs to consider with respect to initiatives designed to manage changing demands on servicing various locations, especially infrastructure and ways to support businesses in delivering benefits to society as a whole. With WFH being seen as one of, if not the most, impactful transport policy instrument available for many years, the policy settings that flow from this WFH and WNH 'next normal' are expected to include infrastructure investments that align more with suburban investments to benefit walking and cycling and the broader agenda of the 20-minute city where reduced commuting distances become a greater priority[7]. Importantly, the changed profile of commuting may look more like reduced frequency over a week while preserving much of the

[6] So called Central Business District (CBD) needs to be given new nomenclature as Downtown Activity Precinct (DAP) given an unlikely return to pre-COVID-19 office activity and growing interest in using space for residential accommodation and leisure centres.

[7] The return to office when encouraged needs to contemplate many issues to make the office attractive. Having a window cf. not, increases productivity by 13% (many homes have a window in a study/office). Offices with light penetration are a concern with many offices (except if open office design). Meeting rooms may be less windows compared to where people sit most of the time.

longer distance commute over fewer days while either avoiding commuting at all on some days or commuting to a close by satellite office.

Among these changes, the role of the Central Business District (CBD) needs consideration in many economies. As much as suburbanisation of work can lead society closer to the idea of a 30 (or 20, or 15) minute city, given their size and strategic locations at populations centres, the idea of a central business district will likely need reimaging. As worker density decreases, it affords the opportunity for a change in the nature of the office space itself, with less of a focus on maximising the per square metre (hot)desk space and more as a venue for greater social interaction, facilitated by better common and meeting spaces, along with improved access to outdoor or green working spaces. This aligns well with the popular idea of a mobility or city hub. To further increase the value proposition of the central office, there is perhaps the need to think creatively about other attractors like exercise spaces, in-house restaurants, and potentially employer subsided (public) transport. Rather than simply returning to work, an organisation will need to systematically re-evaluate what the office brings to the organisation.

The cityscape itself will also likely need to change, with improved greenspace and pedestrian amenity, a more diverse and vibrant nightlife, and a greater emphasis on cultural aspects often associated with CBDs such as density of museums, galleries, and performance spaces. As greater work flexibility becomes more normalised, employees are likely to spread out work which in turn has implications for the provision of public transport in non-peak times. A potential spill-over of these changes is that CBD as Downtown Activity Precinct (DAP) locations may become more attractive places to live, rather than just places for work alone. COVID-19 has accelerated the move for commercial real estate to become more adaptable, allowing industries to be reborn and rethink their place in their evolving surroundings. With appropriate vision and support, CBDs/DAPs can be restructured in ways that are more inclusive and affordable. As a final note, we also observe that many governments need to reconcile their paradoxical messaging bought about by the duality of a desire for the 20-minute city contrasted with public messaging about the role of the CBD/DAP as an economic powerhouse and the posturing that must return else economic ruin.

2.11 Noting the impacts on retail and supply chains

As a consequence of the pandemic there are changes associated with passenger and freight movements, the latter linked to the growing demand for online shopping and the replacement of some passenger trips by a freight trip (usually a light commercial vehicle), although click-and-collect means the retention of a passenger trip. Throughout the pandemic, many consumers trialled online shopping substantively for the first time. It is likely that this behaviour will stick. According to Australia Post (2022) 9.2 million Australian households shopped online in 2021, spending $62 billion dollars; representing a 23.4% year on year growth (compared to 4.3% year on year growth for overall retail spend). Online now accounts for one out of every five dollars spent in Australia. In the first half of 2020 in the US, the increase in e-commerce equivalent to that of the previous ten years. This has placed inordinate strain on supply chains globally, and just as pressingly, 60% of businesses feel they are only moderately prepared to capture e-commerce-growth opportunities (McKinsey & Company, 2020)

The Institute of Transport and Logistics Studies September 2022 Transport Opinion Survey (TOPS)[8] found more Australians have shopped online compared to March 2022. More than three-quarters (76.4%) of Australians shopped online, spending an average of $375 per month. Online shoppers in Queensland, South Australia and NSW spent the most, ranging between $400 and $420 per month. Groceries and fashion were the top purchases, accounting for 27 percent and 20 percent of online spending respectively, followed by hobbies (13 percent) and health & beauty products (10 percent). The preferred delivery method for online shopping varied by products, with over 70 percent of online shoppers choosing home delivery for fashion and hobby products, while up to 45 percent of shoppers chose click-n-collect for groceries, specialty food, liquors, variety stores, and home and garden products. Online shopping has moved many passenger trips towards a goods delivery trip, increasing the number of light commercial vehicles on our roads. The greatest impact is being felt at the suburban levels as delivery vehicles compete with cars, resulting in increased traffic despite the reduction in commuting trips.

The role of the supply chain, and the infrastructure that underpins the movement of goods, is placed in sharp focus by this rapid growth. COVID-19 revealed vulnerabilities in the widespread globalised supply chains of many companies. When the supply chain was disrupted in even one location, often times this created a lack of critical components that shutdown production. A sharper focus may also need to be placed on communication and data sharing within the supply chain, where smaller companies upstream may play critical roles, but where there is little visibility from companies downstream. Given narrowing differences in costs of production between global locations and the realisation that disruptions are increasingly more frequent, there could potentially be a trend of moving production back within the borders of major consumer markets, but more likely a diversification of supply networks (particular in critical industries such as healthcare manufacturing and microelectronics), with a greater focus on security and resilience than "just-in-time". This may be exacerbated by the recent energy price shocks.

[8] https://www.sydney.edu.au/business/our-research/institute-of-transport-and-logistics-studies/transport-opinion-survey.html

2.12 The regional and rural context

It is striking to note that amongst the growing literature of the reported impact of COVID-19 on travel behaviour there is relatively little documented experience of how rural travel behaviour has been impacted and yet the longer-term impacts of COVID-19 on mobility in rural areas should also be considered (Nelson & Caulfield, 2022). Underlying issues of social exclusion are likely to be exacerbated by policies which place strong emphasis on digital interventions unless they are accompanied by the necessary investment in digital infrastructure (it is harder to work from home in many rural areas on account of inadequate internet bandwidth). Such investment would need to include programmes to combat digital literacy and lack of confidence amongst certain segments of the population when using the Internet and Apps (e.g., the elderly). OECD (2020) identify a number of opportunities for rural areas emerging from the COVID-19 crisis. Several of these are strongly dependent on a sufficiently robust digital infrastructure to support (for example) remote and distributed work and greater accessibility to services such as e-health and e-education.

Other policies that could be promoted include a switch to consuming habits that favour local products and destinations (also relevant in the context of tourism) and a greater focus on strengthening local networks which will also build in resilience to the threat of future shocks. Nelson & Caulfield (2022) discuss some of the responses that public transport operators and shared transport providers have implemented during the pandemic and highlight the role that Demand Responsive Transport (DRT) and community transport (CT) has played a strategic role in sustaining rural communities. More attention should be given to flexible and responsive forms of transport and to MaaS-type solutions in rural environments which also recognise the role of the private car.

Potentially, if WFH becomes an even stronger feature of the workplace, we could see the rise of digital nomads in a non-trivial fashion. These workers can be thought of as those whose jobs are largely digital and unconstrained by locational factors (Hardy & Robards, 2015). Given the lack of constraints placed by geography, regional areas have the opportunity to attract these knowledge/high-skill workers, if appropriate infrastructure is available. In particular, regional centres within striking distance of major urban locations are especially well-placed to grow as these workers prioritise cheaper housing, weather, and quality of life (Gretzel & Hardy, 2019; Hall et al., 2019). Even though in the short-term there is limited evidence for inter-city relocation, this is a possibility worth monitoring, particularly as more employment becomes digitised.

2.13 Implications for infrastructure

As discussed, investment digital infrastructure is paramount. Given the pandemic experience, it is likely that many companies will now seek to accelerate digital transformation to ensure business continuity, improve productivity and launch new business models to remain competitive. COVID-19 has already had a disruptive impact on labour markets. OECD data indicates that declining household incomes coupled with tax reforms linked to the pandemic led to widespread decline in effective taxes on wages (OECD, 2021). Border closures in many countries has resulted in skill shortages, and industries particularly disrupted by COVID-19 restrictions have lost large percentages of their workforce as employees left the sector in pursuit of other work. To avoid future adverse social and economic outcomes, reskilling and upskilling of the workforce will be a priority. The education and training systems will need to adapt to help the workforce quickly reskill and upskill, with investment in virtual solutions and human-centric technology to drive communication, and knowledge and skill transfer.

Given that digital flexibility can reduce crowding and congestion on the transport network, investment in such digital infrastructure can be viewed as a substitute for investment in physical transport alternatives. As more people move and work in their local areas, the role of suburban amenity and how investment in local infrastructure is supported will need to be reconsidered. Active local transport planning and facilities will become increasingly important, especially cycling and pedestrian infrastructure, and even more so as e-bicycle and e-scooter technology becomes more diffused.

Better modelling of more localised travel patterns will also be needed. Most jurisdictions employ a strategic transport model to evaluate the impacts of alternative transportation and land use investments as well as presenting any changes in travel demand in response to different input assumptions. We have been working on embedding the impact of WFH into these models (e.g., Hensher, Balbontin, et al., 2022), but more detail on the impacts such behaviour on suburban land use, particularly with reference to shared office space in these localised areas, is needed. Beyond the strategic models, the funding models themselves also need to be reassessed. As social and work interaction becomes more local so will the use of public spaces, other social infrastructure, and transport networks. Authorities will likely see increased demand for national parks and green spaces, particularly amongst those living in high density areas. Most local amenity investment is made by local governments, however moving forward these local assets may require more substantive funding from “revenue richer” governments at a State or Federal level. There is perhaps the need to restructure and formalise local amenity investment at these higher levels, to promote better working near home experiences. A positive of these localised investments is that they have shorter lead times, are less expensive, and as smaller projects have a much lower risk of going significantly over time or over budget. The dividend to the public is also achieved much more quickly.

The resilience of infrastructure, both physical and digital, has been bought into sharp focus by the pandemic, but also in the face of a changing and increasing chaotic climate. In Australia, late 2019/early 2020 was marred by extensive and unprecedented bushfires where a total of 24.3 million hectares was burnt (the size of the United Kingdom is 24.5 million ha). In 2022, Australia experienced one of the nation's worst recorded flood disasters with property damage last estimated at AU$4.8 billion (as at June 2022). Sydney received 1290mm of rain in total in 2021; by the start of November 2022 the city had recorded 2585mm. The pandemic experience and embedded WFH has shown that with appropriate infrastructure, negative impacts of economic productivity from disaster events can be mitigated. Invest in climate-resilient infrastructure to withstand or to adapt to the detrimental impacts of climate change is even more essential moving forward. To highlight this point, the Wave 5 data collection was significantly delayed due to ongoing flooding in QLD and NSW (the primary states for data collection), along with industrial disrupts that further disrupted transport networks. It is anticipated that disruption will only become increasingly more prevalent.

This sharper focus on sustainability is also being driven by business, as the costs of pollution and the benefits of environmental sustainability are increasingly recognised and as they respond to the sustainability concerns of investors. In some respects, the pandemic, as a global, systematic, fast-moving phenomenon, has shown what an extreme climate crisis could look. To avoid such disruption from climate change, there is the need to take action to limit climate risks with more climate resistant capital investments, or by diversifying supply chains. Perhaps more directly, there is a direct financial motive to invest in sustainable infrastructure such as green energy, efficient batteries, sustainable mobility, carbon-capture, and agriculture innovations could well be the next boom in investment returns, much like digital-economy companies have powered recent stock-market returns. These investments don't need to be macro-economic infrastructure, there is also the scope for micro improvements such as introducing better insulation requirements, developing energy-efficient appliances and equipment, and designing cities to be more resilient to climate change events such as flooding and heatwaves. Following the Global Financial Crisis, infrastructure investments were used to boost economic activity, but very few had a sustainable focus. While many economies are currently trying to cool economic activity given rising inflation, should infrastructure be used as a stimulus moving forward, such investment should also come with a green focus.

Finally, the pandemic may deliver some insight into the nature of contractual models or investment frameworks were able to withstand volatilities in markets, including demand, and also how systems, assets and projects were able to manage risks or shocks and absorb losses. There are likely going to be exemplars of how finance and capital, along with regulatory flexibility, can impact on credit risk and access to financing, along with the role of insurance.

2.14 A reflection on headline policy discussions

In the context of this final report, we also briefly outline some of the key policy recommendations that we have made after each wave of data collection; drawn from the subsequently papers written (and either published or still under review). Note that this is not a comprehensive summary, rather a number of notable headline policy implications that arose from each round of data collection. It is interesting that many of the policy recommendations still hold currency, and in large part were enacted by relevant jurisdictions across the country. While we cannot claim direct credit for the implementation of policies, it nonetheless demonstrates how iMOVE projects are timely, informative, impactful and have currency among business and government.

After Wave 1 (Feb/Mar-20):

- Swifter implementation of purchase limits on staple items and a designated shopping time, rapid cooperation among food and consumer necessity supply chain operators to overcome disruption.
- Aviation required to focus on domestic travel as a means to recovery.
- Overt cleaning of public transport, mandated mask wearing, and provisions for social distancing (including maintaining service levels in order to facilitate distance as well as public good / social inclusion requirement).
- Car use will likely be further entrenched due to the pandemic. Revisiting "difficult" policies of road-pricing and car-pooling may be required. Intelligent ways to leverage greater work flexibility to spread the peak can be found.
- Encourage active transport, particularly for short trips, as a substitute for car use. Think about embedding active transport within all transport infrastructure investment.
- Authorities should think very carefully about any future infrastructure investment, particularly while post-COVID-19 behaviours remain unknown and unpredictable. Indeed, governments may wish to give some thought to pausing large infrastructure projects.

After Wave 2 (Apr/May-20):

- Social and recreational activities is returning more strongly than other activities; as people express comfort in meeting with friends social activity is planned to return even more strongly.
- As restrictions are slowly rolled back, governments need to think carefully about how they allow the resumption of activities, which activities are indeed allowed, while messaging very strongly that the need for continued social distancing and mask wearing in public places else risk another outbreak.
- The work from home experience is lumpy and more predominantly available to middle and high-income groups. However, given the dividends to the transport network, more conversations about working from home, or the structuring of work so that some component can be completed from home should be encouraged by governments.

- Governments should look to support research into how the work from home experience can be improved, and business should look to guide staff in how to apportion focus and concentration over the course of a working day, and equally respect the boundaries between home and work.

- Significantly positive initial signs indicate that working from home will be a bigger part of the mix moving forward, and as the work from home experience becomes more embedded and new routines are formed, it is also likely that the experience will improve.

- Working from home should be viewed as a transport investment and should be encouraged with appropriate spending and support (i.e., investment in facilitating and tax breaks for individual uptake). As highlighted by WCTRS; “this is clearly a unique and rare opportunity for policy makers and transport researchers to work together and seize the momentum to devise new policies in order to change our everyday living and choices toward more environmentally sustainable life and work”.

After Wave 3 (Aug/Sep-21):

- Benefits associated with reduced travel demand could quickly erode should Australians en masse prefer to travel by private car as they also return to work. To that end, work from home and greater work flexibility represents potentially the largest policy level governments have ever had to reduce congestion, which has significant time and cost savings for society.

- Resuscitating confidence in public transport remains an important, though challenging, outcome to achieve coming out of COVID-19. Demonstrable and overt cleaning should take place to reduce the level of concern with the overall cleanliness of each public transport mode.

- There may be the requirement to think in a novel fashion about the role of pricing as a mechanism to attract users back to public transport.

- While related to the public perception of public transport, innovative operators could consider how they might use their current spare capacity to assist in the day-to-day freight task as a potential way to offset revenue losses from lower patronage.

- Transit operators and authorities should reconsider the messaging used around public transport. Particularly in the context of Australia where case numbers continue to remain low, the “stay away” message regarding public transport that was sent earlier in the pandemic and often re-iterated in later periods, needs to be reframed to increase public trust in the mode.

- Perhaps the bigger challenge for policy makers is the way in which restrictions are removed rather than enforced. Authorities will need to continue to make sure that communication is clear, encouragement is given, and validation of behaviour reinforced in order to ensure compliance with any mitigation strategies, particularly as changes to behaviour continue and pandemic fatigue becomes a significant concern.

After Wave 4, 4A and 4B (Mar/Jul/Nov-22)

- The GSMA experienced sixth months of relatively minimal restrictions before entering a lockdown that was meant to be short but ended up lasting 107 days.

- SEQ had also experienced a long period of time with minimal restrictions, and at the same time as the GSMA they entered a lockdown that only lasted for a approx. one week.

- MELB had experienced a preceding 12 months marked by extended lockdowns, and shortly after regaining most of their freedom the city (and large parts of the state) returned to lockdown at roughly the same time as GSMA and SEQ, which lasted another 78 days.

- Despite these radically different experiences, the perspectives towards working from home in each jurisdiction are statistically unchanged and robustly positive. Relative productivity in each region remained strong across all three regions. Attitudes towards the work from home experience remained unchanged; statistically the same level of positive outcomes being found after the lockdowns as before.

- Rather than lockdowns diminishing the desire to work from home, it appears that the lockdown experiences in the GSMA and MELB have only strengthened the desire to spend more time working from home. Indeed, in MELB, the region most affected by lockdowns overall, there is a greater propensity to want to work from home than in the other two locations.

- Equipping staff with appropriate technology is important, with provision of WFH technology infrastructure seen equally important as a potential investment in the transportation network, and workers should be encouraged to develop ways to better separate work from home life while working from home in order to make the experience more rewarding.

- Interestingly, the workers most positive towards WFH are more likely to have children and are more likely to have found a better balance between work and home. This result emphasises how WFH could be a positive for those with families rather than families being a distraction for those WFH. This has important, and positive, societal implications.

- The desire to WFH seems to become greater as the WFH experience intensifies. One possible explanation for this is that those working from home can use the extended experience to form habits and norms that are more conducive to WFH and that the benefits of saved commuting time and better flexibility are accumulated in significantly greater quantities. Equally, there may also be some cognitive dissonance in that as WFH intensifies during lockdowns, attitudes shift so that those who WFH, to a large extent, can feel like they enjoy the experience

3 The policy message and structural change: Has COVID-19 helped or hindered?

‘Flexibility is here to stay’ and ‘employers who offer a balance of WFH and in office will attract more high-quality employees’ (The Future of Office Space Summit, 17 Feb 2021)

If “done right”, WFH/remote working is possibly the greatest transport policy lever available to policy makers for many years. A defining outcome will be that more people will WFH to some extent, likely averaging 1 to 2 days a week in what has been broadly termed a hybrid work model (with fluctuations around this in the next few years) and using the reduction in commuting time to engage in increased leisure and work activity. Flexibility and convenience and reluctance to go back to pre-pandemic working norms will be key drivers of this outcome with norms around WFH being redefined. While there are advantages and disadvantages to working from home, in a non-lockdown circumstance where children are at school and businesses are open, but biosecurity conditions are front and centre, the positives seemingly outweigh the negatives. Wider literature outlines the bigger impact that WFH has had on women in families with children (particularly during periods of lockdown where schools have been closed) while prolonged working from home during lockdown periods may result in more women leaving the workforce. Conversely, it may also be possible that woman could return to the workforce if they could work from home given the flexibility such work offers. While a recurring finding is that women carry the bulk of the domestic responsibilities while working flexibly, government and business should view more flexible working arrangements through a less gendered lens, giving families more choice in how they make work and care decisions, with the ultimate potential being a higher workforce participation of women.

“More than half 54% of employees surveyed around the world said they would consider leaving their jobs if they are not given some form of flexibility regarding where and when they work.” (Ernst & Young, 2021).

Many employees will want this option in their employment contracts - it will become part of negotiation and crucial to retention. Organisational resilience will need redefining or recrafting. New workers to the labour market will benefit more from face-to-face interaction to build networks (but no need to do it 5 days a week). Indeed, WFH has also become a key factor in the value proposition of different places of employment. Surveys conducted by the BBC (2021) in the United Kingdom show that 60% of workers want to work from home at least some of the time, along with a large increase in the number of job adverts referencing flexible working arrangements. A report by McKinsey finds similar results in the US, further noting a potential talent drain for companies that return to fully onsite work (Alexander et al., 2021). Organisational resilience will thus need redefining or recrafting, opening up continuing paid and unpaid work from home plus some additionally released leisure time with reduced commuting activity.

With hybrid work settings, many high-density office hubs will have a reduced number of workers at any one time, typically 80% of pre-COVID levels (Beck & Hensher, 2020b). It can be expected that there will be greater opportunities to provide satellite/third party office space under “office space as a service” (OSaaS), including new apartment blocks with a designated office floor (‘commute to work by lift’). Density then becomes increasingly a bio-security risk linked to continuing nervousness in using public transport, especially if crowding returns, and indeed the associated higher density nodes in central metropolitan areas. Marginal residential relocation away from capital cities (exception maybe the second home) is likely to increase, noting that in Australia in the 12 months to the end of March 2021, 22,651 Melburnians moved to regional Victoria while 24,500 Sydneysiders moved to regional NSW; although a large amount was occurring regardless of COVID and WFH due to the regular cycle of residential mobility.

The enticement to relocate to outside of metropolitan areas will be driven strictly by better access and jobs in the regions. Residential choices are likely to be selected with more flexibility relative to work locations, and work locations will be chosen more flexibly relative to residential locations. There is, however, a growing view that with a day or two working from home and three to four days in the office, big cities will not wither away[9]; however remote work is likely to move the city's borders to the edge of the metropolitan area, a reflection of expanding regional labour markets. Rather than drastically changing cities, WFH has subtly reimagined city life by giving more workers more flexibility. The Brookings analysis of the USPS migration data[10] concluded that remote work will settle into a new level, higher than pre-pandemic but lower than the present. The hybrid-work environment is pushing people to live within travelling distance near work, but not quite as close as they used to. Local amenity and the built environment will likely play a large role and require a more localised focus on what constitutes areas that are accessible for active travel, which has spiked during the pandemic.

It is anticipated that there will be greater use of cars for all trip purposes and increased local (suburban) trip congestion (linked also with higher rates of passenger car registrations) in large measure due to the bio-security concerns in using public transport: Google Mobility data has consistently shown car usage to rise to above pre-pandemic levels in many countries. Staggered working hours are hypothesised to contribute to changing levels of road traffic as a result of more single–occupant car use; spreading demand better over the day, with the level of traffic in the peak hours associated with commuting lowering as offices reduce capacity at any one time. However non-commuting traffic is also changing and some of this is moving to peak periods as a result of greater flexibility in when work is done, while also adding to traffic throughout the day, in both the traditional peak and off-peak periods. Finally, cost constraints on using the car to commute may also be reduced as a person travels to work fewer times during a given week. Additionally, it has been shown that, for a variety of reasons, telecommunications and travel are complementary (Choo & Mokhtarian, 2007), which could further lead to increased localised travel in particular by car.

How this change in car usage may impact on congestion is unknown at this stage and needs careful monitoring by transport authorities. Ideally, increased working from home would help reduce congestion and crowding due to a lower aggregate number of commuting trips. However, should barriers to car use be reduced (in particular cost) and to public transport be increased (due to bio-security concerns), it is likely that when commuting is done, the car will become an even more dominant alternative. If this is the case, then transport authorities should work closely with businesses to ensure peak spreading is encouraged, and ultimately it may indeed strengthen the need for a more efficient form of road pricing than currently exists.

The quality of the living environment will become more important including larger units, an office at home, and enhanced digital connectivity. Linked to WFH, increased online activity by workers reinforces the possibility of a 15-30-minute city, a residential urban concept in which most daily necessities can be accomplished by either walking or cycling from residents' homes, which in the past has been especially hampered given it is mainly related to closer commuting locations with satellite offices.

The unintended positive consequences of COVID-19 have cushioned the severity of the pandemic to some degree, and this should be recognised as an immediate benefit. More

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[9] https://www.businessinsider.com.au/remote-work-made-cities-bigger-nyc-san-francisco-metro-areas-2021-9

[10] https://www.brookings.edu/blog/the-avenue/2021/06/24/remote-work-wont-save-the-heartland/

importantly, however, is the potential for longer term gain in well-being and lifestyle that may not have been offered up if life had continued along the journey associated with the pre-COVID-19 state of travel, commuting and associated pressures on work-home balance. Given that it is likely that working from home and/or working near home will continue to feature as a greater proportion of where work is completed, it is crucial to develop and implement best practices for WFH and WNH[11] to maintain a good level of productivity, achieve the right level of work and life balance and maintain a good level for physical and mental health.

While we would have preferred that the virus had not taken hold, we must look forward and use this extreme event experience to obtain positive benefits to individuals, households, businesses, and society more broadly. This position must recognise that mental health and well-being, including social exclusion has not gone away and that it remains a high priority for governments as well as for business more generally; however, let us recognise that some good has come out of the pandemic to provide some directions to better support well-being that was not on offer before COVID-19. The policy implication is very clear; namely, to continue to ensure that people can work from home successfully, and know they are making a contribution while doing so. Meaningful work provides meaning to life.

These structural changes are evolving to become a permanent fixture of the mobility land use scape. The new catch phrase may might be best stated as “Let’s give everybody access – democratise the office place and give them better choices – so it is about giving people better access to choices.” We caution overestimating the impact of the short run; there is no ‘normal’ – we will not return to the past and why would we want to? However, long term structural reform as elicited in this paper appears to be a welcomed feature of the ‘next normal’.

[11] One initiative with great appeal is the construction of a floor of an apartment block dedicated to shared working space that is available through booking to all tenant. This enables social interaction as well as relieving pressure on small apartments where the design of a separate office space may be unattainable.

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Appendices

Appendix A. Key Events and Data Collection during COVID-19

Table A.1: Summarising Key Events in an Ongoing COVID-19 Timeline

1-Mar-20	**First Covid-19 Fatality**	*Perth man from Diamond Princess cruise ship passes away.*
7-Mar-20	**Panic Buying**	*Supermarket panic buying starts gaining attention in media.*
12-Mar-20	**Shares Crash**	*Global stock market records largest fall since 1987.*
13-Mar-20	**National Cabinet**	*Federal and State leaders unite. $17.6b assistance package announced.*
16-Mar-20	**Large Gatherings**	*Gatherings of > 500 banned.* *People arriving in Australia must self-isolate for 14 days.* *Supermarkets impose buying limits.*
17-Mar-20	**Travel Ban**	*All international travel by Australian's banned.*
18-Mar-20	**Indoor Gatherings**	*Indoor gatherings > 100 banned.*
19-Mar-20	**Monetary Response**	*RBA reduces cash rate to record low of 0.25%.*
21-Mar-20	**Further Restrictions**	*Travel ban for non-citizens and non-residents from entering.* *Strict 4sqm social distancing rule imposed.*
22-Mar-20	**JobSeeker**	*$66b assistance package announced (primarily JobSeeker policy)*
23-Mar-20	**Lockdown Begins**	*Bars, clubs, cinemas, places of worship, casinos and gyms are closed.* *Schools start to close.*
25-Mar-20	**All Borders Closed**	*Australia closes its borders to all travel.* *Majority of states close borders for domestic travel (New South Wales, Victoria and Australian Capital Territory remain open).*
26-Mar-20	**Further Lockdown**	*Restaurants, cafes, food courts, auction houses are closed; house inspections banned.* *Weddings restricted to 5 people; funerals to 10.*
29-Mar-20	**Lockdown Peak**	*Stay at home other than for food shopping, medical or care needs, exercise or work/education that cannot be done at home.* *Max of 2 people together in public.*
30-Mar-20	**JobKeeper**	*$130b financial assistance (primarily JobKeeper wage subsidies backdated to 1 March).* *Six month moratorium on rental evictions.*
2-Apr-20	**Free Childcare**	*Childcare will be free for all workers during the Covid-19 crisis.* *Supermarkets impose instore limits on customer numbers.*
5-Apr-20	**Easter Stay at Home**	*Australians urged not to go on Easter holidays and to stay at home.*
7-Apr-20	**Commercial Rents**	*Mandatory Code of Conduct for commercial tenancies.*
11-Apr-20	QLD Borders Tighten	Entry passes required including for QLD residents VIC and NSW borders remain open; all others remain closed

14-Apr-20	COVIDSafe Announced	Development of COVID-19 track and trace app announced
17-Apr-20	**Aviation Assistance**	*Guaranteed domestic aviation network to capital cities and regional centres.*
21-Apr-20	**Medical Easing**	*Restrictions on elective surgery will gradually ease from Tuesday 28 April.*
26-Apr-20	COVIDSafe Launched	Uptake reaches 5 million by 5th of May (plateaus at this approx. number)
27-Apr-20	WA Easing (1)	Indoor and outdoor non-work gatherings of 10. Outdoor training and recreational activities allowed.
28-Apr-20	SA Easing (1)	Non-work gatherings of up to 10. Cafes and restaurants open limit of 10.
1-May-20	NT Easing (1)	Non-work gatherings of up to 10, Cafes and restaurants open limit of 10. Outdoor gathering restrictions relaxed, access given to NT Parks and Reserves
2-May-20	QLD Easing (1)	Gatherings in home of up to 5 guests, limit of 10 on outdoor and large spaces. Recreational travel up to 150 km from home, cafes and restaurants open limit of 10.
8-May-20	COVIDSafe Plan	National Cabinet announces nationwide 3 step guidelines for easing restrictions
11-May-20	Schools Partially Reopen	Most schools across Australia open for attendance of at least one day per week
15-May-20	NT Easing (2)	Almost all activities resume, limited to 2 h and 4sqm rule applies
	NSW Easing (1)	Gatherings in homes of up to 5 guests, outdoor gatherings of up to 10. Cafes and restaurants can seat 10, places of worship open with limit of 10
18-May-20	WA Easing (2)	Indoor and outdoor non-work gatherings of 20. Cafes, Restaurants, Pubs, Bars open with 20-person limit (with 4sqm rule).
	TAS Easing (1)	Gatherings in homes of up to 5 guests, outdoor gatherings of up to 10. Cafes and restaurants can seat 10, outside gyms allowed up to 10 people.
19-May-20	**100 Deaths Nationally**	

25-May-20	Schools Fully Reopen	Most schools across Australia open for fulltime attendance
01-Jun-20	NSW Easing (3)	Pubs, clubs, cafes, and restaurants limit of 50 customers
	QLD Easing (2)	Gatherings of up to 20 in homes and public spaces, gyms and non-contact sport allowed, Museums and galleries open, no limit on recreational travel
	SA Easing (2)	Non-work gatherings of up to 20. Cafes and restaurants open limit of 20, pubs and clubs remain closed.
	VIC Easing (1)	Up to 20 people can gather at homes, indoor, outdoor, or public space gatherings. Cafes, Restaurants, Pubs, Bars open with 2 person limit (with 4sqm rule).
5-Jun-20	NT Easing (3)	All but 4sqm resumes, some small venues allowed 2sqm per person
	TAS Easing (2)	Gatherings increase to 20 people at a time for indoor and outdoor. Visitors to households increase to 10 people at any one time.
6-Jun-20	WA Easing (3)	Revision of spacing to 2sqm, non-work gatherings limited to 200. Venues with appropriate space limit of 300, gyms, cinemas and galleries reopen
26/06/2020 (Current position for all states)	WA Easing (3)	Revision of spacing to 2sqm, non-work gatherings limited to 200. Venues with appropriate space limit of 300, gyms, cinemas and galleries reopen
	NSW Easing (3)	Pubs, clubs, cafes and restaurants limit of 50 customers
	SA Easing (3)	No limit on non-work gatherings other than 4sqm rule. 2sqm rule may apply to smaller venues, nightclubs remain closed
	NT Easing (3)	All but 4sqm rule remains, some small venues allowed 2sqm per person
	TAS Easing (3)	Gatherings at households remain limited to up to 20 people. Space require now 2sqm, upper limit of 250 indoors and 1000 outdoors
	QLD Easing (2)	Gatherings of up to 20 in homes and public spaces, gyms and non-contact sport allowed. Museums and galleries open, no limit on recreational travel
	ACT Easing (2)	Face to face higher education resumes, cinemas and movies open, theatres and galleries open, max of 100 people for indoor and outdoor with 4sqm rule
	VIC Easing (2)	Cafes, Restaurants, Pubs, Bars, museums, galleries have 50-person limit. Cinemas, concert venues, theatres open with limit of 50 (with 4sqm rule)
30-Jun-20	VIC Tightening (1)	Re-enforced local lockdowns across 10 different Melbourne postcodes
1-Jul-20	NSW Easing (4)	All businesses, can reopen with exception night clubs. No limit of numbers other than 4sqm rule being observed
2-Jul-20	WA Easing (4)	All existing gathering limits and the 100/300 rule removed.

		All events permitted except for large scale, multi-stage music festivals
6-Jul-20	VIC Tightening (2)	Additional two postcodes affected by the lockdown
8-Jul-20	NSW Borders Tighten (1)	NSW closes border to VIC due to Melbourne outbreak. First time since the 1919 Spanish Flu epidemic
9-Jul-20	VIC Tightening (3)	Metro Melbourne and Mitchell Shire in lockdown 6 weeks
10-Jul-20	QLD Easing (3)	Gatherings 100 people permitted, community sport and fitness resumes, casinos, gaming and gambling venues and nightclubs open, 4sqm rule applies, visitors from all states and territories other than Victoria (border pass required)
16-Jul-20	NT Border Easing	NT opens border with all states except for hotspots (GSMA & VIC)
17-Jul-20	NSW Tightening (1)	Per-table seating reduced from 20 to 10, max of 300 in any venue
19-Jul-20	VIC Tightening (4)	Face coverings mandatory in metro Melbourne and Mitchell Shire outside of home
22-Jul-20	VIC Tightening (5)	Visit in aged/health care restricted to carers only and a limit of one hour per day
2-Aug-20	VIC Lockdown	State of disaster declared, curfew in Melbourne from 8pm to 5am enforced
2-Aug-20		**200 National Deaths**
8-Aug-20	QLD Borders Tighten (1)	Closure of border to New South Wales and the ACT
10-Aug-20	ACT Easing (3)	In and outdoor gatherings limited to 100 people, casinos and gambling venues, food courts, spas, gyms reopen
11-Aug-20		**300 National Deaths**
18-Aug-20		**400 National Deaths**
24-Aug-20		**500 National Deaths**
24-Aug-20	SA Border Easing (2)	Border with NSW reopens
28-Aug-20	SA Easing (4)	Residential gatherings allowed to have a max of 50 people
30-Aug-20		**600 National Deaths**
5-Sep-20		**700 National Deaths**
5-Sep-20	SA Easing (5)	Wedding or funeral increase to 150 people, food and alcohol service resumes for those seated at a bar
13-Sep-20		**800 National Deaths**
18-Sep-20	ACT Easing (3.1)	Small sized venues and facilities return to their pre-COVID capacity (25 max)
28-Sep-20	NSW Easing (5)	Theatres, cinemas and concert halls new capacity of 50%, to a max of 1000
3-Oct-20	SA Easing (6)	Private functions, weddings and funerals allowed 150 people, dancing permitted, standing consumption of food and beverages at both indoor or outdoor events
4-Oct-20	QLD Easing (4)	Standing eating and drinking permitted at indoor and outdoor venues, outdoor venues 2sqm rule, max of 1000 at outdoor event, stadium seated capacity to rise to 75%

9-Oct-20	ACT Easing (4)	Gatherings max of 200 people, cinemas and theatres 50% capacity, large indoor venues 50% (up to 1000)
1-Nov-20		**Australia records zero cases of community transmission since 09-Jun-20**
16-Nov-20		South Australia introduces significant restrictions due to an outbreak in a northern suburb of Adelaide
21-Nov-20		South Australia short lockdown ends
24-Nov-20		Victoria records no active cases for first time since 29-Feb-20. Most state boarders are open.
20-Dec-20		Following outbreak on the Northern Beaches (53 cases), NSW places restrictions on size of private gatherings and activities in the Greater Sydney Metro Area WA closes borders to all of NSW, remaining states and territories implement restrictions on those travelling from the GSMA
02-Jan-21		Face masks made mandatory indoors in NSW
08-Jan-21		Federal Government halves the weekly cap of international arrivals to 1,500 in NSW and 500 in WA and Queensland until 15 February. Mandates that that all international travellers test negative for COVID-19 before flying to Australia. Greater Brisbane placed into 3-day lockdown.
31-Jan-21		Perth and Surrounds placed into 5-day lockdown after security guard at quarantine hotel was infectious in the community (ending a 10-month period of no community transmission). Lockdown ends 5th of Feb, all restrictions eased 14th of Feb. States and territories place restrictions on those travelling from WA.
05-Feb-21		National Cabinet increases number of international arrivals (repatriation flights only allowed at this stage – along with international travel with permitted exemptions).
12-Feb-21		Victoria enters state-wide lockdown after outbreak at a quarantine hotel (grown to 12 cases).
16-Feb-21		First shipment of Pfizer vaccine delivered to Australia. AstraZeneca vaccine approved by Therapeutic Goods Assoc.
17-Feb-21		Victoria lockdown ends.
21-Feb-21		Vaccination program begins (with limited supply).
24-Feb-21		Restrictions in NSW eases people limits on many activities.
02-Mar-21		Closure of Australian borders extended until 17-Jun-21.
29-Mar-21		Brisbane placed into 3-day lockdown after emerging UK Strain cluster grew to 7 cases.
19-Apr-21		NZ travel bubble started (Australians can return from NZ and not quarantine on arrival).
23-Apr-21		Perth and surrounds enter 3-day lockdown after two cases of community transmission.

05-May-21	Restrictions increased in GSMA due to an infectious man highly active in the community (mask mandates, no singing or dancing, limits on visitors to private homes).
17-May-21	Restrictions in GSMA eased.
27-May-21	Victoria enters 4th lockdown after 26 cases across 150 exposure sites and 11,000 traced contacts. All states and territories place travel restrictions on Victorians
22-Jun-21	Growing cluster in Sydney means some parts of GSMA are placed into restricted movements within the metro area.
23-Jun-21	Social distancing measures tightened across GSMA in response to growing Delta variant cluster (31 cases). States and territories placed border restrictions on those from GSMA or in some instances the state of NSW.
26-Jun-21	Growing Delta variant outbreak (80 cases) results in the Sydney lockdown is extended to the whole of the GSMA. Travel bubble with NZ is suspended for all of Australia.
28-Jun-21	In WA, Perth and surrounds go into four-day lockdown after a tightening of restrictions on 27-Jun-21.
29-Jun-21	Brisbane lockdown expanded to all of the SEQ for 3 days
01-Jul-21	All of NSW placed into lockdown (175 cases of Delta by this time) for one week
05-Jul-21	NZ lifts travel ban for those from WA.
07-Jul-21	NSW lockdown extended for another week.
14-Jul-21	NSW lockdown extended for another two weeks. VIC introduces mask mandates and other restrictions.
15-Jul-21	VIC enters 4-day snap lockdown (third of 2021).
17-Jul-21	Restrictions were tightened in Sydney LGAs of concern (including stay at home orders).
19-Jul-21	GSMA close all non-essential businesses and restaurants serve takeout only. Construction industry is shutdown. Restrictions tightened in SA (Level 4 – limits on size of gatherings, mask mandates, social distancing limits, large vents cancelled).
20-Jul-21	SA placed into 7-day lockdown. VIC extends lockdown for another 7 days.
21-Jul-21	In NSW lockdown areas expanded to parts of regional NSW.
27-Jul-21	VIC relaxes lockdown restrictions.
28-Jul-21	In NSW lockdown extended for another four weeks
29-Jul-21	In NSW 8 LGAs of concern were declared. Defence for assistance requested.
31-Jul-21	SEQ placed into immediate 3-day lockdown due to 6 Delta cases, which was extended on 02-Aug-21.
05-Aug-21	VIC enters sixth pandemic lockdown for 7 days.

08-Aug-21	SEQ lockdown is eased, but several restrictions in place for 14 days.
11-Aug-21	VIC extends lockdown for an additional 7 days.
14-Aug-21	All of regional NSW joins GSMA in lockdown.
16-Aug-21	VIC extends lockdown for 14 days.
30-Aug-21	**Australia records 1000th COVID-19 death**
02-Sep-21	VIC extends lockdown.
11-Sep-21	In NSW regional lockdowns are mostly lifted.
06-Oct-21	In NSW several regional lockdowns extended.
11-Oct-21	NSW state-wide lockdown significantly eased.
05-Oct-21	**Australia achieves 80% one-dose vaccination rates for eligible pop. (57% with two)**
11-Oct-21	NSW state-wide lockdown significantly eased.
16-Oct-21	NSW achieves 80% fully vaccinated rate (two-doses)
22-Oct-21	VIC ends lockdown
12-Nov-21	90% of Australian eligible population fully vaccinated
30-Nov-21	**Australia records 2000th COVID-19 death (doubled in 2mths)**

From this period of time onwards, given the large number of fully vaccinated citizens, Australia dispensed with the policy of lockdowns, slowly gave back freedom around crowd/people restrictions on events, made use of softer measures such as mask mandates, and generally shifted the burden of risk assessment onto the individual to engage in events and behaviours they felt appropriate for them as an individual.

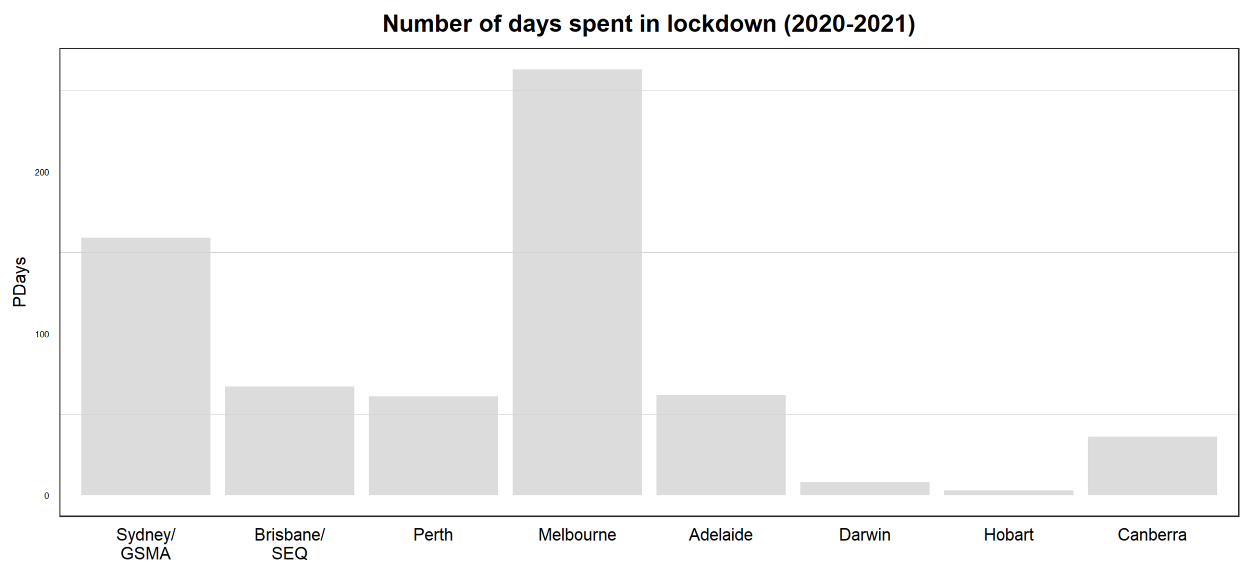

Figure A.1: Number of days spent in lockdown

Appendix B. List of Publications

Congratulations to David Hensher and Matthew Beck who made multiple entries in this prestigious TP citation lists! Excellent, David. Tae (Prof.) Tae Hoon Oum, Editor-in Chief Transport Policy, 28 May 2022.

1.1 Published

Beck, M. and Hensher, D.A. (2020) Insights into the Impact of Covid-19 on Household Travel, Work, Activities and Shopping in Australia – the early days under restrictions, **Paper #1**, *Transport Policy,* 96, 76-93. DOI: 10.1016/j.tranpol.2020.07.001 (one of topmost downloaded papers in the journal)

Hensher, D.A., Beck, M. J. and Wei, E. (2021) Working from home and its implications for strategic transport modelling based on the early days of the COVID-19 pandemic, **Paper #2**, *Transportation Research Part A: Policy and Practice*, 148, 64-78. DOI: 10.1016/j.tra.2021.03.027

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1.3 Podcasts

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- Academy of Social Sciences Australia (ASSA)
- https://seriouslysocial.org.au/podcasts/how-avoiding-the-commute-is-making-us-happier-2/
- https://soundcloud.com/sydneybusinessinsights/corona-business-insights-urban-mobility
- https://www.sydney.edu.au/content/dam/corporate/podcasts/business-school/the-early-days-of-the pandemic.mp3

1.4 Webinars

- Australian Institute of Transport Planning and Management (AITPM)
- PRESENTATIONS 8 October 2020: https://www.youtube.com/watch?v=qDNDox3oPhU
- Q&A 15 October 2020: https://youtu.be/aUr3Y5E0x4w
- ACSPRI 2020 Conference on Social Science Methodology: the Australian Consortium for Social and Political Research, Inc. 3 December 2020
- Engineers Australia, Transport Australia Society 3 February 2021:
- https://www.engineersaustralia.org.au/event/2021/01/integrating-multi-modal-end-end-journey-transportation-and-their-interaction-34826
- TfNSW's TDM Session #3: iMOVE/ ITLS speakers Wed 7/07/2021 12:00 PM - 1:45 PM. TDM talk for the AITPM group. This is the third talk in our four part TDM series. https://youtu.be/rBcl3IXewOU
- Third online free Bridging Transport Researcher (BTR) conference (5th & 6th August).
- AUSTRALIAN INSTITUTE OF TRAFFIC PLANNING AND MANAGEMENT LTD
- Meeting agenda of 2021 transport modelling knowledge sharing workshop
- Meeting location: Online via MS Teams, 17 August 2021
- AITPM National Conference Plenary session (David Hensher) speakers at the AITPM National Conference 1 on a "*Impact of COVID on mobility, place-making, shared mobility models or other interesting and innovative solutions to the 'new normal'*". Online 6 September 2021.
- AITPM update webinar AITPM 2 March COVID-19 and WFH
- ITANZ webinar 9 March 2022.

1.5 Other Material

- https://www.sydney.edu.au/business/news-and-events/news/2020/12/07/what-might-the-changing-incidence-of-working-from-home--wfh--tel.html
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Appendix C. Paper #1: Insights into the Impact of COVID-19 on Household Travel and Activities in Australia – the early days under restrictions

Matthew J. Beck
David A. Hensher

Abstract

When 2020 began, we had no idea what was to unfold globally as we learnt about the Novel-Coronavirus in Wuhan, in the Hubei province of China. As this virus spread rapidly, it became a matter of time before many countries began to implement measures to try and contain the spread of the disease. COVID-19 as it is referred to, resulted in two main approaches to fighting the viral pandemic, either through a progressive set of measures to slow down the number of identified cases designed to 'flatten the curve' over time (anticipated to be at least six months), or to attack it by the severest of measures including a total lock-down and/or herding exposure to fast track 'immunisation' while we await a vaccine. The paper reports the findings from the first phase of an ongoing survey designed to identify the changing patterns in travel activity of Australian residents as a result of the stage 2 restrictions imposed by the Australian government. The main restrictions, in addition to social distancing of at least 1.5 metres, are closure of entry to Australia (except residents returning), and closure of non-essential venues such as night clubs, restaurants, mass attendee sporting events, churches, weddings, and all social gatherings in any circumstance. With some employers encouraging working from home and others requiring it, in addition to job losses, and many children attending school online from home, the implications on travel activity is extreme. We identify the initial impacts associated with the first month of stricter social distancing measures introduced in Australia.

Keywords: Coronavirus, COVID-19, travel activity, working, working from home, air travel, shopping, attitudes, survey, Australia

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1 Introduction

The coronavirus disease 2019 (COVID-19) has created disruption to travel and activities unlike anything seen since perhaps the Second World War. The first outbreak occurring in late 2019 in Wuhan, the capital of the Hubei Province in China, quickly spread to become a global pandemic. While China was emerging from their peak of the curve in mid to late March, the rest of the world was starting to feel the exponential growth of infection and the resulting pressure on public health systems, and countries like Italy and the United States of America (particularly New York City) experienced devastating loss of life.

In the early half of March, discussion in many countries focused on the most effective forms of intervention to slow the spread of COVID-19 while grappling with the consequence of many measures to respective economies, civil liberties and social impacts that such measures would have. However, by March 31st there were over three-quarter of a million reported COVID-19 cases (754,933) and 36,522 deaths[1], by this time governments had no choice but to act.

1.1 Outlining the Australian Response

Some countries like the United Kingdom initially opted for a herd immunity approach, while others such as New Zealand opted for a full-scale shutdown of social and economic activity. Australia approached COVID-19 in a systematic way. A key component of the response was the formation of the National Cabinet on the 13th of March, an intergovernmental (state and federal) committee to coordinate and deliver a consistent national response to COVID-19. A key report to the National Cabinet is the Australian Health Protection Principal Committee, chaired by the National Chief Medical Officer and includes state and territory chief health officers. Business and labour union representations were also made to Cabinet.

The purpose of the cabinet was to ensure uniform risk management and timeliness of response, along with clarity and coherence in jurisdictional responses. National Cabinet developed uniform policy responses, with each state jurisdiction left to determine how to implement the policy in their own context. While some discrepancies in implementation existed, such as New South Wales keeping schools open longer than other states and maintain open state, through to marginally tougher social distancing policies in Victoria, the response to COVID-19 across Australia was in the main, uniform.

In quick succession, National Cabinet made a number of announcements pertaining to increasing restrictions and assistance measures in light of those restrictions. Figure 1 provides a timeline overviewing the key developments in the response to COVID-19, along with milestones in the development of the survey and collection of data. Table 1 gives more details about each of these milestones. Importantly, it was the 29th of March when restrictions in Australia reached highest point. At this time public gatherings were limited to no more than two people, those with chronic illness or over the age of 70 urged to stay home and the outlining of only four acceptable reasons for Australians to leave their houses: shopping for essentials; for medical or compassionate needs; exercise in compliance with the public gathering restriction of two people; and for work or education purposes. Violation of the restrictions carried fines of $1,000 per person and $5,000 per business[2].

[1] https://covid19.who.int/

[2] The amount varied by State, with NSW introducing the fines outlined in the text.

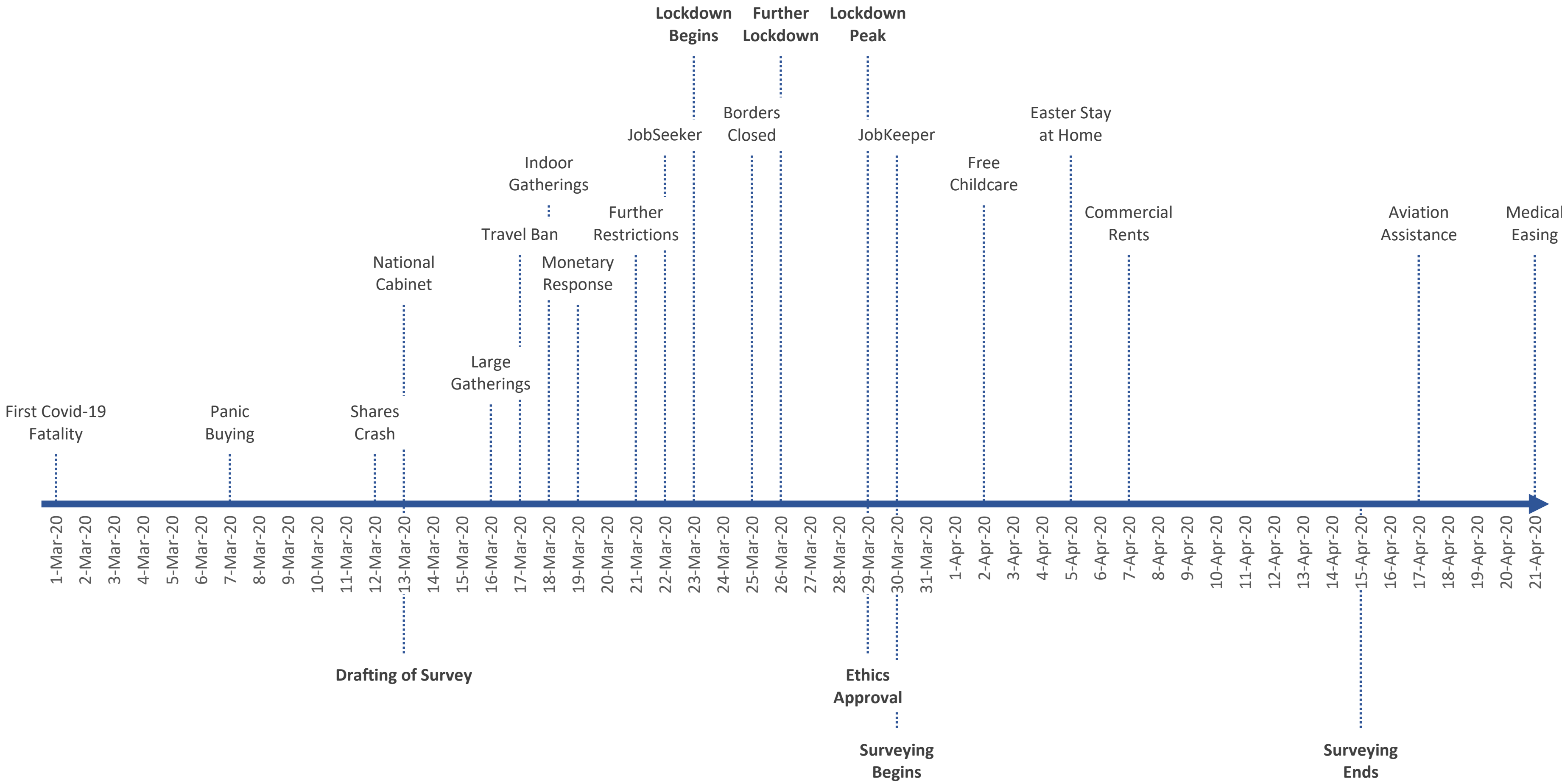

Figure 1: Key Events in the Initial Stages of COVID-19

Table 1: Detailing Key Events in Initial Stages of COVID-19

1-Mar-20	**First Covid-19 Fatality**	*Perth man from Diamond Princess cruise ship passes away.*
7-Mar-20	**Panic Buying**	*Supermarket panic buying starts gaining attention in media.*
12-Mar-20	**Shares Crash**	*Global stock markets records largest fall since 1987.*
13-Mar-20	**National Cabinet**	*Federal and State leaders unit. $17.6b assistance package announced.*
16-Mar-20	**Large Gatherings**	*Gatherings of >500 banned.* *People arriving in Australia must self-isolate for 14 days.* *Supermarkets impose buying limits.*
17-Mar-20	**Travel Ban**	*All international travel by Australian's banned.*
18-Mar-20	**Indoor Gatherings**	*Indoor gatherings > 100 banned.*
19-Mar-20	**Monetary Response**	*RBA reduces cash rate to record low of 0.25%.*
21-Mar-20	**Further Restrictions**	*Travel ban for non-citizens and non-residents from entering.* *Strict 4sqm social distancing rule imposed.*
22-Mar-20	**JobSeeker**	*$66b assistance package announced (primarily JobSeeker policy)*
23-Mar-20	**Lockdown Begins**	*Bars, clubs, cinemas, places of worship, casinos and gyms are closed.* *Schools start to close.*
25-Mar-20	**All Borders Closed**	*Australia closes its borders to all travel.* *Majority of states close borders for domestic travel (New South Wales, Victoria and Australian Capital Territory remain open).*
26-Mar-20	**Further Lockdown**	*Restaurants, cafes, food courts, auction houses are closed; house inspections banned.* *Weddings restricted to 5 people; funerals to 10*
29-Mar-20	**Lockdown Peak**	*Stay at home other than for food shopping, medical or care needs, exercise or work/education that cannot be done at home.* *Max of 2 people together in public.*
30-Mar-20	**JobKeeper**	*$130b financial assistance (primarily JobKeeper wage subsidies backdated to 1 March).* *Six month moratorium on rental evictions.*
2-Apr-20	**Free Childcare**	*Childcare will be free for all workers during the Covid-19 crisis.* *Supermarkets impose instore limits on customer numbers.*
5-Apr-20	**Easter Stay at Home**	*Australians urged not to go on Easter holidays and to stay at home.*
7-Apr-20	**Commercial Rents**	*Mandatory Code of Conduct for commercial tenancies*
17-Apr-20	**Aviation Assistance**	*Guaranteed domestic aviation network to capital cities and regional centres.*
21-Apr-20	**Medical Easing**	*Restrictions on elective surgery will gradually ease from Tuesday 28 April*

The evidence is that these measures, and the willingness of the Australian public to adopt the recommended behaviours, have been successful in turning around the growth of COVID-19 tranmission. Following the highest recorded number of 469 new cases on the 29th of March, the number of new cases has fallen, indicating that that curve has initially flattened in Australia. Figure 2 shows the distribution of daily new cases as per the Australian Department of Health (2020). As of the 3rd of May when this paper was written, Australia has had a total of 6,801 reported cases of COVID-19, and 95 deaths.

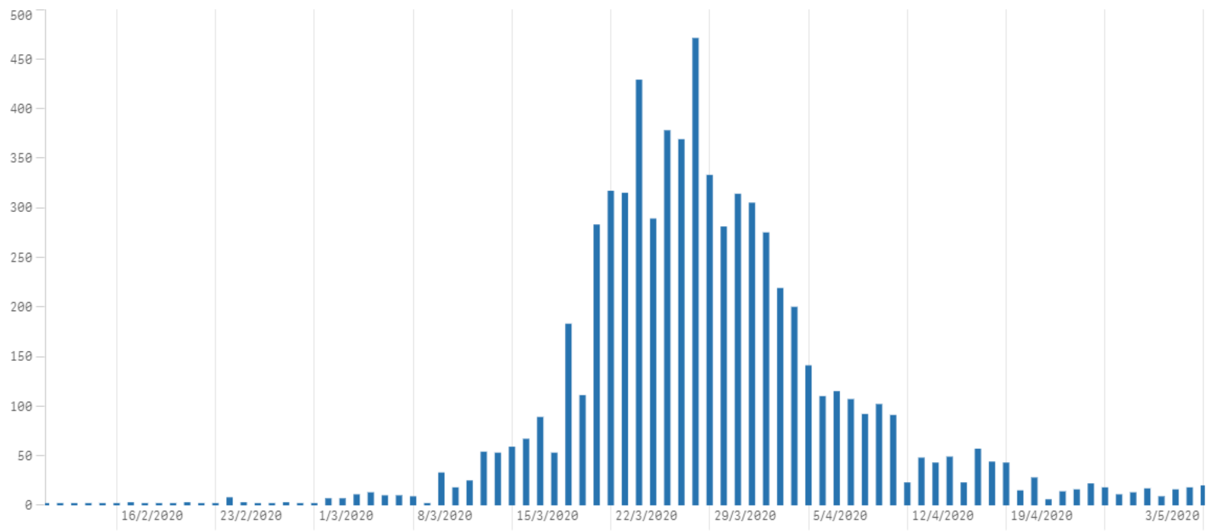

Figure 2: Daily Number of Reported Cases

1.2 Aggregate Impacts: Work and Travel

While Australia has, to this stage, been relatively successful in battling the health risk presented by COVID-19, the impact on the economy has been just as large. Based on a recent survey conducted by the Australian Bureau of Statistics (ABS 2020), the number of people who were working paid hours fell from 64% prior to the restrictions, to 56% in the first week of April, with a total possible increase in unemployment of 1.5 to 2 million people as a result of COVID-19 and associated measures.

In response to the economic shocks, governments at all levels have announced unprecedented levels of support. On the 22nd of March the Federal Government announced the $550 JobSeeker supplement for those on unemployment benefits, to remain in place for up to six months. This was followed by the $130 billion JobKeeper initiative announced on the 30th of March designed to keep employees attached to their place of employment, with $1500 per week being made available for eligible employees and paid via their employer. Along with a range of other measures designed to support the economy, the Federal government has committed to approximately $320 billion in stimulus spending, approximately 16.4% of annual GDP (Treasury 2020). Similarly state governments have also injected money into the economy, for example NSW announced $2.3 billion in spending on the 17th of March, followed by a further raft of measures on the 27th of March.

The impact of COVID-19 mitigation policies on the movement of people has also been significant. For example, Figure 3 displays the CityMapper Mobility Index (2020), an aggregate measure of use of public transport, walking and cycling, over the last three months, and demonstrates a large change in both Sydney and Melbourne.

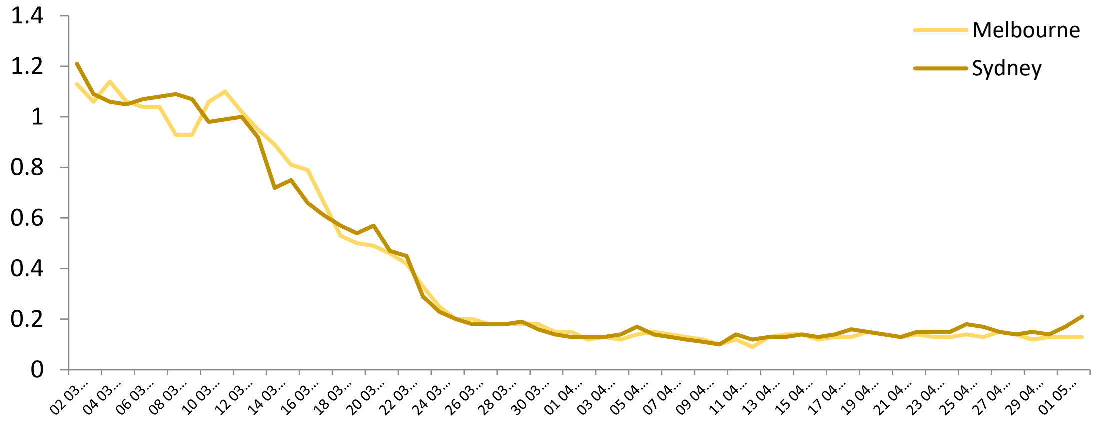

Figure 3: CityMapper Mobility Index

The Google Community Mobility Report (2020) uses location data from mobile phones to highlight the percent change in visits to places like grocery stores and parks within a geographic area, relative to baseline travel. As can be seen in Figure 4 which aggregates this information for Australia as a whole, the amount of time spent at home has increased, while that spent at workplaces, retail and recreation, and transit locations has fallen dramatically since mid-March.

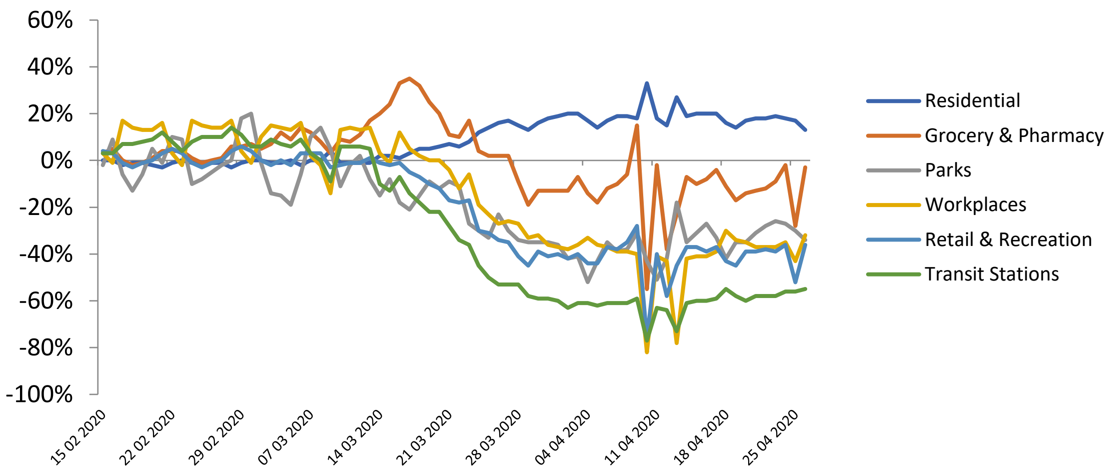

Figure 4: Google Mobility Report for Whole of Australia

In order to gain insight at a more disaggregate level, we deployed a survey examining household travel and activity patterns, employment and working from home, aviation travel, experiences in grocery shopping and general attitudes towards COVID-19. In the next section we give an overview of the survey and discuss the sample, followed by a presentation of preliminary findings, then ending with a discussion of the results and concluding remarks. This survey is the first of a series we are undertaking to track responses over time to the COVID-19 pandemic and how to monitor how Australia is responding as we move out of the most severe restrictions to the 'new normal'.

2 Survey and Data Collection

The survey was designed in the last week of March, and asked respondents to provide information on their level of employment prior to the COVID-19 outbreak as well as after, including their ability and instances of working from home. Respondents were then asked to think about weekly travel activity of the household in the early part of March, prior to the emergence of COVID-19 as a significant public health threat, and to complete a short travel activity survey asking them to recall what trips the household made by different modes of transport and for different purposes. They were then asked if the household had changed their travel activity as a result of COVID-19 and if the answer was yes, they completed a second set of travel questions outlining the changed travel. For those that had not changed but had plans to do so, and those who had changed and planned even more, they also completed a travel diary asking what their planned change might look like.

Outside of travel activity, questions were also asked about the level of car use of the household, their level of comfort with using public transport given new biosecurity concerns, behaviours with respect to potential air travel and the nature of disruption to that activity, experiences with grocery shopping and a series of attitudinal questions about the threat of COVID-19 and the response of governments, businesses and people in general.

The online panel survey company PureProfile was used to sample respondents, and the survey was available across Australia in order to examine the widespread impact of COVID-19. The survey went into the field on the 30th of March and a sample of 1073 usable responses was collected by the 15th of April, 2020. A summary of the final sample is provided in Table 2.

Table 2: Overview of Survey Sample

Female	52%
Age	46.3 (σ = 17.5)
Income	$92,826, (σ = $58,896)
Have children	32%
Number of children	1.8 (σ = 0.8)
Age of children	11.2 (σ = 8.6)

New South Wales	22%
Australian Capital Territory	2%
Victoria	28%
Queensland	22%
South Australia	11%
Western Australia	11%
Northern Territory	1%
Tasmania	2%

It should be noted that the majority of questions in the survey were based on the behaviour and attitudes of the individual respondent, however the travel activity diary asked the respondent for information about trips at a household level (subsequent waves will look at individual-based travel behaviours). For the purposes of preliminary analysis, socio-demographics differences are explored based on gender, age (younger (18 to 34, n=322); middle-age (35 to 54, n=352); older (55 or older, n=410)), and household income (lower income (less than $100,000, n=617); middle income ($100,000 to $200,000, n=276) and high income (more than $200,000, n= 121)[3].

[3] In discussing the results of tests based on individual and household characteristics, all testing is performed at a 5% level of significance. The authors can provide the outputs of any test upon request.

3 Results

3.1 Impact of COVID-19 on Travel

The survey went into field on the 30th of March, when the most extreme of the Australian social distancing measures came into effect. At this point in time, 78% of respondent households had already made many changes to their weekly household travel (females more likely to report that changes had already been made), 15% had not made changes nor were they planning any (lower income households more likely to not have changed) and 7% were planning to change (men more likely to report changes being planned). Of those households who had already changed, 32% were planning further changes moving forward (with younger households more likely to be planning further change).

The following sections report reductions in overall travel, travel by modes and travel for different purposes. Similar work is being completed globally, and one such of interest is a project of IVT, ETH Zurich and WWZ, University of Basel, the MOBIS-Covid19 study[4]. This study uses mobile phone GPS tracking data from 3,700 participants who completed a prior mobility study in between September 2019 and January 2020, to examine the impact of COVID-19 on the French and German speaking part of Switzerland. Our results, using a household travel survey, are consistent with those found via the MOBIS GPS tracking, as well as those found by aggregate location data in Australia such as Google and CityMapper.

Note that we present weekly averages for three periods of time; an normal week prior to COVID-19 (*Before COVID-19*), travel for the week preceding the completion of the survey (*Data Collection*), and any further changes to travel the household was planning in the week following the completion of the survey (*Planned Changes*). Refer to Figure 1 for timeline of events.

3.1.1 Overall Travel

Consistent with information provided by more aggregate sources such as Google Mobility Reports and CityMapper, we find that reported trips have reduced significantly from an average of 23.9 trips per week (for different purposes using different modes) down to 11.0, a reduction of over 50% in weekly household trips (Figure 5). Moving forward, planned further changes were marginally different to those that had already occurred, averaging 9.4 per week.

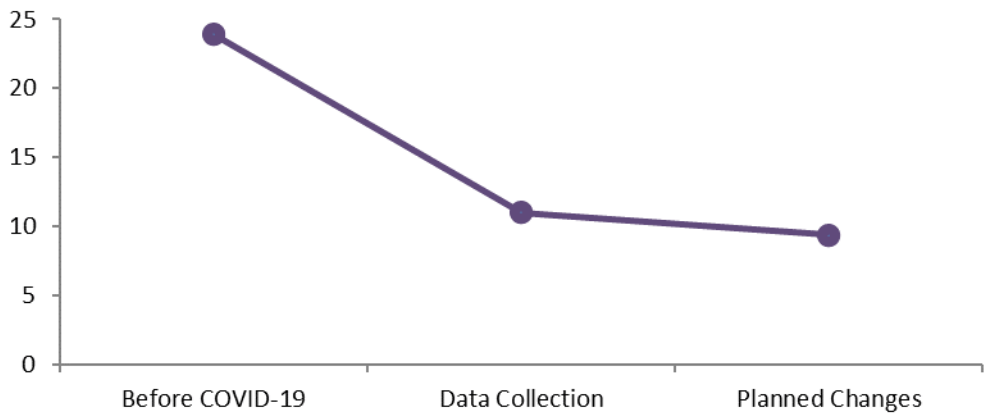

Figure 5: Impact of COVID-19 on Reported Household Weekly Trips

Before the COVID-19 outbreak, younger households made significantly more trips than middle and older aged households, and middle aged households in turn made significantly more than

[4] https://ivtmobis.ethz.ch/mobis/covid19. Using MOBIS and GPS tracking, they found ~50% reduction in tracked trips, more or less mirroring the Australian findings in this paper.

older households. During the data collection period, the number of trips made per week by middle and older households were no longer different; however younger households while making less trips, still reported making significantly more than middle and older households. With regards to further changes planned, younger households still planned more weekly trips on average than older households, but planned to revise the number of trips down to similar levels to middle aged households.

Lower income households made significantly less trips per week than middle or higher income households prior to COVID-19; however during the data collection period this difference largely disappeared as households of all incomes reduced the number of trips made.

3.1.2 Travel by Mode

In terms of how different modes of transport are affected by changing travel behaviours (Figure 6), the biggest reduction in aggregate trips was via the private car, falling from an average of 17 trips a week down to eight. Similarly, the use of public transport has also fallen, with significant reductions in train and bus usage.

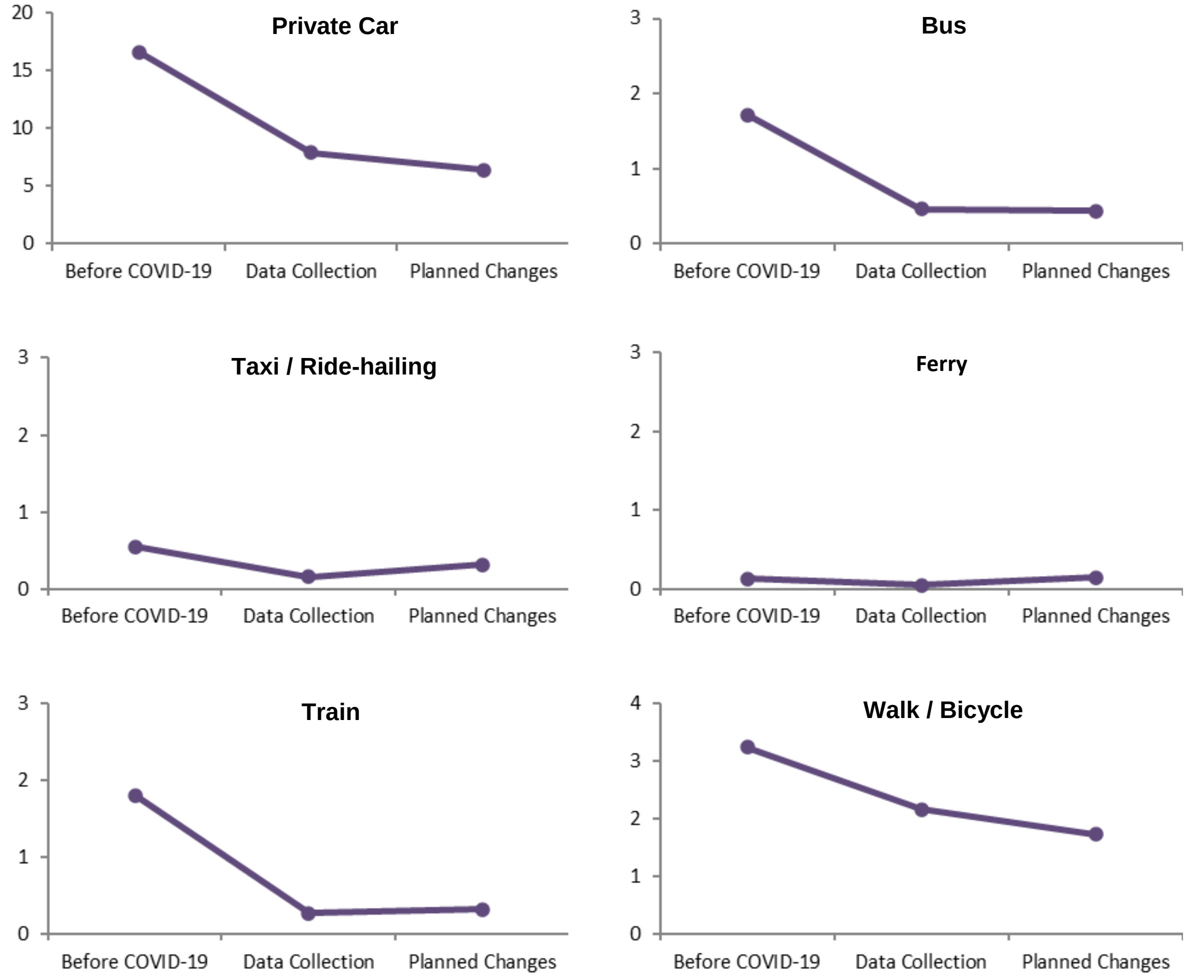

Figure 6: Reported Weekly Household Trips by Mode

Interestingly, as a proportion of overall household trips, the private vehicle remains relatively stable at around 70% before COVID-19 as well as during data collection, or for any planned future changes, but the use of public transport falls from around 15% of trips on average down to 7%. Active transport, while lower in absolute terms, increases from 14% of household weekly trips prior, to accounting for one in five (20%) of trips during the data collection period.

Looking at perceptions of different modes in a little more detail, respondents were presented with the following list of modes presented in Figure 7 and asked to highlight which single mode they would feel most comfortable in using, and which one they would be least comfortable using, if they were required to travel (respondents could select any mode they thought to be most or least irrespective of ownership or availability). The figure highlights that the private vehicle is clearly dominant in terms of which mode a respondent would feel most comfortable. The perception of the train and bus are quite negative in the context of COVID-19 with 33% and 42% of respondents rating these modes as their least comfortable respectively. These perceptions are largely invariant to socio-demographics, with only middle age respondents displaying a greater propensity to rate taxi or ride-sharing as their most comfortable option.

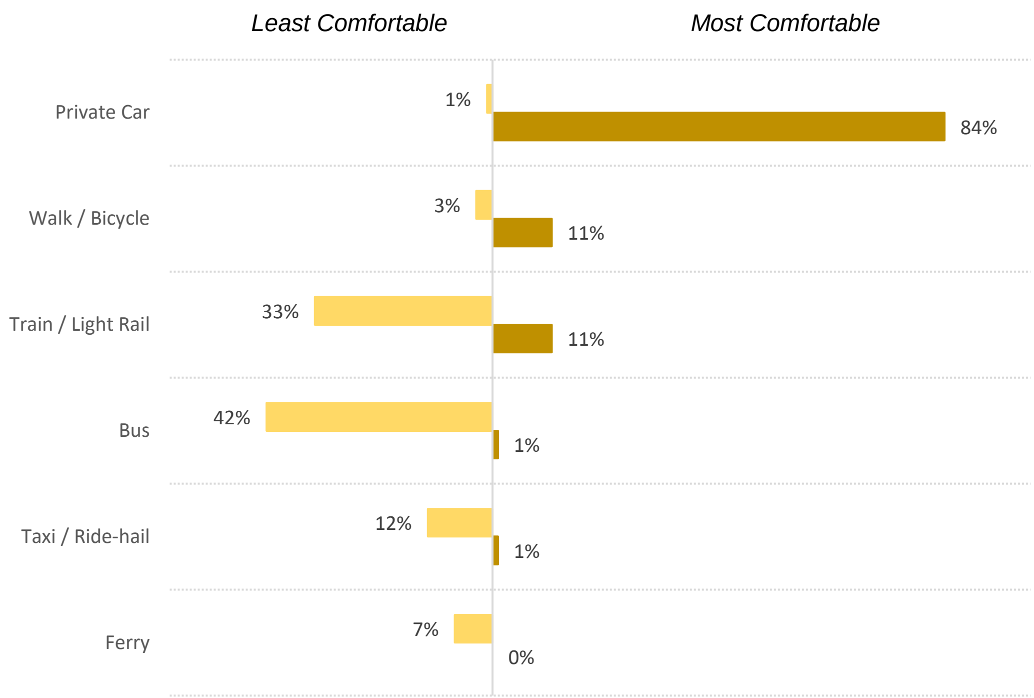

Figure 7: Most and Least Comfortable Mode of Transport

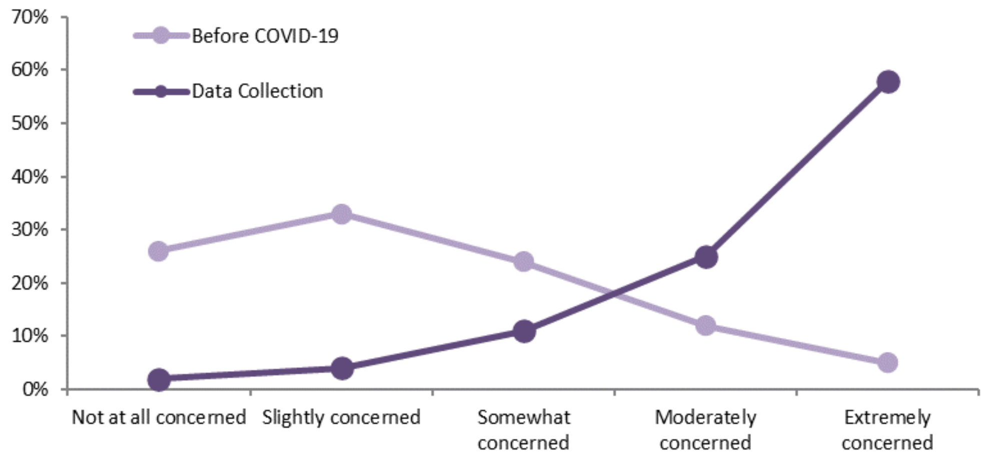

Figure 8: Level of Concern about Hygiene on Public Transport

The impact of COVID-19 on public transport is further demonstrated when looking at how concerned respondents were about the level of hygiene on public transportation prior to the COVID-19 and during data collection (Figure 8). Over half of respondents (58%) are now extremely concerned about levels of hygiene on public transport, up from just 5% prior to COVID-19. Again, these attitudes are largely invariant across the sample, with females being more concerned both before COVID-19 and during the data collection period, and older people who were significantly less concerned than others prior to COVID-19, but after restrictions hold the same concern as other age groups.

3.1.3 Travel by Purpose

As seen in Figure 9, trips for all purposes examined have fallen, the biggest fall unsurprisingly being in commuting trips, from an average of seven per week down to three. In aggregate, significant falls are also observed for the purposes of childcare and education, social and recreation, general shopping, personal business and for purposes of caring for the sick or elderly. Interestingly, while the average number of food shopping trips falls from 4.1 per week before COVID-19, to 3.1 during the data collection period, this difference is not significant, due mainly to the large degree of variability in how often households engaged in food shopping both prior to COVID-19 and after the outbreak. This may also be a result of some households building up stockpiles of food in the early stages of “panic buying” while others did not (discussed in Section 3.5). Again, as a proportion of household trips, commuting remains relatively constant at approximately 30% of all household trips, with falls in childcare and education (from 10% to 4%) and social and recreation (18% to 13%), but food shopping now accounts for 29% of trips (up from 17%).

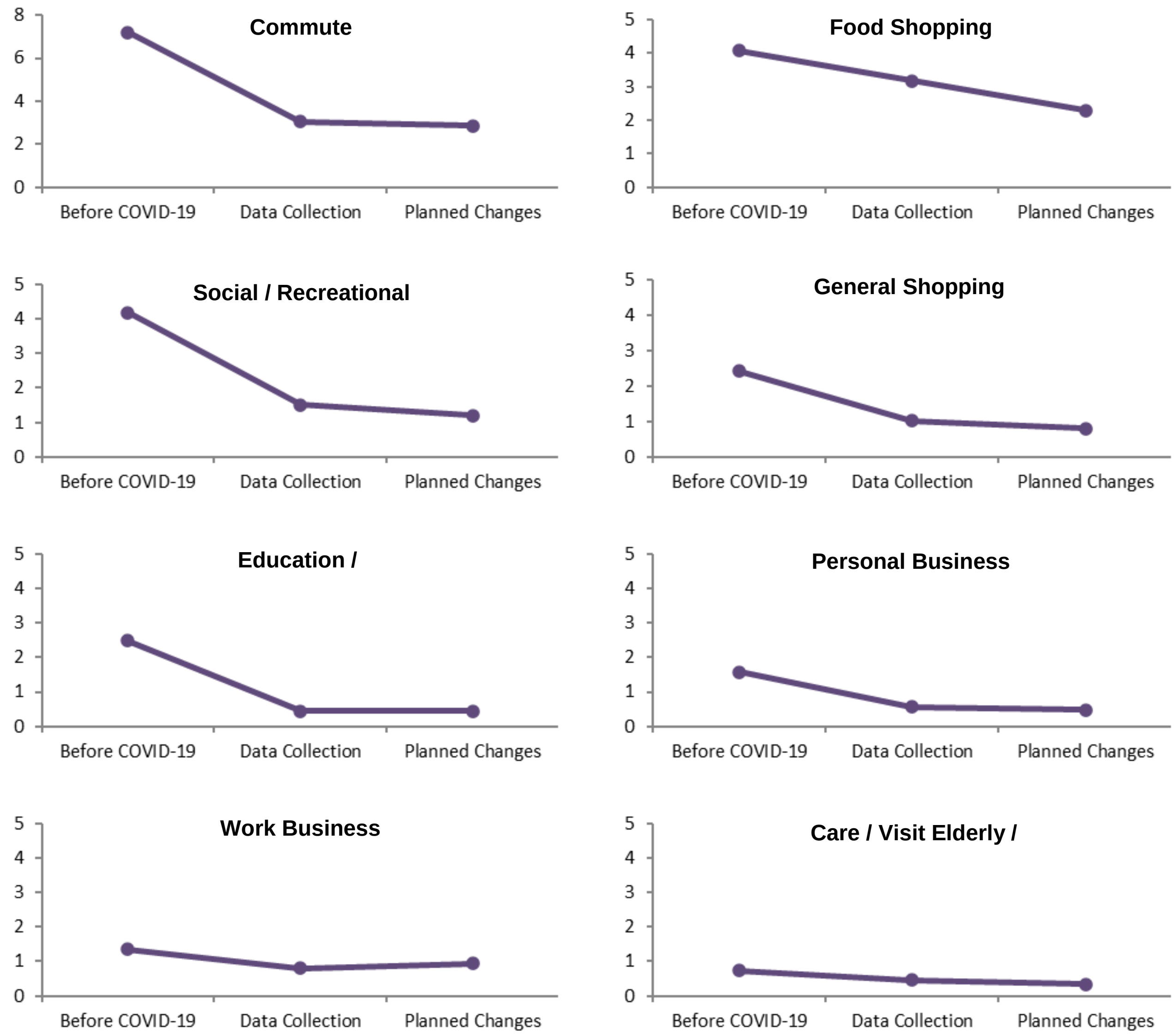

Figure 9: Reported Weekly Household Trips by Purpose

3.1.4 A Closer Look at Car Travel

While Figure 6 shows a fall in the number of trips made by car to be approximately 50%, Figure 10 below shows that two-thirds of respondents (66%) report a reduction in household car use, 15% having car use that is about the same, and 8% of households report using their car more. Females are more likely to report a decrease in household car use, along with older respondents. Low income or younger households, however, are more likely to not own a car or less likely to report decreased car use.

Overall, car use as a percentage of kilometres driven has decreased by 35% in aggregate (standard deviation = 42%). Among those households to have decreased their car use, the estimated reduction is 60% on average (median = 60%, standard deviation = 27%); lower income households report a significantly lower average reduction, with high income households reducing car use the most. In terms of the small number of households who have increased car use, the average increase is 44% (median = 35%, standard deviation = 30%).

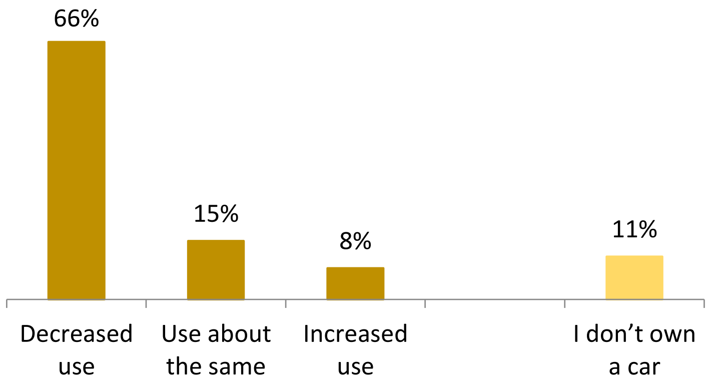

Figure 10: Changes in Car Use over Previous Week

To explain these broad changes in use of the car, a series of ordered logit models (Greene and Hensher 2010) were estimated, where the ordered choice were based on the response to a question that indicated whether a respondent would be more or less likely to decrease car use (0), keep car use constant (1), or increase their use of the motor vehicle (2). Many covariates were tested, and the best model is presented in Table 3[5]. A full range of socio-economic and demographic variables were trialled and found not to be significant and were excluded from the model. The reduction in car use has been widespread over all demographics, and indeed what this model actually shows is that it is the ability to do work from home and the support of the employer to do so, that really determines WFH and thus reductions in car use, rather than industry, occupation, age, gender or income per se. In explaining a broad change in car use, we found statistical significance associated with being able to do work from home, being directed to work from home by the employer, and where the car was the main mode of transport to work prior to the outbreak of COVID-19.

The mean direct elasticities presented in Table 4 provide insights into the impact of the variables on car use. If someone is directed to work from home by their employer, on average there is a 34% increase in the probability of a household decreasing their use of the car. Similarly, if someone's work can be completed from home, or if they mainly used the car to commute prior to COVID-19 or if they live in Western Australia, the probability of the household decreasing the use of their car also rises (and conversely for these variables, the probability of car use staying the same or increasing is lower for these households). Though the effect is relatively weak, if a bus was the main mode of commuting prior to COVID-19, the probability of car use staying the same, and particularly increasing car use, is higher. This is likely due to the high level of discomfort attached to bus travel[6], and concern over the relative hygiene of that mode; with the preference now being for the hygiene of their own vehicle.

[5] "While it is the case that overall goodness of fit is low (outside a typical logit range I fit between 0.2 and 0.4 (Domencich and McFadden 1975, page 124), it should be noted that this is after allowing for the constant where we are assuming the base is known shares. Importantly however, many well respected modellers have argued that there is important information associated with statistically significant variables regardless of what overall fit is obtained. Hence the statistical significance of the reported variable has behavioural merit."

[6] This concern also applies to trains and ride share, although they were not found to be statistically significant. We suspect this is because bus is the dominant mode in most cities and outside of the major metropolitan areas.

Table 3: Ordered Logit Model Explaining Changes to Car Use

LL_{Model}	-864.17
LL_{Base}	-896.30
Pseudo R^2	0.04
χ^2	64.25
AIC	1742.30
n_{obs}	1073

Variable	Coefficient	Std. Err	Z value
Constant	*0.20*	*1.27*	*0.20*
Directed to work from home	-1.08	0.20	-5.30
Work can be completed from home	0.001	0.0002	4.69
Commute by driving car (prior)	-0.84	0.18	-4.67
Resides in Western Australia	-0.40	0.22	-1.82
Commute by bus (prior)	0.44	0.27	1.57
Threshold Parameter μ_1	1.90	0.11	17.53

Table 4: Elasticities from Ordered Logit Explaining Changes to Car Use

Variable	Decrease	Same	Increase
Directed to work from home	0.34	-0.52	-0.63
Work can be completed from home	0.11	-0.16	-0.23
Commute by driving car (prior)	0.14	-0.21	-0.27
Resides in Western Australia	0.30	-0.43	-0.62
Commute by bus (prior)	-0.17	0.23	0.40

While the number of significant explanatory variables at this aggregate level is small, there are more factors when examining the magnitude of the change. Given that two-thirds of households have decreased the use of their car, we opt to look at this change in detail in this paper as there is preliminary evidence that cars will be relatively more attractive when travel restrictions are eased. It should be noted that the model fits are low, primarily because of the uniformity in the way in which the sample adapted their travel and car use in order to combat Covid-19. To use an Australian term, agree or disagree with the measures, it appears that people have complied with government recommendations.

Where commuting was undertaken primarily via bus, the probability of increasing car use increases (and conversely the probability of reducing the use of the bus is less). This result, combined with the findings that respondents would be least comfortable travelling on buses (followed by trains), and that 83% of the sample express concern about hygiene on public transport, indicates a likely high aversion to public transport at least in the short term. Additionally, the likely reality is that capacity on public transport will be significantly reduced due to social distancing requirements, creating a further disincentive for these modes. As people return to work, the attractiveness of the private vehicle may create worse congestion than what was seen prior to COVID-19, so understanding why people are decreasing car use is important in being able to develop policies to keep use suppressed as restrictions are eased.

Table 5 presents the results of a regression modelling examining drivers of decreased car use[7]. Again we see that the large drivers of reduced usage are changes to work and important life activities, which is expected. Those who did more days working prior to COVID-19 (compared to the data collection period) report a higher percentage decrease in the overall number of trips after the outbreak (the dependent variable is negative to represent a percentage drop). Those who worked more days from home after the outbreak than before, have a higher percentage decrease than those who work from home the same amount or less. Respondents who reported that shopping activities and meeting with friends were usual activities that had been interrupted by COVID-19 reported significantly decreased car use relative to others, as did those who felt that the outbreak was a significant threat to the health of the economy (possibly supporting this view through decreased car use). Individuals who could not work from home had significantly less reduction but still a decrease, in car usage (recall that these people were also more likely to keep car use the same or increase it), and those who agreed more strongly that COVID-19 is a significant public health threat reduce car use by a lesser percentage.

Table 5: Explaining the Magnitude of Decreased Car Use

R^2	0.101
Adj. R^2	0.091
$F_{(8,689)}$	9.700
F_{sig}	0.000
Std. Err. Est.	25.905

Variable	Coefficient	Std. Err	t value
Constant	*-34.27*	*3.90*	*-8.79*
Difference in days of employment (Prior vs Data Collection)	-3.08	0.50	-6.13
Difference in days worked from home (Prior vs Data Collection)	3.07	0.50	6.13
Shopping affected by COVID-19 outbreak	-7.52	2.42	-3.11
Meeting friends affected by COVID-19 outbreak	-6.93	2.78	-2.49
Work cannot be done from home	7.02	2.68	2.62
Drive car as main mode (Prior)	-7.51	2.77	-2.71
COVID-19 is a threat to public health	1.24	0.52	2.40
COVID-19 is a threat to economic health	-1.23	0.52	-2.38

These findings align well with what we are seeing in the grey press and media about the challenges in making public transport attractive again. In Australia, service levels and schedules were unchanged during COVID-19 with resultant movement of almost empty carriages and buses. Public transport Authorities are already planning new strategies to support public transport which include regular deep cleaning and enforcing the wearing of masks while on board, on platforms and at public transport terminals. Social distancing will mean that seats adjacent to passengers must remain unfilled, dropping passenger capacity to around 30 percent for most public transport modes. The latter may indeed be acceptably achievable if working from home continues at a rate that might not be as high as at present but substantially higher than prior to COVID-19. With offices obliged to comply with social distancing rules as restrictions are lifted, the staggering of working hours is likely to provide

[7] The R^2 value could be considered relatively low, but it should be noted that this model is produced at a time where government restrictions (a dominating explanatory variable) were implemented giving people little choice but to reduce their travel, irrespective of attitude or characteristics. This model is, in effect, looking at changes that can be made at the margins of already reduced travel.

some support in achieving a public transport system that is no longer typified for the high peaks (the camel effect), but rather becomes like the horse (flat throughout the day).

3.2 Impact of COVID-19 on Work

3.2.1 Employment

A large driver of travel activity is employment, and there is no doubt that COVID-19 has had a large impact on the availability of work and the way in which work is done. With changes to retail and shopping behaviour already occurring due to COVID-19, the restrictions on trading announced by the Federal government, coming into effect on the 30th of March, had further impacts on the economy.

Figure 11 highlights just how widespread these impacts were, with only one-third of respondents being unaffected or perhaps more impactful, 70% were impacted by the regulations or knew someone who was. Females were more likely to either be impacted or know someone who was, and respondents from high income households were more likely to have someone in the household affected (and low income less likely).

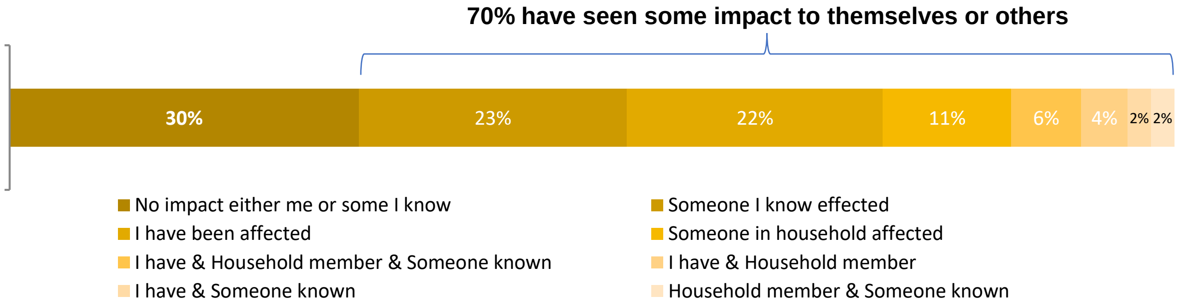

Figure 11: Impact of Government Regulations on Availability of Work

In this sample, 33% of respondents were not working prior to COVID-19 (either retired, or a stay at home parent, or unemployed); but looking at only those who work at least one day a week, prior to COVID-19 more than half of respondents worked 5 days per week (57%), with the average among those working being 4.5 days a week. However, during the data collection period, over a quarter of respondents (26%) are no longer employed and the number who work 5 days per week has fallen dramatically to 39%, as can be seen in Figure 12. Younger households and those on lower incomes are impacted more heavily as a result of COVID-19, with these two groups now working significantly less days per week on average than other respective age and income groups. These unemployment results may seem high, given the implementation of the JobKeeper scheme, designed to keep employees connected their place of work. However, this support package was announced on the day the survey went into field, and we unfortunately do not have any questions in this wave pertaining to either JobSeeker or JobKeeper.

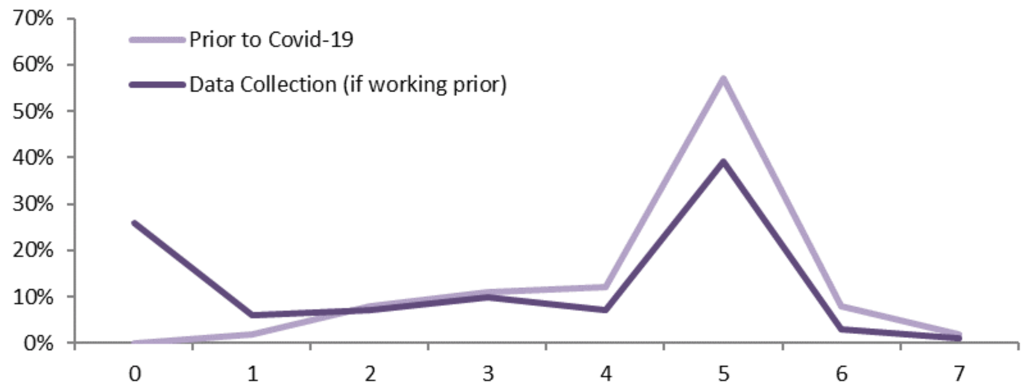

Figure 12: Days Worked per Week (if employed prior to COVID-19)

3.2.2 Working from Home

For those who still have employment, many have been able to shift their work such that they are now working from home. As shown in Figure 13, almost half of those employed have stated that their work can be done from home (47%), with those from higher incomes or from middle aged households being more likely to be able to complete their work from home.

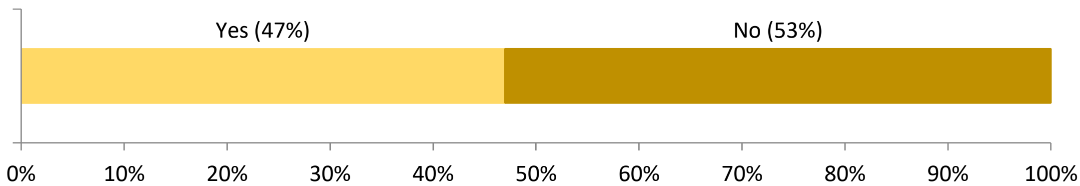

Figure 13: Ability to Complete Work from Home

In terms of the policy of the workplace in which respondents are employed (Figure 14), 41% are in workplaces that either direct employees to work from home, or give them the choice to do so; half either cannot work from home given the nature of the job or their workplace does not support it, while 9% unfortunately work for a business that has now closed as a result of COVID-19. Many of the latter businesses are restaurants, pubs, clubs, gyms, tattoo parlours and shops.

In terms of differences based on socio-demographics, females are more likely to have worked in places that have closed, those in lower income households or respondents who are younger are more likely to be in workplaces that have no plans to allow working from home or in jobs where work cannot be done from home, and higher income households are more likely to either be given the choice or directed to work from homes.

Prior to COVID-19, of those who were employed, the vast majority did not work from home (71%); however following the COVID-19 restrictions, that number almost halved (down to 39%), with a quarter of respondents now working from home five days a week, see Figure 15. As a result the overall average number of days worked from home per week swelled to 2.5, up from 0.8 days prior. While middle aged respondents work more from home on average (both prior to and during data collection), the number of days worked from home is independent of age, gender or income.

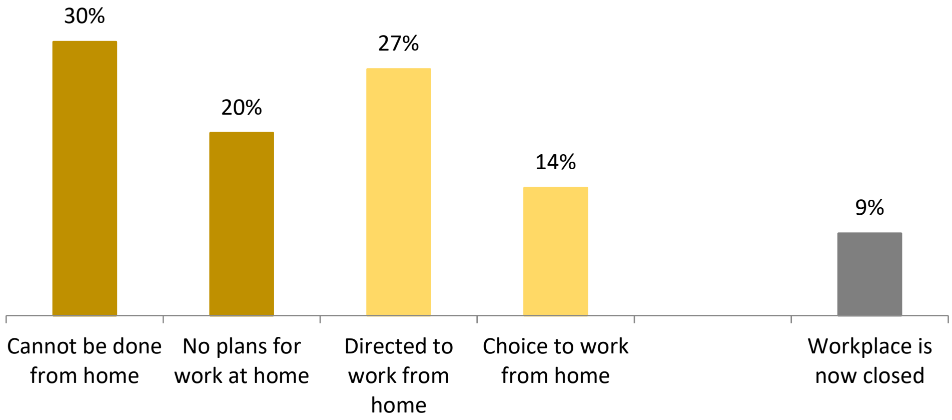

Figure 14: Workplace Policy to Working from Home

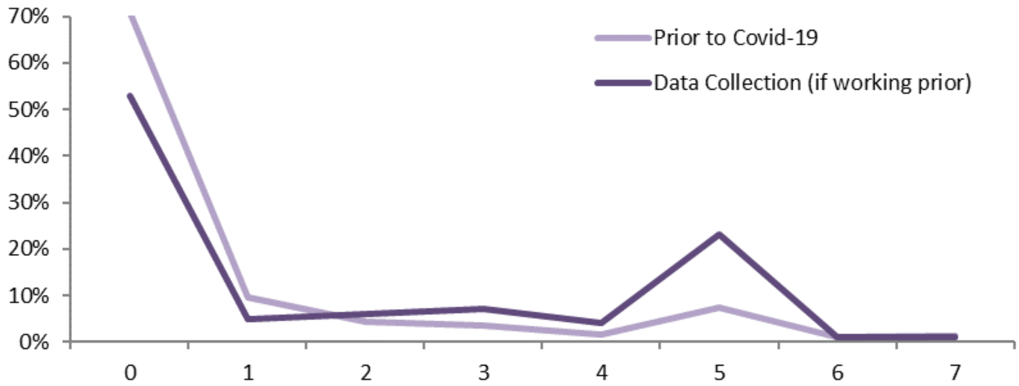

Figure 15: Number of Days Working from Home

3.3 Impact on Activities

The impact of COVID-19 on regular activities outside of work has been just as profound (Figure 16), with large numbers of respondents reporting interruptions to meeting with friends (80%), visiting restaurants (76%), and going to the shops (76%). Interestingly, only 34% of the sample stated that watching professional sport was a regular activity that had been interrupted, possibly because many do not watch these events.

There are many differences in the impact based on socio-demographics. Females are more likely to state that meeting with friends, going to the shops, and doctor's appointments had been interrupted; males that watching professional sport or playing organised sport had been interrupted. Younger respondents were more likely to report interruptions to going to the shops, going to movies, going to pubs or bars, gyms and exercise, and attending music events; middle-aged respondents are more likely to experience disruption to schooling or childcare; and generally older respondents report less disruption overall, with the exception of doctor's appointments where they are more likely than other age groups to have this activity disrupted[8]. With respect to income, lower income households are less likely to report disruption to visiting restaurants, going to pubs or bars, gyms or exercise, watching professional sport, playing organised sport, or work functions; middle income households were more likely to find that going to restaurants and pubs or bars has been interrupted; and higher income

[8] The Federal government introduced free tele-health to enable appointment with a GP to be made from home.

households were more likely to report disruption to gyms and exercise, watching professional sport and work functions.

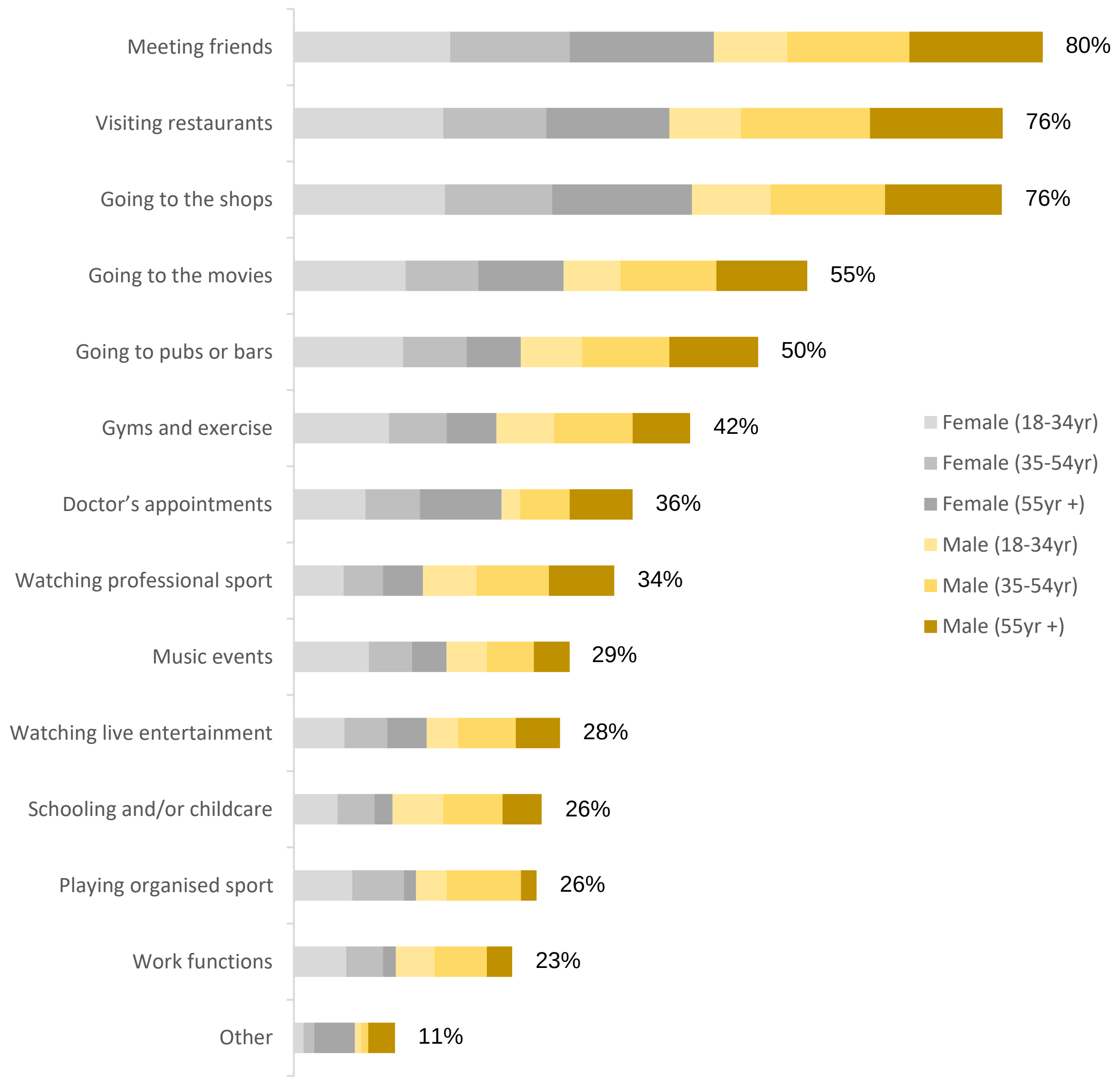

Figure 16: Interruption to Normal Activities due to COVID-19

3.4 Impact on Air Travel

Another point of interest in this survey was the impact on the aviation industry. As at the end of the first week of April, only 2% of the survey was still planning on making a flight of some kind, with 52% delaying travel voluntarily and 46% doing so because of government regulations. For those who still intended on travelling, 63% were going to do so domestically, while 54% were still intending to make international travel during the COVID-19 pandemic (selecting both was possible). The majority of intended travel was personal travel (79%) as compared to business (29%).

Figure 17 highlights the bigger impact on planned air travel that has been disrupted by COVID-19, with over a third (37%) of respondents experiencing some kind of disruption to their planned travel. Unlike travel that was still intended, interrupted travel was primarily international (63%) compared to domestic (55%), and almost all personal travel (94%) rather than for business (12%). Almost half of respondents cancelled travel (49%), a large number returned the ticket for a voucher or credit with the airline, with 11% having rebooked their flights for a later date. Females are more likely to have returned their ticket for a voucher or credit.

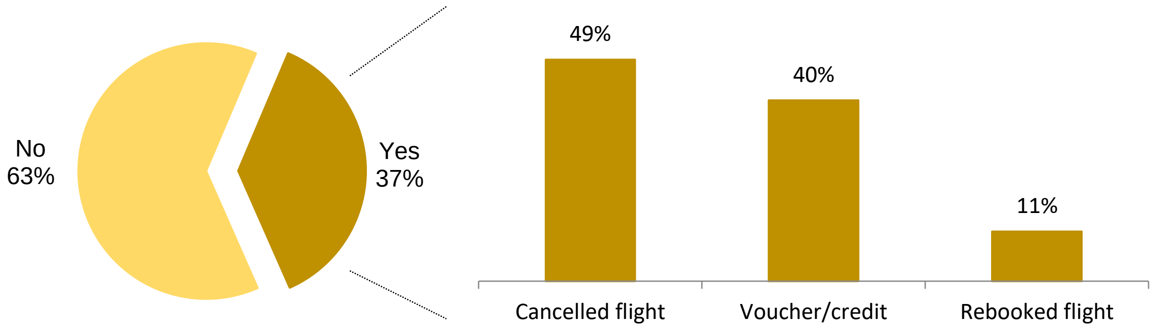

Figure 17: Air Travel Interrupted by COVID-19

3.5 Impact on Shopping

The COVID-19 outbreak resulted in widespread instances of panic shopping, particularly for toilet paper, sanitisers, and staple foods such as pasta, rice and minced meats. The survey asked respondents if they encountered difficulty shopping for a number of key items, and Figure 18 shows that 80% of respondents experienced problems shopping for toilet papers, along with food (73%) and tissues (63%). Females were more likely to report difficulty in shopping for toilet paper, food and non-prescription medicine, and males more likely to report shopping for sanitary products. Interestingly, older respondents were less likely to report difficulty in shopping for food, sanitary products and non-prescription medicine, perhaps due to supermarkets (as of the 16th of March) providing shopping time between 7am and 8am exclusively for older people and those with disabilities.

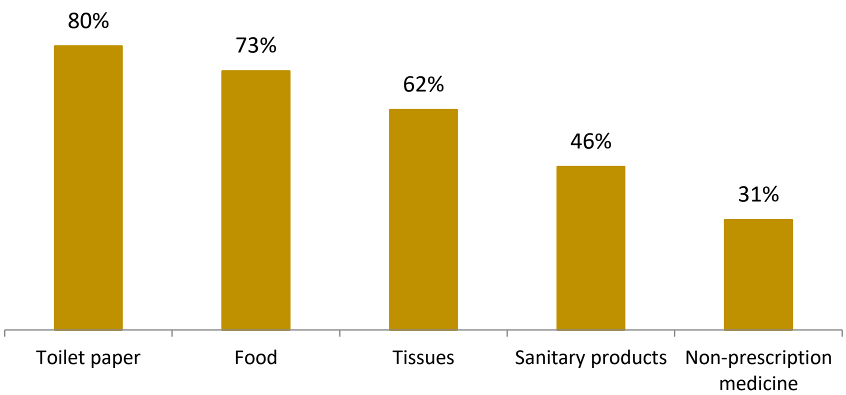

Figure 18: Difficulties Shopping for Items (Y)

Almost a quarter of respondents were using online grocery shopping prior to the 1st of March, and a further 18% reported using online grocery shopping as a result of the COVID-19 outbreak; though older households were less likely to use it both before the pandemic and during the data collection period.

The survey also explored if respondents engaged in any “stocking up” behaviour themselves (Figure 19), and almost half the sample (47%) reported doing so for food, and one-third for toilet paper. Older respondents were less likely to have stocked up on food or sanitary items, and lower income households less likely to have stocked up on toilet paper.

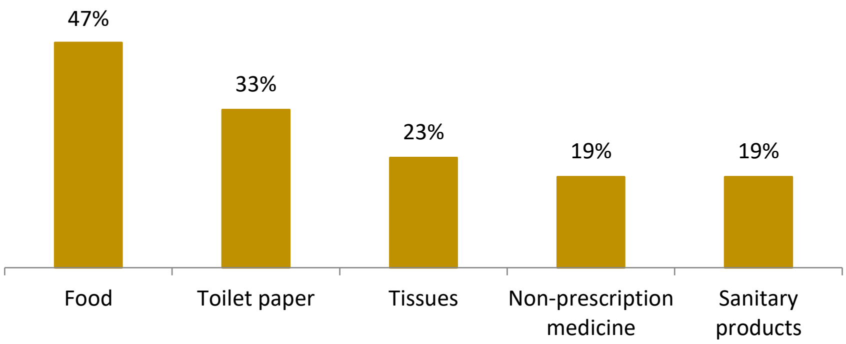

Figure 19: Stocking Up on Selected Items (Y)

In terms of the number of days of stock for each of these items, there was a great degree of variability in the data (as indicated by the error bars in Figure 20), but households held an average of approximately three weeks of stock for toilet paper, tissues and non-prescription medicines. Stock of food was the most consistent among responding households, estimated to be at a week and a half of supplies. Females reported a higher average number of stocked sanitary items; older people a higher average stock of food and less sanitary products, and higher income households holding a higher average stock of non-prescription medicine.

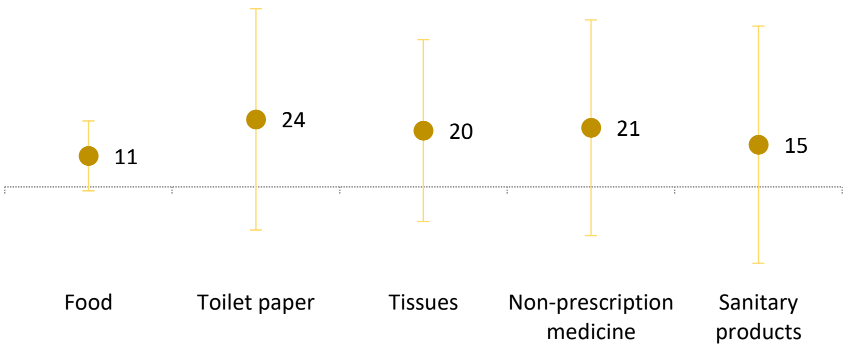

Figure 20: Average Days Stock of Selected Items

Interestingly, when looking at the variation in household supplies, 7% of households reported having only one day of food in stock, whereas 2% reported having two months or more. With respect to toilet paper, 10% felt they only had enough stock to last a day compared to 11% who felt they held two months or more worth of supplies. Twenty percent of households reported only having one day of tissues and 9% having two months or more; 27% one day of non-prescription medicines and 9% two or more months; and lastly 32% report one day of sanitary products compared to 5% feeling they hold two or more months of supply.

3.6 Attitudinal Analysis

The survey also explored the attitudes held towards various aspects of the COVID-19 outbreak with respondents asked to state their level of agreement with a number of statements (Figure 21; error bars represent 95% confidence interval). Across all statements, respondents exhibit significant levels of agreement, however the thought that COVID-19 is a serious public health concern, requires drastic measure and will affect the way people travel is significantly higher than other statements. On the other hand, agreement with the statement that I will go to work to avoid social isolation is significantly lower than all other statements. Interestingly, there is significantly lower agreement with the trust in other people to respond in the future, the appropriate self-isolating and social distancing of others and the response of the wider community, as compared to the response of the governments and business and their actions moving forward[9].

In terms of sociodemographic differences, older respondents reported significantly higher levels of agreement across all statements; females higher average agreement with COVID-19 being a serious public health concern, requiring drastic measures, that it will affect how people travel, that the response of business has been appropriate and that the response of the state government has been appropriate. Males and middle income respondents exhibit significantly higher average agreement with the statement that they will go to work from time to time to avoid social isolation.

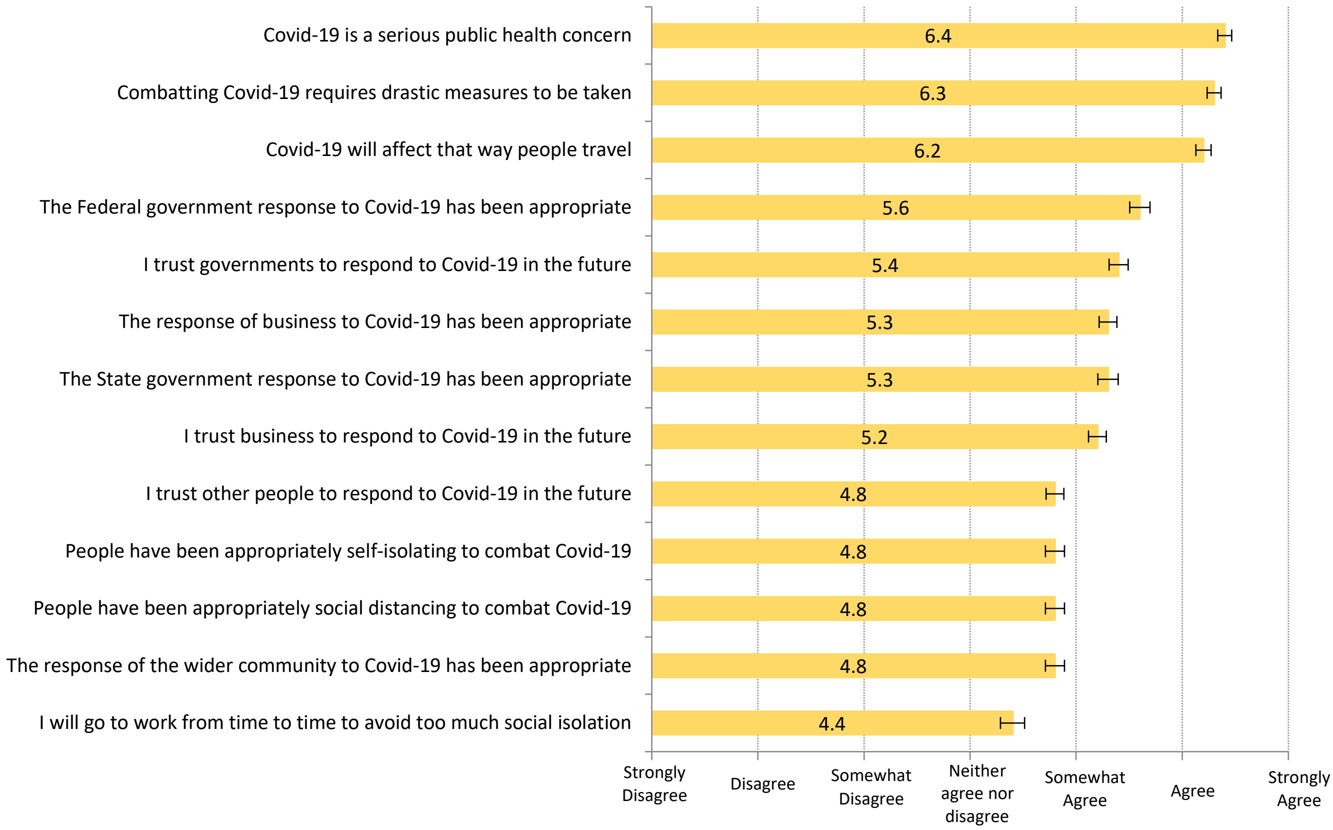

Figure 21: Level of Agreement with Statements regarding COVID-19

With respect to the risk that COVID-19 presents (on a scale from 1 = extremely low risk to 10 = extremely high risk – Figure 22; error bars represent 95% confidence interval), the risk of COVID-19 to the health of the economy is viewed to be significantly higher than the risk to someone known to the respondent, the general public, or the health of the respondent themselves. However, COVID-19 is still thought to be a very high risk to someone known to the respondent or themselves; indeed while respondents do view COVID-19 as a risk to themselves, on average their own health is at the lowest perceived risk.

[9] The perceived appropriateness of state government responses will need to be examined on a state-by-state basis, particularly to see if there is any impact of the Ruby Princess disembarkation in NSW. NSW instigated an inquiry in mid-April which is likely to run for at least 6 months.

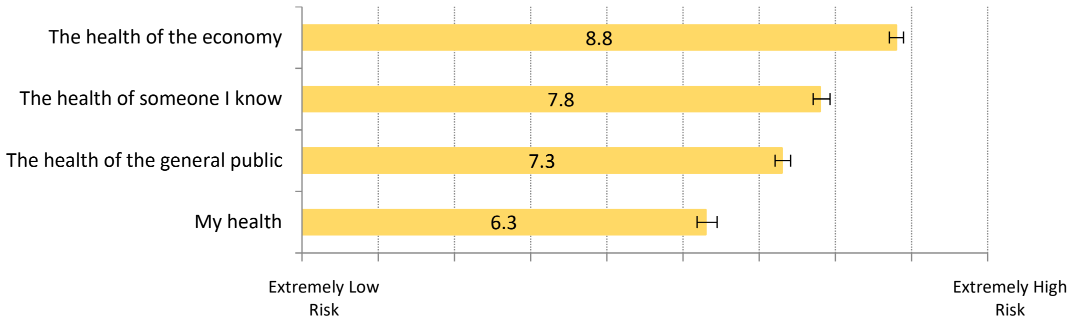

Figure 22: Risk of COVID-19 to Human and Economic Health

In terms of socio demographic different, older respondents exhibit significantly higher levels of agreement that COVID-19 is a threat to "my health" (and average of 1 unit higher than both younger respondents and those in the middle age group). Interestingly, older people also exhibit significantly higher agreement that the virus is a threat to the economy than younger and middle-aged respondents. There are no differences in terms of gender or household income.

4 Discussion of Policy Implications

4.1 Overview of Results

The changes brought by the COVID-19 outbreak are widespread and unparalleled. Following the restrictions announced by National Cabinet implemented on the 30th of March, we can see that travel activity has significantly decreased, as a function of a reduction in travel via every mode, and for every purpose. This evidence suggests that the government's request to 'stay at home' has been heeded. Early modelling of COVID-19 indicated that a level of compliance with recommended guidelines below 70% would be unlikely to succeed, whereas compliance with social distancing measures at a 90% level would likely control the disease within 13–14 weeks, when coupled with effective case isolation and international travel restrictions (Chang et al. 2020). National COVID-19 statistics provide tentative evidence that this changed behaviour has been effective thus far in "flattening the curve" of COVID-19 infection rates, indicating that compliance has been strongly embraced within Australia.

Attitudinal analysis provides some broad insight into why Australia has been relatively successful in combatting COVID-19 thus far; our results indicate that the virus was widely viewed as a serious public health concern that required drastic action, particularly disruption to travel, as it presented a health risk to someone that they knew. While there may have been an underlying motivation to comply with national guidelines for altruistic reasons, there equally may also be the realisation that COVID-19 presented a threat to the economy and that decisive action would be needed to minimise that economic impact. Our data indicates that in these early stages, the general mood was one of support of the actions taken by Federal and State governments, and the response of business to the COVID-19 impact.

The rest of this section will address each of the areas of analysis in the preceding section, looking to extract further insight and to interpret the findings in the context of potential policy implications for both dealing with the COVID-19 pandemic, but also thinking about what could be implemented for other pandemic events which may occur in the future.

4.2 Food Logistics and Freight

Significant disruption was witnessed in grocery shopping, with large numbers experiencing difficulty shopping for toilet paper and food, with many stocking up on both. While not ostensibly related to human transport and mobility and transport behaviour, it is an interesting highlight of the human response to the COVID-19 pandemic and does have significant ramifications for freight transport policy. It should be noted that there are no food security problems in Australia with approximately 71% of what is produced in Australia being exported, and 11% of what is consumed in Australia being imported (ABARES 2020) so the predominant concern is about timely logistics responses.

Learning from COVID-19, future pandemic situations will need to see a swifter implementation of purchase limits on staple items and a designated shopping time for the elderly and disabled to be created sooner, along with anticipating a likely surge in demand for staple items popular in home-cooking. This has implications for early stage planning, particularly around staffing and inventory requirements. A major policy implication of COVID-19 has been the response of the Australian Consumer and Competition Commission, temporality suspending anti-competition regulation to allow supermarkets to coordinate with each other when working with manufacturers, suppliers, and transport and logistics providers (though still prohibiting price fixing). This sets a precedent for early stage cooperation in future pandemic scenarios.

Overall, the implementation of these policies seemed to stabilise the buying behaviour during the data collection phase for this survey suggesting that results households have enough stock of necessities to cope with disruption, though stock levels are variable and food stocks are relatively lower at an average of 11 days[10]. The supply chain operations of supermarkets and producers have seemingly caught up with rapidly changing demand, but should remain prepared for future disruptions which might occur.

4.3 Aviation Sector

The aviation industry, like all industry, has experienced dramatic upheaval. At the time of sampling, only 2% of people still intended to make a flight and over a third of people had air travel disrupted by COVID-19, with the majority of this group cancelling flights for a refund, or suspending bookings in return for a 12 month credit with the airline. How good that credit might be could be questionable, for example Virgin Australia has gone into voluntary administration, brought on as a result of COVID-19. Most of the interrupted travel was personal travel, and more was for international travel than domestic.

With state and international borders closed, air travel is significantly reduced. It is unclear exactly when international borders will reopen, perhaps the most definitive trigger for relaxation of global travel restrictions will be the advent of a vaccine but that is at least 12-18 months away, ignoring the further time it would take to mass produce a vaccine on the scale that would be required. There is very little indication as to how individuals will react. While some may be less inclined to travel, growth in international travel continued unabated under previous shocks like the Oil Crisis, Gulf Crisis, 9/11 attacks, and SARS (IATA 2020).

The recent growth in air travel, however, has been predicated on the fact that international travel was becoming more affordable, thanks to new technology and fiercer competition in the industry. Yet, with a prolonged global recession there may be less competition in the sector moving forward and what was once affordable may no longer be so, and the number of competing airlines may well be less . While it is likely that preference for international travel may be suppressed, or unaffordable, for some time this will increase the relative attractiveness of domestic travel. To that end, Australian-based airlines will likely need to investigate, and have already started to do so, strategies to encourage air travel within Australia, perhaps working with state-based tourism organisations to develop package deals for consumers, or advertising about tourist destinations within national borders. Following the bushfires, there were many well received campaigns to travel and buy local, and the sector will need to recapture that momentum and sense of 'Australian-ness'.

[10] As of May 6, the supermarkets have advised that there is no shortage of stock, and in some cases they overstocked since people have started hoarding, with soup the most popular purchase.

4.4 Public Transport

Public transport will face some of the greatest challenges if we are to make it attractive again as we emerge slowly out of the COVID-19 pandemic. In Australia, service levels and schedules were unchanged during COVID-19 with resultant movement of almost empty carriages and buses. Our results indicate a high degree of trepidation with public transport, particularly with respect to hygiene. To combat this, public transport authorities may need to consider overt demonstrations of “deep-cleaning” (possibly via social media platforms or service provider websites). There may also be the need to employ staff to provide visible cleaning while services are operational, such as cleaning surfaces regularly, or wiping down seats when passengers alight. Staff maybe deployed at stations or stops to encourage social distancing and efficient movement. It may also be beneficial to provide hand sanitiser at stations and onboard services. The purpose of these demonstrable actions are to reduce the level of concern with the overall cleanliness of each public transport mode, particularly with respect to the “threat” presented to the traveller by other members of the public, that they may not trust as much as people they know.

Clearly social distancing will need to be enforced on public transportation until restrictions are eased (in Australia the restriction is set at one person for every 4sqm of space). This will place very significant capacity constraints on the network. Lastly, public transport service providers may need to think about innovative technological solutions to make the public transport experience easier to engage with during the pandemic. They might perhaps look towards investment in the development of a service wherein prospective users can receive alerts about when a good time to travel is or when is a bad time, via a simple “green” or “red” indicator in a phone app[11].

4.5 Motor Vehicle and Road Use

Overall, car use is down by over a third (35%) and for the majority of respondents who were able to decrease car use, that reduction is even larger at 60% less than before COVID-19. The benefits of that reduction include improved air quality and visibility in our capital cities, and in less congestion on the roads for those essential workers who need to travel. However, our analysis indicates that it is likely that as COVID-19 restrictions ease, the car will return in a dominant way and could cause congestion at levels not seen prior to the outbreak should sensible measures not be introduced. Preliminary evidence in the Swiss MOBIS study shows the start of slow recovery in kilometres travelled by car (and a large increase in bicycle use) while public transport modes stay comparatively flat (Mobis 2020).

Maintaining flexibility with respect to working from home and work starting and finishing times will be as important for road congestion as or public transport crowding, so transport authorities should be encouraged to lobby government and business to ensure that support for these working arrangements are in place for at least as long as restrictions stand. Innovative thinking may also need to occur, perhaps bus lanes might be given over to mixed traffic for the duration of the pandemic to facilitate traffic flow. If, as suggested by government, that temporary additional parking should be provided given the likely increase in car use, especially in central business districts, they must monitor parking providers to avoid price gouging behaviour. There may also be the opportunity to revisit older perhaps previously impossible policies such as car-pooling. With the likely increase popularity of the car, there may be mechanisms that can be designed to better coordinate car-pooling between known/trusted persons, for both work and recreational purposes, as the restriction on social-distancing and gatherings ease (i.e. more combined trips with those in your family or among members of social networks whose health can be “trusted”).

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[11] Skedgo has recently developed this capability in their TripGo App.

Transport authorities could perhaps leverage the current enjoyment of better amenity, combined with significant improvement to health as a result of less tailpipe emissions, to encourage lower levels of car use to be ongoing. Lastly, with interruptions to meeting with friends and shopping being a key contributor to reduced travel, authorities could also appeal to Australians to still be patient with regards to meeting friends and engaging in widespread discretionary shopping particularly during the week, as people do hopefully start to return to work, at a staggered time of day rate.

4.6 Active Transport

There may be scope to encourage active transport, particularly for short trips, as a substitute for car use. If not given over to cars, perhaps bus lanes could be given to active transport modes and authorities should also consider removing restrictions on bicycle riding on footpaths (currently illegal in many states of Australia) within sensible parameters. Careful thought should be given to the bicycle networks within cities, and in strategic locations there may be scope to limit on-street parking to create “pop-up” bicycle lanes which, if successful, could become permanent infrastructure. Nascent modes such as e-bikes and e-scooters (which are currently illegal in New South Wales for example) could also receive policy and regulatory support for shorter trips, or perhaps with increased spacing between passengers on public transport, commuters could take these modes more easily onto public transport to improve access and egress at stops or stations.

In the longer term, authorities should use the COVID-19 pandemic as a starting point to think about embedding active transport within all transport infrastructure investment. In looking for infrastructure-based stimulus spending, thinking laterally about increased infrastructure for active transport such as improved bicycle lanes and accessibility would provide viable alternatives to car use. For example, as the WestConnex project continues (a 33 kilometre, $16.8b toll road project in the west of Sydney), maybe some space can be provided for a bicycle super-highway next to the orbital, or bicycle lanes could be developed alongside heavy rail infrastructure and away from roads.

4.7 Flexible Working Arrangements

The way in which work is undertaken has changed; the number of people working zero days from home has fallen from 71% to 39%, and the number working five days a week from home has increased from 7% to 30%. Almost half of the sample have the ability to complete their work from home and have been either given the choice or been told to do so. The ability to work from home or staggering working hours is perhaps the biggest tool in the kit to combat excessive levels of road congestion and reduce public transport crowding.

As children slowly return to school, working from home for many may become easier, and while there is mild agreement that people would like to go to work to avoid social isolation, that feeling of social isolation may be less of a concern as people are slowly allowed to visit friends and family again. Governments will need to sit down with representatives of employer and employee organisations and look at what incentives and investment is required to make working from home a viable long-term proposition for more Australians. The survey suggests a high incidence of choosing to work from home. While it is likely that, as a function of the 4sqm social distancing regulations currently in effect, offices will need to continue to support flexible work arrangements, if not widely adopted by industry then governments might need to consider extreme response such as mandating some form of work from home arrangement where business is required to allow staff to work from home one or two days a week on a rotating basis.

4.8 Infrastructure Investment and Funding

Typically, infrastructure investment in transport projects is used as a stimulus measure in economic recovery efforts. However, with the present amount of disruption, authorities should think very carefully about any future infrastructure investment, particularly while post-COVID-19 behaviours remain unknown and unpredictable. Indeed, governments may wish to give some thought to pausing large infrastructure projects in the public transport space (and potentially even those like the second Sydney Airport), perhaps thinking laterally about increased infrastructure spend on a smaller scale such as investment in improved bicycle lanes and accessibility. If looking to spending on a larger scale, investment should support infrastructure that would facilitate the ability for more people to work from home or engage in flexible working hours. Perhaps somewhat controversially coming from those working in transport, there may be a need to move large scale priority funding towards increasing the provision of essential services such as health care, education, or social infrastructure. If there is one thing governments should be wary of, it would be any investment in transport infrastructure that would serve to further exacerbate the dominance of the motor vehicle in a post-COVID-19 world.

With respect to funding infrastructure investment in roads, the time might be right to revisit road pricing as a viable mechanism, particularly if the travelling public truly sees the value of significantly reduced traffic congestion (Butt 2020). The impact of COVID-19 on toll road revenue has been significant, with Transurban reporting a 29% fall on its Sydney roads, 43% fall on its Melbourne toll road, and a 27% fall on the assets owned in Queensland (Rabe and Hatch 2020). If there is a permanent shift to more people working at home following the COVID-19 outbreak, there would be a significantly detrimental impact on the viability of toll roads and thus road funding via this mechanism. A recent white paper by management consultancy WSP outlines the similar impact of COVID-19 on revenue for transportation, and calls for an expanding use of tolling (akin to widespread road pricing) as a backstop lost revenue and prevent the return of saturated congestion (WSP 2020). With respect to road pricing schemes, research indications that such schemes can gain support from the general public (Krupnick and Alberini 2001), and be devised without any cost impost to user greater than those that exist (Hensher and Bliemer 2014).

5 Limitations and Future Research

5.1 Limitations of the Current Study

As with all studies, there are a number of trade-offs that need to be considered when balancing the need for speed of getting into field given the rapidly growing disruption, the overall length of the survey as it stood, and limited budgets given university wide spending freezes placing further cost pressures. There are likely a number of ways in which this research could be improved, but perhaps most importantly is that the data analysed herein does not have sufficient freedom to understand the working from home experience in great detail. We know that many are doing so, but as of yet we do not know how positive or negative that experience has been, nor how productive employees have been. What we do know from the data that we have collected is that in these initial stages there is likely a “two speed economy” wherein there are those who have the ability to work from home and are successfully doing so, and those who cannot.

Future research should look to examine work from home and flexible working hours in far greater depth, and *in particular* look to understand the likelihood of the employer supporting working from home moving forward. It should also examining working from home over the longer term. Ongoing work by the authors will seek to do this. It should also be noted that the focus of this paper was working from home, but equally a large number of educational activities were interrupted by COVID-19. There is an opportunity to look at the disruption to these activities, particularly as in some jurisdictions educational travel (especially at a tertiary level) accounts for a high percentage of transport volume.

Understanding the support and propensity to work from home continuing will be a crucial opportunity for transport policy makers not only in the current climate but also in combatting the persistence of congestion. While perhaps not at the extreme of the COVID-19 panic, a small reduction in daily travel by a small and sustained increase in working from home will have significant benefits in terms of reduced traffic congestion and less crowding on public transport. While some may argue that a survey comprised of online panel members may overstate the ability to work from home, we would argue that it would not take a large reduction in traffic to remove pressure on transport bottlenecks and increase the overall efficiency of the network. Given that BITRE (2015) claim a loss of $30billion plus in travel time benefits due to congestion, understanding work from home and gaining insight into how to sustain increased levels will potentially return large societal gains.

Future waves of this study will also seek to understand household characteristics in more detail, such as car and bicycle ownership, the availability of transport modes with respect to daily travel and a more nuanced examination of the impact of COVID-19 on employment as well as potential uptake of support programs such as JobSeeker and JobKeeper. Future research should also examine freight transport in more detail than completed herein, in particular the response of the retail and food sector to securing supply whilst under unforeseen demand pressures. Additionally, there is scope to examine the preparedness of the parcel and last mile delivery services, which experienced significant delays resulting in well publicised dissatisfaction (e.g. Stanley and Wong 2020)

5.2 Future Research Directions

While the disruption to travel is widespread, the unfortunate reality is that a large part of that disruption is because of changes to work and employment. More than two-thirds of household's surveyed (70%) have been impacted, or know of someone whose availability of work was impacted, by the government regulations introduced to combat the spread of COVID-19. The impact can be seen most dramatically in the findings that the number of people working five days a week has fallen from 57% to 39%; and 27% of the sample who were working at least one day prior to COVID-19 are no longer working. It is clear that there is great need for research in to the impact of COVID-19 on work, not only because of the demand for transport that is derived from work and other activities.

Interestingly, there are important implications for the future of work that may emerge from the COVID-19 experience. Our preliminary evidence is that those who have experienced the largest disruption to the availability or safety of their work have been those involved in human facing industries: personal service and retail; restaurants, cafés and bars; the arts and creativity. These industries have been long argued to be the bastion of future employment, where interpersonal and creative skills will be central to the future of work, as they are jobs which are the hardest to automate. We have now flirted with the concept of a universal basic income, with the lifting of the unemployment benefit (JobSeeker) and the government subsidisation of wages (JobKeeper) (Australian Government 2020).

To conclude this section with a short number of interesting research directions that may arise from the disruption cause by COVID-19:

- In the longer term, there may be architectural and urban design issues that will arise from the different way in which work is done; office spaces previously designed for hot-desking and open plan face a redesign, and homes might also need to be rethought with a dedicated space for work. Ultimately, this may have impact on the need to be close to places of work, and as that evaporates there may even be a move towards less dense living, reversing the densification seen over the course of the last decade. Research should examine any such changes, or lack thereof.

- Perhaps authorities can leverage the current enjoyment of better amenity in terms of congestion and resultant pollution, combined with significant improvement to health as a result of less tailpipe emissions, to encourage lower levels of car use to be ongoing. Should demand for private car travel return in a significant way, it may also be worthwhile to accelerate the adoption of electric vehicles as a means of reducing tail-pipe pollution. It will be interesting to see if the COVID-19 disruption has any impact on potential growth of alternatively fuelled vehicles.

- There is a high degree of uniformity in the behavioural response of Australian's to COVID-19 measures. It is possible that the behaviour is motivated either altruistically through the recognition that COVID-19 presented a serious threat to the health of someone known to the respondent, or the egoistic motivation of the risk posed by COVID-19 to the economy. To our mind, this is an interesting social phenomena that is worthy of greater research.

6 Conclusion

This paper presents the preliminary findings from a survey conducted in the middle of March 2020, at what was the height of first (and hopefully only) outbreak of the COVID-19 pandemic in Australia. Importantly, data was collected at the height of the COVID-19 restrictions (assuming there is no second wave of infections), which will provide a very useful reference position as we come out of Covid-19 restrictions and collect subsequent waves of date to identify what changes in travel behaviour in particular might continue at least in the short run if not longer. We use our results to provide policy suggestions across seven separate domains: food and freight; aviation; public transport; motor vehicle and road use; active transport; flexible working; and infrastructure investment.

The survey covered a large number of behaviours and attitudes, and in doing so we are able to provide a thorough depiction of the mood of the nation toward the threat of COVID-19, the response to the pandemic, and the disruption to travel and activities experienced. Our key finding is Australians have followed the urgings of National Cabinet and all levels of government, to limit travel and social contact, which has thus far resulted in a "flattening of the curve". In the short-term, our results point towards a significant need to think about public transport policy (indeed policy on all shared modes) in time of concern around hygiene and limitations on capacity die to social distancing. In the longer term, our research highlights the need to be wary about any policy or investment that would further entrench the motor vehicle as the predominant form of transport.

Finally, we urge policy makers and researchers alike to look more fully at the role of working from home in the "new normal" that follows COVID-19. It is clear that there is a dyadic impact of COVID-19 restrictions on those who can work from home and those who cannot, as well as the impediments and experiences of working from home by those who have been able to do so. However, despite the ills of COVID-19, we have an opportunity not to be foregone by industry and government. Increased levels of working from home may result in being a policy lever that can most significantly reduce congestion and crowding, potentially to benefit climate change, wellbeing and infrastructure priority funding, enabling a greater amount of funding directed to essential services such as health services and care support.

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Appendix D. Paper #2: Working from home and its implications for strategic transport modelling based on the early days of the COVID-19 pandemic

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Abstract

The COVID-19 pandemic has changed the way we go about our daily lives in ways that are unlikely to return to the pre-COVID-19 levels. A key feature of the COVID-19 era is likely to be a rethink of the way we work and the implications this may have on commuting activity. Working from home (WFH) has been the 'new normal' during the period of lockdown, except for essential services that require commuting. In recognition of the new normal as represented by an increasing amount of WFH, this paper develops a model to identify the incidence of WFH and what impact this could have on the amount of weekly one-way commuting trips by car and public transport. Using Wave 1 of an ongoing data collection effort done at the height of the restrictions in March and April 2020 in Australia, we develop a number of days WFH ordered logit model and link it to a zero-inflated Poisson (ZIP) regression model for the number of weekly one-way commuting trips by car and public transport. Scenario analysis is undertaken to highlight the way in which WFH might change the amount of commuting activity when restrictions are relaxed to enable changing patterns of WFH and commuting. The findings will provide one reference point as we continue to undertake similar analysis at different points through time during the pandemic and after when restrictions are effectively removed.

Keywords: Coronavirus, COVID-19, travel activity, working from home (WFH), ordered logit WFH model, Frequency of modal commuting, zero inflation Poisson Regression (ZIP), strategic transport models

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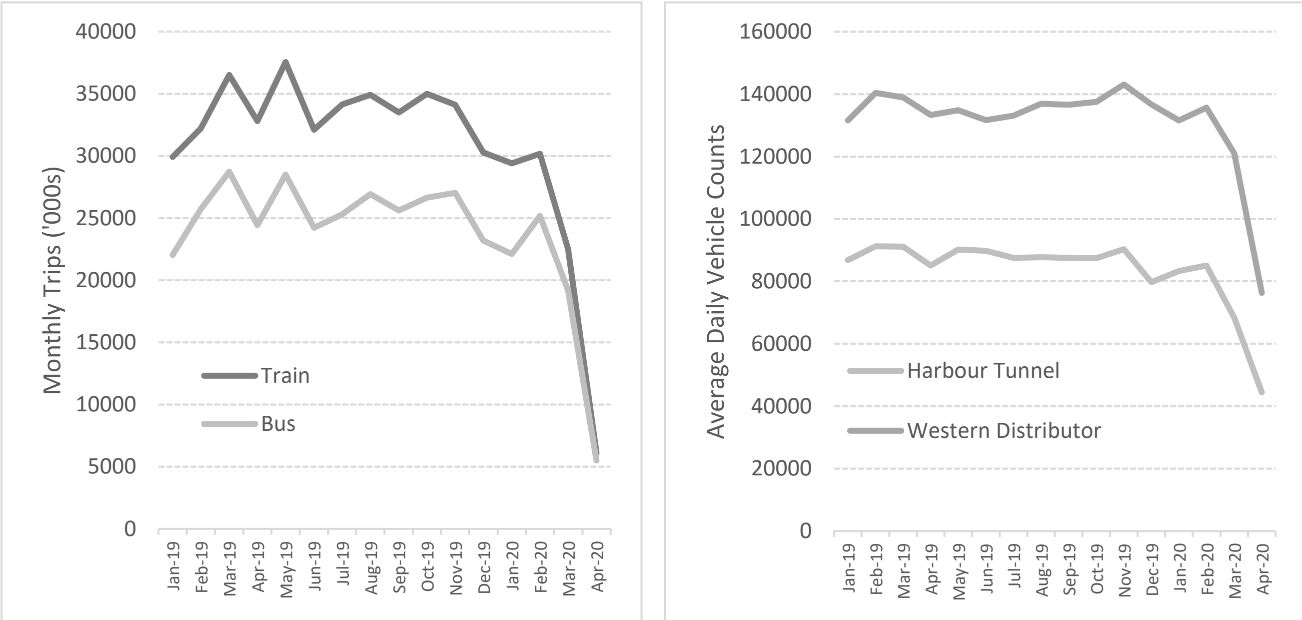
1 Introduction

In the first quarter of 2020, the novel coronavirus - named COVID-19 by the World Health Organisation - began spreading around the world causing widespread illness, disruption and death. At the time of writing this paper (27th of May, 2020), approximately 5.4 million cases had been recorded; resulting in 343,514 deaths. The impact of COVID-19 differs dramatically from country to country, and relatively speaking, Australia has done well in combating the spread of the virus, with a total of 7,142 cases and 103 deaths being recorded, equivalent to 285 cases and 4.12 deaths per million population.

A large part of the relative success of the Australian response has been the speed at which Australia recognised COVID-19, brought in regulations and associated mandated restrictions to control the spread, and the overarching compliance of the Australian public with both the recommended and regulated approaches (c.f. Beck and Hensher 2020). The suppression of travel and other activity has been widespread, and the impacts on the transport network have been substantial. Figure 1 highlights the reduction in (a) the number of trips made per month on major public transport modes, and (b) the average daily vehicle counts on two major roads in the Sydney metropolitan region.



a) Public Transport Patronage **(b) Traffic Counts on Major Roads**

Figure 1: Impact of COVID-19 Restrictions on the Transport Network

While travel activity has been reduced, there has been a significantly large uptake in working from home (WFH). While many are still unable to WFH, in a national survey in April 2020 Beck and Hensher (2020) found that the overall number of people working from home at least one day a week had increased from 30% to 60%, and the number working from home five days a week had risen from 7% to 30%.

Thus, one unintended consequence of COVID-19 is that many may now see working from home as a viable option, including employers. While Australia entered working from home in a haphazard manner, there are indications that major organisations are seeing improvements in productivity as a result of working from home (Smith 2020), with technology companies like Google and Facebook planning to allow, indeed encourage if not mandate, staff to work from home until 2021 if not beyond (Paul, 2020). Research by Gartner (2020) reveals that 74% of Chief Financial Officers are planning to move at least 5% of their previously on-site workforce to permanently remote positions post-COVID-19. Equally, workers are seeing some benefits from this arrangement. A recent global survey conducted by Citrix (2020) showed that 70% of respondents believed their productivity at home to be the same or higher than at the office. One of the biggest advantages is being able to use the time otherwise spent commuting to be more productive, or spend it with family and on leisure activities.

The aim of this paper is to identify, at the height of the restrictions in March and April 2020 in Australia, the incidence of WFH and what impact this was likely to have on the amount of weekly one-way commuting trips by car and public transport. We develop a number of days WFH ordered logit model and link it to a zero-inflated Poisson (ZIP) regression model for the number of weekly one-way commuting trips by car and public transport. Scenario analysis is undertaken to highlight the way in which WFH might change the amount of commuting activity when restrictions are relaxed, to enable changing patterns of WFH and commuting. The findings will provide one reference point as we continue to undertake similar analyses at different points through time during the pandemic, and after when restrictions are effectively removed.

2 Literature Review

The increased acceptance of WFH by both employees and employers has important ramifications for the transport network, and has long been seen as a mechanism through which congestion and emissions can be reduced. Telecommuting was a term first coined by Nilles (1976), who proposed the replacement of commuting with “telecommuting” (working at home made possible by technological advances) in response to traffic, sprawl, and scarcity of non-renewable resources. Salomon and Salomon (1984) provide an overview of the nascent literature on telecommuting, with early research focused on white collar workers with particular reference to computer-based information workers. The authors highlight that some studies project a technology-based economy where 50% of white-collar workers would work from home. They questioned whether such projections were valid and suggested the importance of social interaction at work and the need to separate home and work roles which act as important barriers to such scenarios.

Indeed, early sociological research pointed to barriers in the adoption, namely (i) individuals required social interaction inherent in being at work, (ii) had a need to separate or create a buffer between home and work roles, and (iii) felt the need to be visibly present to achieve professional advancement (Salomon 1986, Hall 1989). However, telecommuting was a policy lever that gained traction within the world of transportation, initially because it was something that could be implemented quickly, relatively inexpensively, and addressed a variety of public and private sector concerns such as congestion, work-life balance, and facility use (Mokhtarian 1991).

Pendyala et al. (1991) used travel diaries to explore differences in behaviour before and after telecommuting. They found that telecommuters make proportionately fewer linked trips as a result of few trips being made overall, that they tend to shift activities to destinations closer to home, and to make proportionately fewer peak-period trips. Hensher et al. (1994) examined the changing nature of labour force participation and work practices, finding shifts that would likely impact on mobility and road transport needs. Interestingly, they forecast a rise in small freight delivery volumes, and a steady increase in shopping and personal business travel relative to work travel as a result of distributed work practices. In the current pandemic setting, both distributed work practices and these increases are the result of COVID-19.

In response to a call to start thinking about how to incorporate telecommuting and home-based work into the traditional urban travel demand forecasting process (Mokhtarian 1991), Ben-Akiva et al. (1996) proposed a travel demand modelling framework for the information era. They outlined a three-stage approach to incrementally updating the forecasting process through understanding how lifestyle decisions impact on mobility choices and how both impact on daily activity patterns. While Ben-Akiva et al. (1996) included sampling of both employees and employers, Yen and Mahmassani (1997) included both from the same organisation, and Brewer and Hensher (2000) provided a framework to look at the endogenous nature of the choice to telecommute between the employee and their employer or supervisor. The role of social influence and social contact on telecommuting has also been explored (Wilton et al. 2011). 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), Singh et al. (2013) and Paleti and Vukovic (2017). Brewer and Hensher (2000) proposed and implemented an interactive agency choice experiment (IACE), in which they involved employees and employers in revealing their joint preferences for distributed work practices. They found that many employees liked the idea but were reticent about how their employers would respond, and surprisingly many employers were supportive once their preferences were revealed to employees, who subsequently revised their position.

In terms of the effect of telecommuting on travel behaviour, Mokhtarian et al. (1995) found that both commute and non-commute travel (measured in person-miles) decreased as a result of telecommuting. Mokhtarian et al. (2004) found that one-way commute distances were longer for telecommuters than for non-telecommuters, but average commute miles overall were less for non-telecommuters due to trip infrequency. Zhu (2012), however, found that telecommuting generated longer one-way commute trips, and also longer and more frequent daily total work trips and total non-work trips, arguing that there is a significant complementary effect of telecommuting on personal travel. Research by Kim et al. (2015) also found that telecommuting can indeed be a complement, particularly when it releases the household vehicle from mandatory work travel, to be used for non-commute trips.

More recently, Shabanpour et al. (2018) examine the choice to telecommute across five broad levels (do not telecommute; a few times a year; once a month; once a week; and almost every day) using a zero-inflated hierarchical ordered probit model. The authors find that, in the sample, 12% of respondents currently have work flexibility (defined as the ability to adjust their work schedule or not), and that such flexibility has positive impacts on both the potential to telecommute (to make telecommute at some level) and the level incidence of telecommuting (how often they do so). Using their model of telecommuting participation and frequency, they simulated a scenario where 50% of workers had such work flexibility, and if this were the case it could be possible to reduce total daily vehicle miles travelled (VMT) and vehicle hours travelled (VHT) up to 0.69% and 2.09%, respectively. It should be noted[12] that while telecommuting refers to spatial flexibility, and work flexibility refers to temporal flexibility (and thus are not one and the same), the paper does suggest that those with greater flexibility in their working hours appear to be able to opt into telecommuting more easily. With employers in Australia having seen now that WFH may work (Beck and Hensher 2020), and indeed is an opportunity to perhaps recoup the estimated $30 billion of productivity lost to congestion (Infrastructure Australia 2019), WFH may be a more formalised policy for organisations moving forward.

If increased levels of working from home is to be the so called ‘new normal’ as we move beyond COVID-19, there are important ramifications of this changed behaviour for strategic transport models that are used to forecast transport demand and simulate network flows[13]. In response to the potential change in the way people may work and move, this paper develops

[12] As highlighted by one anonymous reviewer.

[13] See the sceptical view recently presented by Patricia Mokhtarian.

(https://protect-au.mimecast.com/s/LYpCCoV1kpfmVJWmuzuP1A?domain=youtube.com), in which she points out (among other arguments) that employers have had ample previous opportunity, during countless past extreme events, to "see that WFH may work".

an approach to identify the incidence of WFH and what impact this is likely to have on the amount of weekly one-way commuting trips by car and public transport, such that the model can be easily integrated into existing strategic model frameworks. Equally, it is important that scenario planning in the short-term be undertaken as we seek to understand how the transport network may respond to the ongoing changes in travel due to COVID-19.

The rest of this paper is structured as follows. In the next section we outline the survey and data collection process, as well as providing some contextual information about when the data was collected. In section 4, we provide an overview of interesting results from the survey in the context of working from home and travel, followed by the development of a model structure in Section 5, summarising the results from the model in section 6. In section 7, we provide scenario analyses to simulate the impact of different working from home conditions, before providing concluding remarks in section 8.

3 Survey and Data Collection

Recognising that COVID-19 was impacting on travel and activity patterns, which would again change profoundly as a result of increased regulations restricting movements further, a survey was developed in mid-March 2020. The survey[14] asked respondents to provide information on their level of employment prior to the COVID-19 outbreak as well as after, including their ability and instances of working from home. Respondents were then asked to think about weekly travel activity of the household in the early part of March, prior to the emergence of COVID-19 as a significant public health threat, and to complete a short travel activity survey asking them to recall what trips the household made by different modes of transport and for different purposes. They were then asked if the household had changed their travel activity as a result of COVID-19 and if the answer was yes, they completed a second set of travel questions outlining the changed travel. For those that had not changed but had plans to do so, and those who had changed and planned even more, they were asked what their planned change might look like.

The on-line survey was distributed for completion on 23 March 2020. Those initially contacted were a convenience sample based on membership lists of organisations associated with the Institute of Transport and Logistics Studies[15], along with members of the Institute email list itself. A convenience sample was used as, along with many universities globally, the University of Sydney froze all spending in response to an uncertain budget position due to COVID-19. For context, Figure 2 shows the number of COVID-19 cases in Australia (also in the state of New South Wales, and the rest of the country combined).

[14] A PDF of the survey instrument can be provided on request. It is noteworthy that we provided the same survey to colleagues in Chile and South Africa who are part of the Volvo Research and Education Foundation Bus Rapid Transit (BRT+) Centre.
[15] This list has over 4,000 email addresses and is a broad cross-section of the professional community in government, business and academia, mainly in Australia.

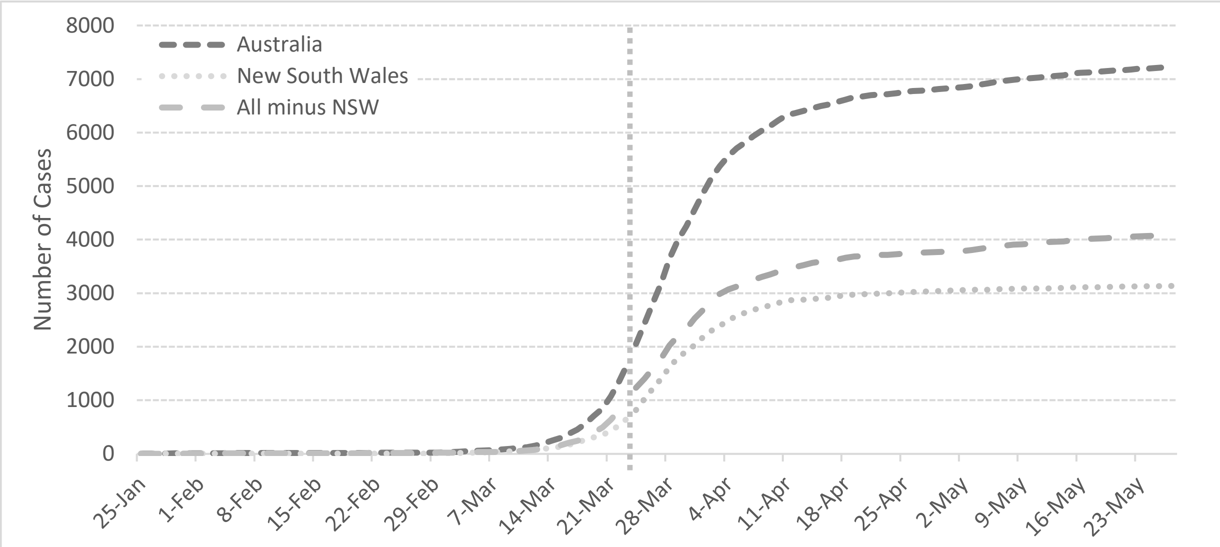


Figure 2: COVID-19 Cases Before and After Survey Distribution

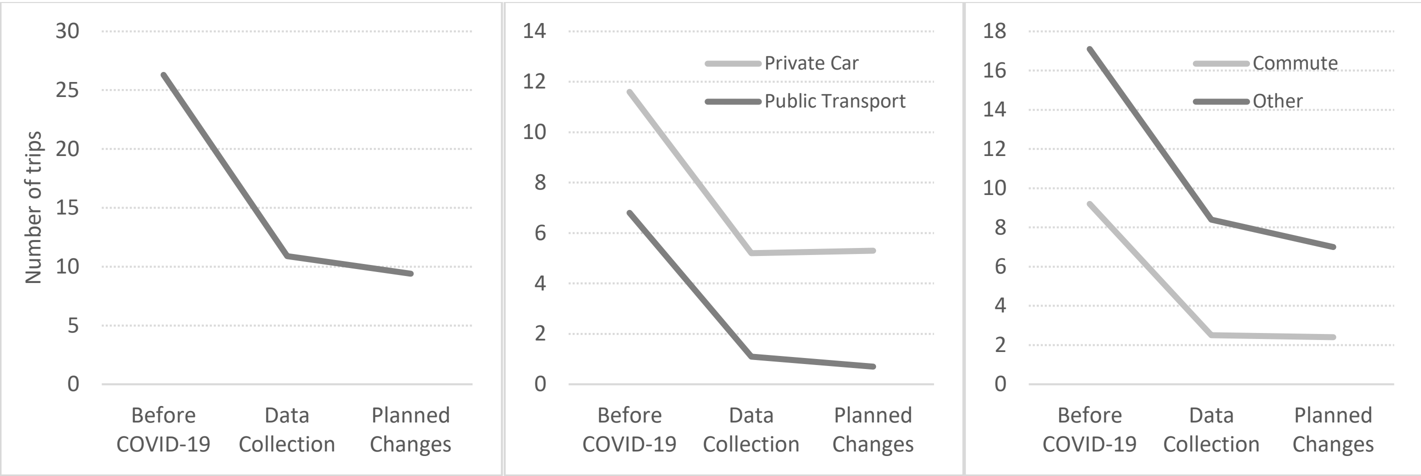
At the time period at which data was collected, Australia had been staging a series of ever tightening restrictions; on 19 March international borders were closed to non-citizens and permanent residents, on 20 March limits were placed on the size of public gatherings, which were further tightened on the day the survey went into field (23 March). A week into data collection, tighter restrictions on the size of public gatherings (no more than two persons) and travel (essential travel for work, health or exercise) were announced on 29 March coming into effect at midnight on the 30th with border closures in Queensland and Western Australia. A total of 348 respondents submitted a complete set of responses, the majority of which were from the Sydney metropolitan region (299). The average age of respondents is 46 years, with an average household income of $AUD185,398; 63% of the sample are male. It should be noted that data collection is ongoing[16], and as we achieve more responses, the sample will become increasingly more representative in terms of socio-demographics, but equally as behaviours stabilise across the pre, during and post COVID-19 experiences.

4 Overview of Travel Activity and Work

Within the convenience sample obtained, 17% of respondents reported that the government regulations surrounding COVID-19 had impacted on the availability of their work, with those from the lowest income groups significantly more likely to be affected. This, in part can be explained by the fact that a proportion of the sample completed the survey prior to the strictest of government regulations being enforced. It can equally be due to 89% of the sample also reporting that their work can be completed from home, where women and younger respondents being more likely to be able to work from home, and low income groups less likely.

As shown in Figure 3, we see a significant drop in average weekly trips for an individual, for all purposes and modes, falling from a little over 25 trips per week down to 10. This fall is consistent with aggregate measures such as those provided by the Google Mobility Report and CityMapper, as well as international studies using GPS tracking (Mobis 2020). We also see similar proportional and significant drops in trips for car and public transport modes (train, bus and ferry combined), and for commute trips and those for other purposes.

[16] With five more waves planned over a 6-to-8-month period.



(a) Total Trips **(b) Trips by Mode** **(c) Trips by Purpose**

Figure 3: Changes in Per-person Average Weekly Trips

Figure 4 displays the work from home policy of the organisation in which the respondents worked, the vast majority having either been given the choice to work from home (45%) or have been directed to do so by their employer (43%). The impact of this flexibility can be seen in Figure 5, where there is very little differentiation in the number of days worked before and after COVID-19 restrictions, and a sizeable fall in the proportion of respondents working zero days from home (from 57% to 11%). Almost half the sample now working from home five days a week (48%). Females report a significantly higher number of average days worked from home, and those in the lowest income group a significantly lower number of average days worked from home than those in high income categories.

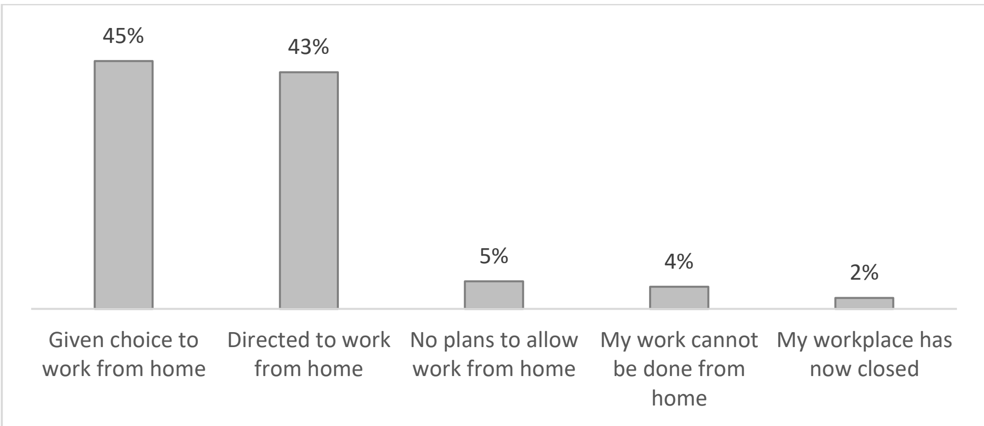
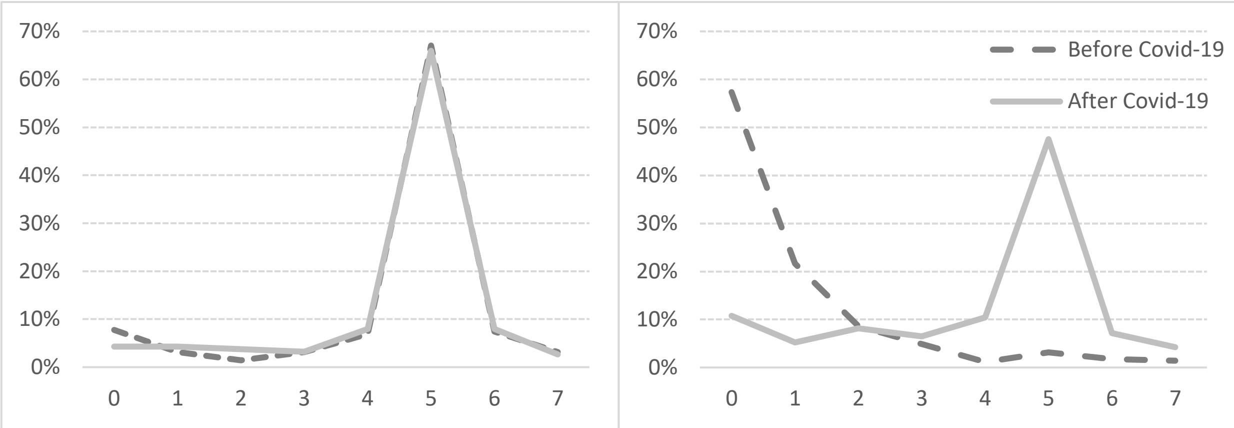


Figure 4: Work from Home Policy of Employer



(a) Number of Days Worked **(b) Days Worked From Home**

Figure 5: Impact of COVID-19 on Work and Work from Home

Although this is a convenience sample, and likely overstates the ability to work from home relative to the general population, the sample is very relevant for establishing a model structure and investigating how changed working from home conditions could be understood, and how it might impact on travel demand. The sample used in the subsequent modelling sections are the 177 respondents from the Greater Sydney metropolitan area who were in paid work. For these, we have details of all modes used for commuting and network information around distance, zones, times and costs. This sample is illustrative in nature and the models outputs discussed hereafter can easily be updated as more data becomes available.

5 Modelling Approach

The focus of this paper is on identifying the relationship between the number of days working from home during the early days of COVID-19 restrictions and the amount of travel associated with commuting to and from the pre-COVID-19 work place (see Figure 6). As might be expected, and as shown above, the amount of commuting activity outside of the home was severely curtailed either by choice or by government restrictions[17]. Two models are proposed as an appropriate framework within which to study these behavioural linkages[18]. The first represents the number of days each week (defined as 7 days to include weekends) WFH, specified as an ordered choice model of the logit form. WFH has a natural ordering and hence can be defined by a dependent variable taking the values from 0 up to the maximum number of days of WFH (noting later that we defined the last category as 5 to 7 days given the small amount of non-zero weekend WFH activity). The second model defines the number of one-way weekly commuting trips by each mode. Recognising the count data nature of the number of trips, a Poisson regression is proposed. The predicted probability of the number of days WFH obtained from the ordered logit model is fed into separate Poisson regression models

[17] The number of daily one-way trips using public transport in the Sydney metropolitan area declined to 27.7 percent of its pre-COVID-19 levels (from 2.2 million to 600,000). These figures refer to all trip purposes and we expect that commuting activity decreased even more.

[18] A referee made the comment "In most cases, can we not guess the number of commute trips by just subtracting the number of WFH days? Are they not just perfect substitutes in most cases?" This is not the case as we now explain. Specifically, we are looking at the number of commuting trips separately by car and by public transport, and thus knowing the number of days WFH (e.g., 3), does not mean that the balance of 2 days are all commuting by car or all by public transport; and indeed on some days they do not work at all (people who work 4 days a week, for example). There are a few people who use public transport to go to work and are picked up by car to go home. The pairwise correlations are -.45 for #days WFH and # car trips and -0.28 for #days WFH and # public transport trips.

for one-way weekly car and one-way weekly public transport commuting trips. Estimation at both steps is consistent; however we need to correct the estimated asymptotic covariance matrix for the estimator at step 2 for the randomness of the estimator carried forward from the ordered logit WFH choice model. The standard Murphy and Topel (1985) correction was implemented, so that the standard errors and hence the t-values of the Poisson model are asymptotically efficient.

We discuss in more detail the ordered logit model and the Poisson Regression of the zero inflation (ZIP) form, and then present the final models.

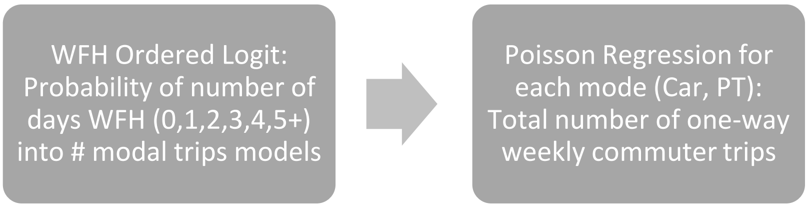


Figure 6: The Model System

The ordered logit model allows one to include an ordinal dependent variable into the choice model in a way that explicitly recognises the ordinality, and which avoids arbitrary assumptions about scale. It does this by defining points on the *observed scale* as thresholds that recognise, in preference space, that the numerical levels of the dependent variable are not strictly linear (Winship and Mare, 1984; Greene and Hensher 2010). Formally, let Y_i^* denote an unobserved (or latent) continuous variable that represents the latent continuous tendency to work from home for more days ($-\infty < Y_i^* < +\infty$), defined in utility space; $\mu_{-1}, \mu_0, \mu_1, \ldots, \mu_{J-1}$ denote the threshold utility points in the distribution of Y_i^*, where $\mu_{-1} = -\infty$ and $\mu_{J-1} = +\infty$.

Now, define Y_i to be an ordinal (observed) variable for WFH such that $Y_i = j$ if $\mu_{j-1} < Y_i^* \le \mu_j$; $j = 0,1,2,\ldots,J$ response levels. Since Y_i^* is not observed, its mean and variance are not separately identifiable from the β and μ parameters. For ease of interpretation, we fix its mean at 0 and its variance at 1. To make the model operational, we need to define a relationship between Y_i^* and Y_i. The ordered choice model is based on a latent regression model given as equation (1).

$$Y_i^* = \boldsymbol{\beta}'\mathbf{x}_i + \varepsilon_i, \quad \varepsilon_i \sim F(\varepsilon_i \,|\boldsymbol{\theta}), \; E(\varepsilon_i) = 0, \; Var(\varepsilon_i) = 1 \qquad (1)$$

where $\boldsymbol{\theta}$ collects the mean and threshold parameters[19]. The observation mechanism results from a complete censoring of the latent dependent variable as follows:

[19] The number of estimable thresholds is the number of response categories minus one, but collectively the thresholds are not separately identifiable from the constant term in the index function. In this application we have six response categories, so with the NLOGIT estimation package used in this paper, we estimate the constant term plus four additional threshold parameters.

$$
\begin{aligned}
Y_i \quad &= 0 \text{ if } Y_i^* \le \mu_0,\\
&= 1 \text{ if } \mu_0 < Y_i^* \le \mu_1,\\
&= 2 \text{ if } \mu_1 < Y_i^* \le \mu_2,\\
&\ldots\\
&= J \text{ if } Y_i^* > \mu_{J-1}.
\end{aligned} \tag{2}
$$

The probabilities which enter the log likelihood function are given by equations (3) and (4).

$$\text{Prob}(Y_i = j) = \text{Prob}(Y_i^* \text{ is in the } j\text{th range}) \tag{3}$$

$$= F(\mu_j - \boldsymbol{\beta}'\mathbf{x}_i) - F(\mu_{j-1} - \boldsymbol{\beta}'\mathbf{x}_i),\ j = 0,1,\ldots,J \tag{4}$$

A direct interpretation of the parameter estimates from the ordered logit model is not informative, given the logit transformation of the choice dependent variable. Therefore, we provide the marginal or partial effects which have substantive behavioural meaning, defined as the derivatives of the choice probabilities (Hensher *et. al*., 2015). An extension of the partial effects yields the well-known elasticity estimates. A marginal effect is the instantaneous rate of change in the probability of selecting a particular outcome, with respect to a continuous-valued explanatory variable, *ceteris paribus*. For dummy (1, 0) variables, which are the main variables in the models below, the marginal effects are discrete changes in the probabilities given a change in the dummy variable from 0 to 1. The marginal effects need not have the same sign as the model parameters. Hence, the statistical significance of an estimated parameter does not imply the same significance for the marginal effect.

The marginal effect for a continuous variable in an ordered logit model is

$\frac{\partial E[y_i \mid \mathbf{x}_i]}{\partial \mathbf{x}_i} = \Lambda(\boldsymbol{\gamma}'\mathbf{x}_i)[1-\Lambda(\boldsymbol{\gamma}'\mathbf{x}_i)]\boldsymbol{\gamma}$. Λ is the logistics distribution $\Lambda(t) = \exp(t) / [1 + \exp(t)]$.

The marginal effect for a dummy variable = [Prob($y_i = 1 \mid \bar{\mathbf{x}}_{(d)}, d_i = 1$)] − [Prob($y_i = 1 \mid \bar{\mathbf{x}}_{(d)}, d_i = 0$)], where $\bar{\mathbf{x}}_{(d)}$, denotes the means of all the other variables in the model.

In contrast to the ordinal specification of WFH, the number of weekly one way trips by car and public transport is a positive number compliant with a count model such as zero inflation Poisson (ZIP) with latent heterogeneity[20]. As a non-negative discrete count value, with truncation at zero, discrete random variable, *Y,* observed over a period of length T_n (i.e., a 7 day week) and observed trips, y_n, (where n refers to the n^{th} respondent), the Poisson regression model is given as equation (5).

$$\Pr ob(Y = y_n \mid x_n) = \frac{\exp(-\lambda_n)\lambda_n^{y_n}}{y_n!}, y_n = 0,1,\ldots; \log \lambda_n = \beta' x_n \tag{5}$$

[20] We also proposed and estimated a negative binomial model which is appropriate, like Poisson, for count data. The overall fit and statistical significance of parameters was inferior to Poisson.

In this model, λ_n is both the mean and variance of y_n; $E[y_n|\mathbf{x}_n] = \lambda_n$. We allow for unobserved heterogeneity as well as consider the ZIP form for count data (see Greene 2003) to recognise the possibility of partial observability if data on weekly one-way trips being observed, exhibit zero trips. Specifically, the answer 'zero' could arise from two underlying responses. If we were unable to capture any trips, we would only observe a zero; however, the zero may be due to the measurement period (i.e., a particular week) and the response might be some positive number in other periods. In the current data under the pandemic, zero is in the main a legitimate value. We define z = 0 if the respondent always worked from home, 1 if a Poisson model applies; y = the response from the Poisson model; then zy = the observed response. The probabilities of the various outcomes in the ZIP model are:

$$\Pr ob[y=0] = \Pr ob[z=0] + \Pr ob[z=1] * \Pr ob[y=0 \mid Poisson] \quad (6a)$$

$$\Pr ob[y=r>0] = \Pr ob[z=1] * \Pr ob[y=r \mid Poisson] \quad (6b)$$

The ZIP model is given as $Y_n = 0$ with probability q_n and $Y_i \sim$ Poisson (λ_n) with probability 1 – q_n so that (Greene 2017):

$$\Pr ob[y_n = 0] = q_n + [1 - q_n] R_n(0) \text{, and}$$

$$\Pr ob[y_n = r < 0] = [1 - q_n] R_n(r) \quad (7)$$

where $R_n(y)$ = the Poisson probability = $\frac{\exp(-\lambda_n)\lambda_n^{y_n}}{y_n'!}$ and $\lambda_n = \exp(\beta' x_n)$. We assume that the ancillary, state probability, q_n, is distributed normal (i.e., ~Normal (υ_i). Let F[υ_i] denote the normal CDF. Then, υ_i can be defined by the form in equation (8) labelled the ZIP(τ) model (Greene 2017, E988).

$$v_n = \tau \ln[\lambda_n] = \tau \beta' x_n \quad (8)$$

Equation (8) defines a single new parameter τ which may be positive or negative. If there is evidence of zero trips in any observations, then we can expect the τ parameter to be statistically significant; otherwise we default to the Poisson form with normal latent heterogeneity.

6 Model Results

6.1 The ordered logit model for the incidence of working from home

The final ordered logit model for WFH is summarised in Table 2. The model was estimated on 177 respondents who had a paid job, and who exhibited a mix of commuting activity and working from home, with some jobs deemed essential outside of the home. Hence, they must commute to some extent[21].

In selecting and testing candidate explanatory variables, we wanted to identify influences on WFH that related to an employee's situation where they could choose to WFH or otherwise and the position supported by their employer under government restrictions in the early days of the COVID-19 lockdown. We were also mindful of the need to include variables that could be used in applications that are representative of the socioeconomic characteristic of respondents, which can be used to identify classes of employees who are more likely to WFH either because they chose to and/or their employer allows it[22]. This is especially important as we continue to collect data during the COVID-19 period to see when the WFH profile starts to stabilise and becomes an important piece of evidence in building in this feature to strategic transport planning models[23].

The evidence in this paper is limited to the Wave 1 data, and although we anticipate richer data as we continue to repeat the survey over five more waves, this information has enabled us to obtain some behaviourally appealing models. A descriptive profile of the data is summarised in Table 1, for the top six occupation classes that represent 95.1% of the sample, noting that we specifically targeted professionals instead of a general population. Given the influence of occupation, we also present the incidence of WFH in Figure 7 for all eight classes. Despite the sample being a convenience sample, and relatively small, the average age of 45.9 (standard deviation of 15) compares well with a representative sample mean of 46.3 (standard deviation of 17.5). The gender mix has a higher percentage of males (65%) compared to 50% in the general population.

Table 1: Descriptive Profile of WFH Model Variables on the 177 workers During COVID-19 (late March 2020)

Variable	Units	Mean (SD)
Number of days working from home per week	Number	3.86 (1.74)
Have a choice to work from home pre-COVID-19	1,0	0.497
Employer directs employee to work from home post-COVID-19	1,0	0.395
Type of work can be completed from home	1,0	0.904
Manager	1,0	0.133
Professional	1,0	0.588
Technicians and trades	1,0	0.067
Community and personal services	1,0	0.024
Clerical and administration	1,0	0.097
Sales	1,0	0.042

[21] This distinction is ambiguous, since there are essential tasks that can be done from home (e.g., call centre type work) in contrast to someone involved in looking after aged people in a retirement village or driving a bus or train. We have not used this distinction in the model estimation given it is so ambiguous.
[22] We did investigate random thresholds with systematic socioeconomic influences and tested for age, gender and household income, but did not find any statistically significant effects. This may be due, as is always possible, to the nature of the specific sample; however we will investigate this matter gain when we have future waves of data that are to be sampled from the wider population throughout Australia.

[23] The pre-COVID-19 strategic transport model system might have to be changed to reflect the conditions during COVID-19 in response to network performance, especially travel times and a high incidence of free flow travel times on the road network. Also to the extent to which existing parameters associated with the demand side model system (e.g., levels of service parameters in mode choice models), are sufficiently robust to accommodate significant new levels of service which did not exist when such models were estimated and calibrated.

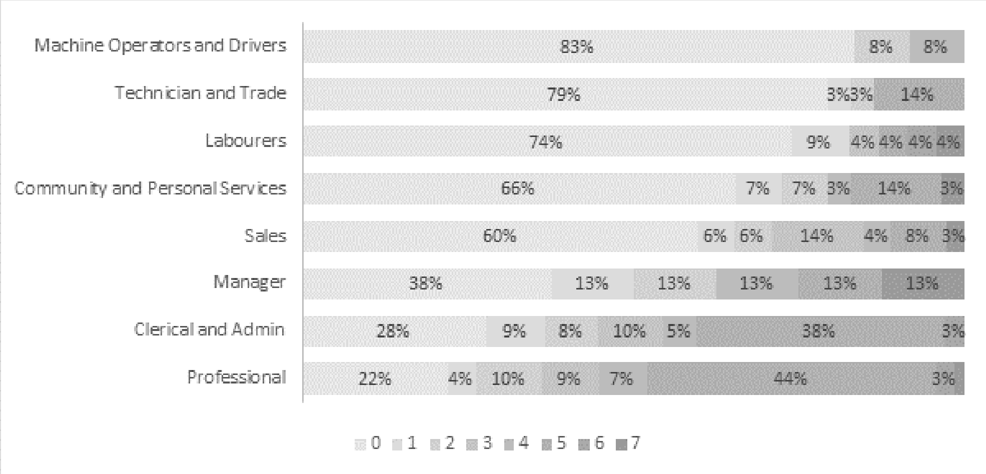


Figure 7: Number of Days Worked from Home in Last Week by Occupation for the 177 workers (Note: Each row sums to 100%)

There are three statistically significant employer-policy dummy variables, namely (i) an employee having a choice to work from home pre-COVID-19, (ii) an employer directs the employee to work from home during COVID-19, and (iii) the type of work undertaken by the employee can be completed from home[24].

All three dummy variables have positive parameter estimates, indicating that Y*, the latent continuous tendency to work from home more days, increases when each of these policy settings are on offer, or that the probability of WFH zero days decreases and the probability of WFH 5 or more days increases while the probabilities of intermediate choices are ambiguous (Greene 2003) when each of these policy settings are on offer. We tested all available socioeconomic characteristics (i.e., occupation, age, gender and household income) and found that occupation was the best indicator for establishing the extent to which WFH occurred (see Table 2). We used the Australian Bureaus of Statistics 8-category Classification[25] and found that six of the eight occupation categories were statistically significant relative to Machine Operators and Drivers, and Labourers, both of which were set to zero for the dummy variable definition. All six occupation classes are statistically significant with positive parameter estimates. We also used the Brant Test (see Greene and Hensher 2010) to test the null hypothesis that $\beta_0 - \beta_1 = \mathbf{0}$, $\beta_0 - \beta_2 = \mathbf{0}$, etc. We implemented the test, but did not find any evidence on the Chi-square test to reject the null hypothesis of equality of parameter estimates.

[24] While it is true that the reported percentage in Figure 4 were directed by their employer to WFH, many workers were still allowed to do a small amount of work elsewhere. By accounting for the degree of enforcement through explanatory variables in Table 2, we are able to account for the degree of 'no choice' in the sample; however it is clear than many were indeed able to exercise a choice themselves.
[25] https://www.abs.gov.au/ausstats/abs@.nsf/Lookup/by%20Subject/6102.0.55.001~Feb%202018~Main%20Features~Classifications%20Used%20in%20Labour%20Statistics~15

Table 2: Ordered Logit Choice model for WFH

Note: Mean probability of number of days per week WFH are 0.116 (0 days), 0.051 (1 day), 0.064 (2 days), 0.062 (3 days), 0.10 (4 days) and 0.598 (5 days or more), 177 respondents.

Variable	Units	Estimated parameter (t-value)	95% confidence interval
Constant		-3.0494 (-6.81)	-3.927 to -2.171
Have a choice to work from home pre-COVID-19	1,0	1.8874 (6.72)	1.336 to 2.437
Employer directs employee to work from home during -COVID-19	1,0	2.8918 (9.55)	2.297 to 3.485
Type of work can be completed from home	1,0	3.5363 (8.28)	2.699 to 4.373
Occupation (ABS 8 classes):			
Manager	1,0	0.7449 (2.85)	0.232 to 1.257
Professional	1,0	0.5403 (3.51)	0.238 to 0.842
Technicians and trades	1,0	1.1677 (2.51)	.0.256 to 2.079
Community and personal services	1,0	4.2600 (5.18)	2.928 to 5.528
Clerical and administration	1,0	4.2287 (6.38)	2.928 to 5.528
Sales	1,0	3.3695 (4.84)	2.004 to 4.734
Threshold parameters:			
μ_1		0.6975 (9.05)	0.546 to 0.848
μ_2		1.3068 (16.3)	1.149 to 1.464
μ_3		1.7652 (22.3)	1.609 to 1.920
μ_4		2.4215 (28.1)	2.252 to 2.590
Goodness of Fit:			
Log-likelihood at zero betas		-1351.56	
Log-likelihood at convergence		-1145.03	

Furthermore, for linking the WFH model to the trip frequency model under COVID-19, we had to calculate the probability of choosing[26] a number of days WFH[27]. The probability of each WFH level is shown in Figure 8, where as we know the dominance of zero (0.116) and 5 days (0.598) WFH exists. We expected this during the restriction period since those whose work is

[26] The formula used for the ordered logit model is different to a standard unordered labelled choice model. An example for four alternatives is:

U_{fit} = b(1)+b(2)*x1+b(3)*x_2 where this is the utility expression for a constant and 2 explanatory variables;
$f_0=\exp(-U_{fit})/(1+\exp(-U_{fit}))$;
$f_1=\exp(\mu_1- U_{fit})/(1+\exp(\mu_1- U_{fit}))$;
$f_2=\exp(\mu_2- U_{fit})/(1+\exp(\mu_2- U_{fit}))$;
$p_0=f_0$; $p1=f_1-f_0$; $p2=f_2-f_1$; $p3=1-f_2$; and the expected value of Y (or P_{model})
p_{model}=(y=0)*p0 + (y=1)*p1 + (y=2)*p2 + (y=3)*p3, where p= the choice probability for that level.

[27] Another possible set of models includes a commuter mode choice model; however, in the COVID-19 period with so little commuting (indeed many respondents undertook zero commuting activity), such a model is both uninformative and problematic to estimate because too many people did not ‘choose’ any modes for commuting. The WFH model is in one sense a reflection of an alternative in a mode choice model, namely no modes chosen. We did attempt to estimate such a model using free flow travel tines and modal cost data, but decided to put this on hold until we start to see a return to some amount of commuting activity.

not deemed 'essential'[28] were asked to stay at home, although this mandate from government was interpreted very broadly to include staying at home and WFH.

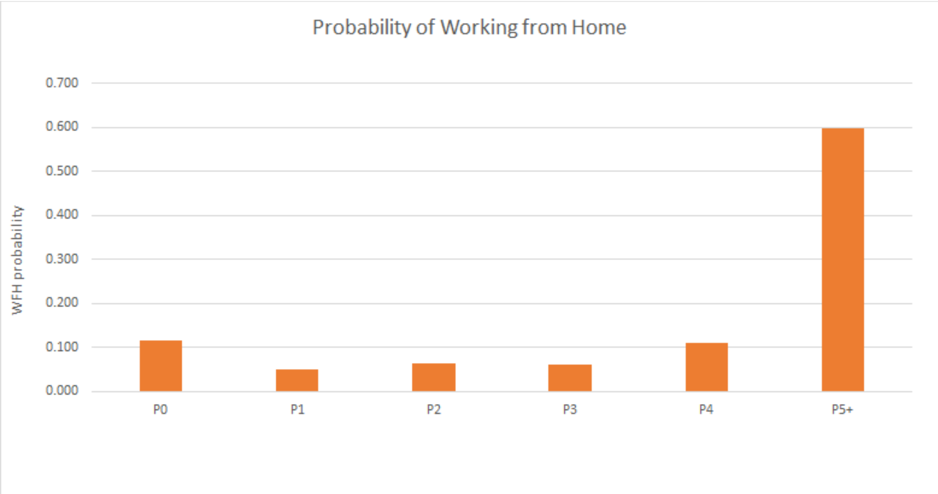


Figure 8: The incidence of days per week WFH

Although the parameter estimates are statistically significant, they are not behaviourally very interesting; instead, care must be taken in interpreting the numerical magnitude of each parameter estimate since they are non-comparable in this logit non-linear form (as suggested in the model specification section). In Table 3 we present partial (or marginal) effects and elasticities as a way of meaningfully comparing the influence of each explanatory variable on WFH. The behavioural sensitivity of the probability of WFH for each of the explanatory variables can be given by an elasticity or partial effects indicator (Greene and Hensher 2010). For the logit form, the elasticity of the probability is given in equation (10) which is related to the partial (or marginal) effect in equation (11), noting that we have dropped the subscript for a respondent (i.e., *n*).

$$\frac{\partial \log P(y\,|\,x)}{\partial \log x_k} = \frac{x_k}{P(y\,|\,x)} \cdot \frac{\partial P(y\,|\,x)}{\partial x_k} = \frac{x_k}{P(y\,|\,x)} \cdot \text{marginal effect} \qquad (10)$$

The marginal effect was defined in Section 5.

In Table 3, the partial and elasticity estimates are generally greater and negative for the three employment policy variables when there is no WFH. They also decline in magnitude while becoming positive in sign for situations where there is no commuting and WFH occurs five or more days per week. Looking at 'have a choice to work from home pre-COVID-19', all other influences being held constant, since this is a dummy (binary) variable, the pseudo-elasticity of -3.5 is the average percentage change in probability of WFH 0 days associated with the change from not having a choice to WFH to having the choice. If you have a higher opportunity to WFH pre-COVID-19, then you are more likely to WFH 5+ days per week (the positive and higher elasticity estimate of +0.55).

The marginal effect parameter for this variable is -0.1095 which is specifically for the 0 days WFH alternative, being the average change in actual probability when the variable changes from 0 to 1. This is also supported by the fact that all those numbers add to zero across each

[28] The word 'essential' was used by the Prime Minister to determine who should go to work and who should stay at home.

row of Table 3, indicating the redistribution of probabilities across the alternatives while keeping the sum of all probabilities fixed at 1.

Table 3: Direct elasticity of choice and partial effects

Note: Measures are associated with the number of days WFH with respect to given variable (partial or marginal effects in brackets).

Note: The elasticity as a percent change=partial effect/probability of WFH for that response level. All elasticities are statistically significant at 95 percent confidence level or better with the exception of 'Type of work can be completed from home' for WFH = 3 days. They are weighted averages, across the sample, of the individual-specific elasticities, with weights being the probability of the level of WFH being chosen.

Working from Home Days per week:	*0*	*1*	*2*	*3*	*4*	*5 or more*
Have a choice to work from home pre-COVID-19	-3.50 (-0.109)	-2.86 (-0.080)	-2.25 (-0.092)	-1.65 (-0.071)	-0.93 (-0.074)	0.55 (0.425)
Employer directs employee to work from home during COVID-19	-4.70 (-0.147)	-3.75 (-0.105)	-2.93 (-0.119)	-2.18 (-0.093)	-1.37 (-0.109)	0.74 (0.573)
Type of work can be completed from home	-17.7 (-0.552)	-4.09 (-0.115)	-1.01 (-0.041)	0.27 (0.012)	0.97 (0.077)	0.80 (0.619)
Occupation (ABS 8 classes):						
Manager	-0.97 (-0.030)	-0.97 (-0.026)	-0.83 (-0.034)	-0.72 (-0.031)	-0.54 (-0.043)	0.21 (0.163)
Professional	-0.85 (-0.027)	-0.77 (-0.022)	-0.67 (-0.027)	-0.54 (-0.023)	-0.35 (-0.028)	0.16 (0.126)
Technicians and trades	-1.26 (-0.039)	-1.21 (-0.034)	-1.14 (-0.046)	-1.04 (-0.045)	-0.86 (-0.068)	0.30 (0.233)
Community and personal services	-1.85 (-0.058)	-1.84 (-0.052)	-1.84 (-0.075)	-1.82 (-0.078)	-1.78 (-0.141)	0.52 (0.403)
Clerical and administration	-2.12 (-0.066)	-2.07 (-0.058)	-2.02 (-0.082)	-1.95 (-0.084)	-1.84 (-0.146)	0.56 (0.436)
Sales	-1.86 (-0.058)	-1.84 (-0.052)	-1.82 (-0.074)	-1.78 (-0.076)	-1.71 (-0.136)	0.51 (0.395)

The same calculations can be undertaken for each variable and WFH response level. The behavioural sensitivity associated with each explanatory variable is presented in more detail in a later section where we assess various scenarios.

6.2 The Poisson Regression model results for commuting activity

Turning to the Poisson regression exercise, first a descriptive profile of the data is given in Table 4.

Table 4: Descriptive profile of commuter trips model variables

Variable		*Car*	*Public Transport*
Number of one-way weekly trips	Number	1.266 (3.02)	0.689 (2.34)
Age	Years	43.13	
Male	1,0	0.62	
Probability of WFH 2 or 3 days per week	1,0	0.126	
Probability of WFH 4 or 5 plus days per week	1,0	0.707	

The Poisson regression models results are shown in Table 5. With the number of weekly one-way modal trips defined as an integer for the Poisson count model, the overall goodness of fit of the two models are excellent for a non-linear model, varying from 0.48 to 0.50. The tau (τ) parameter (equation 8) associated with the zero inflated Poisson model with normal heterogeneity was statistically significant in all three models, as was the sigma (σ) parameter for both models, the standard deviation of heterogeneity, which is statistically significant at the

1 percent level. The Vuong statistics of 13.71 for car and 8.77 for public transport suggest that the estimated extended Poisson model is favoured over an unaltered Poisson model, hence censoring using Probit. That is, the dependent variable is over-dispersed and has an excessive number of zeros.

Table 5: Influence of WFH on Number of Weekly One-way Modal Commuter Trips

Note: t-value in brackets for parameter estimates. *= Vuong test favours extended model; Murphy and Topel correction of standard errors

One-way weekly commuting trips:	*Car*	*Public Transport*
Constant	0.6301 (1.57)	-0.5512 (-0.60)
Age (years)	0.0206 (4.43)	0.0260 (1.98)
Male (1,0)	0.5090 (3.96)	-
Probability WFH 2 or 3 days per week	3.5705 (2.77)	11.0166 (4.30)
Probability WFH 4 or 5 plus days per week	-2.1443 (-6.02)	-3.2650 (-4.88)
Tau	0.2194 (5.10)	0.5204 (6.46)
Sigma (latent heterogeneity)	0.6996 (10.6)	1.0834 (4.62)
Goodness of Fit:		
Pseudo R^2	0.480	0.500
Vuong stat vs Poisson	13.71*	8.77*
Partial Effects:		
Age (years)	0.0199 (4.41)	0.008 (2.21)
Male (1,0)	0.4915 (3.83)	-
Probability WFH 2 or 3 days per week	3.447 (2.94)	3.369 (2.58)
Probability WFH 4 or 5 plus days per week	-2.070 (-5.79)	-0.999 (-2.61)

Poisson regression models the natural logarithm of the expected number of weekly trips as a function of the predictor variables, and thus we interpret an estimated parameter as follows (Wooldridge 2002): for a one unit change in the predictor variable, the difference in the natural logarithms of expected counts is expected to change by the respective parameter, given the other predictor variables in the model are held constant. For a binary variable such as gender, the difference in the logs of expected number of weekly car trips is expected to be 0.509 higher for males compared to females, *ceteris paribus*. For a continuous explanatory variable such as the probability of WFH 4 or 5 plus days, if a commuter were to increase the probability of WFH 4 or 5 plus days by from say 0.1 to 0.2, the difference in the natural logarithms of expected number of weekly car trips would be expected to decrease by 2.1443, *ceteris paribus*. The same logic, but for an increase, occurs for the probability of WFH 2 or 3 days a week; however, the positive sign can be explained as follows. In the sample, there were few respondents who did not work from home at all; hence the comparison is mainly between 2-3 days, and 4 to 5 plus days WFH and hence the positive sign. Likewise, as age increases by 1 year, the difference in the natural logarithms of the expected number of weekly car trips would be expected to increase by 0.0206, *ceteris paribus*.

Again, like the ordered logit model, a more informed way of illustrating the behavioural response associated with changes in the probability of WFH, age and gender is to undertake a number of scenario applications, which we now present and discuss in the following section.

7 Simulating Working from Home and Expected Commuting Trips

We have selected several scenario examples to illustrate the application of the models[29]. The impact of COVID-19 was simulated to predict the number of WFH days and related number of one-way weekly commuting trips by car and public transport for different scenarios with potential policy implications. The levels of the explanatory variables in the base scenario were set at the sample averages to represent the status of WFH and commuting activity for the period (see Tables 1 and 4). Of particular interest are the findings that 49.72% of respondents could choose whether to work from home and 39.55% were directed by their employers to work from home. 90.4% of the respondents indicated that their work could be performed from home. The average age of the sample respondents was 43 years, with 62% being male.

7.1 Scenario One: All or half of the working people can choose to WFH

Assuming all work can be performed from home instead of the sample average of 90.4%, we tested scenarios where all or half of the employees can freely choose whether to work from home, but no one would be asked to do so by their employers (see Table 6). In the scenario that all employees can choose to WFH, the average number of WFH days would increase from 3.86 to 4.10 days, just a small increase from the base scenario. The average per-person weekly number of commuting trips by car would drop from 1.27 trips to 0.91 trips, and the average per-person weekly number of commuting trips by public transport would drop to 0.34 trips from 0.68 trips. Although these results may not vary greatly in absolute terms, because of the already high levels of WFH in the base (COVID-influenced) scenario, 0.68 to 0.34 is a drop of 50%, and 1.27 to 0.91 is a drop of 28%[30].

Table 6: Impact of all or half of the employees having choices to work from home

	Current / Base Scenario	*100% can choose to WFH*	*50% can choose to WFH*
Average WFH days	3.86	4.10	3.31
Sample averages:			
Car trips per week	1.27	0.91	1.77
PT trips per week	0.68	0.34	1.47
30 year-old and evenly split males/females:			
Car trips per week	0.95	0.68	1.32
PT trips per week	0.50	0.25	1.09
50 year-old and evenly split males/females:			
Car trips per week	1.36	0.98	1.89
PT trips per week	0.81	0.40	1.71

On the other hand, if only 50% of the employees could make these choices, the average number of days working from home would drop substantially from 3.86 days to 3.31 days, the average per-person weekly number of commuting trips by car would increase from 1.27 trips to 1.77 trips, and the average per-person weekly number of commuting trips by public transport would increase from 0.68 to 1.47 trips.

[29] We ran a number of scenarios on all explanatory variables for both models but have selected the most interesting results herein. Other results are available on request.

[30] To be clear on how to interpret Table 6, the 50% who hypothetically have the choice in the scenario are randomly assigned to that status, and therefore differ substantially from the specific 49.72% who currently have the choice. The distribution of those who will have the choice to WFH will realistically not be independent of other characteristics pertinent to the frequencies of WFH and of commuting.

To assess some socioeconomic segment effects, we compared the differences of 30-year-old and 50-year-old employees, both with an even gender split. The models predict that 50-year-old employees would likely undertake more trips compared to the overall group, even more so for the 30-year-old employees. In the base scenario, commuters in the 50-year-old group would on average make 1.36 weekly car trips and 0.81 weekly public transport trips, compared to the 0.95 weekly car trips and 0.50 weekly public transport trips by commuters in the 30-year-old group. The same pattern can be observed in the scenario with all or half of the respondents having a choice to work from home. In both scenarios, commuters in the 50-year-old group are predicted on average to undertake 40% to 60% more weekly trips by car or public transport compared to the 30-year old group.

7.2 Scenario Two: 25% to 100% of the working people are asked to WFH

In the following scenario, we assume that working people cannot choose to work from home but will be directed/asked to work from home by their employer. We then tested to see what the impact would be if 25%, 50%, 75%, and 100% of working people were asked to work from home. As shown in Figure 9, when the proportion of working people who are asked by their employer to work from home drops from 100% to 25%, the average number of WFH days is predicted to decrease linearly from 4.61 days to 3.09 days a week. Similarly, the average per-person number of weekly commuting trips by car would increase from 0.56 trips to 2.06 trips and the average per-person number of weekly trips by public transport would increase from 0.11 trips to 2.00 trips[31].

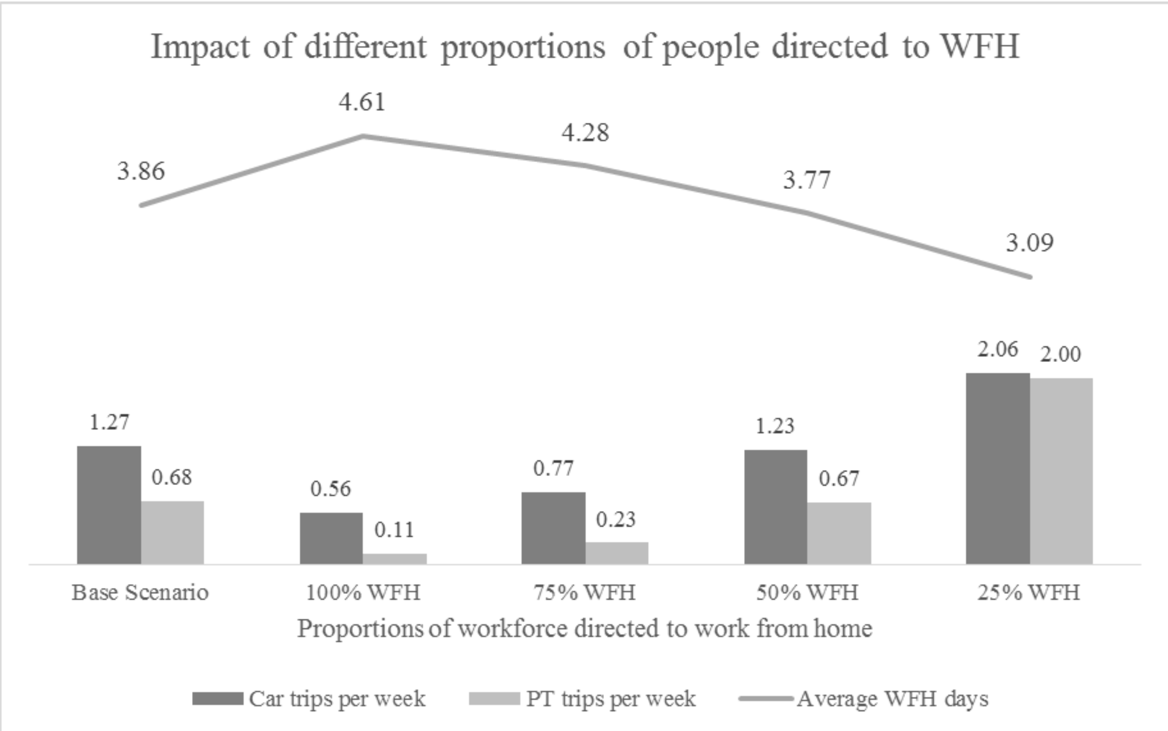


Figure 9: Impact of different proportions of people directed to WFH

Further examination of an increase in the number of one-way weekly commuting trips by car and public transport, shows that both grow exponentially instead of linearly, as shown in Figure 10[32]. This suggests an increasing rate of change for car and public transport usage when the

[31] The logic in interpreting Table 6 also applies to interpreting Figure 9.
[32] The Poisson model is non-linear given the exponential functional form.

proportion of the workforce asked to work from home decreases. For example, when the proportion of the workforce directed to work from home drops from 50% to 25%, the average weekly usage of public transport for commuting would increase at a much faster rate than the situation when the WFH proportion decreases from 100% to 75%. This pattern of change to commuting activity is very informative for policymakers in determining possible situations when restrictions are eased, such as keeping the required social distancing and other measures during the pandemic and for periods afterwards.

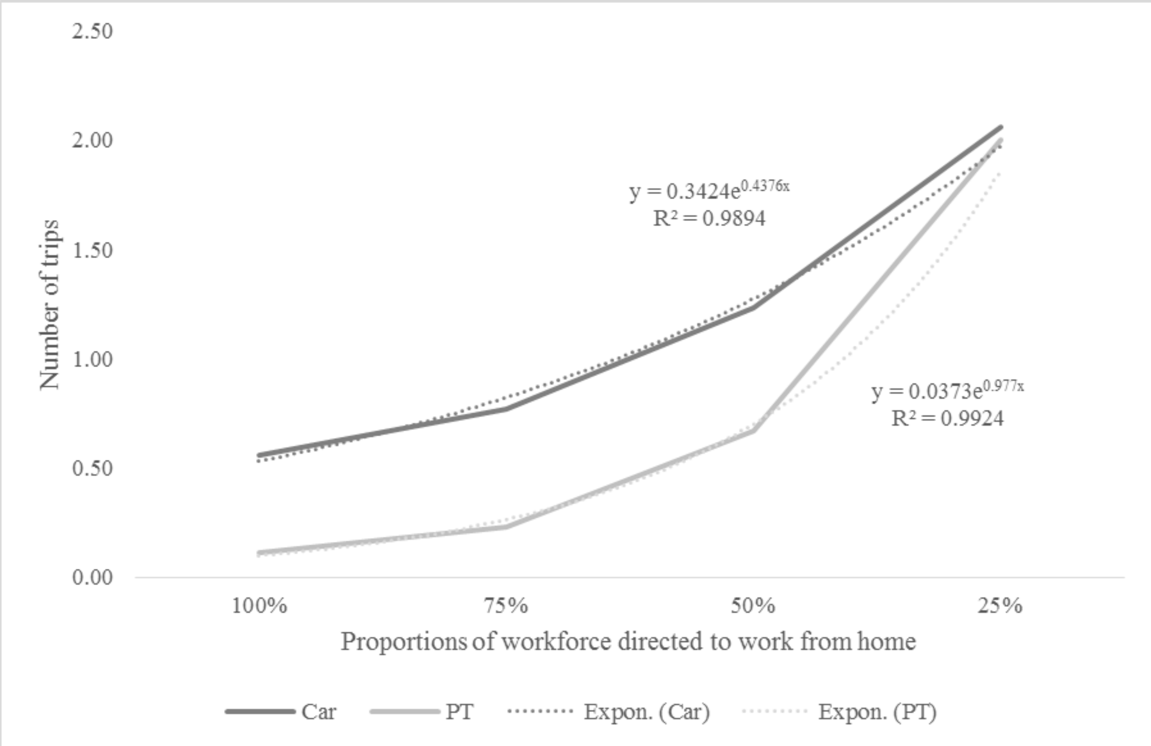


Figure 10: The increase in the per-person weekly trips with a decrease in the incidence of WFH

8 Conclusions

Transport models need to adapt to changes in the way that people live, work and move. New technology and data present opportunities to improve the way that infrastructure and services are planned. The modelling framework presented in this paper is a response to the need to recognise that, in the future, an increasing incidence of working from home is likely to be part of the way in which workers undertake productive work-related activity. In the pre-COVID-19 past, there was limited recognition of the role that WFH played in commuting activity and its impact on the network performance of roads and public transport.

Although distributive work practices (e.g., telecommuting) have existed for many years (Brewer and Hensher 1998) they have rarely been incorporated into integrated transport and land use (ITLU) model systems; a rare exception is MetroScan (Ho et al. 2017)[33] and its predecessor TRESIS (Hensher and Ton 2002). Now it is clear that the growing popularity of WFH as proven to some extent through the forced staying at home under the COVID-19 pandemic, must become an important behavioural choice feature of modelling ITLU systems during COVID-19 after all restrictions are removed.

[33] Although the parameter estimates are unlikely to be appropriate for the post-COVID-19 context.

The age-old assumption of focussing on a typical commuting day in modelling modal choice and expanding travel behaviour up to a week and a year is no longer valid, indeed if it ever was. The necessity to develop a model to predict the number of weekly days working from home (as well as the time of day of travel as staggered working hours also change), should now be a priority action. At a population scale we have a policy lever to assist in managing the transport network not observed previously[34]. This is a non-transport polity initiative (WFH) that should be encouraged and supported by government and employers before the opportunity is frittered away and we return to the bad habits that delivered high levels of traffic congestion and crowding in public transport (Beck and Hensher 2020). This has, however, to be balanced against the desire to ensure that a return to the office and some amount of reduced working from home, does not support the growth in car use at the cost of reduced public transport use (and implications on fare revenue and subsidy support).

The modelling framework proposed and implemented in this paper draws on new data collected at the height of restrictions associated with COVID-19, wherein we observed a significant cessation in commuting (often being zero travel activity). This was in part a response to government mandating staying at home unless going to work where work was essential and could not be performed from home (with a fine over $1,000 if an individual contravened the mandate and $5,000 for businesses). But it is also a directive from an employer or the ability to exercise a choice that was already available. The data enabled us to estimate models to predict the probability of WFH and what this would mean for the predicted number of weekly one-way commuting trips by car and public transport.

What we have in the models herein might be best described as the extreme response to the pandemic, with significant reductions in modal commuting activity and an associated high incidence of WFH all the time. As a consequence, the data collected just in Wave 1, has limitations in respect of the transferability of the evidence to time points over the next months. Possibly longer, as restrictions are slowly lifted and some amount on return to commuting and working away from home occurs, including the pressures off of families who had to school their children from home.

In ongoing research, we are collecting additional waves of data on a progressively longer gap between waves, with Wave 2 completed in late May and Wave 3 that begun in late June 2020. The models presented in this paper can then be revisited and updated as new data and stabilising commuting patterns as well as WFH regimes settle down. This should not change the types of models developed, but may include an additional commuter mode choice model (as discussed in footnote 16) as well as updated parameter estimates for the WFH model and the commuter trips models. The additional waves of data, up to at least early 2021, should enable us to establish some likely equilibrium in respect of network performance and WFH regimes. When this occurs, a full integration into existing strategic transport model systems should be undertaken. Efforts to undertake such a task prior to this outcome should be supported, but with the caveat that the evidence should be qualified.

[34] Flextime and compressed work schedules have been promoted as transportation demand management strategies for decades, as has working from home, but the incidence of its occurrence has been very small compared to what we are witnessing during the COVID-19 pandemic.

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Appendix E. Paper #3: Slowly coming out of COVID-19 restrictions in Australia: implications for working from home and commuting trips by car and public transport

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Edward Wei

Abstract

With the onset of COVID-19 restrictions and the slow relaxing of many restrictions, it is imperative that we understand what this means for the performance of the transport network. In going from almost no commuting, except for essential workers, to a slow increase in travel activity with working from home (WFH) continuing to be both popular and preferred, this paper draws on two surveys, one in late March at the height of restrictions and one in late May as restrictions are starting to be partially relaxed, to develop models for WFH and weekly one-way commuting travel by car and public transport. We compare the findings as one way to inform us of the extent to which a sample of Australian residents have responded through changes in WFH and commuting. While it is early days to claim any sense of a new stable pattern of commuting activity, this paper sets the context for ongoing monitoring of adjustments in travel activity and WFH, which can inform changes required in the revision of strategic metropolitan transport models as well as more general perspectives on future transport and land use policy and planning.

Keywords: Coronavirus, COVID-19, travel activity, working from home (WFH), ordered logit WFH model, Frequency of modal commuting, Poisson regression, household surveys, Australian evidence

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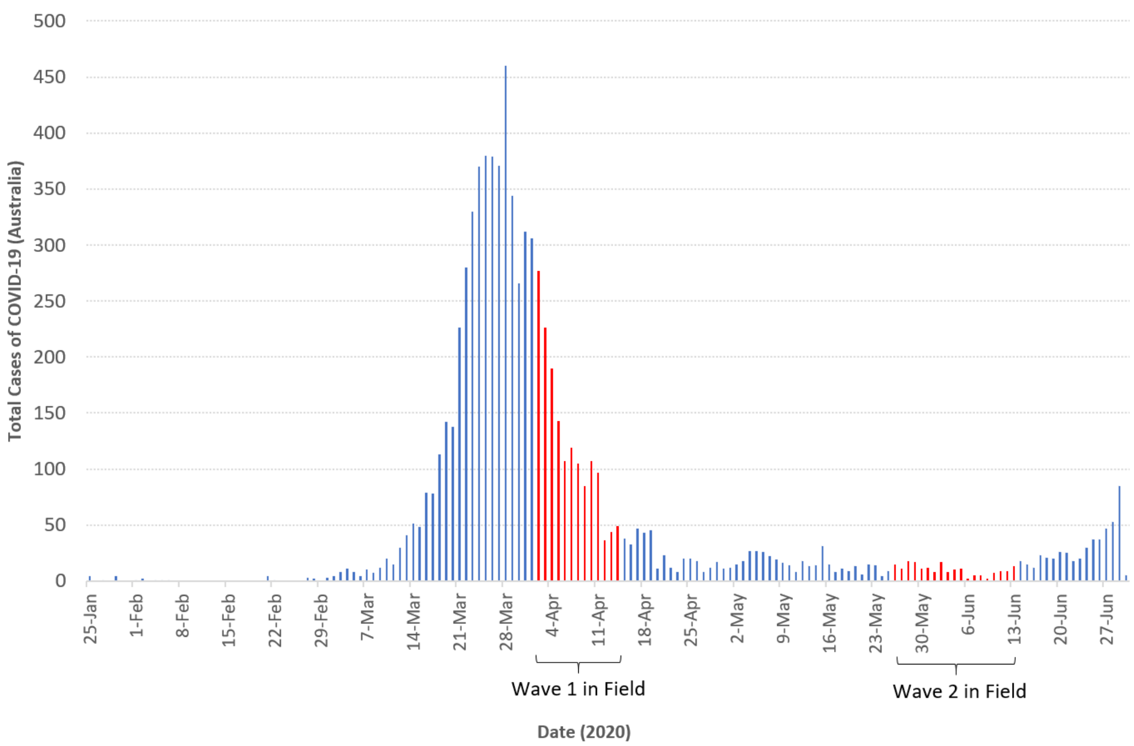
1 Introduction

The COVID-19 pandemic was brought to the centre of Australian consciousness at the beginning of March 2020, with the first death in Australia occurring on the 1st of March. On the 13th of March, Australia formed the National Cabinet, designed to coordinate government response at all levels to the rising infection rate within the country. As a result, a series of regulations were brought to bear, many of which curtailed movement and changed the nature of work and commuting in Australia. Research conducted early in the restriction process (first two weeks of April) revealed just how widespread those changes were (Beck and Hensher 2020).

As a result of the suppression of travel and activities, Australia has been able to also supress the rate of COVID-19 infection. Figure 1 shows the number of daily new cases of COVID-19, with the two waves of the survey carried out as part of the research reported below. 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.



Source: https://www.health.gov.au/news/health-alerts/novel-coronavirus-2019-ncov-health-alert

Figure 1: Daily New Cases of COVID-19 in Australia

In early May, the Federal government announced a three-stage plan devised by National Cabinet to ease restrictions across the country, with each state and territory to decide when each stage will be implemented within their jurisdiction. For example, a key date in NSW was July 1st, wherein the number of people allowed inside indoor venues is now determined by the 'one person per 4 square metre' rule, with no upper limit. Cultural and sporting events at outdoor venues with a maximum capacity of 40,000 were allowed, but only up to 25 percent of their normal capacity. On compassionate grounds, restrictions on funerals were eased to allow the four-square metre rule to apply. Restrictions including 20 guests inside the home and 20 for outside gatherings remained the same.

As a note, Figure 1 also reveals a climbing number of new cases towards the end of June, in part due to travellers returning home to Australia testing positive (returning travellers are tested and are required to quarantine in hotels for 14 days upon arrival, the cost of which is borne by the government)[35], but more concerning a sharp rise in community transfer of COVID-19 in a number of suburbs in Melbourne[36]. This emphasises the importance of not only the continual monitoring of COVID-19 infection rates, but also the regular assessment and modelling of travel and activity patterns of Australians during this period of instability.

Previous insight on working from home had been provided in Australian Bureau of Statistics Labour Force surveys (ABS 2020a) and Personal Employed at Home surveys (ABS 2020b), but little work has been done to link that with travel data. The current context offers an opportunity for a fresh examination of this issue. As such, the focus of this paper is identifying the relationship between the number of days working from home at the height of COVID-19 restrictions (late March 2020) and as restriction began to be relaxed in late May, and the amount of modal travel associated with commuting to and from the pre-COVID-19 work place. As might be expected, and as shown above, the amount of commuting activity outside of the home was initially severely curtailed either by employee choice, by employer command, or by government restrictions[37] and slowly began to increase as restrictions were relaxed.

The objective of this paper is not to discuss working from home and related issues in great detail, which is the main focus of two other papers by Beck and Hensher (2020, 2020a); rather we attempt to set the context for ongoing monitoring of adjustments in travel activity and WFH, which can inform changes required in the revision of strategic metropolitan transport models as well as more general perspectives on future transport and land use policy and planning. However, detail on experiences with working from home will be provided for context within this paper.

This paper is structured as follows: section two provides an overview of the working from home literature, section three provides results on the level of working from home and the experiences therein for the collected data; section four outlines the modelling approach to estimate the influences on days worked from home and number of commuting trips made; section five discusses the results of the modelling; section six presents scenario analysis wherein working from home and commuting trips are simulated under different assumptions; section seven provides discussion of results and suggestions for future research to address the limitations of this study; and section eight provides the conclusion.

2 Literature Review

Working from home has long been of interest to transport researchers, with the concept of telecommuting first being formed by Nilles (1973) who proposed the substitution of commuting for “telecommuting” (working at home made possibly by technological advances) in response

[35] Which has been increased by an additional 10 days in NSW, Victoria and Queensland if after Day 11 these individuals refuse to undertake a swab test, with up to 20% of such persons refusing in Melbourne, the new hotspot.

[36] On July 6, the NSW government announced that the closing of the borders with Victoria until the number of cases associated with this new ‘bump or spike’ of over 100 cases per day are under control.

[37] The number of monthly trips by train and bus in NSW in April slumped to just 18% of peak use during 2020 (from 66.1 million trips to 11.6 million), in May that number had rebounded somewhat to 27% of peak use, rising to 17.8 million trips (https://www.transport.nsw.gov.au/data-and-research/passenger-travel/public-transport-patronage) These figures refer to all trip purposes and we expect that commuting activity decreased even more.

to traffic, sprawl, and scarcity of non-renewable resources. In early work the focus was mainly on white collar workers in the information technology sector (Salomon and Salomon 1984), and many looked barriers which might exist to working from home such as lack of social interaction, inability to separate home from work, and feeling that there was a need to be seen in order to advance (Salomon 1986, Hall 1989). Nonetheless, the concept of working from home gained traction in the transport literature as a relatively fast and inexpensive way to overcome several problems associated with congestion and it was argued that the impact of telecommuting on traditional transport demand models needed to be considered (Mokhtarian 1991).

Ben-Akiva et al. (1996) proposed a travel demand modelling framework for the information era. They outline a three stage approach to incrementally updating the forecasting process through understanding how lifestyle decisions impact on mobility choices and how both impact on daily activity patterns. While Ben-Akiva et al. (1996) include sampling of both employees and employers, Yen and Mahmassani (1997) include both from the same organisation. The role of social influence and social contact on telecommuting has also been explored (Wilton et al. 2011). 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), Singh et al. (2013) and Paleti and Vukovic (2017) . Brewer and Hensher (2000) proposed and implemented an interactive agency choice experiment (IACE) in which they involved employees and employees in revealing their joint preferences for distributed work practices. They found that many employees liked the idea but were reticent about how their employers would respond, and surprisingly many employers were supportive once there preference were revealed to employees who subsequently revised their position.

In terms of the effect of telecommuting on travel behaviour, Mokhtarian et al. (1995) found that both commute and non-commute travel (measured in person-miles) decreased as a result of telecommuting. Mokhtarian et al. (2004) found that one-way commute distances were longer for telecommuters than for non-telecommuters, but average commute miles overall were less than non-telecommuters due to trip infrequency. Hensher and Golob (2002) updated the current thinking on the role of the interaction between telecommunications and travel which at the time was described as ‘the opportunity to appraise the potential for telecommunications to facilitate and/or enhance the exchange of information with/without travel’. Zhu (2012), however, found that telecommuting generated longer one-way commute trips but also longer and more frequent daily total work trips and total non-work trips, arguing that there is in fact a significant complementary effect of telecommuting on personal travel. Research by Kim et al. (2015) also found that telecommuting can indeed be a complement, particularly when it releases the household vehicle from mandatory work travel, to be used for non-commute trips.

However, in Australia the incidence of working from home remained persistently low, the Australian Household Income and Labour Dynamics survey (DSS 2020) shows that over the duration of the survey, which first commenced in 2001, approximately 25% of respondents worked from home regularly at an average of 11 hours per week. In exploring barriers to working from home, Hopkins and McKay (2019) find that it was a managerial decision rather than a function of the type of work that suppressed uptake. Such barriers are also prevalent in precarious and unskilled areas of the economy have restricted access to flexible work practices (van den Broek and Keating 2011). There are other inequities in working from home, such as differences in outcomes to employed women and men with children, particularly in the areas of job satisfaction and satisfaction with the distribution of childcare tasks (Troup and Rose 2012), whereas other have found some evidence is found that working from home contributes to better relationships and a more equitable division of household responsibilities for couples with children (Dockery and Bawa 2019). With regards to COVID-19 it has been found that the impact has been disproportionately large on women (Nash and Churchill 2020, Craig and Churchill 2020, Lister 2020).

In April 2020, Linkedin developed the Workforce Confidence Index (Anders 2020), which shows that in Australia almost a quarter of respondents stated they felt safer at home, and another quarter would not want to go back to back to full-time office based employment (See also Smith 2020 and Paul 2020). As a result of COVID-19, it may be possible that we will see the rise in working from home that was anticipated in the early work as far back as the 1970's. Should this indeed be the case, then there are significant ramifications for future travel demand and the model systems on which demand forecasts are made. For example, in the context of Sydney, the Strategic Transport Model (STM) is the primary tool used to test alternative settlement and employment scenarios; and determine the travel demand impacts from proposed transport policies, transport infrastructure or services. Many of these tools do not consider working from home in any significant way, as prior to COVID-19 working from home was not systematic.

The objective of this paper, is to provide a framework via which the increased working from home observed during COVID-19 can be introduced to such strategic models, to guide policy makers on appropriate decisions during the life of the pandemic and also to help forecast a future with increased working from home to guide important transport investment decisions, and updated easily as new data on working and commuting is collected.

3 Sample and Survey

This paper presents analysis on working from home and commuting data collected in two waves of study, Wave 1 (30th of March to the 15th of April; for the purposes of this paper modelling is conducted on 476 observations who work) and Wave 2 (23rd of May to 15th of June; analysis is conducted on 705 observations who travel for work)[38]. Table 1 provides an overview of the sample demographics for each of the two waves of data collection thus far. Note that numbers may vary in the margins from wave to wave, as the priority is on recruiting as many recompletes as possible in order to build a panel, and thus an ability to eventually investigate panel effects within respondents. That being said, both samples compare favourably to the general characteristics of the Australia population as per Australian Bureau of Statistics (ABS) census data.

Table 1: Sample Characteristics

	Australia (ABS)	**Wave 1** (n=1073)	**Wave 2** (n=1258)
		Demographics	
Female	51%	52%	58%
Age	48.1 (*those 18+*)	46.3 (σ = 17.5)	48.2 (σ = 16.2)
Income	$92,102.40	$92,826 (σ = $58,896)	$92,891 (σ = $59,320)
Have children	32%	32%	35%
Number of children	1.8	1.8 (σ = 0.8)	1.7 (σ = 0.9)

[38] Approximately 68 percent of the sample reside in capital cities and the balance in rural/regional locations.

	State		
New South Wales	32%	22%	32%
ACT	2%	2%	2%
Victoria	26%	28%	24%
Queensland	20%	22%	18%
South Australia	7%	11%	11%
Western Australia	10%	11%	10%
Northern Territory	1%	1%	1%
Tasmania	2%	2%	3%
	Occupation		
Manager	9%	1%	2%
Professional	39%	38%	35%
Technician & Trade	11%	5%	6%
Community & Personal Services	15%	8%	10%
Clerical & Administration	9%	17%	17%
Sales	2%	23%	22%
Machine Operators & Drivers	6%	2%	2%
Labourers	9%	5%	5%

Note: Occupation classes were coded by researchers and thus may differ from the classification used by the ABS. For example, there are over 700 occupations divided into the eight occupation classes (https://australianjobs.employment.gov.au/occupation-matrix).

4 Work and Working from Home Overview

Overall employment in Australia was hit hard by the COVID-19 restrictions. Derwin (2020) reports that the unemployment rate climbed to 7.1% in May after 227,700 jobs were lost on the back of 600,000 which were lost in April, and that the unemployment figure would likely be closer to 11% had people not given up looking for employment and exited the labour market. Based on the latest ABS figure, the unemployment rate rose to 7.4%, with a large increase in part-time employment. Overall, hours worked remain 6.8% lower in June than they were in March (ABS 2020c). Research by Roy Morgan (2020) showed that 68% of Australians have had ‘a change to their employment’ due to the pandemic

Our results display similar levels of disruption, however we only ask the number of days worked in the last week (not whether they have lost their job or not) and we don’t know if they are casual, part-time or full-time employees, nor if they have exited the labour market. Additionally, there is also the JobKeeper program in Australia which pays a temporary subsidy to businesses significantly affected by COVID-19, providing up to $1,500 per eligible employee per fortnight to keep that employee attached to their place of employment, regardless of if there is work available for them or not. Those receiving JobKeeper do not show up in unemployment statistics, even if they are not working, In April there were 860,489 applications, and 906,484 in May (Treasury 2020).

4.1 Days Worked and Work from Home

The impact of COVID-19 restrictions on the availability of work and where work is completed has been profound. Among those respondents who were working prior to the COVID-19 outbreak, after Wave 1 the number who worked 5 days per week fell from 58% to 39%, with a marginal improvement to 41% in Wave 2. Similarly, among those who worked at least one day before the pandemic, 26% found themselves without employment during the Wave 1 data collection period, though perhaps showing some form of recovery, that number reduced to 17% as of Wave 2.

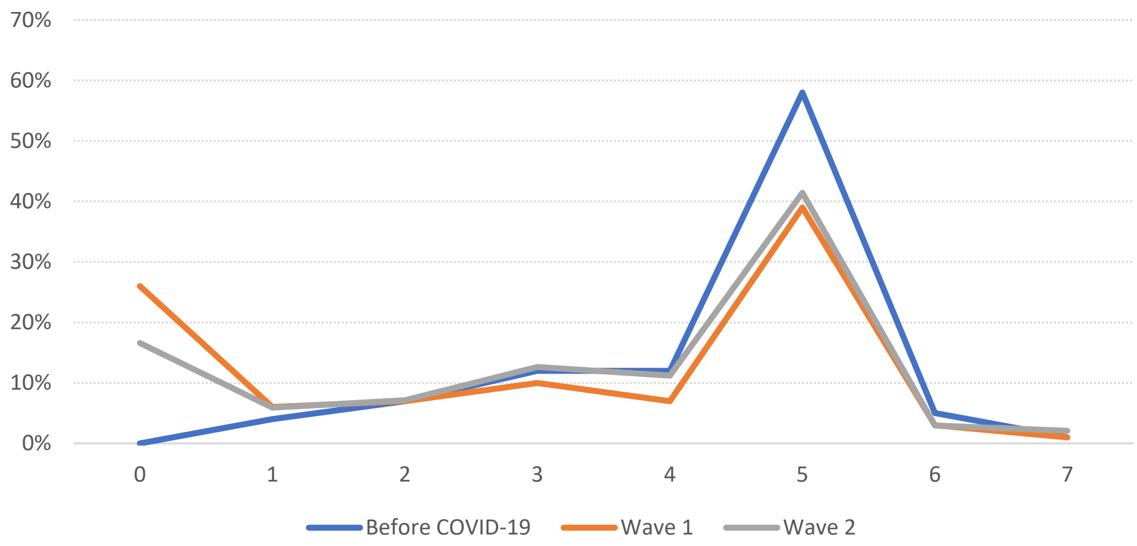


Figure 2: Number of Days Worked in Week

While overall employment (measured in days worked) has contracted, we have seen 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, the number not working from home dropped to 39%, with those working 5 days at home rising from 7% to 30%. In the most recent data collected in Wave 2, however, we started to see the beginning of a return to the long term trend, with 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 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.

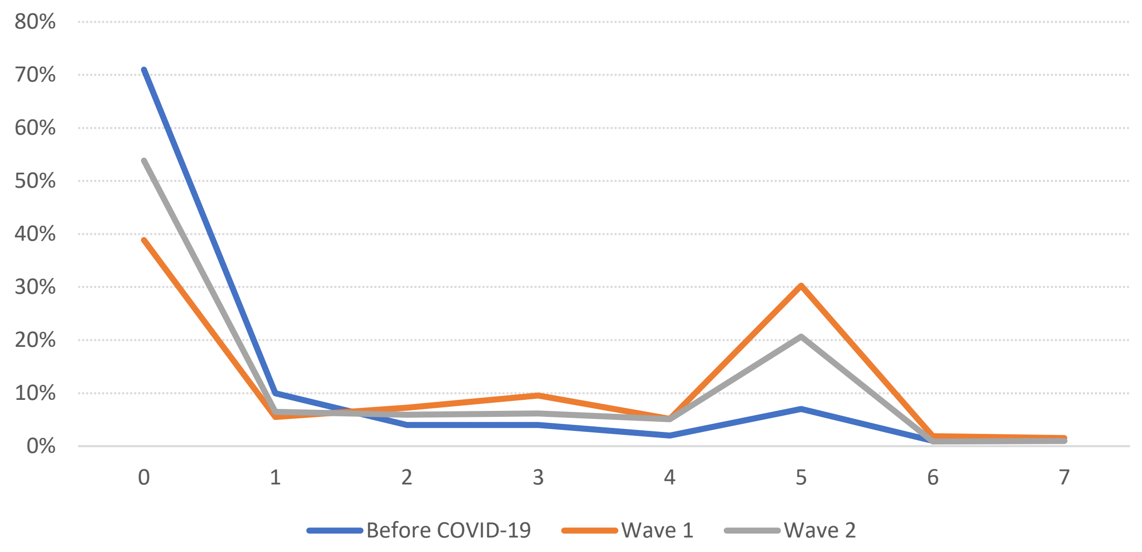


Figure 3: Number of Days Worked from Home in Week

Figure 4 shows the policy of the workplace with respect to work from home arrangements. Although the composition of the two samples is different (new respondents were contacted to supplement the sample of respondents who participated in Wave 1), we see a changing mix of workplace policies, with more workplaces having closed, and conversely less respondents being directed or given the choice to work from home.

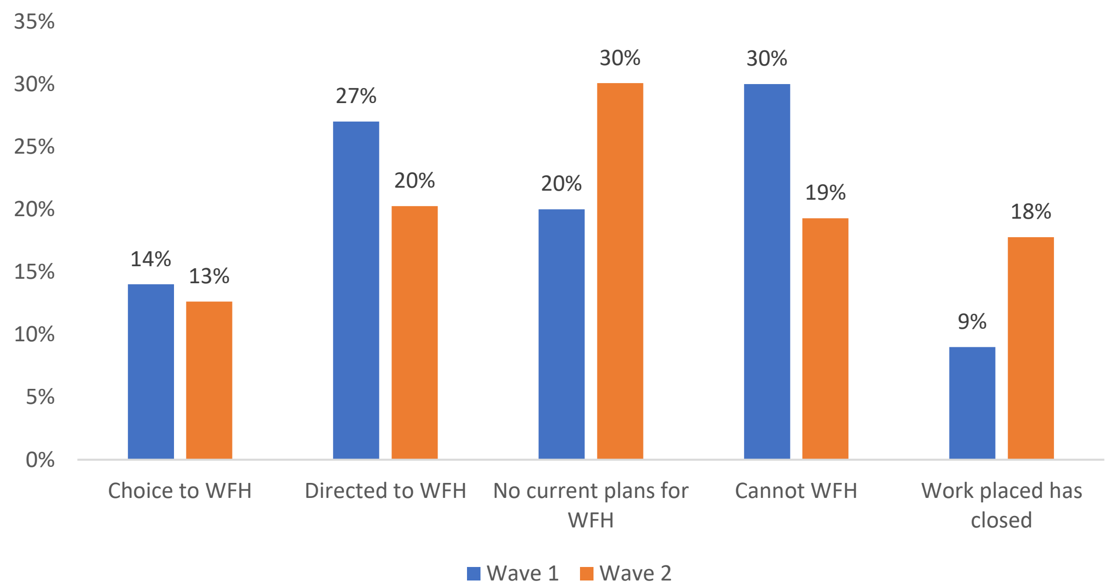


Figure 4: Workplace Policy towards Working from Home

4.2 Attitudes towards Working from Home

In Wave 2 of the survey, respondents were asked a number of attitudinal questions in order to gain insight into their experiences working from home. Figure 5 shows the level of agreement (1 = Strongly Disagree to 7 = Strongly Agree) to five attitudinal statements. There are significant levels of agreement across all statements, with respondents finding the WFH experience to be largely positive, that they have an appropriate space from which work can be completed, and importantly, they would like to work from home more often in the future.

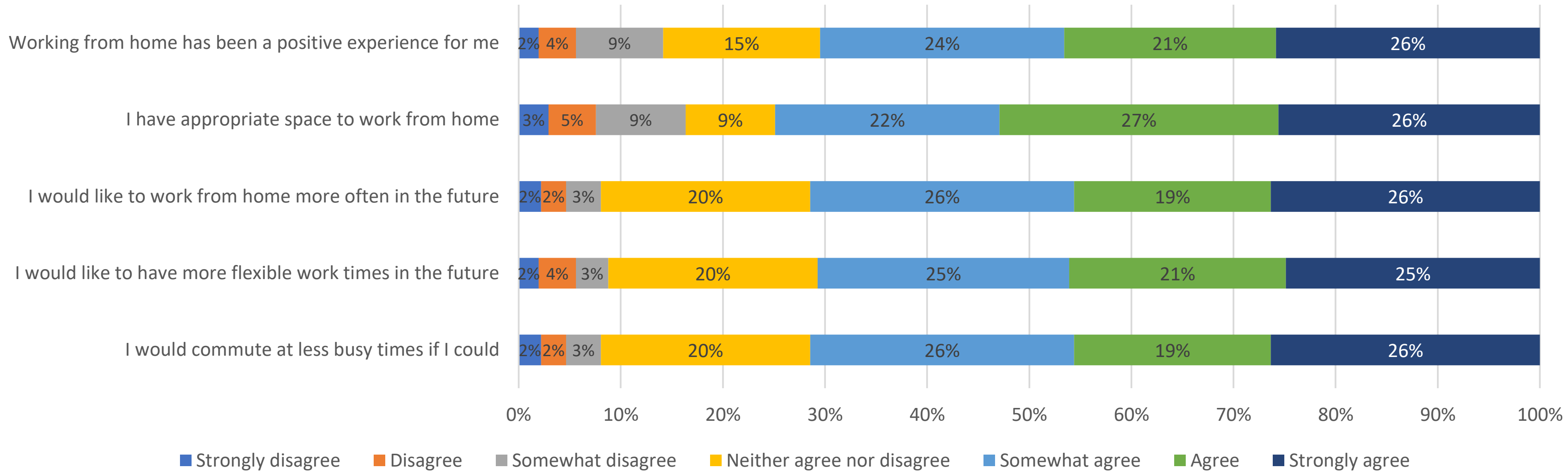


Figure 5: Attitude towards Working from Home

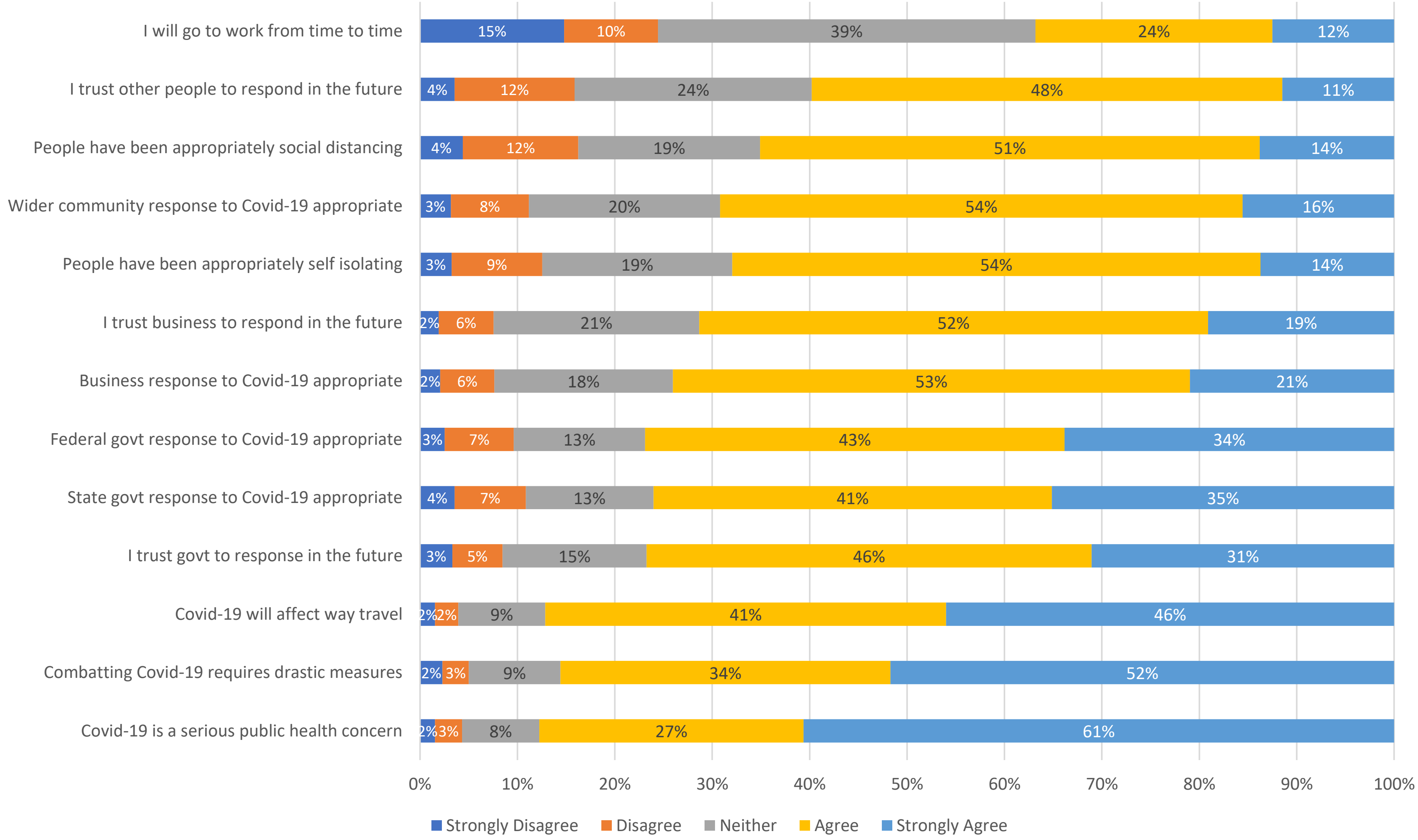


Figure 6: General Attitudes towards COVID-19 Related Issues

While agreement is significant, it overall it is not extreme; however it should be noted that for many respondents, arrangements for WFH were initially haphazard as COVID-19 suddenly forced it upon many, while at the same time schools were closed. With more time to prepare for WFH and with less home-based distractions in the future, the overall experience may become more positive as we move forward, something this research intends to monitor.

Respondents were also asked to assess their level of productivity at home relative to at work, with the result displayed in Figure 7. Overall, respondents rate their productivity as more or less the same while WFH as it would be when completing the same tasks in their normal work environment.

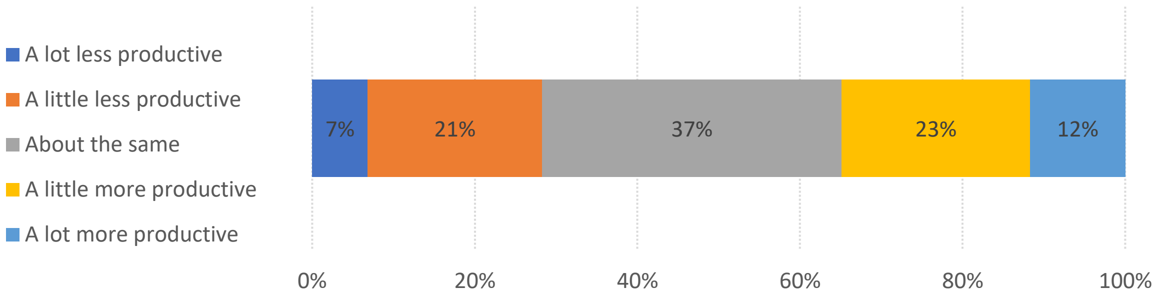


Figure 7: Productivity of WFH compared to Normal

4.3 Working from Home in the Future

Given that working from home has been a largely positive experience, wherein the majority of respondents feel that they are at least as productive at home as they are at work, it is not surprising that overall, 71% of respondents agree with the statement that they would like to WFH more often. To gain insight into what level of WFH might persist into the future, respondents were asked how many days they would like to WFH if they could, as COVID-19 restrictions were eased. Figure 8 displays the preferred number of days WFH. A closer analysis of the data showed older respondents (55 or more) wish to work less days from home on average, compared to younger age groups. Compared to the reported levels of WFH prior to COVID-19, it would seem that as restrictions are eased, WFH will constitute a greater proportion of working days than before.

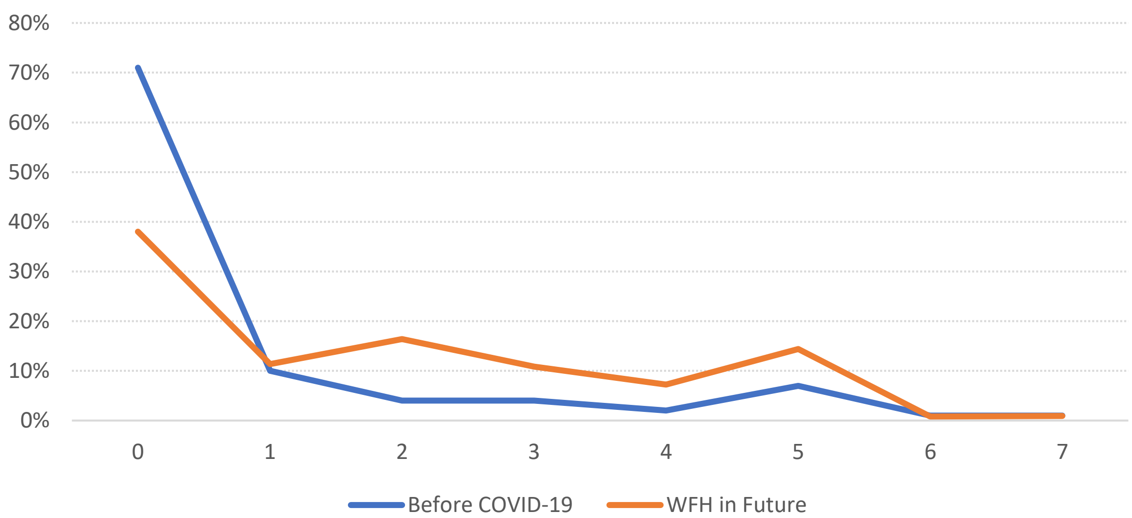


Figure 8: Aggregate Days like to WFH in the Future

Table 2 examines working from home as a proportion of days worked (i.e., days worked from home divided by total days worked) tabulated by quintiles. While we have seen a drift back towards the pre-COVID-19 figures with regards to the number of days worked from home, it was understood that the extremes currently seen are not likely to be sustainable. However, there might be an equilibrium that lies somewhere between the two experiences of WFH before COVID-19 and WFH during the initial height of the pandemic as measured in Wave 1. In terms of the future ideal, we can see a retraction away from the poles (0% or 100% WFH) towards a middle ground, with that middle ground being a sizeable increase in the level of WFH as a proportion of total work.

Table 2: WFH as a Proportion of Days Worked

Proportion of Days WFH	Before COVID-19	Wave 1	Wave 2	Future
Zero percent of work days at home	71%	39%	45%	38%
Up to 20% of work days completed at home	7%	1%	2%	4%
21-40% of work days completed at home	4%	3%	2%	10%
41-60% of work days completed at home	3%	4%	4%	11%
61-80% of work days completed at home	2%	3%	4%	8%
100% of work days completed at home	14%	50%	43%	29%

Looking at the current level of WFH as of Wave 2, overall, 52% of those currently working want to maintain the current level of WFH, but if you exclude those who currently do not work from home, then 16% of people currently WFH want to stay at the level they are currently at, 25% want to WFH more in the future than they do now, and 30% wish to WFH less in the future than they do now (9% wanting to go back to no WFH, but 21% wanting to reduce the amount of WFH, but not completely). Lastly, there is a significant and positive correlation between the proportion of days working from home currently, and the proportion of days someone would like to work in the future as COVID-19 restrictions are eased

4.4 Overview of Commuting Trips

The suppression of travel activity and the increase in working from home has had a significant impact on the commuting behaviour of respondents. Figure 9 shows the average number of one way commuting trips across the two samples, from before COVID-19 restrictions, through each of the survey waves, along with the number of commuting trips respondents are planning for the week following the Wave 2 data collection period. We can see a significant fall in commuting trips from before COVID-19 to Wave 1, but the Wave 2 results indicate that commuting trips are trending up. It should be noted, however, that the error bars on the graph display the standard deviation around the average, and indicates a very high degree of variability in behaviours, particularly in Wave 2, and even more so in the planned number of trips moving forward. This is further indication of the importance of regular data collection, analysis and modelling given the level of flux that currently exists. This diagram is a very powerful indicator of some return back to the office, but with a significant potential residual of WFH days.

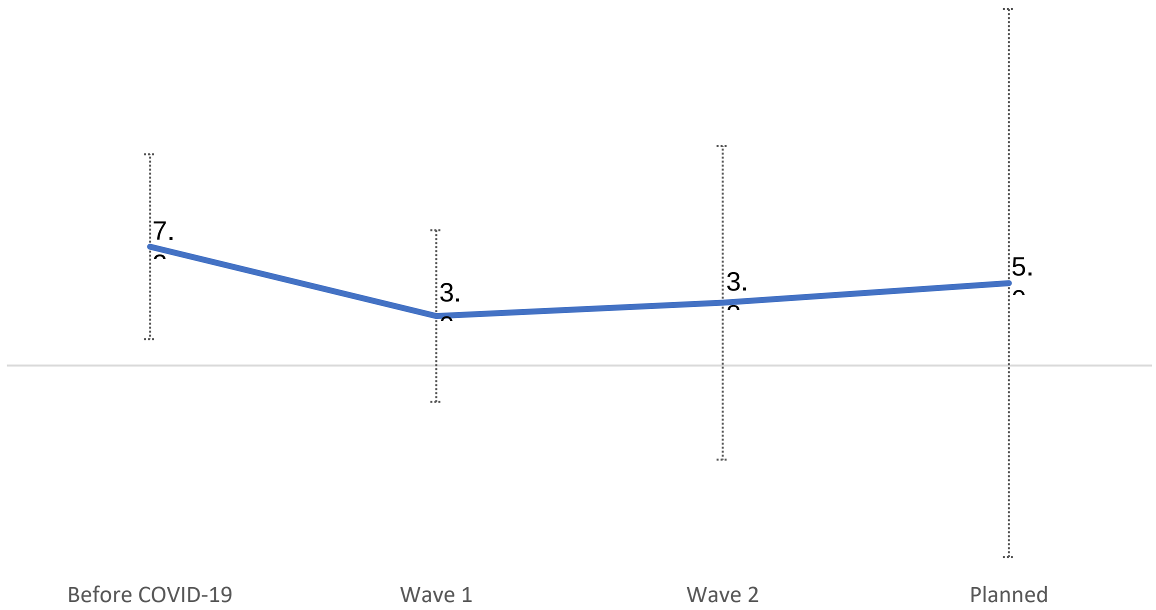


Figure 9: Average Commuting Trips in Last Week (and Planned Next Week)

4.5 Summary of Descriptive Analysis

We have seen a great shock to travel and work behaviours as a result of COVID-19 and associated restrictions. The aggregate analysis shows that while the impact persists, there is preliminary evidence that as restrictions are eased, behaviour will regress toward the pre-COVID-19 state, however it is clear that with respect to work from home, most respondents would like to continue to engage in this style of work at a level greater than before COVID-19. As such, developing model systems to understand the degree to which WFH is adopted, and the impact of WFH on commuting trips will be important to transport planners and authorities as it is clear that increasing working from home will need to be incorporated into strategic transport models and future transport forecasts. Section 3 proposes some key models that need to be integrated into strategic models together with a review and possible re-estimation of other models such as commuter and non-commuter mode choice and time of day models to reflect the changing travel setting.[39]

5 Modelling Approach

Two models are proposed (Figure 10) as an appropriate contributing framework within which to study the behavioural linkages between WFH and commuting activity. The first model, an ordered choice logit model, represents the number of days each week an individual works from home. The second model, a Poisson regression for count data, defines the number of one-way weekly commuting trips by car and by public transport. The predicted probability of the number of days WFH is fed into the Poisson regression models for one-way weekly car and one-way weekly public transport commuting trips as a way of recognising its influence on the quantum of commuting activity. To correct the estimated asymptotic covariance matrix for the estimator at step 2 for the randomness of the estimator carried forward from the ordered

[39] We estimated a commuter mode choice model for Wave 2 but decided not to include it at this stage since we believe it requires more time for travel behaviour to further adjust; we plan to revisit this model (and some extensions to the WFH model to recognise specific days of WFH and the staggered nature of commuting times) with the collection of Wave 3 data in late July.

logit WFH choice model, the standard Murphy and Topel (1985) correction is implemented, so that the standard errors of the Poisson model are asymptotically efficient.

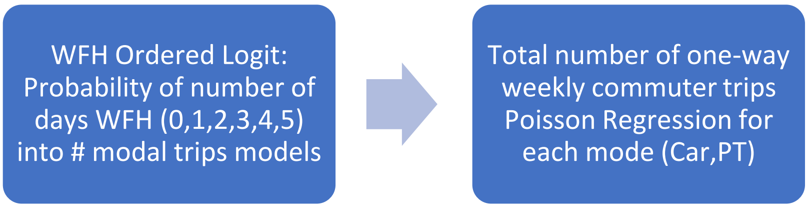


Figure 10: The Model System

For the ordered logit model, let Y_i^* denote an unobserved (or latent) continuous variable ($-\infty < Y_i^* < +\infty$), defined in utility space, and $\mu_0, \mu_1, \ldots, \mu_{J-1}, \mu_J$ denote the threshold utility points in the distribution of Y_i^*, where $\mu_0 = -\infty$ and $\mu_J = +\infty$. Define Y_i to be an ordinal (observed) variable for WFH such that $Y_i = j$ if $\mu_{J-1} \le Y_i^* \le \mu_J$; $j = 1,2,\ldots,J$ response levels. Since Y_i^* is not observed, the mean and variance are unknown. Statistical assumptions must be introduced such that Y_i^* has a mean of zero and a variance of one. To make the model operational, we define a relationship between Y_i^* and Y_i. The ordered choice model is based on a latent regression model given as equation (1) (Winship and Mare 1984; Greene and Hensher 2010).

$$Y_i^* = \beta'\mathbf{x}_i + \varepsilon_i, \quad \varepsilon_i \sim F(\varepsilon_i \mid \theta),\ E(\varepsilon_i) = 0,\ Var(\varepsilon_i) = 1 \qquad (1)$$

where θ collects the mean and threshold parameters. The observation mechanism results from a complete censoring of the latent dependent variable as follows:

$$\begin{aligned} Y_i. \quad &= 0 \text{ if } Y_i^* \le \mu_0, \\ &= 1 \text{ if } \mu_0 < Y_i^* \le \mu_1, \\ &= 2 \text{ if } \mu_1 < Y_i^* \le \mu_2, \qquad (2) \\ &\ldots \\ &= J \text{ if } Y_i^*{}_i > \mu_{J-1}. \end{aligned}$$

The probabilities which enter the log likelihood function are given by equations (3) and (4).

$$\text{Prob}(Y_i = j) = \text{Prob}(Y_i^* \text{ is in the } j\text{th range}) \qquad (3)$$

$$= F(\mu_j - \beta'\mathbf{x}_i) - F(\mu_{j-1} - \beta'\mathbf{x}_i),\ j = 0,1,\ldots,J \qquad (4)$$

The number of weekly one-way trips by car and public transport is a positive number compliant with a count model such as Poisson regression with latent heterogeneity. As a non-negative continuous count value, with truncation at zero, discrete random variable, *Y,* with observed trips, y_n, (n observations), the Poisson regression model is given as equation (5).

$$\text{Prob}(Y = y_n|\mathbf{x}_n) = \frac{\exp(-\lambda_n)\lambda_n^{y_n}}{y_n!}, \; y_n = 0,1,...; \; \log\lambda_n = \boldsymbol{\beta}'\mathbf{x}_n. \quad (5)$$

In this model, λ_n is both the mean and variance of y_n; $E[y_n|\mathbf{x}_n] = \lambda_n$. We allow for unobserved heterogeneity (see Greene 2000). With a greatly reduced number of one-way weekly trips by car and public transport, there are many observations with zero commuting activity. We can allow for this using the ZIP form for count data (see Greene 2000) to recognise the possibility of partial observability if data on weekly one-way trips being observed exhibits zero trips. In the current data under the pandemic, zero is in the main a legitimate value; however the ZIP form is still a valuable way of recognising this spike. We define $z = 0$ if the response would always be 0, 1 if a Poisson model applies; y = the response from the Poisson model; then zy = the observed response. The probabilities of the various outcomes in the ZIP model are:

$$\text{Prob}[y = 0] = \text{Prob}[z = 0] + \text{Prob}[z = 1]\times\text{Prob}[y = 0 \mid \text{Poisson}] \quad (6a)$$

$$\text{Prob}[y = r > 0] = \text{Prob}[z = 1] \times \text{Prob}[y = r \mid \text{Poisson}]. \quad (6b)$$

The ZIP model is given as (Greene 2017) $Y_n = 0$ with probability q_n and $Y_i \sim \text{Poisson}(\lambda_n)$ with probability $1 - q_n$ so that

$$\text{Prob}[Y_n = 0] = q_n + [1 - q_n]R_n(0), \text{ and}$$

$$\text{Prob}[Y_n = r > 0] = [1 - q_n]R_n(r) \quad (7)$$

where $R_n(y)$ = the Poisson probability moel given in equation (5). We assume that the ancillary, state probability, q_n, is distributed normal; $q_n \sim \text{Normal}[v_n]$. Let $F[v_n]$ denote the normal CDF. Then,

$$v_n = \tau\log[\lambda_n] = \tau\boldsymbol{\beta}'\mathbf{x}_n \quad (9)$$

Equation (9) would, under ZIP, replace equation (5) with a single new parameter which may be positive or negative. If there is no (or little) evidence of zero trips in any observations, then we do not expect the τ parameter to be statistically significant, and we can default to the Poisson form with normal latent heterogeneity.

6 Model Results

6.1 The ordered logit model for the incidence of working from home

The final ordered logit models[40] for WFH are summarised in Table 4, with an overview of the variables in the model provided in Table 3. In selecting and testing candidate explanatory variables, we wanted to identify influences on WFH that relate to an employee's situation where they could choose to WFH or otherwise, with the position supported or enforced by their employer, under government restrictions in the early days of the COVID-19 lockdown as well as when restrictions began to be relaxed.

In developing behaviourally rich models to represent the extreme lockdown in the latter half of March (as captured in the Wave 1 data), and the late May Wave 2 context of partial relaxation of restrictions, we recognised that the key drivers of WFH and commuting activity between these two time periods are likely to be very different. Specifically, in late March the decision to

[40] We investigated various models with random parameters, and only three variables were statistically significant (namely employer directs employee to work from home post-COVID-19, productivity when WFH – lot less and little less, and productivity when WFH –little more and lot more), resulting in a slightly lower log likelihood at convergence of -4180.9 compared to Table 3 of -4182.62, with 3 degrees of freedom difference; and they had almost no influence on the simulated findings in Section 5. We will continue to explore different model types as data becomes richer and behaviours more varied.

WFH and cease commuting was largely driven by mandated government directives, but with the great majority of employees and employers supporting WFH unless it is was not a feasible option. Apart from employer policies which included employees having a choice to work from home pre-COVID-19, we anticipated that employee occupation and income may have a role in determining the extent of WFH. We also expected that in late March the shock to the system was still being digested by workers with very limited knowledge of whether WFH would work out, and what strategies governments were putting in place to minimise the risk of exposure to the virus.

As time moved forward between late March and late May, questions in the survey associated with an accumulated experience in WFH and gaining an understanding of the role that government played, started to take on real meaning as people crystallised their views now that they are better informed, and indeed are reflected in the statistical significance of a number of the attitudinal questions, in contrast to late March (Wave 1) where they had no behavioural relevance.

Table 3: Descriptive Profile of WFH Model Variables, Waves 1 and 2

Variable (Mean (SD))	Units	Wave 1	Wave 2
Number of days working from home	Number	2.49 (2.20)	2.18 (2.19)
Have a choice to work from home pre-COVID-19	1,0	0.181	0.203
Employer directs employee to work from home post-COVID-19	1,0	0.347	0.306
Type of work cannot be completed from home	1,0	0.278	0.226
Technicians and trades	1,0	0.055	0.101
Community and personal services	1,0	-	0.180
Clerical and administration	1,0	-	0.162
Sydney/Melbourne/Brisbane metropolitan areas	1,0	0.455	-
Urban location	1,0	-	0.668
Annual household income	$'000s	114	-
Productivity when WFH – lot less and little less	1,0	-	0.149
Productivity when WFH –little more and lot more	1,0	-	0.187
Appropriate space to work – strongly disagree, disagree & somewhat disagree	1,0	-	0.089
Appropriate space to work – somewhat agree, agree & strongly agree	1,0	-	0.404
WFH has a positive experience – strongly disagree, disagree & somewhat disagree	1,0	-	0.075
WFH has a positive experience - somewhat agree, agree & strongly agree	1,0	-	0.384
Like to WFH more often - strongly disagree, disagree & somewhat disagree	1,0	-	0.040
Like to WFH more often - somewhat agree, agree & strongly agree	1,0	-	0.377
I trust government to respond in the future – agree & strongly agree	1,0	-	0.757
I will go to work from time to time – agree & strongly disagree	1,0	-	0.174
I will go to work from time to time – agree & strongly agree	1,0	-	0.505

Both Wave 1 and Wave 2 models have overall goodness of fits within the range for pseudo-R^2 typically obtained (i.e., 0.2 to 0.4) (Hensher et al. 2015). Both waves have identified three statistically significant employer-policy dummy variables, namely an employee having a choice to work from home pre-COVID-19, an employer directs the employee to work from home during COVID-19, and the type of work undertaken by the employee cannot be completed from home. The first two of the dummy variables have positive parameter estimates, suggesting that the probability of having more compared to less days of WFH increases when each of these policy settings are on offer; in contrast when the work cannot be completed at home, the probability of working away from home increases.

We considered all available socioeconomic characteristics (i.e., occupation, age, gender and household income), and found for Wave 1 that only one occupation class (i.e., technician and trades) based on the Australian Bureaus of Statistics 8-category Classification,[41] and household income, were statistically significant indicators for establishing the extent to which WFH occurred. Technician and trade occupations tend to reduce the probability of WFH which makes good sense since such jobs typically include electricians, plumbers and builders. Household income has a positive parameter estimate, suggesting that as household income increases, we can expect a higher probability of being able to, and preferring to, WFH. The residential location of respondents was investigated, and we found that in Wave 1, people living in the three largest metropolitan areas in Australia (Sydney, Melbourne and Brisbane), tended to have a higher probability of WFH, which seems plausible given the mix of occupations compared to regional, rural and small city environments.

Wave 2 included 11 opinion and attitudinal variables together with three occupation classes that were not statistically significant in Wave 1. The three occupation classes (community and personal services, clerical and administration, and sales) were statistically significant while household income was not, suggesting that these occupation classes have a lower probability of working from home as restrictions start to relax and possibly as they are required to spend some amount of time back in the office[42]. We also found that respondents residing in all capital cities had a higher probability of WFH.

The attitudinal variables are all coded as dummy variables relative to a ‘neutral’ opinion, as such the expectation on the sign is that it could be in either direction as these dummy variables now measure agreement or disagreement (rather than some level of agreement). For all attitudinal variables, it is important to emphasise that, in late May, we were still dealing with constrained choices in that people were being directed to work from home, and hence this effect as captured through the employer policy variables was having a significant and dominating influence on the extent of WFH (typically 40% of the sample were WFH 5 days a week) which in itself could prime views about working from home.

We find that productivity when WFH, associated with positive parameters, can be rationalised as follows: regardless of whether an individual believes that they are more or less productive when they WFH, they still prefer to do so, but the parameter estimate is significantly greater when productivity at home is perceived to be higher. The appropriateness of workspace at home also has positive parameters, suggesting that the less concern you have about your workspace, the more likely you are to work from home versus those that have a higher level of concern, but still a preference to WFH. On the positive experience associated with WFH, the positive parameter estimates follow a similar pattern; the more you work from home, probably the less (but still) positive you find it, given anecdotal evidence that a growing number of individuals are wanting some amount of social interaction in the workplace that is not possible online through videoconferencing and/or phone meetings. Indeed, the response to the desire to go to work from time to time, as negative parameters, reinforces the position of some likely increase in the probability of not working from home. Finally, the estimated parameter for trust in government responding to COVID-19 is negative, suggesting that as of late May, for those individuals who agreed with this statement, the greater the probability that they will be prepared to reduce the number of days working from home. This last point is powerful evidence of the importance of messaging by Government.

[41] https://www.abs.gov.au/ausstats/abs@.nsf/Lookup/by%20Subject/6102.0.55.001~Feb%202018~Main%20Features~Classifications%20Used%20in%20Labour%20Statistics~15

[42] Anecdotally, we note that many of these positions are relatively junior or are middle management, with senior management requiring some amount of return to the office or out in the field.

Table 4: Ordered Logit Choice model for WFH

Note: Mean probability of number of days per week WFH are W2 (W1): 0 days: 0.456 (0.381), 1 day: 0.018 (0.063), 2 days: 0.068 (0.075), 3 days: 0.058 (0.089), 4 days: 0.047 (0.046) and 5 days or more: 0.291(0.346).

Note: t-values are provided in brackets within each table and the 95% confidence intervals for each parameter estimate are available on request.

		Wave 1	**Wave 2**
	Units	Estimated parameter (t-value)	Estimated parameter (t-value)
Constant		-0.6967 (-2.91)	-1.0330 (-7.94)
Have a choice to work from home pre-COVID-19	1,0	2.1825 (7.83)	0.5067 (4.65)
Employer directs employee to work from home post-COVID-19	1,0	2.9221 (11.30)	1.5955 (14.5)
Type of work cannot be completed from home	1,0	-1.0764 (-3.66)	-0.7662 (-5.90)
Sydney/Melbourne/Brisbane metropolitan areas	1,0	0.4519 (2.45)	
Urban location	1,0	-	0.1448 (1.86)
Occupation (ABS 8 classes):			
Technicians and trades		-0.8854(-1.75)	-
Community and personal services	1,0	-	-0.5322 (-3.56)
Clerical and administration	1,0	-	-0.4874 (-5.15)
Sales	1,0	-	-0.4090 (-3.96)
Annual household income	$'000s	0.0026(1.97)	-
Attitudinal variables:			
Productivity when WFH – lot less and little less	1,0	-	0.4994 (4.78)
Productivity when WFH –little more and lot more	1,0	-	0.8032 (7.76)
Appropriate space to work – strongly disagree, disagree & somewhat disagree	1,0	-	1.9316 (12.9)
Appropriate space to work – somewhat agree, agree & strongly agree	1,0	-	1.5685 (12.7)
WFH has a positive experience – strongly disagree, disagree & somewhat disagree	1,0	-	1.1929 (7.85)
WFH has a positive experience - somewhat agree, agree & strongly agree	1,0	-	0.6388 (4.67)
Like to WFH more often - strongly disagree, disagree & somewhat disagree	1,0	-	0.8998 (4.97)
Like to WFH more often - somewhat agree, agree & strongly agree	1,0	-	0.8912 (7.29)
I trust government to respond in the future – somewhat & strongly agree	1,0	-	-0.1554 (-1.83)
I will go to work from time to time – somewhat & strongly disagree	1,0	-	-0.4376 (-3.98)
I will go to work from time to time – somewhat & strongly agree	1,0	-	-0.5948 (-7.00)
Threshold parameters:			
μ_1		0.4924 (6.18)	0.8688 (22.04)
μ_2		1.0620 (10.6)	1.5639 (36.61)
μ_3		1.7127 (15.67)	2.1140 (47.79)
μ_4		2.0349 (17.41)	2.5414 (53.34)
Goodness of Fit:			
Pseudo-R^2		0.221	0.314
Restricted log-likelihood		-766.05	-6100.97
Log-likelihood at convergence		-596.34	-4182.62
Sample Size		476	705

Although the parameter estimates are statistically significant, they are not behaviourally very interesting; instead care must be taken in interpreting the numerical magnitude of each parameter estimate since they are non-comparable in this non-linear logit form (Hensher et. al., 2015). In Table 5we present elasticities as a way of meaningfully comparing the influence of each explanatory variable on WFH. For the logit form, the elasticity of the probability is given in equation (10) (Greene and Hensher 2010).

$$\frac{\partial \log E(y|x)}{\partial \log x_k} = \frac{x_k}{E(y|x)} \cdot \frac{\partial E(y|x)}{\partial x_k} = \frac{x_k}{E(y|x)} \cdot \text{marginal effect} \qquad (10)$$

where the marginal effect is given in equation (11).

$$\frac{\partial E(y|x)}{\partial x} = \frac{\partial F(\beta' x)}{\partial x} = \frac{dF(\beta' x)}{d(\beta' x)} \beta = F'(\beta' x)\beta = \mathrm{f}(\beta' x)\beta \qquad (11)$$

A marginal effect for continuous variables is the influence a one unit change in an explanatory variable has on the probability of selecting a particular outcome, *ceteris paribus*. For dummy (1,0) variables, which are the main variables in the models, the marginal effects are the derivatives of the probabilities given a change in the level of the dummy variable. The marginal effects need not have the same sign as the model parameters. Hence, the statistical significance of an estimated parameter does not imply the same significance for the marginal effect (see equation 12). Neither the sign nor the magnitude of $\bar{\boldsymbol{\beta}}$ need bear any relationship to those of $\boldsymbol{\beta}_j$. $\boldsymbol{\beta}_j$, equal to $\partial \log(P_j/P_0)/\partial \mathbf{x}$, is commonly defined as an interpretation of the model parameters.

$$\partial \mathrm{Prob}(Y_i = j)/\partial \mathbf{x} = P_j(\boldsymbol{\beta}_j - \bar{\boldsymbol{\beta}}), \quad \bar{\boldsymbol{\beta}} = \Sigma_j P_j \boldsymbol{\beta}_j. \qquad (12)$$

Looking first at the variables related to employer policy, the mean elasticity estimates suggest that the employer directive to WFH (associated with a government mandated restriction) has the greatest behavioural response, notably for WFH 4 and 5 days a week for both waves, and is noticeably much greater in Wave 1 (late March), as expected. There is evidence of the softening of the response in late May as we see restrictions relaxed, and possibly a greater appreciation of the risks of moving to some amount of not working from home[43]. The negative elasticity estimated for WFH=0 compared to the positive elasticity estimates for WFH 5 days a week is consistent with the view that having a choice to work from home or an employer directive to WFH, reduces the probability of going to work 5 days a week and increases the probability of WFH 5 days a week, with the latter a greater behavioural response.

A similar logic can be applied to all of the direct elasticity estimates. The household income elasticity estimates suggest that as household income increases, the probability of WFH 5 days under Wave 1 increases and decreases for WFH zero days per week. The elasticity estimates are generally greater and negative for the three employment policy variables in Wave 1 when there is WFH, and decline into the positive range for situations where there is commuting five or more days per week.

For the attitudinal variables associated with Wave 2 that have a positive parameter estimate in Table 43, we see that as we move from WFH 5 days a week to no days per week, that the behavioural responsiveness declines from a positive estimate for WFH equal to 2 to 5 days, to a negative estimate for 0 to 1 days. This is plausible and aligned with the interpretation of the Wave 2 model in Table 4 where the relaxation of restrictions is seeing a greater percentage change in the probability of WFH more days than less days over 2 to 5 days a week. The behavioural sensitivity associated with each explanatory variables is presented in more detail in a later section where we assess various scenarios.

[43] This will be an important behavioural feature to track as we add extra waves of data over the next 8 months.

Table 5: Direct elasticity of choice

Note: Measures are associated with the number of days WFH with respect to given variable in Wave 2 (Wave 1 in brackets).

Note: The elasticity as a percent change equals the partial effect/probability of WFH for that response level. All elasticities are statistically significant at the 95 percent confidence level or better and are available on request.

Working from Home Days per week:	***0***	***1***	***2***	***3***	***4***	***5 or more***
Have a choice to work from home pre-COVID-19	-0.301 (-0.817)	-0.056 (-0.726)	0.136 (-0.546)	0.281 (-0.145)	0.372 (0.393)	0.487 (2.715)
Employer directs employee to work from home post-COVID-19	-0.875 (-1.213)	-0.244 (-0.720)	0.269 (-0.405)	0.745 (-0.097)	1.119 (0.688)	1.746 (3.233)
Type of work can be completed from home	0.494 (0.605)	-0.044 (0.179)	-0.287 (-0.087)	-0.421 (-0.398)	-0.489 (-0.627)	-0.562 (-0.943)
Urban location	-0.091 (-0.269)	-0.004 (-0.146)	0.049 (-0.024)	0.082 (0.150)	0.101 (0.297)	0.122 (0.525)
Occupation (ABS 8 classes):						
Technicians and trades	(0.541)	(0.087)	(-0.148)	(-0.387)	(-0.543)	(-0.724)
Community and personal services	0.345	-0.032	-0.203	-0.295	-0.341	-0.387
Clerical and administration	0.313	-0.016	-0.180	-0.273	-0.321	-0.371
Sales	0.262	-0.010	-0.150	-0.230	-0.272	-0.315
Annual household income	(-0.188)	(-0.099)	(-0.013)	(0.109)	(0.210)	(0.358)
Productivity when WFH – lot less and little less	-0.295	-0.061	0.129	0.276	0.369	0.488
Productivity when WFH –little more and lot more	-0.459	-0.122	0.177	0.426	0.597	0.832
Appropriate space to work – strongly disagree, disagree & somewhat disagree	-0.857	-0.527	-0.078	0.521	1.155	2.769
Appropriate space to work – somewhat agree, agree & strongly agree	-0.905	-0.148	0.362	0.782	1.085	1.544
WFH has a positive experience – strongly disagree, disagree & somewhat disagree	-0.612	-0.281	0.110	0.526	0.871	1.468
WFH has a positive experience - somewhat agree, agree & strongly agree	-0.388	-0.048	0.189	0.356	0.458	0.581
Like to WFH more often - strongly disagree, disagree &somewhat disagree	-0.483	-0.192	0.128	0.439	0.676	1.042
Like to WFH more often - somewhat agree, agree & strongly agree	-0.533	-0.079	0.245	0.486	0.639	0.836
I trust government to respond in the future – somewhat and strongly agree	0.096	0.009	-0.049	-0.088	-0.111	-0.137
I will go to work from time to time – disagree & strongly disagree	0.281	-0.012	-0.161	-0.246	-0.290	-0.336
I will go to work from time to time – agree & strongly agree	0.369	0.025	-0.191	-0.334	-0.417	-0.513

In linking the WFH model to the modal trip frequency models, we have to calculate the probability of choosing a number of days WFH. The mean probability of each WFH level for Waves 2 and 1 (the latter in brackets) are 0 days: 0.456 (0.381), 1 day: 0.018 (0.063), 2 days: 0.068 (0.075), 3 days: 0.058 (0.089), 4 days: 0.047 (0.046), and 5 days or more: 0.29 (0.346). Given the estimated parameters obtained from the WFH ordered logit model, we can calculate the probabilities associated with each of the number of days working from home and enter them as explanatory variables into the Poisson regression model. These probabilities are obtained for each respondent using the following formulae, with an example given for four ordered alternatives.

Define U_{fit} = b(1)+b(2)*x1+b(3)*x_2 as the utility expression for a constant and two explanatory variables;
$f_0=\exp(-U_{fit})/(1+\exp(-U_{fit}))$;
$f_1=\exp(\mu_1- U_{fit})/(1+\exp(\mu_1- U_{fit}))$;
$f_2=\exp(\mu_2- U_{fit})/(1+\exp(\mu_2- U_{fit}))$;
$p_0=f_0$; $p1=f_1-f_0$; $p2=f_2-f_1$; $p3=1-f_2$; and
$p_{model}=(y=0)*p0 + (y=1)*p1 + (y=2)*p2 + (y=3)*p3$, where p= the choice probability for that level.

6.2 The Poisson Regression model results for commuting activity

Turning to the Poisson regression model (in Table 7) with the number of weekly one-way modal trips defined as an integer for the Poisson count model , the overall goodness of fit (as pseudo R^2) of all models are excellent for a non-linear model, varying from 0.369 to 0.681. A descriptive profile of the explanatory variables that are statistically significant is given in Table 6. The sigma parameter that is estimated to allow for latent normal heterogeneity was statistically significant in all four models at the 1 percent level. Tau, the ZIP parameter is are statistically significant in Wave 2 but not in Wave 1. The Vuong statistics suggest that the estimated extended Poisson models in Table 7 for Wave 1 are favoured over an unaltered Poisson model. The Vuong statistics of 22.45 for car and 6.45 for public transport for Wave 2 also suggest that the estimated extended Poisson model is favoured over an unaltered Poisson model, but with censoring using Probit. That is, the dependent variable is over-dispersed and has an excessive number of zeros[44].

Table 6 Descriptive profile of commuter trips model variables

	Wave 1		Wave 2	
	Car	*Public Transport*	*Car*	*Public Transport*
One-way weekly commuting trips	1.25 (3.03)	0.60 (2.18)	4.54 (5.78)	0.887 (5.57)
Annual household income ($000s)	114		104	
Professionals (ABS 8 classes) (1,0)	0.400		0.372	
Metro Location (Syd, Brs, Mel) (1,0)	-		0.424	
Other capital cities (1,0)	-		0.244	
Male (1,0)	0.532		-	
Health risk to me personally (10 = extremely high)	-		8.25 (1.78)	
Probability WFH 0 days per week	0.381		0.456	
Probability WFH 1 day per week	-		0.082	

Annual household income was found to be statistically significant for car and public transport trips in both Wave 1 and Wave 2. The positive sign for the car models is indicative of a greater number of weekly one-way trips for higher income households; in contrast the negative sign in the public transport models suggests fewer public transport trips for higher income households. The only other socioeconomic influences that were statistically significant are associated with the professional occupation (relative to all other occupations)[45] and males for Wave 1 public transport, both positive; and professionals for Wave 2 use of both car and public transport, being also positive for both car and public transport.

44 We might have expected this same effect in Wave 1, given so little trip activity, but we were not able to identify a statistically significant estimate for tau.
45 Although a number of other occupations are already accounted for through the probability of working from home estimates.

Residential location was statistically significant in Wave 2, with all urban locations being statistically significant at the same level for car, but a separation of the main metropolitan locations from other capital cities for public transport produced only a marginal difference. The positive parameter estimate in the car model suggests more trips per week in all urban locations compared to regional and rural contexts. This result, may in part be attributable to generally more activity in urban areas but also because of less replacement of car travel with active transport modes. For public transport, the statistical significance was found to exist for separate variables for the three largest capital cities and other capital cities. The difference seems plausible given the greater availability of public transport in the larger cities, but also relatively good public transport in other capital cities compared to rural and regional locations. The public transport distinction compared to car, with a single parameter estimate for urban locations, is suggestive of the lack of influence of public transport on many car user preferences.

The probability of working from home no days a week was statistically significant in both waves for those using car and public transport. In both waves, it was positive for car use suggesting that as expected, all other influences remaining unchanged, as the probability of going to work 5 days a week increases, the number of one-way car commuter trips increases. For car in Wave 2, we also see a higher probability of going to work 4 days a week adding to the total switch back to the workplace. Under COVID-19 with biosecurity a concern, this makes good sense. However, for public transport, we observe a negative sign in Wave 1 which makes sense given that this was at the height of restrictions with government advice to not use public transport; but this changed to a positive sign in Wave 2 when a return, to some extent, to work resulted in an increase in public transport commuting trips, with social distancing in public transport requiring sitting only on seats with an allowable sitting sign[46]. We might anticipate a continuing increase in public transport in ensuing periods as additional capacity is released and the growing evidence of PT being a relatively safe environment increases together with more positive government policy messaging. Finally, for wave 2 only, we obtained a negative sign associated with car use for the question on whether an individual sees a health risk personally to themselves under COVID-19. Although only marginally only statistically significant, this supports the position of an individual whose ranking of health risk is high, so undertaking fewer one-way commuter trips per week for car, translated into reduced commuting.

Given that the dependent variable is a count variable, and Poisson regression models the log of the expected number of weekly trips as a function of the predictor variables, we can interpret an estimated parameter as follows (Wooldridge 2002): for a one unit change in the predictor variable, the difference in the logs of expected counts is expected to change by the respective parameter, given the other predictor variables in the model are held constant. For a binary variable such as gender, the difference in the logs of the expected number of weekly public transport trips in late March (Wave 1) is expected to be 1.231 higher for males compared to females, ceteris paribus. For a continuous explanatory variable such as the probability of WFH one day a week in late May (Wave 2), if a commuter were to increase the probability of WFH 1 day a week from say 0.1 to 0.2, the difference in the logs of expected number of weekly car trips would be expected to increase by 1.404 trips, ceteris paribus.

[46] In late May, this amounted to a 2% level of capacity compared to pre-Covid-19.

Table 7: Influence of WFH on Number of Weekly One-way Modal Commuter Trips

Note: Vuong test favours extended model; Murphy and Topel correction of standard errors. The constants in the models were calibrated to match the predicted average trips to the actual average trips in the sample.

Note: t-values are provided in brackets within each table and the 95% confidence intervals for each parameter estimate are available on request.

	Wave 1		Wave 2	
	Car	*Public Transport*	*Car*	*Public Transport*
Constant	0.468 (3.64)	-2.114 (-9.1)	0.7060 (6.27)	-0.2421 (-5.39)
Annual household income ($000s)	0.0035 (4.49)	-0.0207 (-15.6)	0.0032 (12.95)	-0.0036 (-4.59)
Professionals (ABS 8 classes)		0.498 (5.37)	0.1675 (4.74)	0.3321 (4.03)
Metro Location (Sydney, Brisbane, Melbourne) (1,0)	-	-	-	1.4878 (5.86)
Other capital cities (1,0)	-	-	-	0.4782 (3.80)
Urban (including metro and capital cities) (1,0)	-	-	0.0690 (1.99)	-
Male (1,0)	-	1.231 (12.23)	-	-
Health risk to me personally (10 = extremely high)	-	-	-0.0014 (-1.61)	-
Probability WFH 0 days per week	1.094 (5.97)	-1.9408 (-9.96)	1.4043 (24.29)	0.4303 (3.53)
Probability WFH 1 day per week	-	-	1.6014 (4.40)	-
Tau (ZIP)	-	-	-0.3265 (-25.20)	-0.8627 (-2.93)
Sigma (latent heterogeneity)	1.322 (19.9)	3.5322 (18.96)	0.7274 (38.62)	1.9176 (27.40)
Goodness of Fit:				
Pseudo R^2	0.404	0.671	0.369	0.681
Vuong stat vs Poisson	9.33	4.605	24.25	6.485
Partial Effects:				
Annual household income ($000s)	0.031 (4.28)	-0.378 (-6.1)	0.008 (12.9)	-0.0004 (-6.31)
Professionals (ABS 8 classes)	-	9.12 (4.54)	0.408 (4.72)	0.0394 (4.12)
Urban (including metro and capital cities) (1,0)	-	-	0.1680 (1.98)	
Metro Location (Sydney, Brisbane, Melbourne) (1,0)	-	-	-	0.177 (8.44)
Other capital cities (1,0)	-	-	-	0.0568(5.03)
Male (1,0)	-	22.54 (7.41)	-	-
Health risk to me personally (10 = extremely high)	-	-	-0.003 (-2.2)	-
Probability WFH 0 days per week	9.81 (5.22)	-35.53 (-5.24)	3.418 (23.1)	0.0511 (4.92)
Probability WFH 1 day per week	-	-	3.897(4.41)	-

A more informed way of illustrating the behavioural response for one way weekly commuting trips associated with changes in the probability of WFH and other influences is to undertake a number of scenario applications, which we now present and discuss in the following section.

7 Simulating Working from Home and Expected Commuting Trips

Using the models for Wave 1 and Wave 2, we simulate and test selected scenarios to examine the impact of any possible changes in predictors to the outcomes of WFH and commuting trips. We have selected several scenarios to illustrate the application of the models. We first examine the potential impact when different proportions of the workforce were directed to work from home (Scenario One). We also examined different levels of agreement on WFH related statements and the implications they are predicted to have on the average number of days WFH (Scenario Two). In predicting the numbers of trips by car, we applied a range of probabilities of WFH for 0 days to observe the related influence on the one-way weekly commuting trips by car (Scenario Three), and commuting trips by public transport (Scenario Four).

7.1 Scenario One: the Impact of Workforce Directed to WFH

In this and the following four sections, we have focussed only on Wave 2 primarily because we want to speculate, through simulation, what the next period, under increasingly relaxed restrictions, might look like, and that the best data we have to make such predictions is Wave 2. The further justification is that Wave 1 is a very unusual case of immensely suppressed travel regardless of situation, attitude, work, etc. It is a baseline of "nothing" with few freedoms to vary anything. The simulation using Wave 2 produces more differentiated results compared to Wave 1, given the enhanced variability in the data.

Let us assume that all work can be performed from home instead of the sample average of 78% for Wave 2, which means all work theoretically can be completed by WFH if people were directed to do so. We simulated a scenario wherein 20% and up to 80% of the workforce were directed to work from home, to imitate the different phases of the lockdown or social distancing requirements at the workplace. In this scenario, the average number of WFH days would increase from 2.04 for 20% to 4.02 for 80%, a noticeable increase. The results are shown in Figure 11.

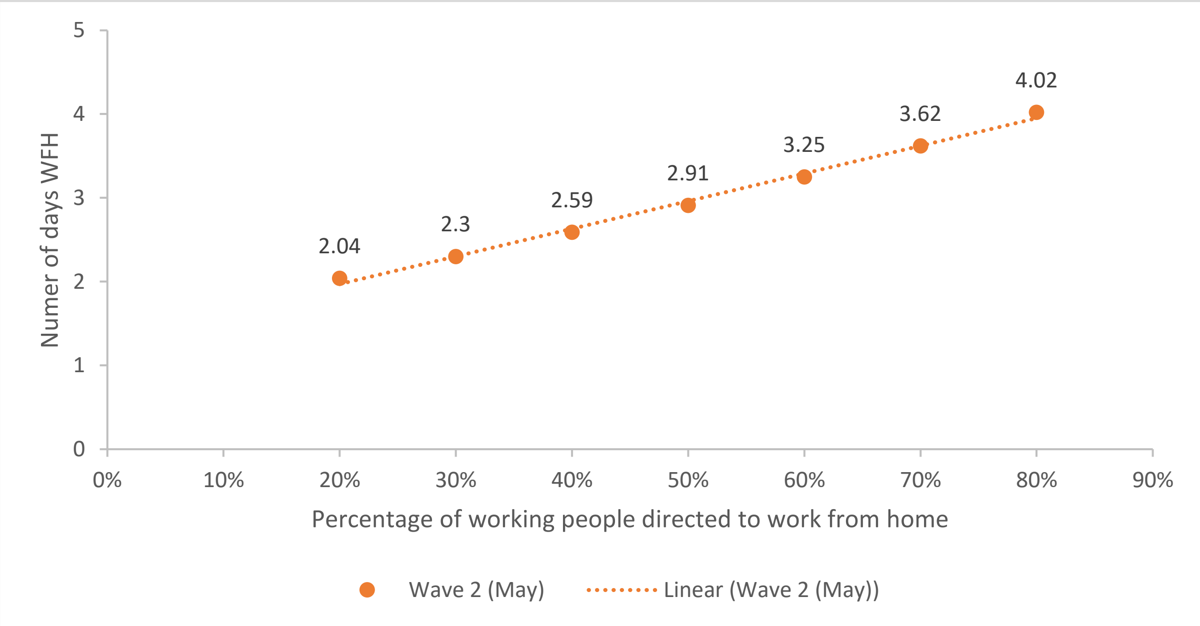


Figure 11: Impact of proportions of people directed to WFH on average number of days of WFH

7.2 Scenario Two: The Impact of Attitudes and Experience on WFH

Using the evidence on individual's attitudes towards various aspects of the COVID-19 lockdown, and coming out of the initial height of the pandemic in late May as some restrictions are relaxed, we simulated changes in the response to the relevant scale used to measure attitudes: relative productivity; appropriateness of home working space; how positive WFH has been experienced, willingness to WFH more in the future. We varied the level of agreement for these statements from 20% to 80% to assess the impact on the average days WFH, as shown in Figure 12.

We see that the most influential perspective regarding WFH choice is having adequate work space at home. The more a respondent agrees to this statement, the more likely they are willing to spend more days WFH. Conversely, low levels of agreement result in the lowest uptake of WFH days (1.6 days compared to all other statements if there was only 20% of agreement). Having a positive experience with WFH on the other hand, has a relatively small role in increasing the average WFH days compared to having adequate space and being productive. This may be a result of the fact that for many, WFH is currently a necessity rather than a choice, hence personal preference and experience play a relatively more minor role. Alternatively, it might also be the case that very few people disagreed with the statement (15%), and such limited ill-will towards the experience has meant that there is insufficient variability in negative experience to estimate a sizeable impact resulting from a bad experience at this stage. If individuals expressed a desire to want to go to work from time to time to avoid social isolation, the average number of WFH days would decline from 2.3 days at the 20% agreement level to 1.8 days at the 80% agreement level.

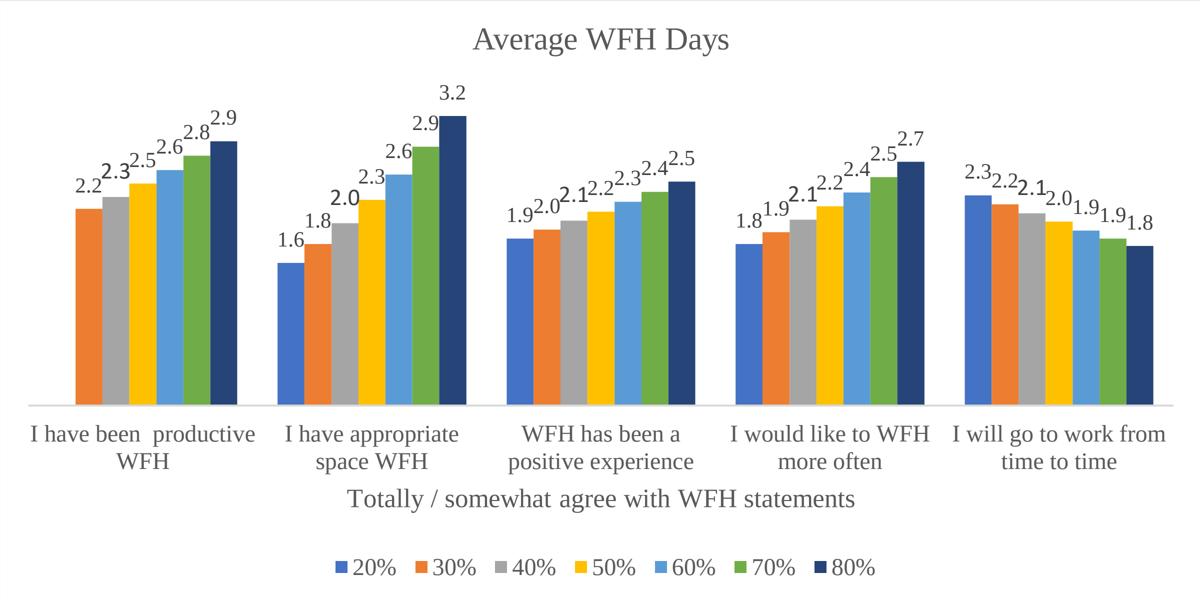


Figure 12: Impact of agreement levels on average days WFH

7.3 Scenario Three: The Impact of WFH on the number of one-way Commuting Car Trips

Using the estimated ordered logit model, we predicted the probabilities that people would work from home zero days per week and what this might mean for the number of predicted weekly one-way car commuting trips. We assume that the average number of WFH days would vary and that its composition may also change over time with the tightening or easing of restrictions. We simulated a scenario with 20% to 80% of people not working from home at all (i.e., WFH 0 days).There is a noticeable increase of one-way weekly commuting trips from 3 trips to 7.8 trips when the proportion of workforce not working from home increases from 20% to 80%, as shown in Figure 13.

The responsiveness of car travel in Wave 2 is likely to be a function of the easing of restrictions that occurred between Wave 1 and Wave 2, giving respondents more flexibility to vary their travel behaviour, within the parameters of the restrictions. Another explanation for the faster uptake in car travel for commuting is that in Wave 2, as more people start to travel, the private car becomes a preferred alternative during a pandemic for reasons of hygiene and the concern thereof related to public transport. For some individuals who used to take public transport pre-

COVID-19, the choice would shift to commuting by car for this period, with an ongoing concern as to whether they will return to public transport at a later date.

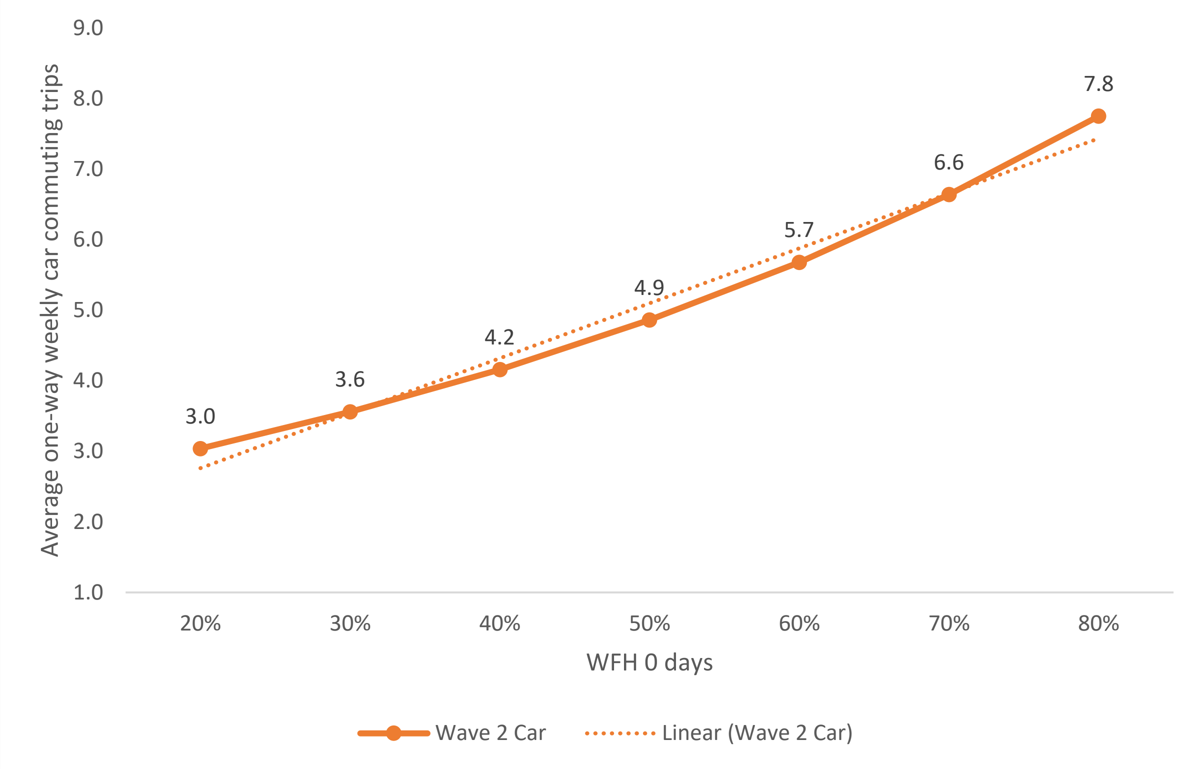


Figure 13: The increase in car commuting trips with a decrease in WFH

7.4 Scenario Four: The Impact of WFH on the number of on-way Commuting Public Transport Trips

For Wave 2, the ZIP models for PT trips predicted a low level of commuting trips by public transport, at 0.89 predicted trips on average. Commuting by public transport during a pandemic lockdown period is not a preferred (or indeed desirable) choice, aided by government messaging to stay away from using public transport. A similar scenario as in Section 5.3 for car, was investigated for PT trips. The increase of PT trips is much slower than the increase for car trips when the proportion of the workforce not working from home increases from 20% to 80% (Figure 14). This shows at least based on the answers taken during Wave 2 that people had no confidence to take more PT trips even if the restrictions were eased and more people were required to not work from home.

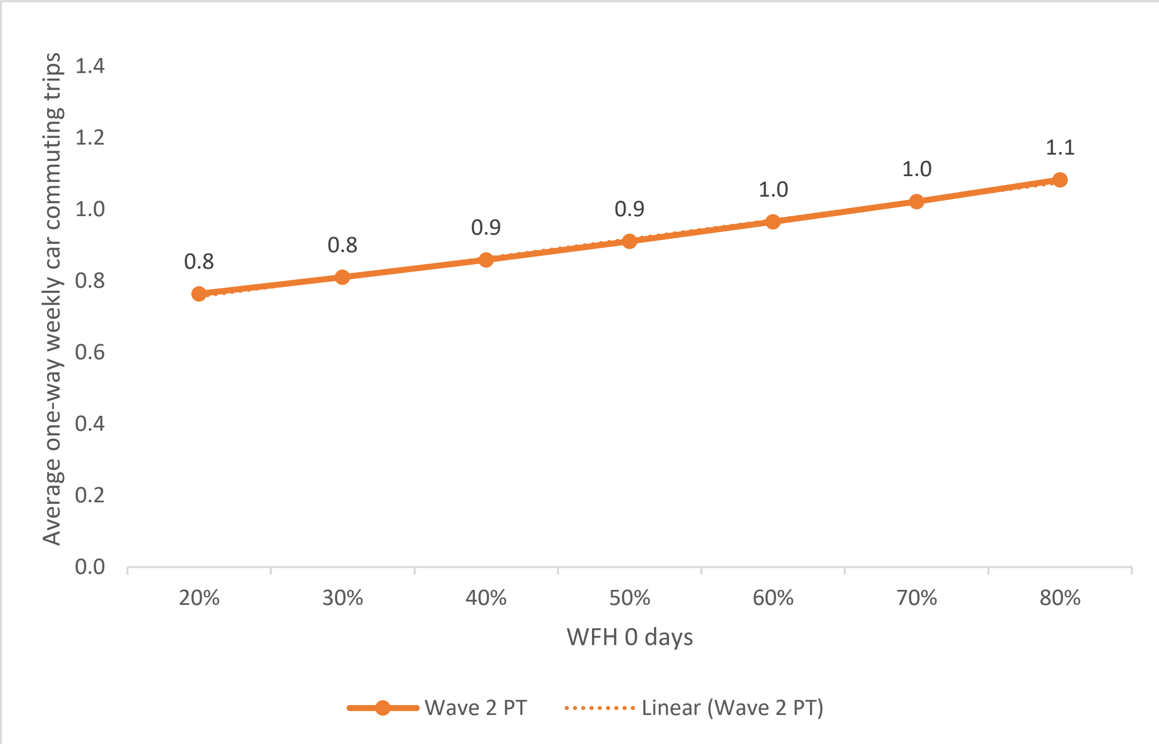


Figure 14: The increase in public transport commuting trips with a decrease in WFH

This shows that regardless of where people are and whether they work more or less from home, the commuting choice using public transport is not generally preferred for now (up to late May), despite the slow return.

7.5 Different Occupations and WFH and Commuting Trips

We identified the influence of specific occupation categories on the probability of working for home and also on the number of one-way weekly trips by car and public transport. During Wave 2 when, on average, 2.19 days people worked from home, in the ordered logit model we found that three occupation groups went back to the workplace more often than others, and hence worked less from home. They are community and personal services workers (WFH 1.80 days), clerical and administration staff (WFH 1.86 days), and sales workers (WFH 1.97 days). Many of their duties require interacting with others and hence are more difficult to do away from the work off-site.

Occupation not only directly affects WFH choices, it also directly influences the quantum of one-way weekly commuting trips. In the Wave 2 model, for car trips, professionals were predicted to have a higher level of one-way weekly commuting trips at 5.13 trips (approximately two one-way trips for two days) compared to 4.54 trips on average. They also commute more by public transport, with predicted 1.19 PT trips compared to 0.89 PT trips on average for the overall sample.

8 Discussion and Future Research

As we move away from the COVID-19 spike and the constrained travel observed in Wave 1, we see the signs of a movement in behaviour in Wave 2 which was collected after a month of a relatively low number of new cases of COVID-19 in Australia. While the general volume of work remains largely unchanged between the waves (with less work available as measured in the number of days worked in a week), we do see a slow move away from levels of work from home observed in Wave 1 towards those that existed prior to the outbreak of COVID-19.

Overall however, the experience with working from home has been largely positive with the majority of respondents finding they have the space to do so, that they are generally as productive at home as they would be at work, and crucially there is an attitude that most respondents would like to work from home more in the future and even more so, a positive attitude towards the desire to commute at times when it not as busy. As a result, looking forward, there is an intention from respondents to work at home, on average, more days in the future than they did prior to COVID-19 along with a shift in the time of day of some car trips.

While behaviours are still relatively constrained, we do observe that in Wave 2 there is more variability in the data and hence an increasing number of variables that can explain the differences in working from home and the commuting trips undertaken. The ongoing monitoring of commuting will be crucially important; while we can already see an intention to start to travel to work more often than is currently the case, but less often than pre-COVID-19 levels, the level of variability in this planned behaviour is very large (our guess is that as restrictions are eased behaviours will remain quite variable for some time).

We also start to see the attitudes of the individual playing a role in determining the levels of working from home. A positive experience with working from home, and the desire to do so more often, all increase the probability of working from home more often. Most important is the availability of an appropriate space to work from home. Any support that can be given to make the home more conducive to work in the short-term will improve the experience, productivity and thus incidence of work from home, and will likely make it a longer term lever in the congestion management tool kit. Given that trust in government response is significant, any support given in this regard will likely strengthen this attitude too. We see a desire to maintain some level of work from home that is greater than it was previously, and as restrictions ease and the work from home experience crystallises, we may find that preferences of the individual start to drive variations in behaviour more significantly.

With regards to future research that will address some of the limitations of this study, ongoing analysis is needed as behaviours are still in a great state of change. The work from home experience for many is new and forced upon them, and most are still likely trying to come to grips with the change while balancing changes on a range of other fronts like the education of their children, the work status of their partner, and so on. We acknowledge that in these early stages, there is a high probability of cognitive dissonance, and we may see that the constrained “choice” to work from home may be determining current attitudes rather than attitude determining behaviour. This is clearly an area that requires more research by the wider community. Nonetheless, it is reasonable that having an appropriate space to work at home will be a key determinant in the choice to do so. To that end, more research is also needed to understand what defines an appropriate space and if it is possible that that space can be created. More work is also needed on the future of commuting via public transport. At present, that behaviour still remains significantly depressed, and more insight is need as to how public transport may begin to attract users again.

Overall, this paper presents an approach to modelling the impact of work from home within a framework that provides plausible and importantly, usable results in the context of travel demand forecasting. While the sample size is relatively small in the context of more formal travel demand models for strategic transport decisions, the sample of 476 respondents taken from Wave 1 and 705 from Wave 2 are sizeable enough to provide a robust proof of concept for utilisation on larger samples or wider studies of travel behaviour.

9 Conclusion

Overall, this paper provides the first insights into what will be an ongoing project to look at the impact of COVID-19 on working from home and commuting. Our modelling indicates that working from home will be a key determinant on commuting behaviour, and as restrictions are relaxed, we can expect to see a quicker increase in commuting trips by car, ceteris paribus. Therefore, understanding the determinants of work from home will be vital as we move forward. In modelling the number of days worked from home we find, unsurprisingly, that the role of the employer is of great importance. The ability to choose to work from home, or the direction to do so, is a large determinant of the number of days worked. If transport authorities wish to keep commuting trips at the current low levels, particularly given the modelled resistance to public transport that currently exists, then governments should encourage ongoing employer support (linked to sustainability goals) for working from home and for those organisations who are currently not allowing staff to do so, they should work with them to identify the barriers and help develop strategies to overcome them if indeed those barriers can be removed. It is interesting to note that working from home is generally more possible for those in urban areas and households with higher incomes, likely because of the nature of employment among these groups of individuals. Perhaps understanding potential barriers that can be overcome is more urgent for those outside these groups.

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Appendix F. Paper #4: Insights into the Impact of COVID-19 on Household Travel and Activities in Australia – The Early Days of Easing Restrictions

Matthew J. Beck
David A. Hensher

Abstract

The COVID-19 disease continues to cause unparalleled disruption to life and the economy world over. This paper is the second in what will be an ongoing series of analyses of a longitudinal travel and activity survey. In this paper we examine data collected over a period of late May to early June in Australia, following four-to-six weeks of relatively flat new cases in COVID-19 after the initial nationwide outbreak, as many state jurisdictions have begun to slowly ease restrictions designed to limit the spread of the SARS-CoV-2 virus. We find that during this period, travel activity has started to slowly return, in particular by private car, and in particular for the purposes of shopping and social or recreational activities. Respondents indicate comfort with the idea of meeting friends or returning to shops, so authorities need to be aware of potential erosion of social distancing and appropriate COVID-safe behaviour in this regard. There is still a concern about using public transport, though it has diminished noticeably since the first wave of data collection. We see that working from home continues to be an important strategy in reducing travel and pressure on constrained transport networks, and a policy measure that if carried over to a post-pandemic world, will be an important step towards a more sustainable transport future. We find that work from home has been a generally positive experience with a significant number of respondents liking to work from home moving forward, with varying degrees of employer support, at a level above those seen before COVID-19. Thus, any investment to capitalise on current levels of work from home should be viewed as an investment in transport.

Keywords: Coronavirus, COVID-19, travel activity, working from home (WFH), household surveys, attitudes, behaviours, longitudinal study, employer support.

Acknowledgments: We thank the University of Sydney Business School for its financial support in funding the collection of Wave 2 data. The comments of two referees have materially improved the paper.

1 Headline Results

1.1 Key Findings

- Aggregate travel has increased by 50% since initial restrictions, but is still less than two-thirds of that which occurred prior to COVID-19.
- Motor vehicle travel rebounding more than other modes, though those who are planning a return to train and bus intended to do so strongly.
- Concerns about public transport are lower than initial restrictions, but still significantly higher than prior to COVID-19.
- Large increases in activity planned for shopping and social and recreation purposes, with people feeling most comfortable about meeting with friends, going to the shops and also relatively comfortable visiting restaurants.

- Working from home continues, though concern about safety of work environment is widely varied.

- Work from home has been largely positive for those who have been able to do so, and the majority of respondents would like to work in increased proportion of days from home in the future. There is good employer support for doing so.

- Concern about the risk of COVID-19 to the community, to someone known to the respondents or to the respondent themselves, has decreased significantly since the initial outbreak.

1.2 Policy Implications

Authorities need to be vigilant as restrictions are eased, particularly with respect to social activity. There is evidence that the desire to return to some form of personal interaction is stronger than a return to other kinds of activity. Twinned with a falling perception of the risk of COVID-19, this could be problematic should appropriate social distancing and COVID safe behaviours diminish. There may be a need to limit travel for the purposes of recreation, particularly to venues where socialising is the norm and behaviours might be conducive to the transmission of the virus.

Work from home may be one behaviour that lasts into the longer term, and it is clear that any action that can embed a greater degree of working from home now will be a sound investment in transport needs and priorities for the future. Measures should be taken to understand how the benefits can be communicated to those less keen to continue to work from home to some degree, in a post-pandemic environment. Government should work with business to understand the appropriate mix of policy and incentives to encourage ongoing uptake. Given that the experiences has been largely positive for many, including employers, authorities should be seeking to capitalise on that experience now, particularly as new habits are formed.

2 Introduction

2.1 The Current Australian Experience

By now the effects of COVID-19 are well known and across the globe the experiences with the virus, in terms of transmission and new cases differs substantially, with the scale of the economic impact and the disruption to economic activity unprecedented outside of war and depression. Australia has been somewhat successful in combatting the first wave of COVID-19 infections through a series of regulations which were quickly implemented to halt the rise in transmissions. Figure 1 displays the number of daily new COVID-19 cases in Australia, which reached an initial peak in late March and at the time of writing this paper, the country has experienced a relatively low number of new daily infections almost exclusively restricted to what is now the largest risk factor in Australia; citizens returning from abroad. While Beck and Hensher (2020) present analysis of data collected in the first wave of study conducted immediately after the peak of transmissions, this paper presents the findings from data collected during the period of relatively low new infections where talk is turning towards a staged relaxation of restrictions.

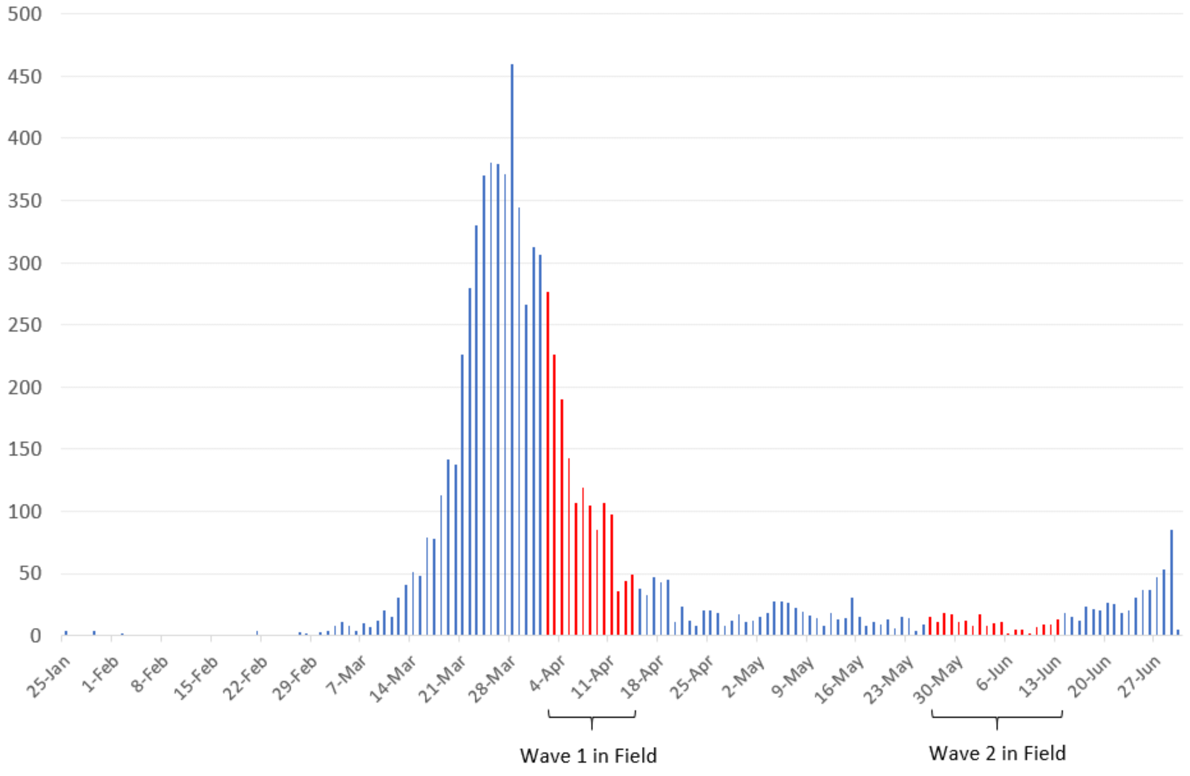

Figure 1: Daily New Cases of COVID-19 in Australia

Figure 2 and Table 1 provide an overview of the key events in the period between Wave 1 and Wave 2, most regarding the staged relaxation of restrictions designed to control the rising spread of COVID-19 that was observed in March. Throughout the entire period, state borders remain largely closed, except for NSW and Victoria which remained open throughout. Two key prongs in the Australian strategy for controlling COVID-19 and resuming more normal activity, are the adoption of a tracking and tracing application (COVIDSafe) and a carefully staged relaxation of restrictions.

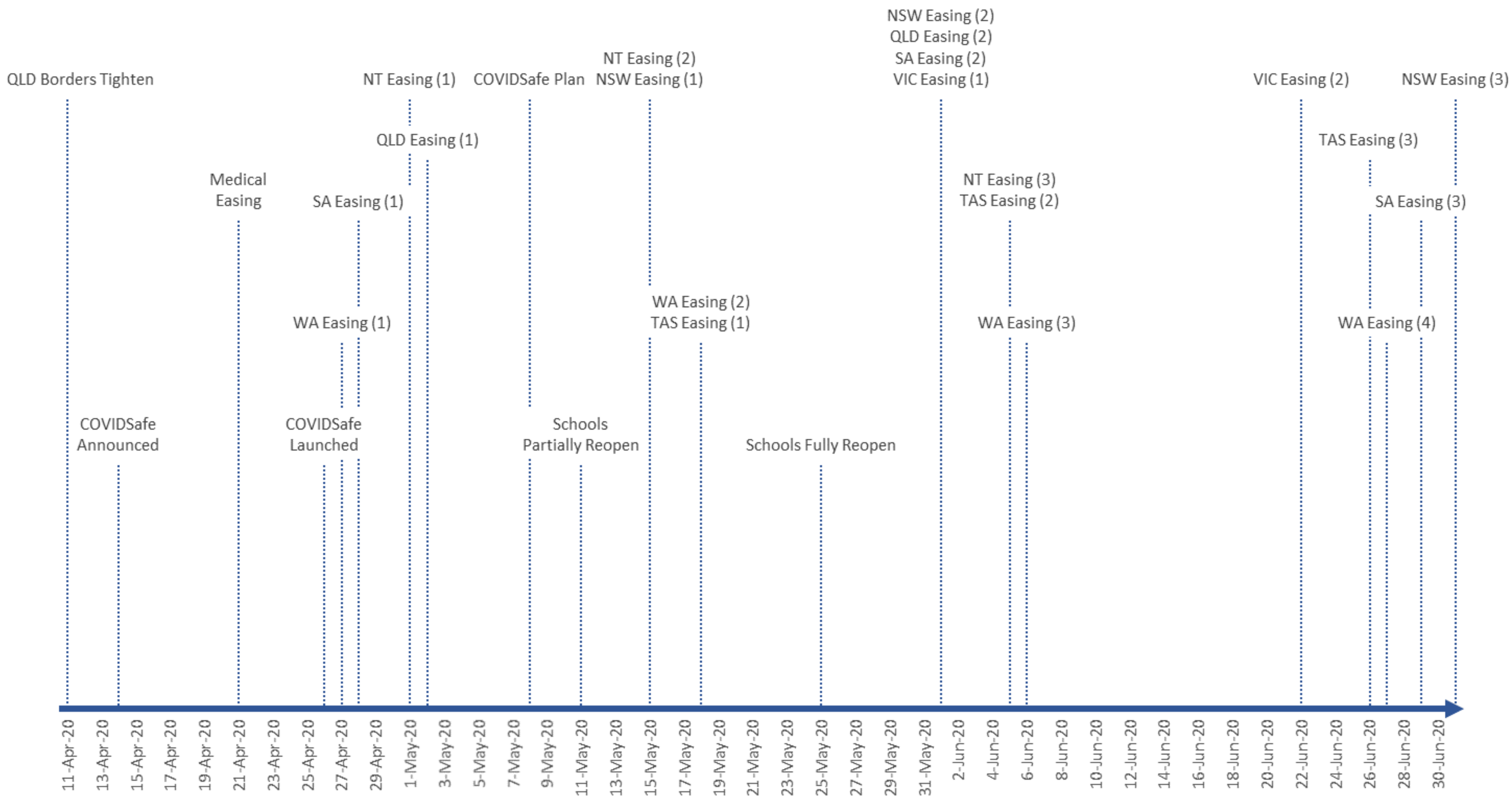

Figure 2: Ongoing Timeline of Key COVID-19 Events

Table 1: Summarising Key Events in Ongoing COVID-19 Timeline

11-Apr-20	QLD Borders Tighten	Entry passes required including for QLD residents VIC and NSW borders remain open; all others remain closed
14-Apr-20	COVIDSafe Announced	Development of COVID-19 track and trace app announced
21-Apr-20	Medical Easing	Restrictions on elective surgery will gradually ease from Tuesday 28 April
26-Apr-20	COVIDSafe Launched	Uptake reaches 5 million by 5th of May (plateaus at this approx. number)
27-Apr-20	WA Easing (1)	Indoor and outdoor non-work gatherings of 10 Outdoor training and recreational activities
28-Apr-20	SA Easing (1)	Non-work gatherings of up to 10 Cafes and restaurants open limit of 10
1-May-20	NT Easing (1)	Non-work gatherings of up to 10, Cafes and restaurants open limit of 10 Outdoor gathering restrictions relaxed, access given to NT Parks and Reserves
2-May-20	QLD Easing (1)	Gatherings in home of up to 5 guests, limit of 10 on outdoor and large spaces Recreational travel up to 150km from home, cafes and restaurants open limit of 10
8-May-20	COVIDSafe Plan	National Cabinet announces nationwide 3 step guidelines for easing restrictions
11-May-20	Schools Partially Reopen	Most schools across Australia open for attendance of at least one day per week
15-May-20	NT Easing (2)	Almost all activities resume, limited to 2 hours and 4sqm rule applies
	NSW Easing (1)	Gatherings in homes of up to 5 guests, outdoor gatherings of up to 10 Cafes and restaurants can seat 10, places of worship open with limit of 10
18-May-20	WA Easing (2)	Indoor and outdoor non-work gatherings of 20 Cafes, Restaurants, Pubs, Bars open with 20-person limit (with 4sqm rule)
	TAS Easing (1)	Gatherings in homes of up to 5 guests, outdoor gatherings of up to 10 Cafes and restaurants can seat 10, outside gyms allowed up to 10 people
19-May-20		**100 Deaths Nationally**
25-May-20	Schools Fully Reopen	Most schools across Australia open for fulltime attendance
1-Jun-20	NSW Easing (3)	Pubs, clubs, cafes, and restaurants limit of 50 customers
	QLD Easing (2)	Gatherings of up to 20 in homes and public spaces, gyms and non-contact sport allowed, Museums and galleries open, no limit on recreational travel
	SA Easing (2)	Non-work gatherings of up to 20 Cafes and restaurants open limit of 20, pubs and clubs remain closed
	VIC Easing (1)	Up to 20 people can gather at homes, indoor, outdoor, or public space gatherings Cafes, Restaurants, Pubs, Bars open with 2 person limit (with 4sqm rule)
5-Jun-20	NT Easing (3)	All but 4sqm resumes, some small venues allowed 2sqm per person
	TAS Easing (2)	Gatherings increase to 20 people at a time for indoor and outdoor Visitors to households increase to 10 people at any one time
6-Jun-20	WA Easing (3)	Revision of spacing to 2sqm, non-work gatherings limited to 200 Venues with appropriate space limit of 300, gyms, cinemas and galleries reopen
22-Jun-20	VIC Easing (2)	Cafes, Restaurants, Pubs, Bars, museums, galleries have 50-person limit Cinemas, concert venues, theatres open with limit of 50 (with 4sqm rule)
26-Jun-20	TAS Easing (3)	Gatherings at households remain limited to up to 20 people Space require now 2sqm, upper limit of 250 indoors and 500 outdoors
27-Jun-20	WA Easing (4)	All existing gathering limits and the 100/300 rule removed All events permitted except for large scale, multi-stage music festivals
29-Jun-20	SA Easing (3)	No limit on non-work gatherings other than 4sqm rule 2sqm rule may apply to smaller venues, nightclubs remain closed
1-Jul-20	NSW Easing (4)	All businesses, can reopen with exception of night clubs No limit of numbers other than 4sqm rule being observed

The national approach to the relaxation of restrictions was announced on the 8th of May, based on the underlying principles of: maintaining a distance of 1.5m from those not in the family unit; regular and thorough hygiene and sanitisation practices, staying at home if unwell, and a COVIDSafe plan for workplaces and premises. The plan involved three stages: (1) allowing groups of people to be together in homes and in the community to reconnect with friends and family; (2) slightly larger gatherings and more businesses reopening, but tight restrictions remaining on activities deemed high risk; and (3) a commitment to reopening business and the community with minimal restrictions, but underpinned by COVIDSafe ways of living. Each state was given the responsibility to enact the staged easing within their state, in a timeframe that best suited that jurisdiction. As can be seen, in both Figure 1 and Table 1, most Australian states had progressed towards the roll-back of restrictions as the number of new cases plateaued.

2.2 Aggregate Impact on Travel Activity

Since the peak of the initial outbreak, the experience in Australia has been one of a steady state of low numbers of new cases, up until most recently[47]. This staging easing of COVID-19 restrictions has resulted in a slow increase in travel and activity in the largest economic and population centres in the country, Sydney (NSW) and Melbourne (VIC). The aggregate data collected by the CityMapper Mobility Index (CityMapper 2020) is presented in Figure 3 and shows that, relative to the baseline period, mobility has been trending upward at a slightly faster rate in Sydney than Melbourne, and while double the amount of activity is now seen compared to early April, mobility is still less than half that measured during the baseline period (4 weeks between Jan 6th and Feb 2nd, 2020).

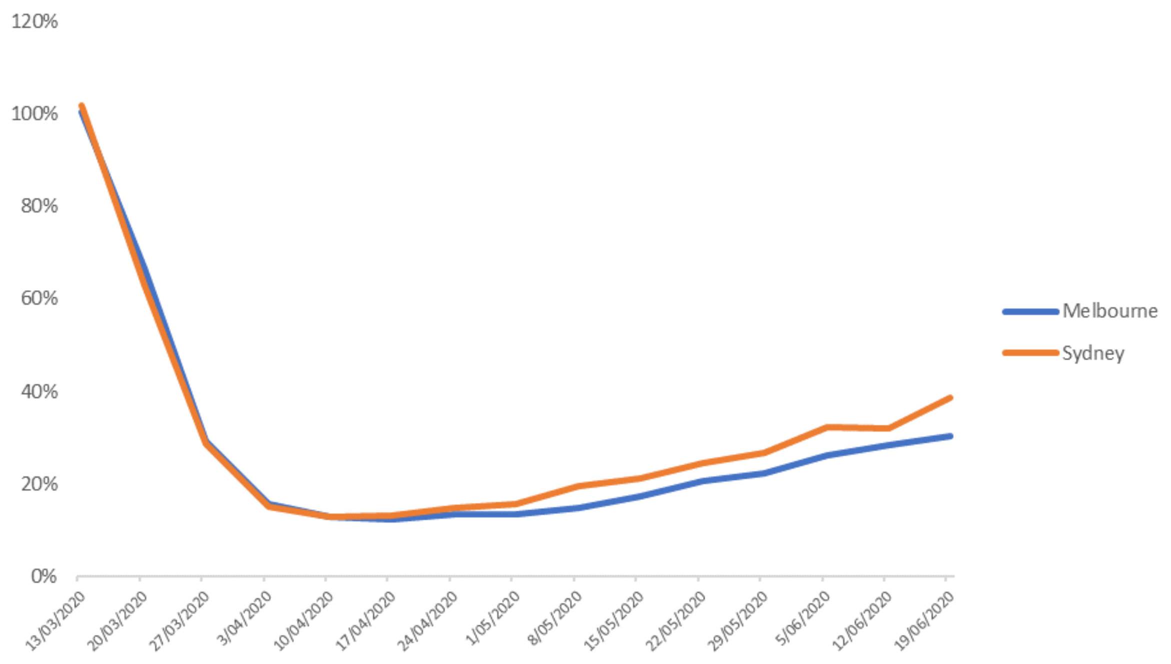

Figure 3: CityMapper Mobility Index Weekly Averages

[47] Following the initial draft of this paper, it was discovered that there were serious lapses in the quarantine protocol implemented by the Victorian government, linked to laxed practices of private sector guards used in hotels where returning overseas residents are quarantined. All cases in the growing community transmission in New South Wales have been linked to Victoria, as a result of not closing the border between the two states.

Likewise, the Google Community Mobility Report (Google 2020) presented in Figure 4 (which aggregates data across Australia and compares to the median value for the corresponding day of the week during the 5-week period Jan 3–Feb 6, 2020 as a baseline) shows a sustained increase in time spent at work, retail and recreation, and parks, while time at home has slowly diminished. The data shows that time at transit stations is recovering at the same rate of increase as other activities but remains lower due to the larger slump that occurred in early April. In totality these two figures seemingly indicate that Australia was returning to some degree of normality given the work and retail results, though in the major capital cities travel for work might be suppressed, particularly travel on public transport.

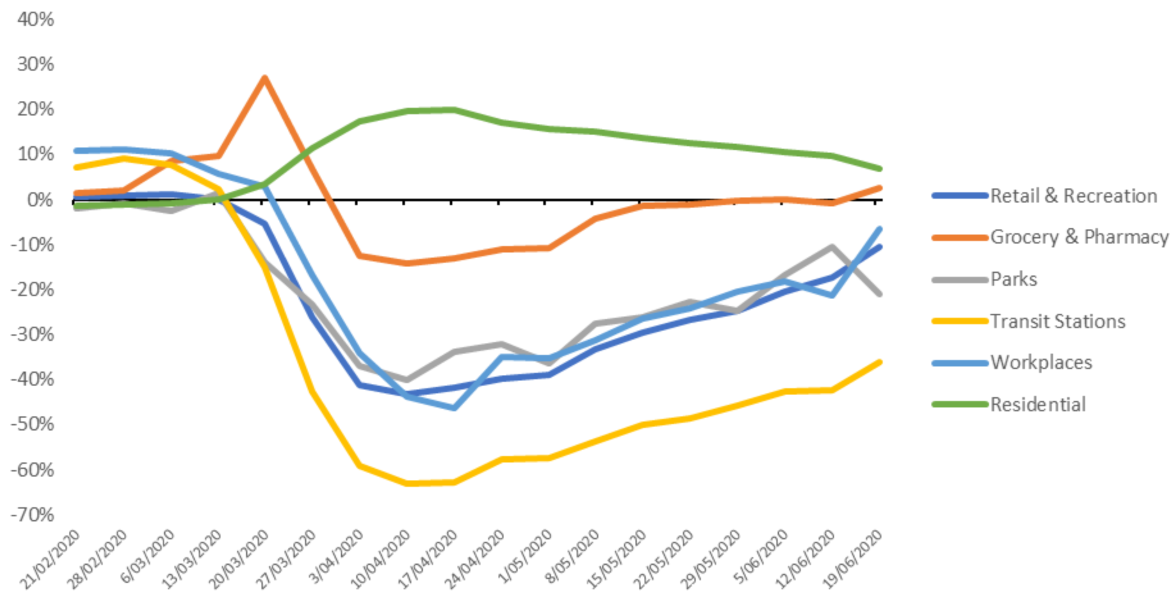

Figure 4: Google Mobility Report Weekly Averages for Australia

In this paper we present analysis on working from home and commuting data collected in the second wave of the ongoing travel survey into the impact of COVID-19. The paper, where possible, compares and contrasts aggregate results from Wave 1 and Wave 2 data collected at different points in the COVID-19 curve, but we also introduce new insights as we focus more on working from home and changes therein. Overall we attempt to continue to update policy makers and those in the transport community on the conditions surrounding travel and work as COVID-19 transmissions patterns change, but also as the restrictions on movements and activities change in response to the shifting conditions of the pandemic. The rest of this paper is structured as follows: section two provides an overview of the sample collected for Wave 2; section three discusses the results of overarching analysis; section four provides a discussion of the results and the potential policy implications that arise from the result found herein; section five discusses limitations of this study and identifies areas for future research; and section six provides the conclusion.

Note that we limit ourselves to aggregated analysis in this paper, given the desire to share timely information and the already large number of results discussed in this work. We recognise that understanding the dynamics of changing behaviour at an individual level is crucial and as the panel nature of the data grows, ongoing work will seek to examine change and adaption at an even more disaggregate level.

3 Sample Description

The second wave of the ongoing COVID-19 Travel Survey was in field from the 23rd of May to the 15th of June, with data being collected in two segments. Firstly, respondents from Wave 1 were approached to complete the survey to begin the panel nature of the survey with as robust a sample size as possible. The Wave 2 data comprises 1,457 observations made up of 762 respondents who participated in Wave 1 of the survey, and an additional 695 new recruits to supplement Wave 2. As with Wave 1, the online survey company PureProfile was used to sample respondents, and the survey was available across Australia in order to examine the widespread impact of COVID-19. A summary of the Wave 2 sample is provided in Table 2.

Table 2: Overview of Survey Sample

Female	58%
Age	48.2 (σ = 16.2)
Income	$92,891 (σ = $59,320)
Have children	35%
Number of children	1.7 (σ = 0.9)

New South Wales	32%
Australian Capital Territory	2%
Victoria	24%
Queensland	18%
South Australia	11%
Western Australia	10%
Northern Territory	1%
Tasmania	3%

For the purposes of this overarching analysis and to be consistent with the same headline analysis in Beck and Hensher (2020), socio-demographics differences are explored based on gender, age (younger (18 to 34, n=361); middle-age (35 to 54, n=461); older (55 or older, n=635)), and household income (lower income (less than $100,000, n=793); middle income ($100,000 to $200,000, n=340) and high income (more than $200,000, n=62). Given that the focus of Wave 2 was to establish a panel that was as large as possible, quotas were not introduced on those completing the survey, other than ensuring representation from all states and territories. The impact of COVID-19 is, however, sufficiently widespread that no demographic can escape the disruption caused.

4 Results

4.1 Travel Activity

4.1.1 Impact of COVID-19 on Overall Travel

Unsurprisingly, and as was the case in Wave 1, the results from Wave 2 presented in Figure 5 in the survey mirror the aggregate findings, and generally also show a comparable rate of trip generation as that found in the weekly GPS tracking project conducted in Switzerland (MOBIS-COVID19 2020). In terms of this overall travel, we see a reported 50% increase in the number of household trips over the week, from Wave 1 to Wave 2, but household travel remains significantly suppressed. In terms of changes to the current level of travel activity, the majority of respondents (83%) report that they are planning to maintain household travel at Wave 2 levels, however among the 17% of households who are planning change we can see a dramatic increase, with the level of planned activity among this group almost returning to that which was reported prior to COVID-19.

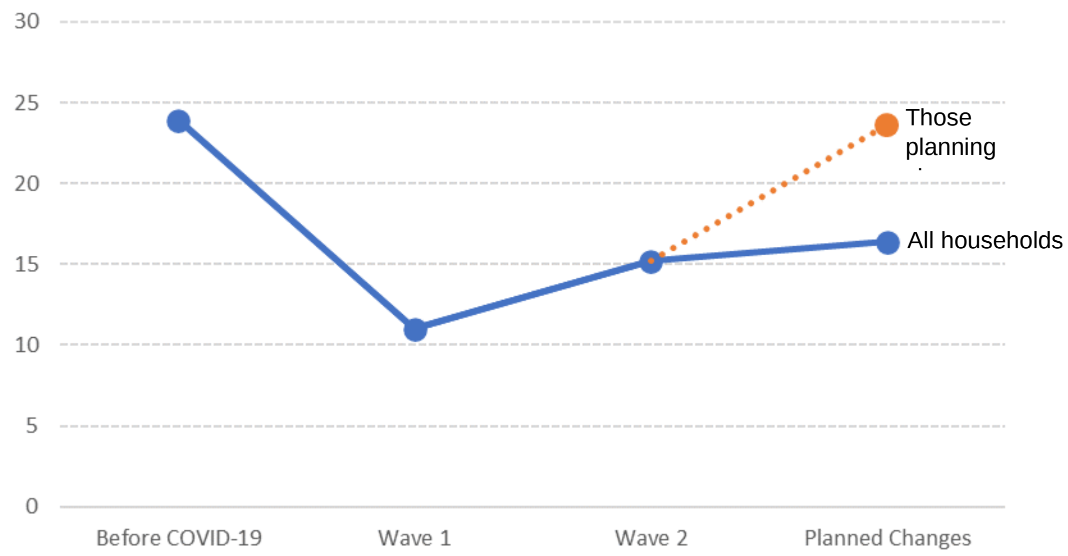

Figure 5: Impact of COVID-19 on Reported Household Weekly Trips

With respect to trips reported in Wave 2, younger respondents are exhibiting a significantly higher average number of household trips (19.8) than both middle-aged (15.8) and older (11.9) respondent households. The difference between middle-aged and older respondents is also significant. This travel behaviour is perhaps a function of the relative risk attitudes and the perceived and/or real threat presented by COVID-19 to each age group. Higher income (22.7) and middle income (18.2) households report significantly more average trips in Wave 2 than lower income households (13.6). There are no differences by gender for household trips reported in Wave 2 or planned in the upcoming week, nor are there differences in planned travel by age and income groups.

4.1.2 Travel by Mode & Purpose

Figure 6 and Figure 7 show reported household travel before the outbreak of COVID-19, during Wave 1 and Wave 2, and projects planned household travel for the upcoming week following Wave 2 data collection. In every instance we see a rebound in travel by mode and for every purpose. As anticipated by many, there is a strong bounce back in travel by car and in aggregate, active transport activity has returned to pre-COVID-19 levels. General shopping has increased, and there is a slight rebound in education and childcare trips, along with general shopping. Commuting and work business trips remain relatively flat, with working from home perhaps proving a more viable option than many initially thought (of course increased unemployment may also play a role in suppression commuting travel).

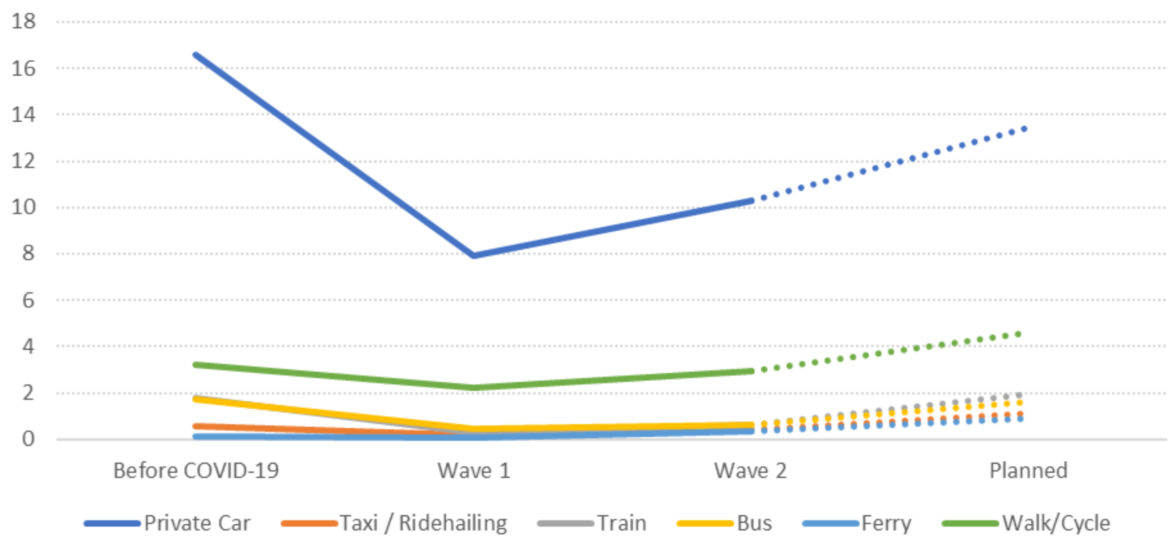

Figure 6: Reported Weekly Household Trips by Mode

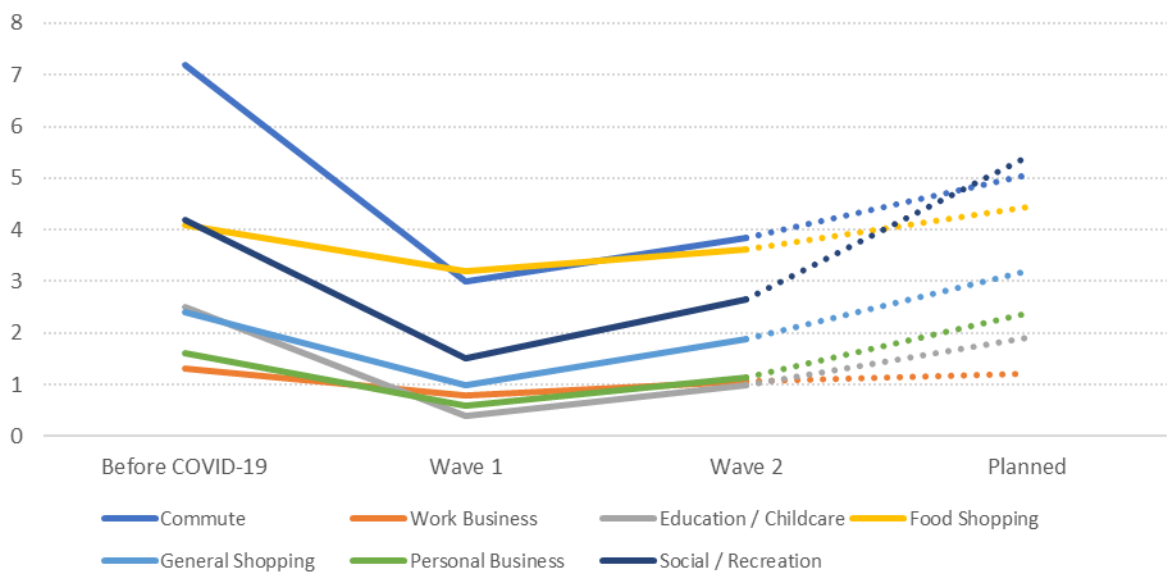

Figure 7: Reported Weekly Household Trips by Purpose

In terms of household plans, we can see that the private motor vehicle is expected to continue the strong return to pre-COVID-19 levels. Interestingly, we also see stated intentions to return to public transport modes of buses and trains, as well as a reported spike in active transport modes of walking and cycling. With respect to travel by purpose, the projected growth in shopping (food and general), personal business, and social and recreation trips suggests that non work trips are more than returning to “normal”, indeed households may even be making up for lost time with respect to these activities. This is particularly true of social and recreation activity, where the planned number of trips in the upcoming week is significantly larger on average, than the number of trips made in the Wave 2 data collection period.

With respect to broad socio-demographic differences, females report an intention to use trains at a significantly higher average amount, exhibit significantly higher average trips for education and childcare purposes (both in Wave 2 and the number of future trips planned), and also plan to engage in more food shopping and social and recreational trips in the week moving forward.

Higher and middle-income households both report a significantly higher average number of trips made by private car than lower income households. High income households also report more train trips than middle-income and lower income households, and taxi or ride-hailing trips than lower income groups. They also plan to take more ferry trips. Higher income and middle-income households report a higher average number of trips for commuting purposes than lower income, higher income groups also report more work-related business trips than households on lower incomes. Higher income households also report significantly more travel for social and recreational purposes than both middle-income and lower income households. Planned travel for different purposes is invariant across income groups.

Younger respondents report higher average household trips by private car, train, and bus during Wave 2 than both middle-aged and older respondents, as well as more active trips on average than older respondents. Younger respondents are also planning significantly more travel by taxi, train, bus, and ferry than older respondents. With respect to travel for different purposes, younger respondents also report more commuting trips, trips for education and childcare, food shopping and general shopping than middle-aged and older respondents. Older respondents plan on making less trips for work-related business and education and childcare than middle-aged and younger respondents, and significantly less trips for food shopping than those in the youngest age category.

4.1.3 Relative Mode Use Changes

Given the anecdotal evidence in new media sources about increased use of active travel modes (Abano 2020, Landis-Hanley 2020) and greater use of public spaces for exercise and recreation (O'Sullivan 2020), questions were included in Wave 2 around whether or not respondents had felt they had increased or decreased use of different modes in the previous week, and how they were planning to change their use as restrictions were eased. The results of these questions are shown in Figure 8. Note that in Wave 1 questions were not asked about the relative change in active transport modes, but were added to the Wave 2 set given the anecdotal evidence from new media that active transport had increased.

Motor vehicle use exhibits the biggest fluctuations in usage, especially compared to the result from Wave 1 when 66% of respondents had decreased car use. Now, however, half of respondents are using their car the same as they did the week prior, 25% have decreased car use relative to the previous week and 16% have increased usage. In terms of planned future use, in the week following data collection a small majority of respondents are planning to use their car the same amount (52%), but we start to see the number of people planning to increase car use exceed those who are planning to decrease. Older respondents are less likely to increase car use than the middle-aged and younger age groups.

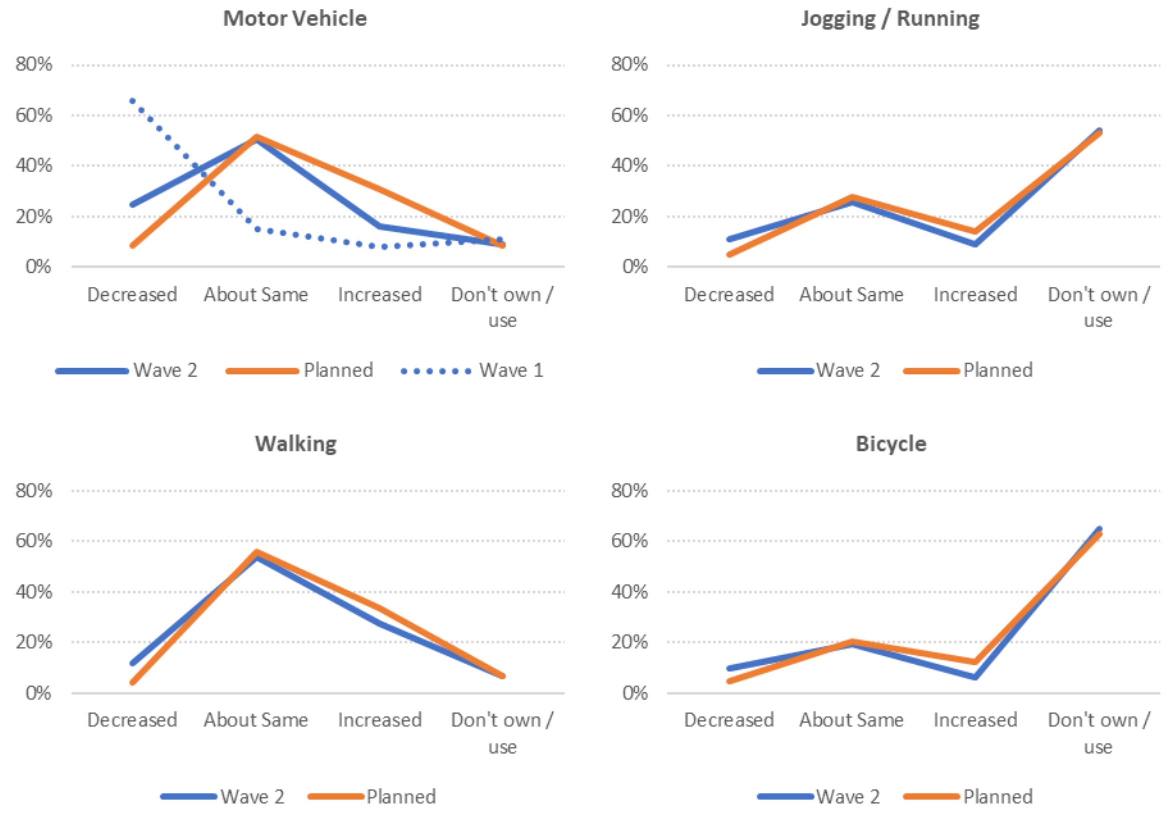

Figure 8: Changes to Use of Active Modes and Motor Vehicle

Breaking down changes in car use in a little more detail, for those respondents who said they decreased use of their car, the average reduction is 59% (σ = 28%), which is largely the same result as discovered in Wave 1 (μ = 60%, σ = 27%). For those that stated increased car use, the average increase is 37% (σ = 27%), which also mirrors Wave 1 (μ = 35%, σ = 30%). Across the sample, including those who stated they use their car about the same (0% change), there is an overall average reduction in car use of 7.8% (σ = 34%). These averages are invariant to gender, age, or income.

In terms of the active modes, what is most striking in these figures is how reported use in Wave 2 and planned use moving forward are largely identical. With respect to walking, more respondents reported an increase in Wave 2 (27%) than a decrease (12%), with younger respondents more likely to have reported an increase. With regards to running or jogging, the number who have increased (9%) or decreased (11%) are roughly balanced, younger people again are more likely to have stated an increase in this activity and unsurprisingly older respondents are more likely to not engage in running. The number of people who reported an increase in bicycling (15%) exceeds the number who have decreased use (4%), again older respondents are less likely to engage in this activity.

In terms of future use, for each of the active modes more respondents report an intention to increase their use of that activity than decrease: 34% vs 4% for walking (with younger respondents more likely to plan an increase in use); 14% vs 5% for walking (with younger respondents more likely to plan an increase in use); and 12% versus 4% for bicycling. While there is evidence that participation in these activities has increased overall, it is has not grown by a sizeable amount, though perhaps growth may be more pronounced in metropolitan areas even more so in locations where population density is high. Interestingly while more respondents plan to increase their use of active modes as compared to decrease, it remains to be seen if this behaviour will eventuate or if it just an indication of good intentions.

4.2 Concern about Public Transport

The perception that people have about the cleanliness and hygiene of public transport was also tracked in Wave 2, and the results are shown in Figure 9. Compared to Wave 1 we have seen a large moderation in concern, with reduction in the number of people extremely concerned about these modes of transport. Indeed, the average response to the concern scale in Wave 2 (μ = 3.7) is significantly lower than in Wave 1 (μ = 4.3), however average concern still remains at a level that is significantly higher than that prior to COVID-19 (μ = 2.4). Females are significantly more concerned about the cleanliness of public transport, as too are younger respondents relative to those in middle-aged and older age categories, this last result perhaps explaining why train, bus and ferry use in this age bracket is significantly higher in Wave 2, and planned to be higher than other age groups moving forward.

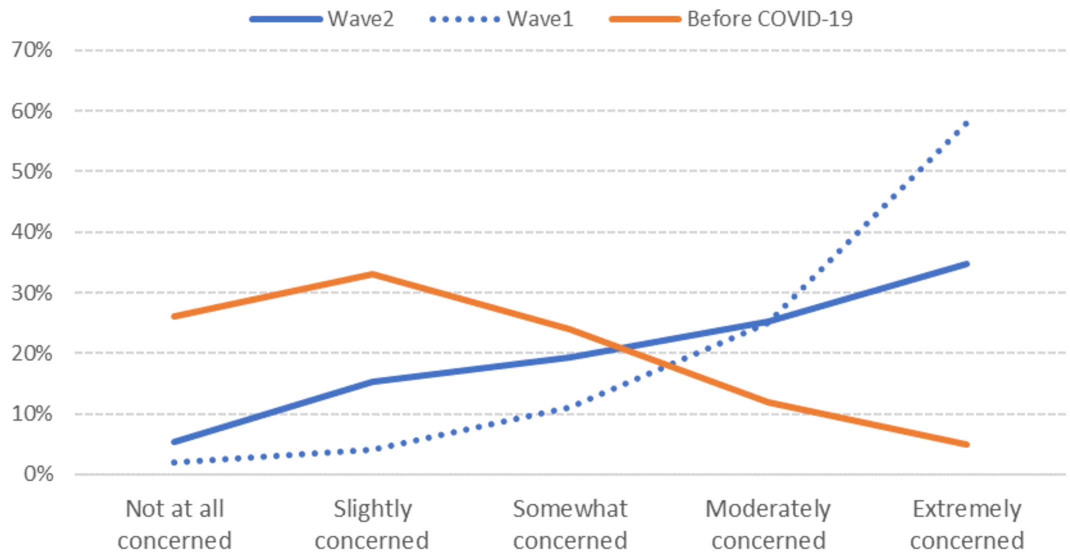

Figure 9: Concern About Public Transport

4.3 Work and Working from Home

4.3.1 Changes to Work and Work Location

The impact of COVID-19 on the nature and availability of work continues to be profound. The government regulations designed to limit the spread of COVID-19, while in the process of being eased, ripple through the economy, as shown in Figure 10a and 10b. Only 37% of sample have not been impacted by government regulations, just over a quarter have been personally impacted, one in five (18%) also report someone in their household having been impacted and one-third know someone whose employment has been impacted as a result of the restrictions. Those in the younger age group are more likely to have been personally impacted (43%) and/or have a household member who has been impacted (23%). Respondents were also asked if their pay had been impacted by COVID-19 measures and while the impact here is lesser than that on employment (two-thirds have not been impacted), a number of respondents are working for less income than prior to COVID-19.[48]

[48] In both waves, with the exception of "Not Impacted", respondents were able to select more than one option.

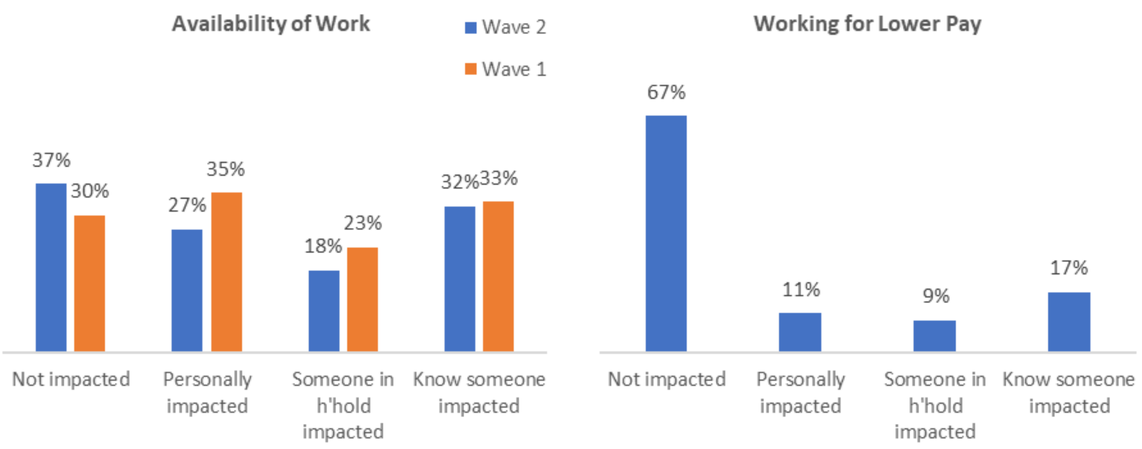

Figure 10a and 10b: Impact of COVID-19 Restrictions on Work and Pay

Looking at the impact on households in more detail, Figure 11a and 11b show the number of household members (including the respondent) who were working fulltime and part-time before COVID-19 and during the Wave 2 data collection period. Note that while these figures are in aggregate and includes respondents who are unemployed, retired or home makers, the number of households who report zero household members in fulltime employment rises from 38% before COVID-19 to 47% in the Wave 2 data, an increase of approximately 25%. The impact on part-time employment thus far, has been less extreme.

In terms of the number of days worked over the last week among those who were working prior to COVID-19, the average number of days has increased from 3.0 days in Wave 1, to 3.4 days in Wave 2, but remains significantly less than the average of 4.3 days, before COVID-19. The number of people working zero days has fallen from 26% in Wave 1 to 17% in Wave 2. Males are working more days on average in Wave 2, and middle-aged respondents are working more on average than those in the younger age group. With respect to working from home, levels still remain well above those prior to COVID-19 (μ = 1.8 days), with respondents spending an average of 3.0 days working from home per week., however this number is down from the Wave 1 average of 3.3 days.

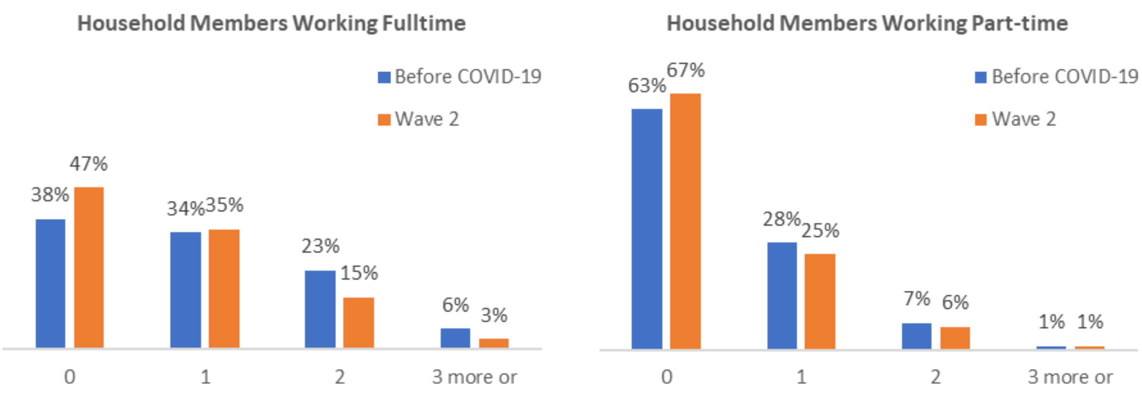

Figure 11a and 11b: Impact of COVID-19 on Household Employment

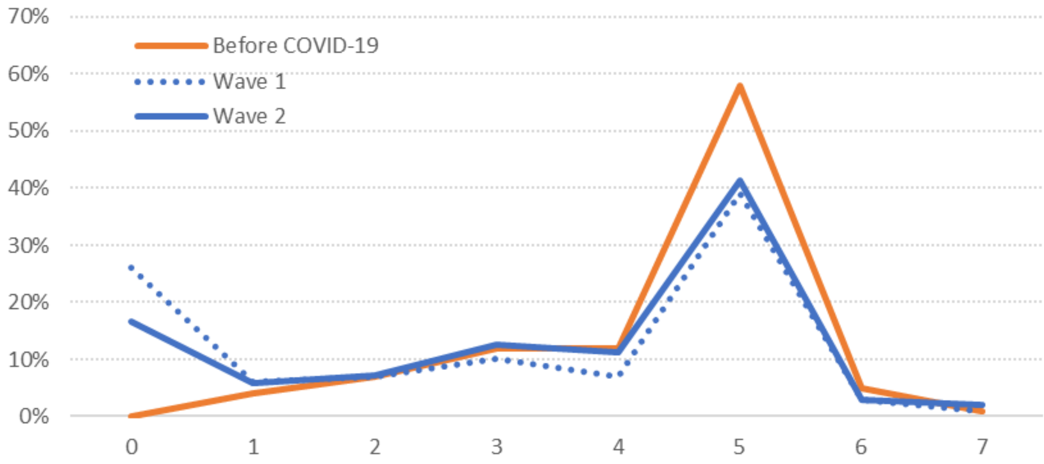

Figure 12: Number of Days Worked in Last Week

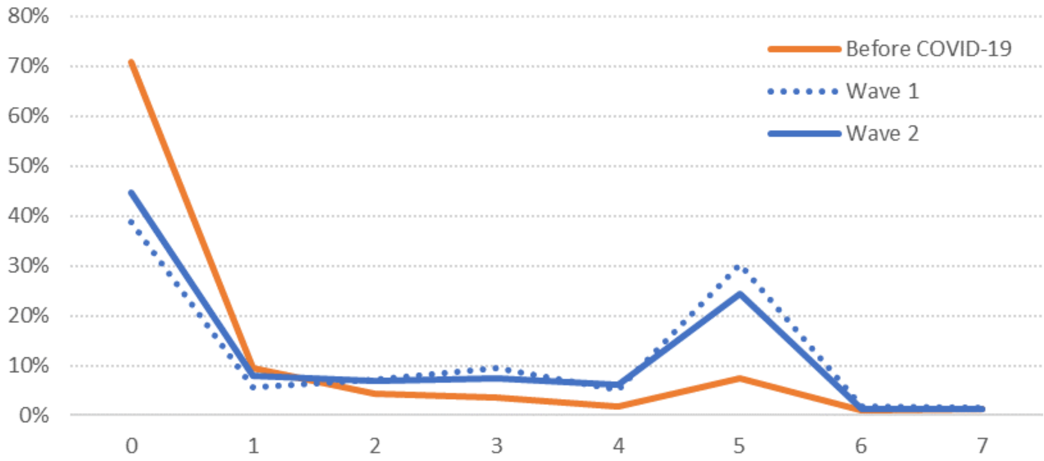

Figure 13: Number of Days Worked from Home Last Week

Respondents were further asked to nominate the type of environment they normally work in, the results of which are shown in Figure 14. The “Other” category predominantly includes those who work from home, out of vehicle, or in hospitals or schools. Females are more likely to work in open plan or shared space offices (32% vs. 23%) and retail environments (14% vs. 9%), whereas males are more likely to have their own office (28% vs. 19%). Younger respondents are less likely to have their own office (19%) and more likely to work in retail environments (19%). Lower income groups are more likely to work in retail environments, indoor spaces with small teams, or outdoor spaces with small teams and less likely to work in open plan offices. As income increases, respondents are more likely to have their own office.

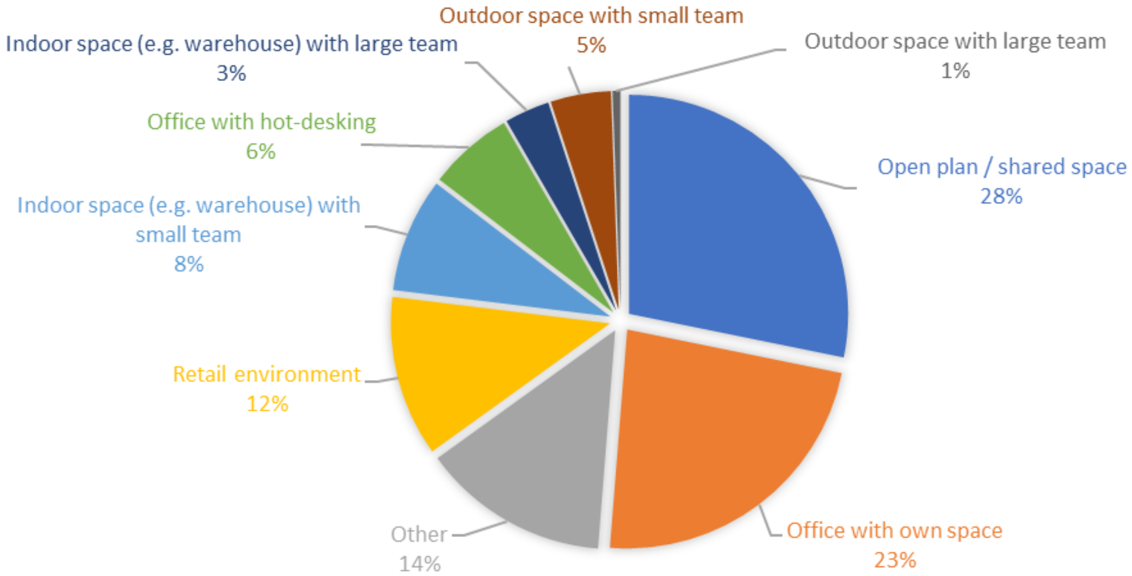

Figure 14: Type of Physical Work Environment

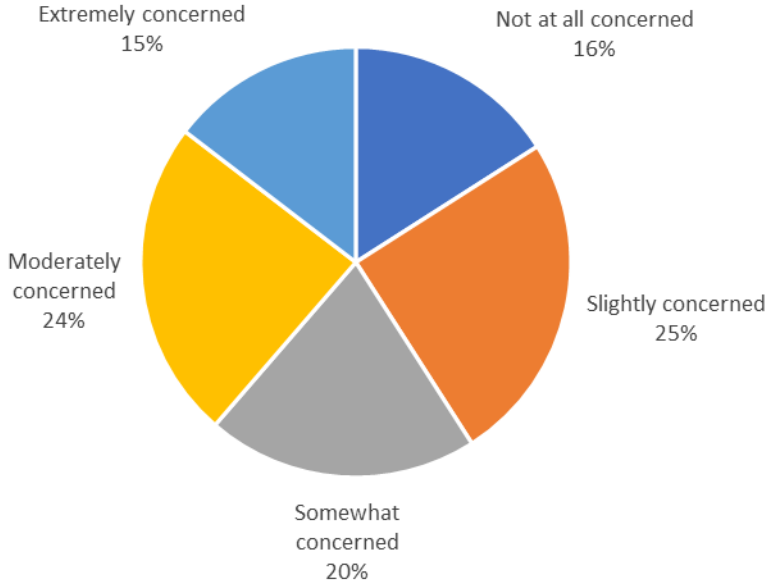

Figure 15: Concern about COVID-19 Given Work Environment

Respondents were also asked to state their level of concern about COVID-19 given the nature of the environment in which they worked. While the average is at the middle point of the scale ($\mu = 3.0$ $\sigma = 1.3$), Figure 15 shows a wide variety of views with approximately the same number of respondents exhibiting either no or slight concern as showing moderate or extreme concern; females are significantly more concerned on average.

4.3.2 Examining the Work from Home Experience

Following the noted increase in working from home observed in Wave 1, Wave 2 attempted to explore the experiences with working from home in more detail (introducing new questions) to better understand the scope of experiences, given that for many there was little time to prepare and while it may work well for some, others face barriers such as children, other household members working from home, inadequate space for working from home, and so on.

With respect to the ability of a respondent to work from home, Figure 16 shows a decrease in the number of respondents whose work cannot be done from home, but an increase in the number whose work place has no plans for working from home and, unfortunately those whose work place has closed. We also observe a reduction in the number of employees who are directed to work from home, perhaps reflecting the erosion in the average number of days worked from home in the last week, discussed in the previous section.

Males are more likely to be employed in workplaces that have no current plans to allow working from home, and females more likely to be in workplaces that are now closed. Respondents in the younger age category are more likely to be employed in a position where work cannot be completed from home. Lower income groups are more likely to be in workplaces that have no plans to allow work from home, or whose workplace has closed. As income increases, it is more likely that a respondent works in a position where they are being directed to work from home.

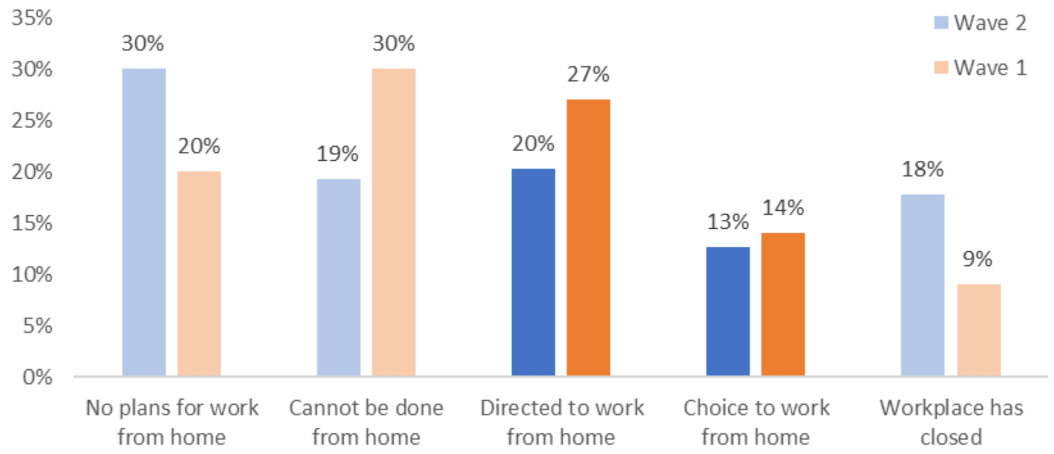

Figure 16: Ability to Work from Home

Respondents were also asked how many hours of work they feel they can complete when working from home. As displayed in Figure 17, 60% of the sample complete somewhere between 5 to 8 hours of work, with an approximate average of 6.2 hours. Those on higher incomes are more likely to report a higher number of hours worked per day, when working from home. Respondents were also asked to assess their level of productivity when working from home, and the sample average of 3.1 ($\sigma = 1.1$) indicates that in aggregate those working from home perceive little difference in productivity. Indeed, almost double the number of respondents find working from home to be a lot more productive (12%) than a lot less (7%). Middle-aged respondents and those on higher incomes report high levels of productivity, on average.

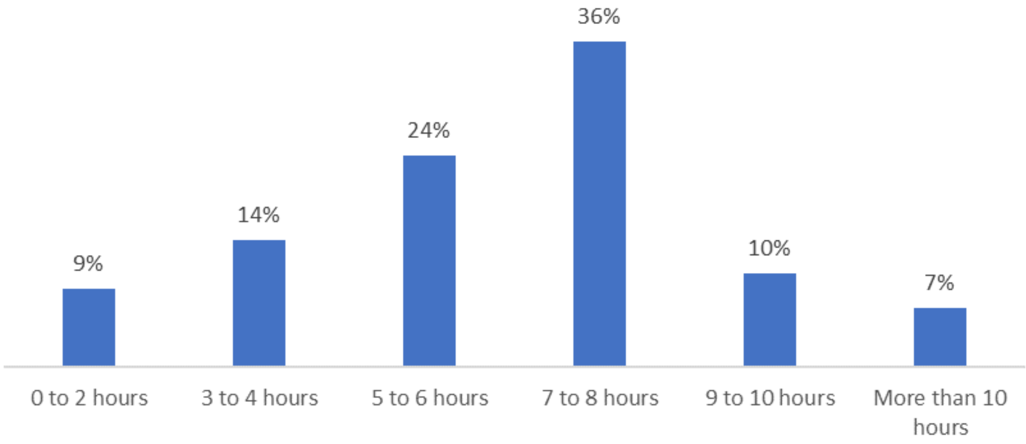

Figure 17: Hours of Work Completed when Working from Home

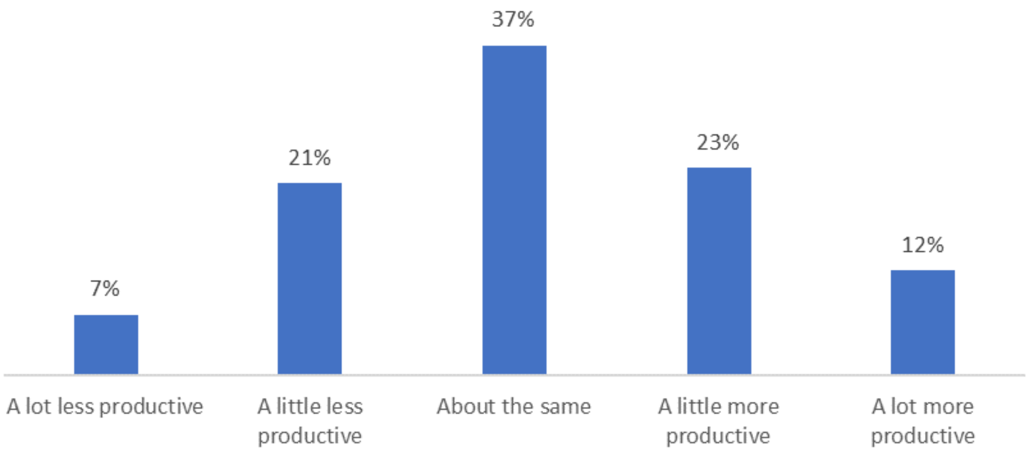

Figure 18: Productivity when Working from Home Compared to Usual (Pre-COVID-19)

To understand the positive and negatives of working from home, and thus obtain insight into what measures may be needed as restrictions ease in order to maintain current levels of work from home, respondents were asked to rank the benefits and challenges that they experience when doing so. The results of this task are presented in Figure 19. With respect to the benefits, the highest ranked benefit is not having to commute followed by the creation of a more flexible work schedule. Males are more likely to rank flexible work schedule as the biggest benefit as are those in the younger age bracket. Older respondents are less likely to rank no commute as the biggest benefit than other age groups. With respect to the challenges of working from home, the disruption from family and children is the one most often ranked highest, but overall the ability to concentrate on work is perhaps the challenge faced by most (with the exception of older respondents who are less likely to rank this challenge as the biggest or second biggest relative to other age groups).

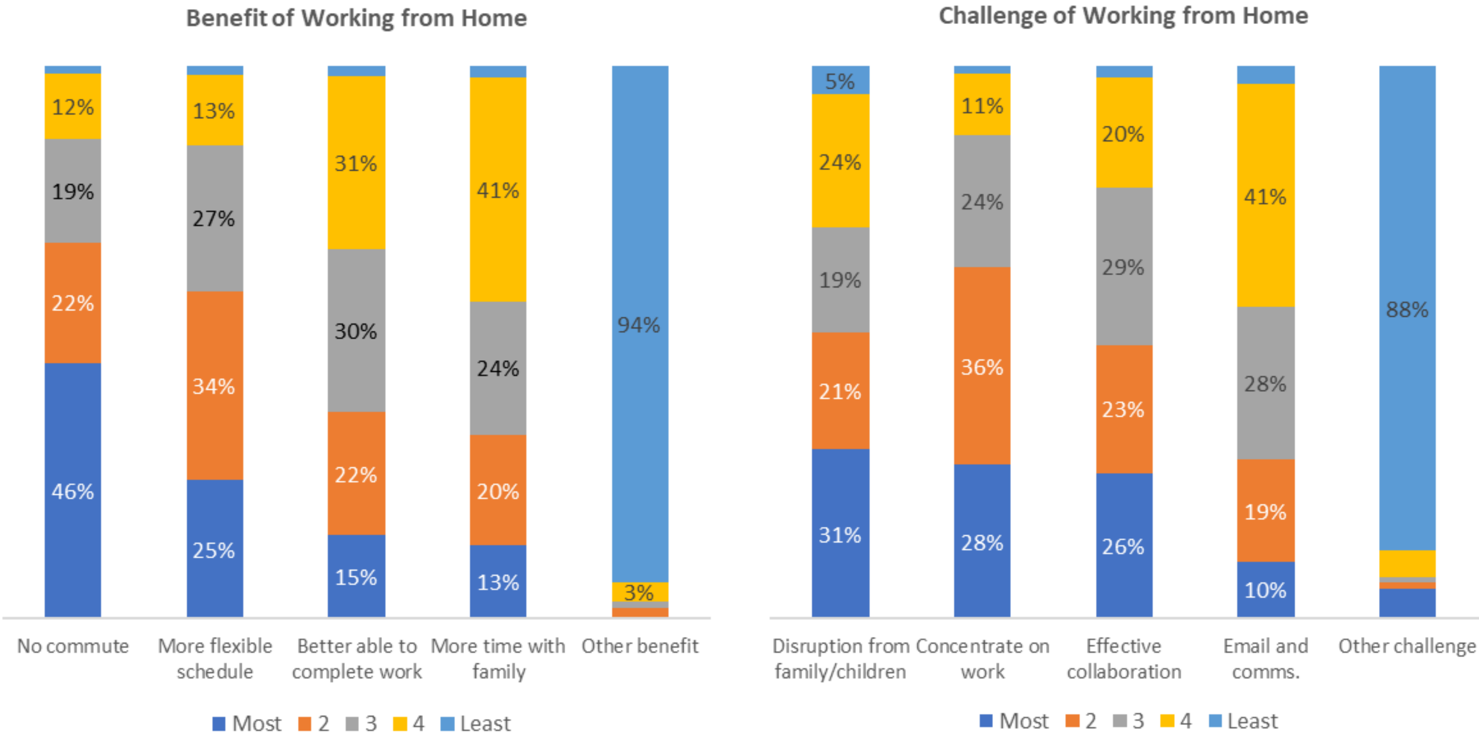

Figure 19: Benefits and Challenges of Working from Home

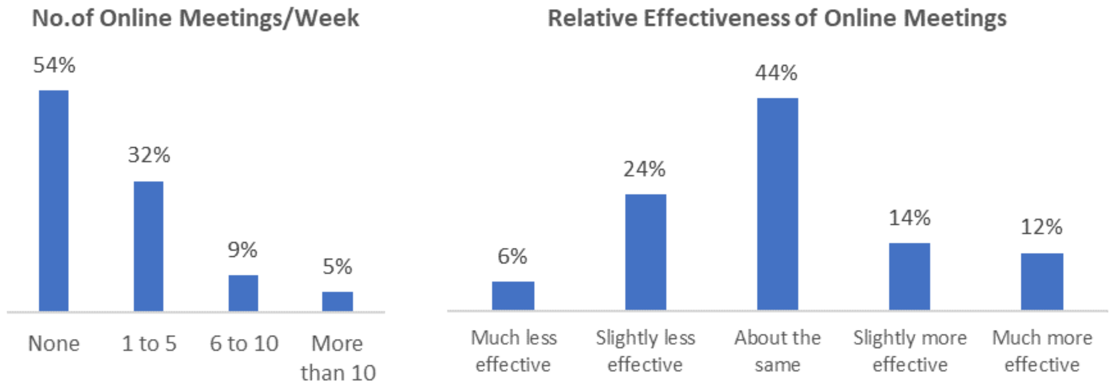

Figure 20: Online Meetings and Relative Effectiveness

Additional questions were asked about the number of online meetings that are had and their relative effectiveness, the results of which are shown in Figure 20. While many respondents do not have online meetings over the course of working from home (54%), among those that do the most common frequency is 1 to 5 per week. In terms of how productive the meetings are, in aggregate it appears that respondents find online meetings just as productive as face-to-face meetings, with those in the middle age reporting a significantly higher average productivity than other age categories. It should also be noted that there is no correlation between the number of online meetings a respondent has per week and their rating of the relative productivity of those online meetings.

Given the benefits and challenges experienced over the previous 2-3 months of working from home as a result of COVID-19, respondents were asked how much they agreed or disagreed with a series of statements related to working from home and more flexible work, the results of which are displayed in Figure 21. Overall agreement is similar across all statements, but there is more agreement (agree and strongly agree) that the appropriate balance between work and not working can be found, and that the space at home is appropriate for work. Older respondents and higher income categories are more likely to agree that they have an appropriate space at home from which to work, and older respondents also are more likely to be able to find the balance between paid and unpaid work. Higher and middle-income groups agree more so than low income groups that more flexible work schedules would be preferred in the future.

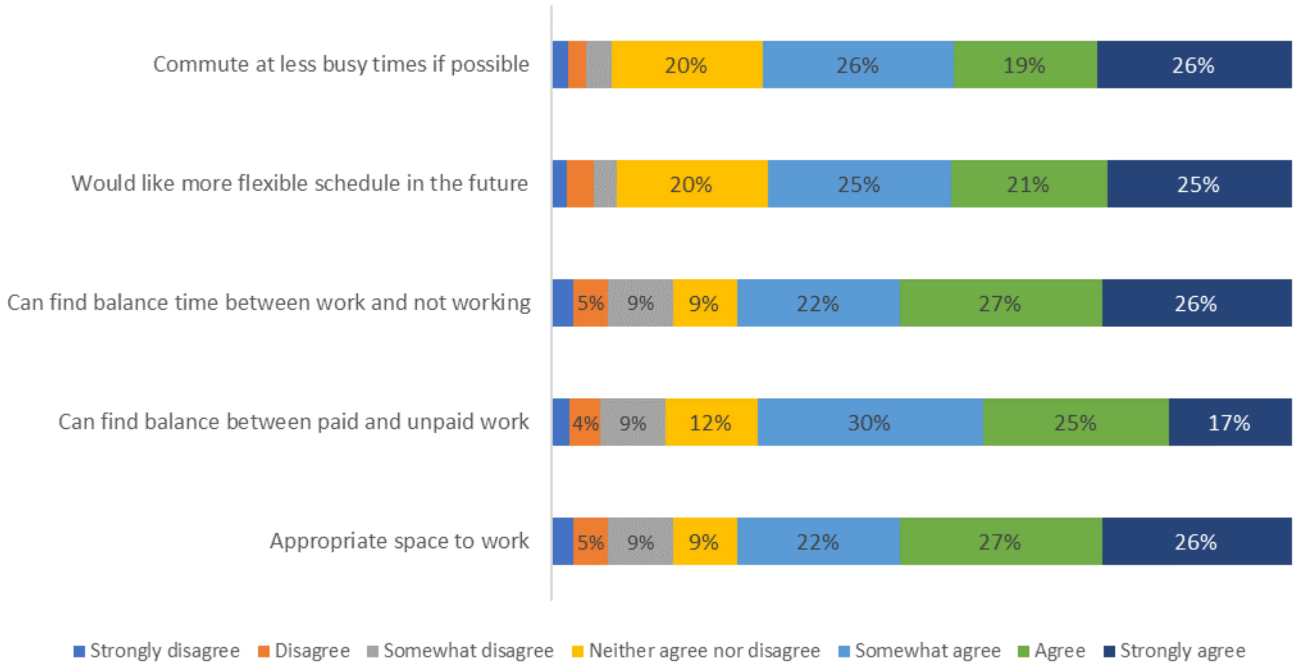

Figure 21: Attitudes about Work from Home and Flexible Work

To gauge the likelihood of working from home being a larger part of the transport mix moving forward, the final question in this set asked respondents whether working from home had been a positive experience for them. As seen in Figure 22, overwhelmingly the experience has been positive with almost half the sample agreeing or strongly agreeing that this is the case, with 71% of agreement overall. As the work from home experience becomes more embedded and new routines are formed, it is also likely that the experience will improve. Interestingly, females report a significantly higher average level of agreement, as do those on higher incomes. Younger respondents report significantly less positive experience than other age categories.

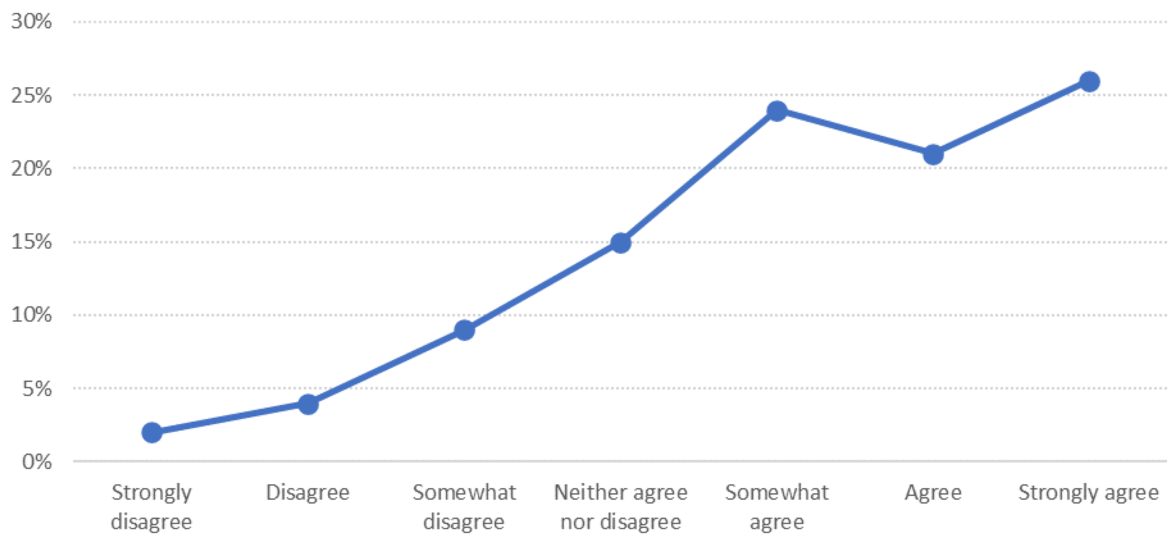

Figure 22: Work from Home has been a Positive Experience

4.3.3 Exploring the Future of Work from Home

To build further on the likelihood of travel and commuting being disrupted by an increased take up of working from home, a series of questions about work in the future were asked. Figure 23 shows the number of days respondents would like to work moving forward as restrictions ease. Interestingly the number of days worked moving forward, while higher than now, is less than the level of employment prior to COVID-19. This may be a function of people overall wanting to work less, but also being somewhat tentative when thinking about how much work might be available as we move forward. The average number of days is invariant across gender, age, and incomes.

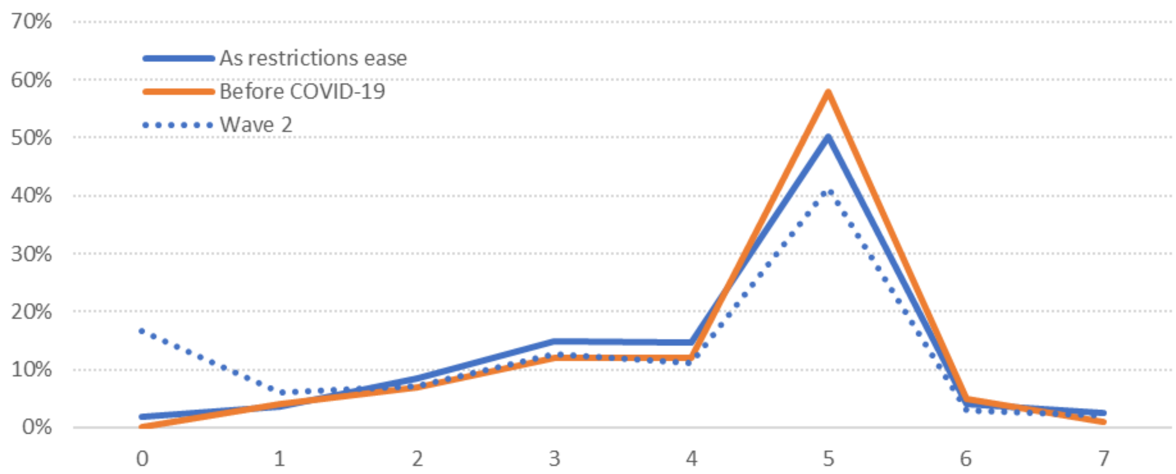

Figure 23: Days Wanting to Work

The future of working from home, shown in Figure 24, follows a similar pattern to the numbers of days worked: the levels of working from home are lower than they are now, but respondents would like to work from home more than they did before COVID-19. Younger and middle-age respondents would, on average, like to work more days from home as restrictions ease, than older respondents.

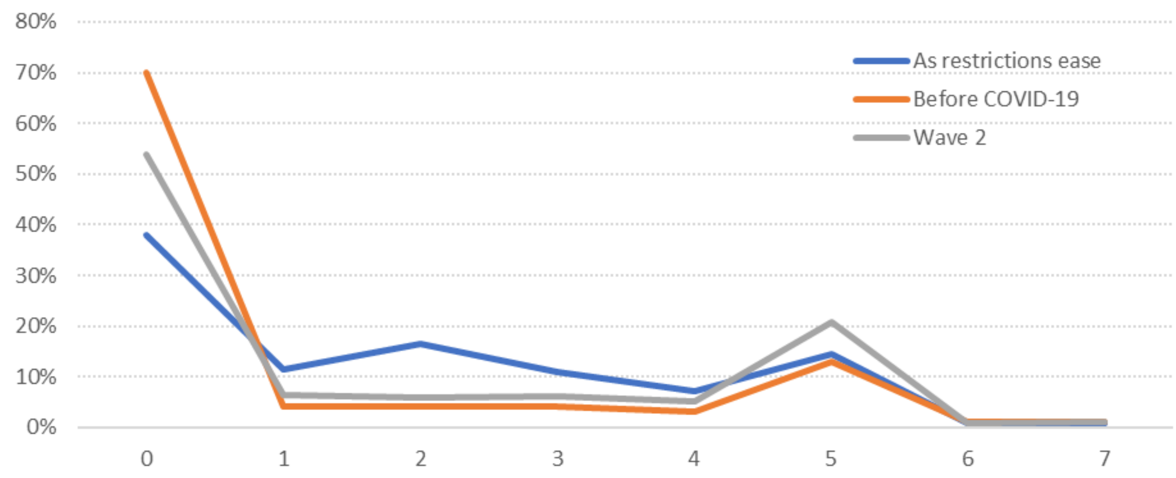

Figure 24: Days Wanting to Work from Home

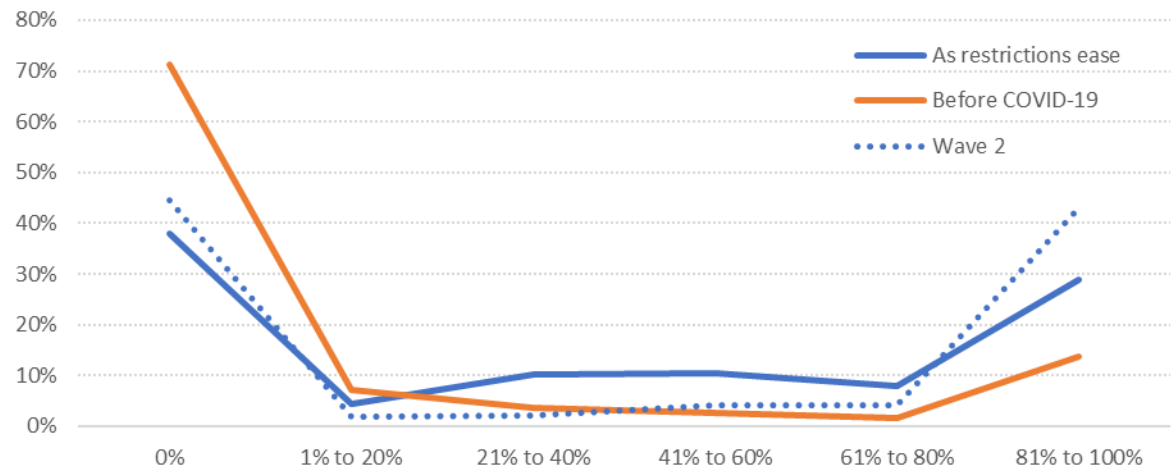

Figure 25: Days Wanting to Work from Home as Proportion of Days Worked

To accommodate the different number of days worked by respondents, the number of days worked from home was converted to a proportion of the total number of days worked and is shown in Figure 25. What is revealed in this graph is the interesting finding that right now, working from home is an all or nothing proposition, with the numbers working 1% to 80% of their days at home being very small, and the number working 80% of more having spiked to 45% during Wave 2. However, as restrictions ease, we see a desire for the extreme levels of work from home to decrease, but a small albeit sustained rise in the number seeking to work somewhere between 20% to 80% from home. Interestingly, there is a significant positive correlation between the proportion of time spent working from home now and the proportion of time someone would like to work from home in the future.

An important component of increased work from home into the future is the ongoing support of companies and employers. As shown in Figure 26, overall, there is an even split between workplaces that have had conversations about working from home and those that have not, which holds across employees, managers and employers.

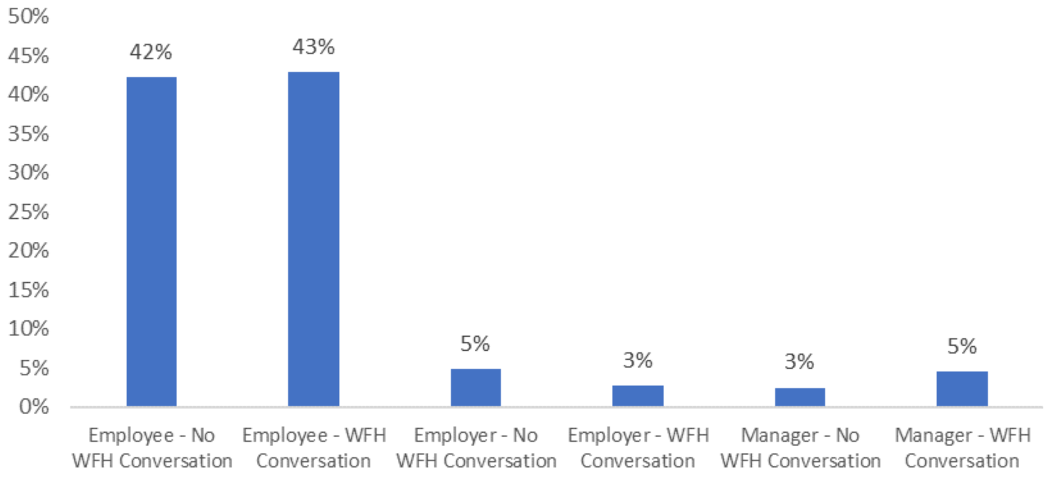

Figure 26: Workplace Conversations about Working from Home (WFH)

Figure 27 shows the perspective of employees about how they think their employer might support working from home. Respondents who are managers are asked what they think the position of the company might be as well, and both managers and employers are asked to provide their personal view on what would be appropriate. The differences observed in the position that work cannot be done from home is likely a function of the nature of the industry employees versus employers are in, but also that managers and employers are able to take a more overarching view of the work done in the company rather than an individual function which would be the focus of the employee. Nonetheless, support for some balance between working from home and the office is markedly higher among managers and employers than employees themselves.

Older employees are less likely to state that their employer would prefer a return to the office, middle-aged employers are less likely to be in roles where work cannot be completed from home and are more likely to state that their employer would support work from home as often as desired and that a balance would be support, relative to other age groups. In terms of the personal views of the employer or manager, as income increases there is a lower likelihood of stating the work of employers cannot be done at home; those on higher incomes are more likely to support working from home as often as desired and along with those on middle incomes, also support the balance of working from home and the office. It should be noted the majority of managers can either approve both the ability to work from home and the number of days (41%); or approve working from home but not the number of days (45%).

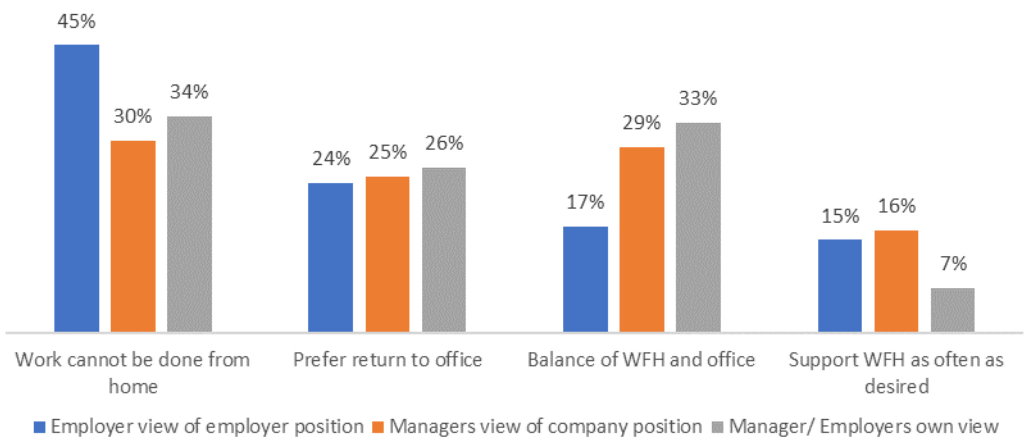

Figure 27: Support for Work from Home (WFH)

Managers and employers were also asked what number of days they felt was appropriate for an employee to work from home and why. Figure 28 shows the diversity of opinion surrounding the number of days, either at the extreme of no work (zero days = 20%) or all work (five or more days = 23%) being done from home, or some balance around two to three days. When asked to explain the reason for the number of days given, those arguing for high levels of work from home did so because it works, it minimises office space or they believe staff like it. Those advocating for a balance tended to cite reasons around maintaining collegiality, keeping connections, generating value through interaction, the need for face-to-face meetings, and mentoring.

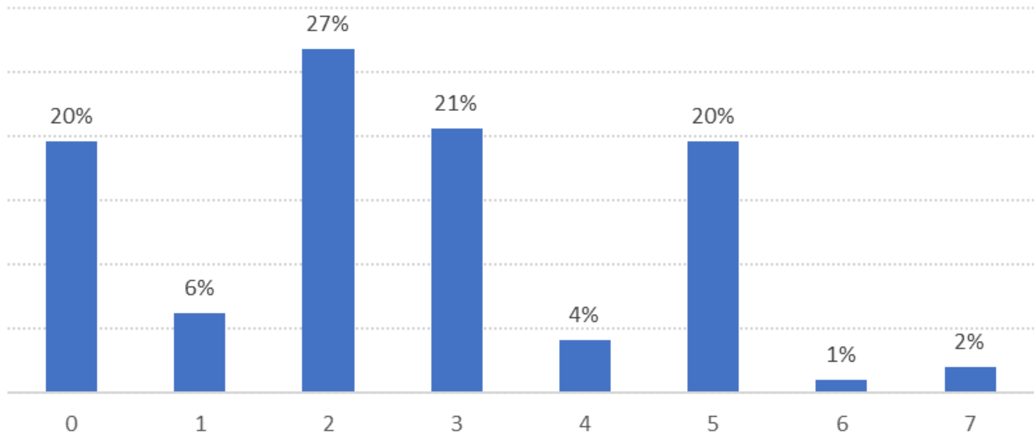

Figure 28: Appropriate Number of Days for Staff to Work from Home

Lastly, in exploring working from home, managers and employers were asked to rate the productivity of staff whilst working from home. Additionally, employees were also asked to give their perspective on the productivity of other staff for comparative purposes. Plotted on Figure 29 are the result of this question, as well as the measure of productivity respondents gave *themselves*. The general pattern of productivity scores is generally similar across three measures, but interestingly employees assign a significantly lower average score to other staff than they assign themselves. Though this is the only difference on average, managers and employers are more inclined to believe that productivity is about the same than either employees, and the rating respondents give themselves, but respondents also rate their own productivity marginally higher than their employer or other employees might. Overall, the results indicate that importantly, the majority of employers and managers believe staff have been as productive working from home as they would be at the office, if not slightly more so.

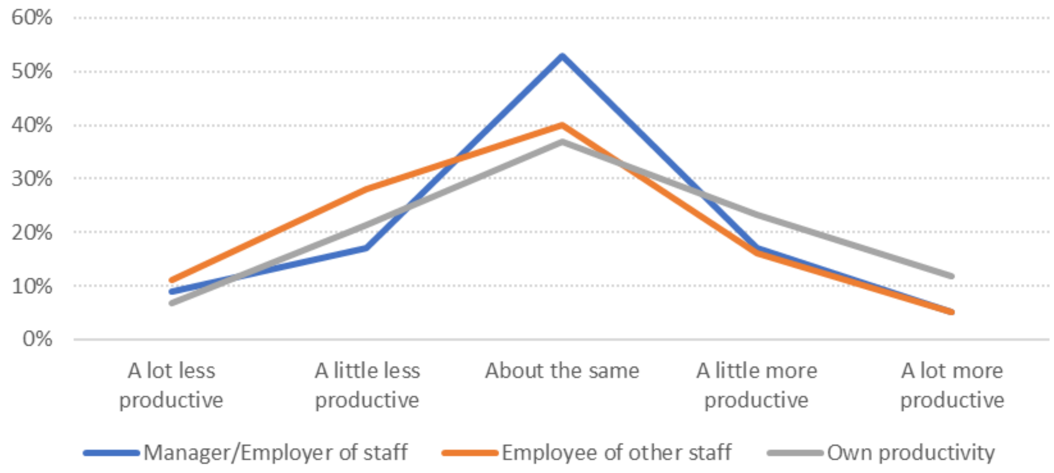

Figure 29: Productivity of Staff (and Others) while Working from Home

4.4 Occupation and Work from Home

Data was collected on employment as per the Australian and New Zealand Standard Classification of Occupations (ANZSCO), and there are significant variations in the workplace policy with regards to working from home, as can be seen in Figure 30. Machine operators and drivers, community and personal service workers and labourers work in places where there are either no plans to work from home, or occupations where the work cannot be done from home. On the other hand, a large number of managers and professionals are being given the choice to work from home or being directed to do so.

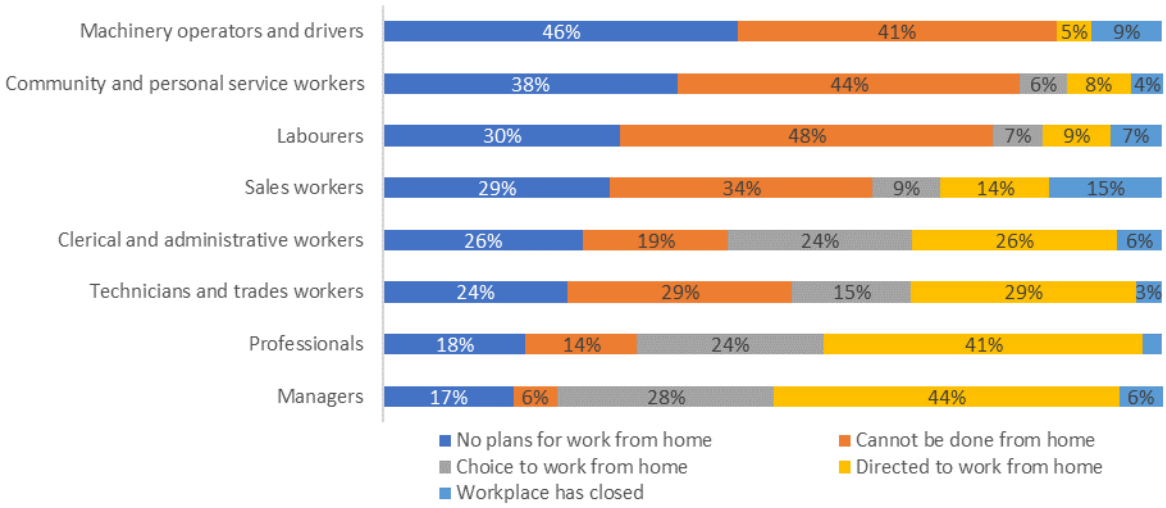

Figure 30: Workplace Policy for Work from Home by Occupation

The workplace policy clearly translates to differences in the incidence of working from home observed in the last week, as shown in Figure 31. Machine operators and drivers, community and personal service workers and labourers are less able to do work from work, whereas clerical workers, professionals and managers have a greater propensity to do so. While different occupations have differing ability to work from home, and thus different preferences with regard to how many days they would like to work from home moving forward (Figure 32), it is interesting to also note that in every occupation there are some respondents who like to do some of their jobs from home. Given this desire, it might be possible for employers to work together with employees to apportion some work to be done at home where feasible.

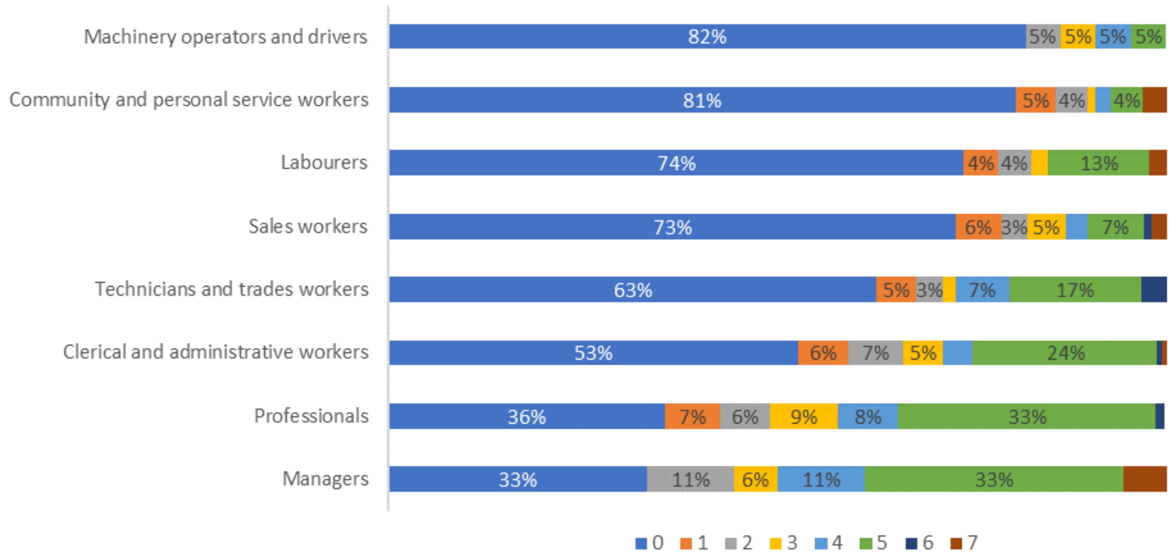

Figure 31: Number of Days Worked from Home in Last Week by Occupation

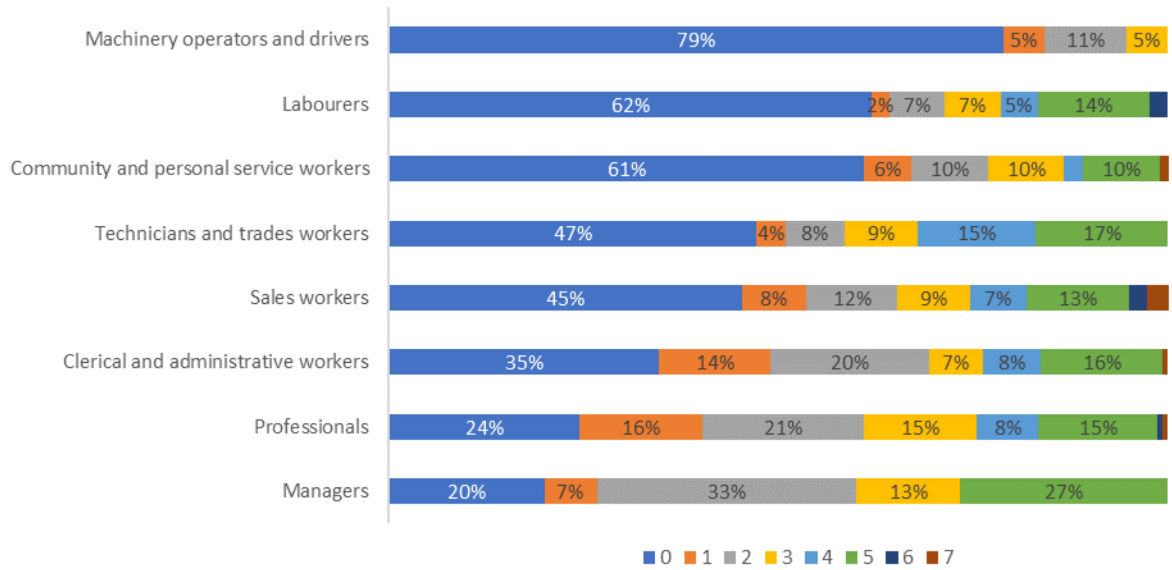

Figure 32: Number of Days Like to Work from Home in the Future by Occupation

Similar patterns also emerge based on the type of work environment, with the work place policy differing (see Figure 33), the number of days worked from home in aggregate differing (Figure 34), and the number of days respondents would like to work from home moving forward also differing by work environment (Figure 35). Again, while some employees may like to work from home, it may not be feasible, but where some component of the work could be done from home for some respondents, employers could think innovatively about how they assign work and the location in which that work is done.

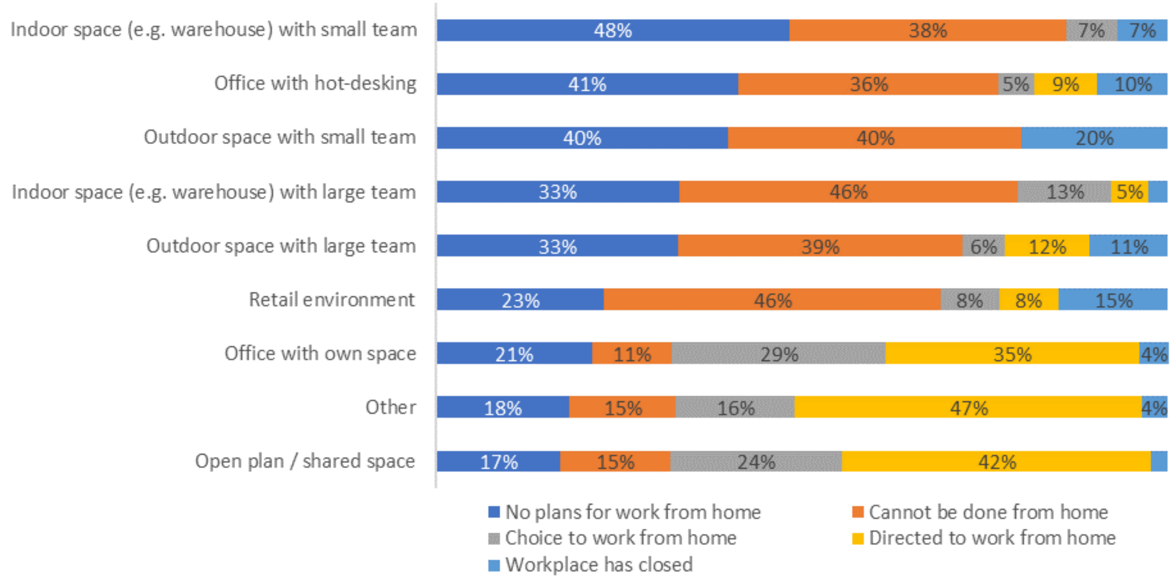

Figure 33: Workplace Policy for Work from Home by Work Environment

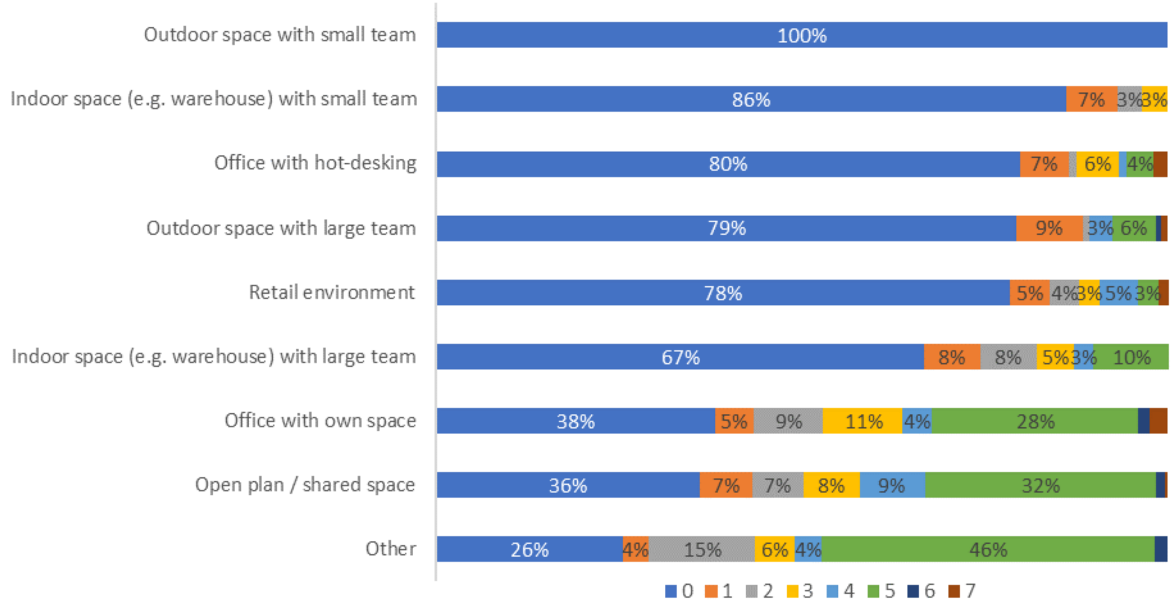

Figure 34: Number of Days Worked from Home in Last Week by Work Environment

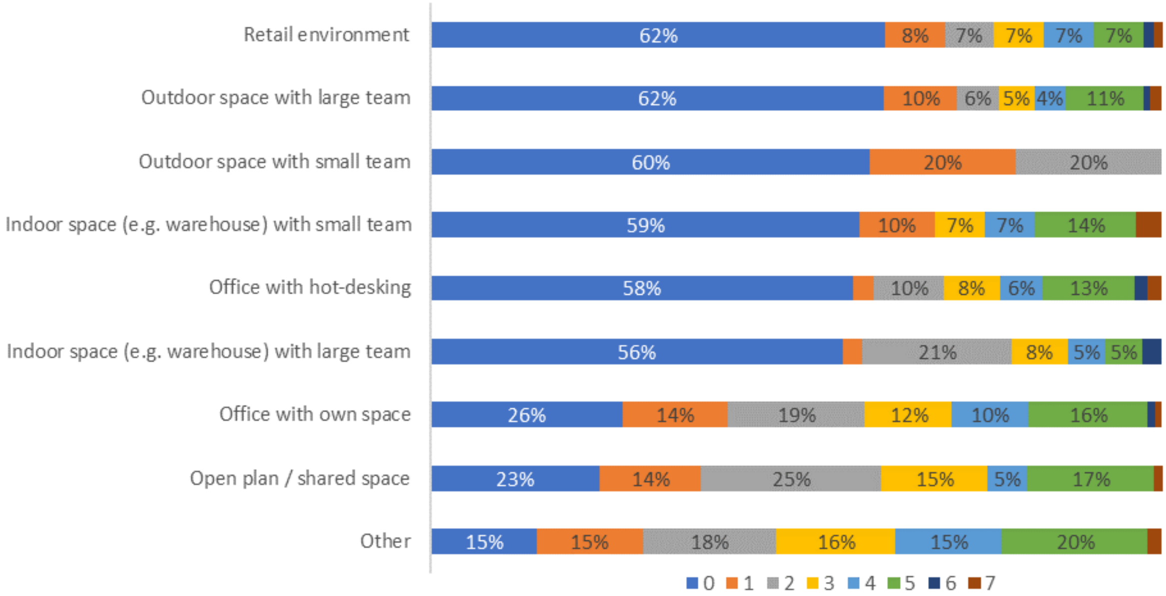

Figure 35: Number of Days Like to Work from Home in the Future by Work Environment

4.5 COVIDSafe – Track and Trace Application

Though not directly related to travel or activity, the Australian government has developed the COVIDSafe track and tracing mobile application, designed to identify and contact people who may have been exposed to COVID-19. The application uses Bluetooth to look for other devices that have the app installed. It takes a note of a contact when it occurs, through a digital handshake. If a person tests positive for COVID-19, a state or territory health official will ask that individual (or parent, guardian, or carer) to consent to uploading the digital handshake information. This type of application is not too dissimilar to GPS tracking applications widely used in travel behaviour research. The survey asked respondents if they had downloaded the application, and the results are shown in Figure 36.

As can be seen, while 41% of the sample are using the application, more than half have not downloaded, or are not using it. Owners of Apple[49] mobiles are more likely to be using (47%) it than those who own android based phones (38%), younger respondents are less likely to be using it (34%), compared to those in the middle-age category (40%) who in turn are less likely to be using it than older respondents (45% have downloaded and are using). Lower income groups are more likely to have not downloaded the application (52%), compared to middle (42%) and higher income groups (35% have not downloaded it).

[49] 53% of the sample own an android based mobile phone, 43% own an Apple. Apple ownership is more likely among those in the younger age category (60%) than middle-aged (47%) or older respondents (37%). Apple ownership is higher in the highest (63%) and middle (58%) income brackets than those on lower incomes (35%).

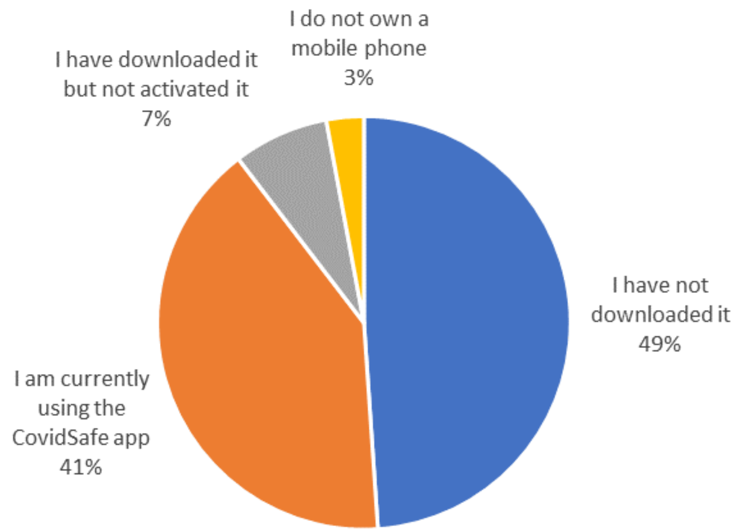

Figure 36: Use of COVIDSafe Track and Trace Application

In terms of reasons given for not downloading the application (Figure 37, the leading reason is that respondents don't trust the government to protect the data (less prevalent among older respondents), and don't want to be tracked in this way (particularly true for middle aged respondents).

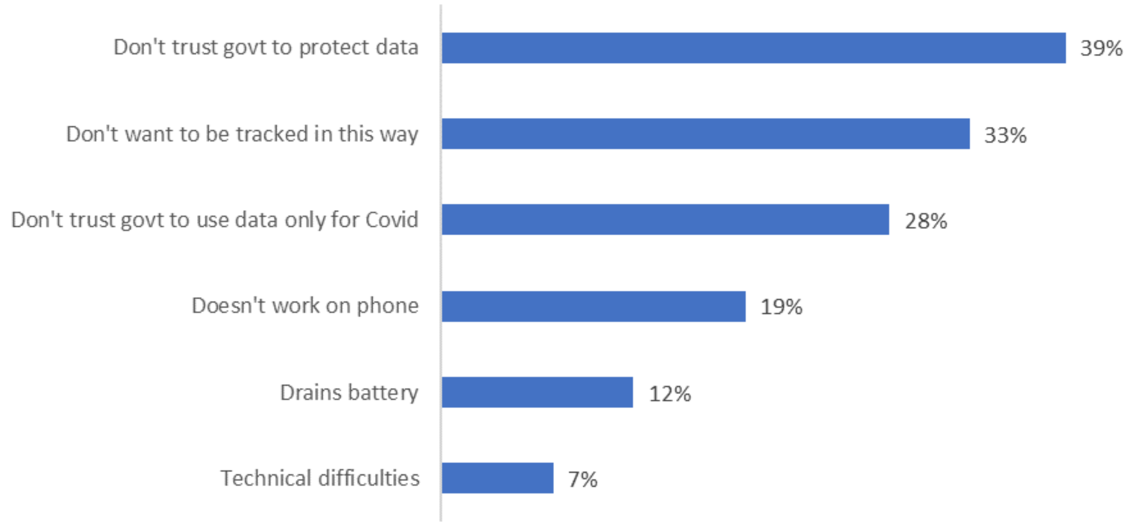

Figure 37: Reasons for Not Using COVIDSafe

4.6 Level of Comfort in Completing Activities

As talk turned towards the easing of restrictions, one moderating factor on the propensity for respondents to begin to vary their travel behaviour would be how confident they would feel engaging in different types of activities. To that end, respondents were asked given the current conditions, how comfortable (1 = very uncomfortable to 7 = very comfortable) would they feel about completing each of the activities shown in Figure 38 (error bars reflect the 95% confidence interval). The darker bars represent an activity which a higher proportion of respondents stated was a regular activity interrupted by COVID-19 (Beck and Hensher 2020).

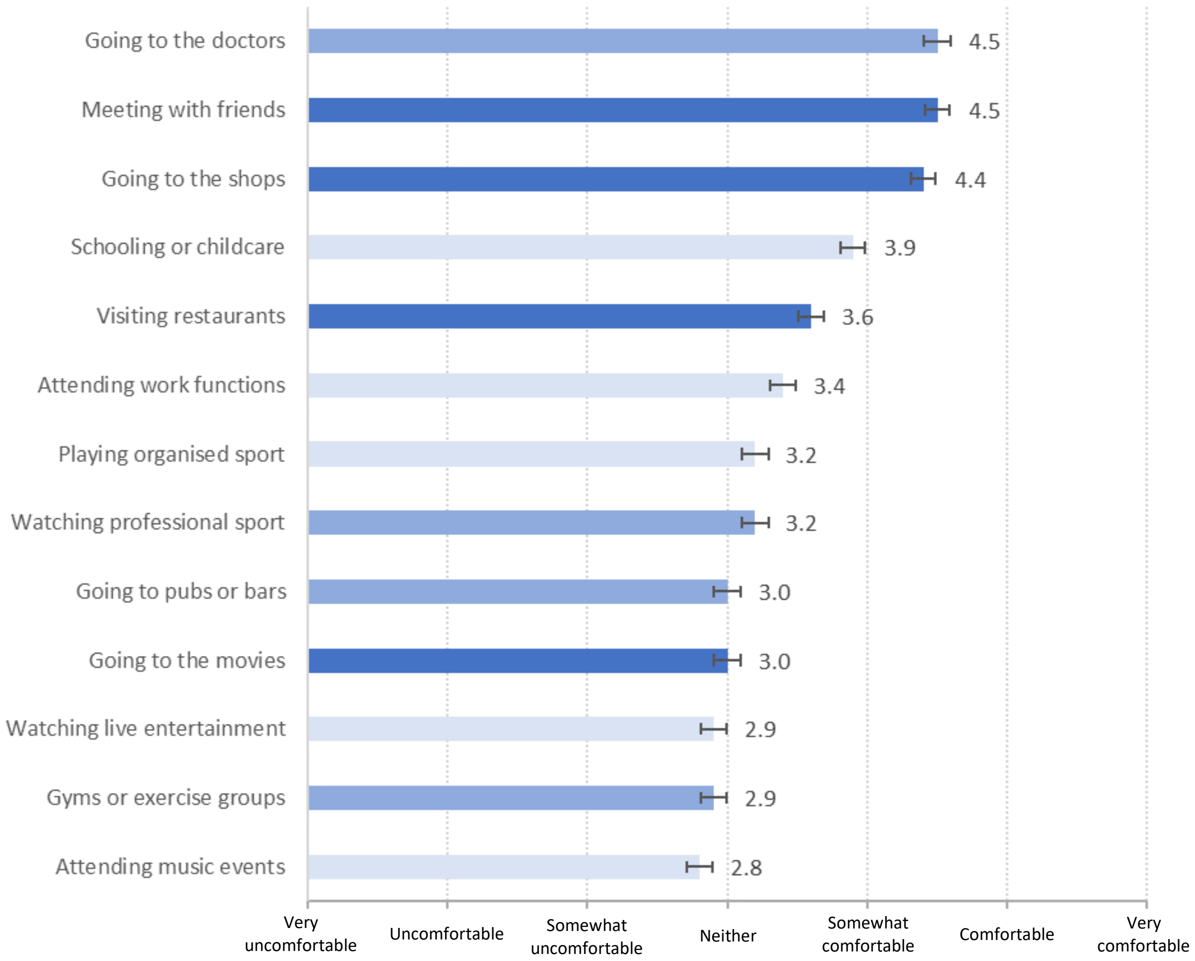

Figure 38: Level of Comfort in Completing Different Activities

Going to the doctors, meeting with friends, and going to the shops are the three activities that respondents feel significantly more comfortable in completing, followed by schooling or childcare activities, in turn followed by visiting restaurants. The level of comfort for the remained activities sit largely at the neutral point, with attending music events and gyms being the activities respondents would feel least comfortable completing.

Overall men generally exhibit a higher degree of confidence, being significantly more comfortable with going to the doctors, going to shops, visiting restaurants, attending work functions, playing organised sport, watching professional sport, going to pubs or bars, watching live entertainment, gyms or exercise groups, and attending music events. Middle income groups are more comfortable going to the doctor. Older respondents are more comfortable going to the shops than other age groups, but less comfortable visiting restaurants, going to the movies, going to pubs or bars, gyms or exercise groups, going to doctors, watching professional sport, attending music events, watching live entertainment, schooling or childcare, playing organised sport, and attending work functions. Younger respondents are more comfortable than other age groups with respect to going to pubs or bars, gyms, or exercise groups, watching professional sport, attending music events, and watching live entertainment.

4.7 Attitudes towards COVID-19 and Government Response

The attitudes of respondents towards COVID-19 and responses by government, business and the general public were re-examined, with respondents again showing significant agreement

(1 = strongly disagree to 5 = strongly agree) with all statements listed in Figure 39, with the exception of the idea of going to work from time to time to avoid social isolation. On average, there is significantly more agreement with the statements that COVID-19 is a serious public health concern that requires drastic measures and will affect travel. Trust in the response of government both now and in the future remains significant[50].

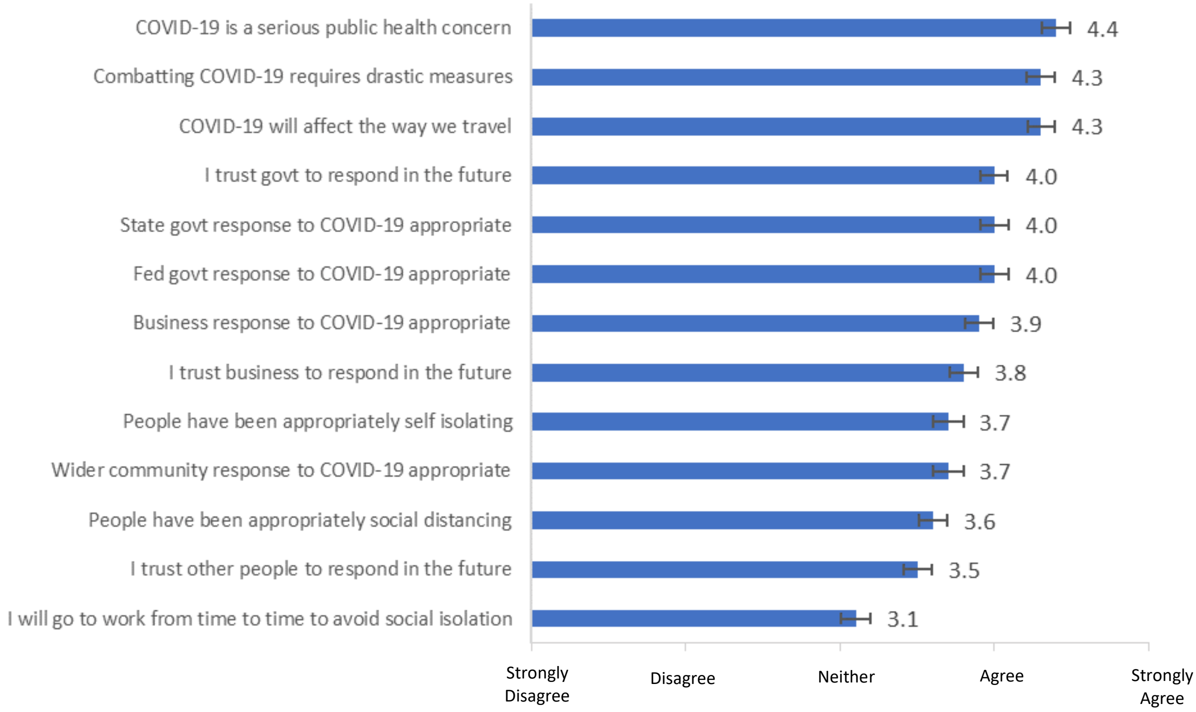

Figure 39: Level of Agreement with Statements regarding COVID-19

Overall, the results mirror those from Wave 1, with a small erosion in the number of people who agree that people can be trusted to respond in the future (overall agreement falling from 66% to 60%), and a large fall in the number who agree that they will go to work from time to time to avoid social isolation (falling from 50% in Wave 1 to 37% overall agreement in Wave 2). Females exhibit significantly higher agreement that COVID-19 is a serious public health concern, that it requires drastic measures, that the state government response has been appropriate, and that business can be trusted to respond in the future. Older respondents agree with all statements significantly more so than younger respondents.

Respondents were also asked their perception of the risk COVID-19 presented to health and the economy (see Figure 40). The pattern is identical to Wave 1, in that agreement is significantly stronger for the statement that COVID-19 is a risk to the economy, followed by a risk to someone known to the respondent, a risk to the general public and lastly a risk to themselves. While this pattern is the same, the average strength of agreement is significantly lower for each statement in Wave 2 than it was in Wave 1.

[50] The questions regarding attitude towards government actions being appropriate and trust in their actions in the future are generic, and not attached to the easing or tightening of restrictions at any point in time, rather the overall appropriateness as felt by the respondent.

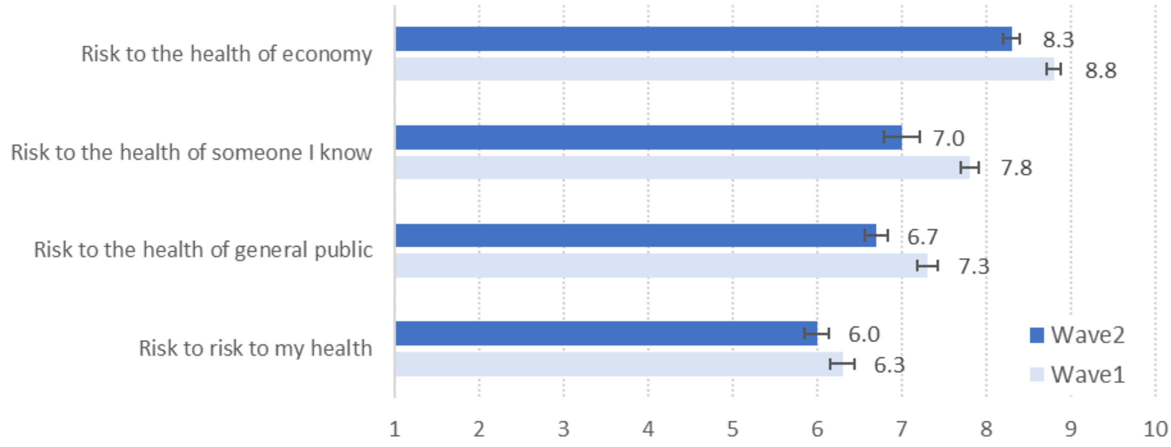

Figure 40: Risk of COVID-19 to Human and Economic Health

As with Wave 1, in Wave 2 females agree significantly more strongly that COVID-19 is a risk to the general public and someone they know, but in Wave 2 females now agree more strongly than men that COVID-19 is a risk to their own health. Lower income groups exhibit significantly less agreement with the risk of COVID-19 to themselves, than those respondents who are in middle or higher-income brackets. With respect to age, younger respondents have a significantly lower perception of the risk COVID-19 presents to their health, and respondents in the oldest age bracket view COVID-19 as a significantly higher risk to the economy than younger or middle-aged respondents.

5 Discussion and Policy Implications

5.1 Implications of Increased Travel

Overall, the results reflect what is happening in Australia as a period of low new COVID-19 cases grows, and restrictions around movement starts to ease. We see an uptake in private vehicle use, as anticipated and people are returning to public transport in a much more measured fashion. While concern about public transport hygiene has diminished, it remains significantly higher than prior to COVID-19. It is our suspicion that confidence might diminish again rather than continue to improve, as more transport users return to the system and individuals become more wary of crowding. It is even more essential that transport authorities continue with demonstrable efforts of cleaning and sanitation to assuage community concern, as before we continue to advocate that it may need to be a requirement to wear a mask while on mass transit to help protect against community transmission, but also make public transport a mode that is more appealing as the number of users start to increase.

In the Sydney context, transport authorities have used signs/stickers to indicate where people may sit on buses and trains to help enforce social distancing, but perhaps authorities should also (or instead) consider labels to indicate where passengers cannot sit or stand, as these stickers are more easily seen (i.e., are not covered by people sitting on them) and perhaps are a better visual or behaviour que that close physical proximity is still not allowed.

With regards to social distancing and travel activity, the data shows that travel for the purpose of social and recreational activities is returning more strongly than other activities, and that these were the activities most interrupted by COVID-19. People express comfort in meeting with friends and social activity is planned to return strongly. As restrictions are slowly rolled back, governments need to think carefully about how they allow the resumption of activities, which activities are indeed allowed, while messaging very strongly that the need for social distancing has not eased and that even close friends could be a source of transmission, or indeed you may be responsible for giving COVID-19 to those you are eager to reconnect with. Authorities need clear and concise messaging, consistently communicated and at most extreme even the adoption of a uniform campaign across the country, about the need to maintain social distancing and think carefully about the difference between essential and non-essential travel.

Lastly, we see some mobility differences across age groups, but also that younger respondents are more comfortable with more social activities than older respondents and exhibit a lower perception of the risk of COVID-19 to their own health. Efforts should be made to ensure that those who are in this age group are aware, not only of the risk posed to them, but to the wider community and potentially their loved ones, should they “lower their guard” with respect to appropriate social distancing and the new behaviours required during the pandemic.

5.2 Implications of Working from Home

Our research continues to explore the prevalence of and experiences with working from home. It is an important mechanism to alleviate the burden on the transport network in the form of increased potential congestion due to strong uptake of private motor vehicle and reduced capacity on transit systems due to physical distancing. Indeed, if positive experiences and lessons learnt can be carried forward into a post-pandemic world, it will likely be the largest tool in the transport tool kit to reduce persistent congestion.

The results herein suggest that the work from home experience is lumpy and more predominantly available to middle and high-income groups. We see that the extent of working from home remains well above the pre-COVID-19 levels, but the degree to which people work from home has diminished from the degree seen in Wave 1 following the initial imposition of restrictions.

Many respondents state that their work cannot be done from home, and while this may be true, there are many who have not yet had a conversation with their employer about the ability to work from home. Given the dividends to the transport network, more conversations about working from home, or the structuring of work so that some component can be completed from home should be encouraged by governments. There are dividends for employers in this regard as well. Many employees stated that they work in open plan offices that would still require appropriate social distancing measures, and environments with hard surfaces that would require regular cleaning. Working from home will enable this to be done more easily and more thoroughly, given that concern about returning to the work environment is split, with a lack of concern with work and trust in some colleagues being misplaced, making it early in the process of learning to live with COVID-19. Should a business become a hub of transmission, the consequences could be devastating.

Overall, for those engaged in working from home the experience has been largely positive, with employees and employers alike finding productivity to be more or less the same than if the work was completed in the more traditional arrangement. Indeed, our results suggest that it may be possible that employees are understating the degree to which their employer would support some work from home, with many employers suggesting that a balance between working from home and working at the office would be supported.

In terms of that experience, the biggest challenges have been interruptions from family and children, and an inability to concentrate on work. As restrictions ease, however, and children go back to school or families begin to resume normal routines, distractions in the home will likely diminish over time. Governments should look to support research into how the work from home experience can be improved, and business should look to guide staff in how to apportion focus and concentration over the course of a working day, and equally respect the boundaries between home and work.

The biggest benefits of working from home nominated by respondents, are not having to commute and the creation of a more flexible work schedule. These benefits are a positive for transport authorities seeking to solve a congestion problem or encourage peak spreading through the generation of flexible work, and indeed the implications on longer term investment priorities. In totality these are positive initial signs that working from home will be a bigger part of the mix moving forward, and as the work from home experience becomes more embedded and new routines are formed, it is also likely that the experience will improve.

5.3 Implications for Other Countries

While some countries have no overt national response to COVID-19, Australia has pursued a suppression strategy where activities deemed high risk have been curtailed, especially in the main environments that encouraged large groups of people together indoors (hotels, pubs, clubs, gyms, restaurants, religious gatherings), whereas other economies such as New Zealand have opted for elimination, with a large number of restrictions on travel and activity (for example, all schools were closed and all non-essential businesses, including large retailers, were shut, cafes and restaurants were shut and not allowed to provide takeaway). Initially the suppression strategy pursued by Australia was relatively successful in turning around the rate of new cases, and as a result the restrictions were slowly lifted, but in turn we have also seen a rise in the number of new cases.

Travel patterns are the key risk factor in the transmission of COVID-19; the virus can only move if people move. First and foremost, other countries need to eliminate movement in areas or groups where the risk of COVID-19 is high. In Australia, this was not done well enough in the context of hotel quarantine in Victoria, where the use of casually employed untrained security guards to ensure quarantine failed. It is also likely that these casual security guards, working many jobs not just in quarantine hotels, spread the disease across the city. The same issue occurred with aged care homes with rotated casual staff between sites. Jurisdictions will likely need to move swiftly to contain travel from COVID-19 hotspots and err on the side of caution in order avoid mass community transmissions.

It is also likely that, with media reports of the relative success of Australia in combatting COVID-19, risk perceptions dropped as seen in this research, and people who became excited about a return to interrupted social activities, may have been less cognisant of the behaviours that are no longer appropriate when combatting a pandemic. Indeed, pandemic response fatigue is also something that may occur in a longer attempt at suppression, and this might need to be weighed against the merit of short and sharper responses. More research is needed here, but other nations should resist the urge to lift any restrictions on movement and gatherings too soon.

With regards to working from home, Australia saw a rather swift and widespread adoption of working from home that has thus far persisted even as restrictions have eased. This has meant that traffic congestion and crowding on public transport has not been as bad as could have otherwise been the case. Government at all levels urged companies to support working from home wherever possible, and it seems that this has been supported by the majority of businesses. Other nations may be able to see that, while not perfect for all, working from home is a viable option and that generally staff have been just as productive at home as from the typical work environment. Much like argued in this paper for Australia, other countries should also see that support of and investment in work from home strategies is a significant investment in transportation and ultimately sustainability.

6 Limitations and Future Research

Clearly experiences with travel and work in the context of COVID-19 are still very much nascent stages and will be for some time. Behaviours and attitudes are still in a great state of flux and it would not be possible for research conducted now to be definitive about what the future might look like. However, insights are needed and research, while beginning to be available, remains limited. It is important that ongoing, timely and consistent research be conducted, and will be beneficial in helping to identify trends and potential for positive intervention before “bad habits” are formed. We will continue to track the changing nature of travel and activity in the Australian context. There is also great scope for work to bring together and synthesise the experiences that are being had around the world. Each jurisdiction will no doubt benefit from learning about the experiences of others.

Preliminary research by Currie et al. (2020) indicates that working from home may indeed be the only long term change that will emerge post pandemic (though the study also acknowledges that findings are also at an early stage much like any research conducted now). It is therefore important to examine the dynamics of this experience and those associated with increased work flexibility. One such allied policy response is peak spreading or staggered work hours, which may be as equally impactful a response to change transport demand and capacity, particularly for those unable to work from home. Future research will look at the degree to which people may be able or willing to stagger working times, but there are unintended consequences of peak spreading such as decreased use of public transport, that also need to be examined (Daniels and Mulley 2013).

More research is needed on the prevalence of active transport. Our survey did not detect any strong trends in the aggregate, but in this paper we only present overarching results of analysis, which are already extensive. The concept of working from home, mixed with active travel and places in which travel activity occurs given a rise in working from home continues to be important. If people increase working from home, then there are likely to be significant implications for more localised transport networks, rather perhaps more profound than those arterial links designed to move large numbers of people between residential and employment centres.

Additionally, Australia was approaching the end of autumn during Wave 1 and winter had begun during Wave 2. Colder climates may be a reason why active transport was found to be less prevalent than media would suggest, in this study. However, using Sydney as a proxy, the average temperature during Wave 1 was 22 degrees ($\sigma = 2.0$) and daily rainfall 1.8mm ($\sigma = 2.7$), compared to 19 degrees ($\sigma = 2.2$) and 3.2mm of rain per day ($\sigma = 3.3$). Wave 2 was conducted during a colder period, but only marginally so. Likewise, any planned changes in activity could be attributable to likely improved weather, those changes in travel were asked for the next week (next 7 days) at the time at which the respondent completed the survey. It is unlikely that their perception of the weather would change too significantly in that time frame when winter had only just started. Lastly, winters are also relatively mild in Australia compared to other parts of the world, so activity pattern changes may be more pronounced in warmer months, or in countries where the climate is more extreme.

Localised amenity may start to become increasingly more important moving forward and there may be more pressure on parking in places where there were previously few concerns. Local streets may require more maintenance or will degrade more quickly with increased local traffic, more formalised organisation of traffic may be required on local roads than is currently the case, and local parks may become more important to wellbeing. Politicians in Australia are already acknowledging that the pandemic had underscored the importance of public space to people's mental, physical and social wellbeing, having launched an ideas competition to reimagine public spaces (O'Sullivan 2020).

Indeed, in the very long term, COVID-19 may change the way in which individuals make decisions about where they live, if working from home grows. Reduced friction from the disutility of commuting (even if a reduced number of days) may mean that people are more able to prioritise the utility of living near social contacts (Guidon et al. 2019). In the very long term, working from home may be an opportunity for regional centres (with cheaper housing and potentially greater local amenity) to capture new residents and new industry, as people may have greater freedom to choose where to live, or in the future need to travel to an urban location significantly less often. These issues are unclear, but research could be devoted to the implications of what we are observing now, desirably through a longitudinal panel survey.

While looking at household travel in terms of repeated or more regular trips, this paper does not examine the impact on tourism or holiday travel. The impact to international travel and both the domestic and international aviation markets are well known and easily observed. What is less well known are future intentions around travel and how preferences towards international and domestic travel may change. In 2019, Tourism Australia (2019) reported that tourism contributed $61 billion towards gross domestic product and makes up approximately 5% of the Australian workforce. Changes to travel choices with respect to tourism will be important to understand, particularly with respect to generating greater domestic tourism when it is allowed.

While these changes may occur, the preliminary finding by Currie et al. (2020) that people initially state that very little may change long-term as a result of COVID-19, adds to the call in this paper for timely and ongoing research. Much like with dealing with the pandemic itself, often a fast response is needed rather than one which is considered but loses efficacy due to its untimely nature. It has been long known in transport that humans are habitual (Hensher 1975, Goodwin 1977, Banister 1978, Verplanken et al. 1994, Aarts and Dijksterhuis 2000) and cognitive dissonance is common (De Vosa and Singleton 2020), and these habits are powerful and hard to change (Bamberg et al. 2010, Walker et al. 2015). Any invention needs to be targeted and dynamic to the changes being experienced now, or it is likely that momentum will be lost. On a positive note, research in other fields suggest that the formation of new habits is possible with the appropriate interventions (Lally and Gardner 2013, Mergelsberg et al. 2020), and reinforcement of positive attitudes (Judah et al. 2012). Interestingly Lally et al (2009) posit that habit formation takes an average of 66 days, a point at which we are now approaching with regards to work and travel with COVID-19. Will new transport and work habits take longer, and are "desirable" habits being formed?

7 Conclusion

In May 2020, the World Conference on Transport Research Society released a Covid-19 Task Force with five recommendations for policy makers who are responsible for deciding when to end the Covid-19 lockdown period (WCTRS 2020). They discussed issues surrounding the timing of restriction relaxation, notably that influential decision makers would typically advocate for a shorter lockdown duration than is socially optimal due to the costs of the virus being spread being an external cost that may be discounted. They also noted a concern around increased private vehicle dependence, with priority investment being needed in transit systems to allow for proper social distancing and cleanliness along with an increased focus on active transportation modes. These recommendations, similar to those found in Beck and

Hensher (2020), are worth highlighting in the context of the results outlined in this paper and the discussion thereof.

Human beings are inherently social creatures and it is not surprising that social activities are planned to rebound given the widespread suppression witnessed during Wave 1 of this ongoing study. However, this does represent a known danger for increased community transmissions. Younger people, who show greater propensity to travel, are also more comfortable with interaction in more dense social environments such as pubs and clubs, gyms and exercise and live events. Authorities need to remain vigilant and carefully consider the risk of opening too soon (as is occurring with a spike or second wave in a growing number of locations), against the benefit of increased activity (which may end up being only for the short term). As the lockdown is ended, it is likely that governments will need to act quickly and decisively to quell any increase in transmission, and resist the urge to discount short-term activity over the potential impact of long-term disruption due to a re-emergence. As can be seen in the first figure presented in this paper, the risk of an increase in new COVID-19 cases is on the rise and governments and authorities need to be alert.

If the policy is the desire to return to social activity is strong, how will that translate to the behaviours that are designed to reduce the risk of transmission? Will fatigue or habit erode social distancing and if so, what measures can be deployed to counter-act a lack of community vigilance? This is particularly important for the transport network that moves not only people and freight, but potentially the virus. With regards to the intervention of COVID-19 strategies on transport in the longer term, it is clear that working from home should be viewed as a transport investment and should be encouraged with appropriate spending and support (i.e., investment in facilitating and tax breaks for individual uptake). As highlighted by WCTRS; “this is clearly a unique and rare opportunity for policy makers and transport researchers to work together and seize the momentum to devise new policies in order to change our everyday living and choices toward more environmentally sustainable life and work”.

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Appendix G. Paper #5: 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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Edward Wei
Matthew J. Beck
Camila Balbontin

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.

Keywords: COVID-19, Before and During COVID-19, Commuting travel cost reduction, car, public transport, time costs, working from home, Sydney evidence

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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. Figure 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[51].

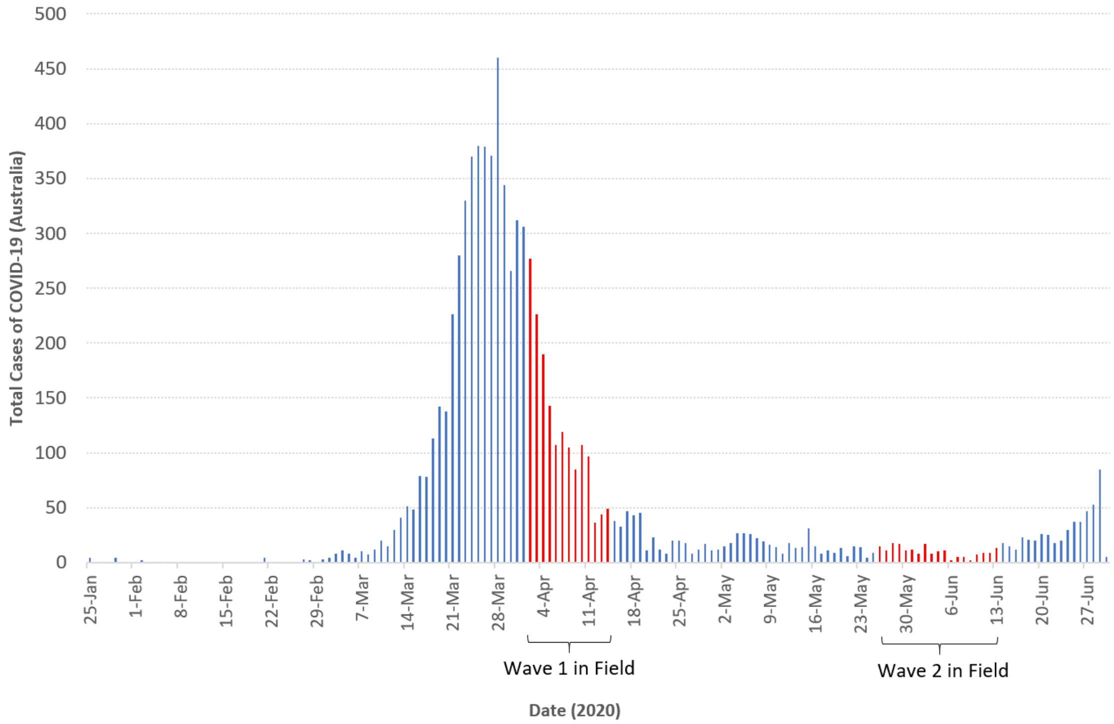
Globally the number of studies that investigate the impact of COVID-19 on transport networks continue to grow. One of the first, the MOBIS-COVID-19 study, that follows respndents from a pre-COVID-19 survey in September 2019 and January 2020 using GPS tracking and shows the nature of change in activities 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

[51] 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.

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 1,000 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.



Source: https://www.health.gov.au/news/health-alerts/novel-coronavirus-2019-ncov-health-alert

Figure 1: Daily New Cases of COVID-19 in Australia (Beck and Hensher 2020)

Beck et al. (2020)[52] 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,

[52] 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.

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 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.

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%

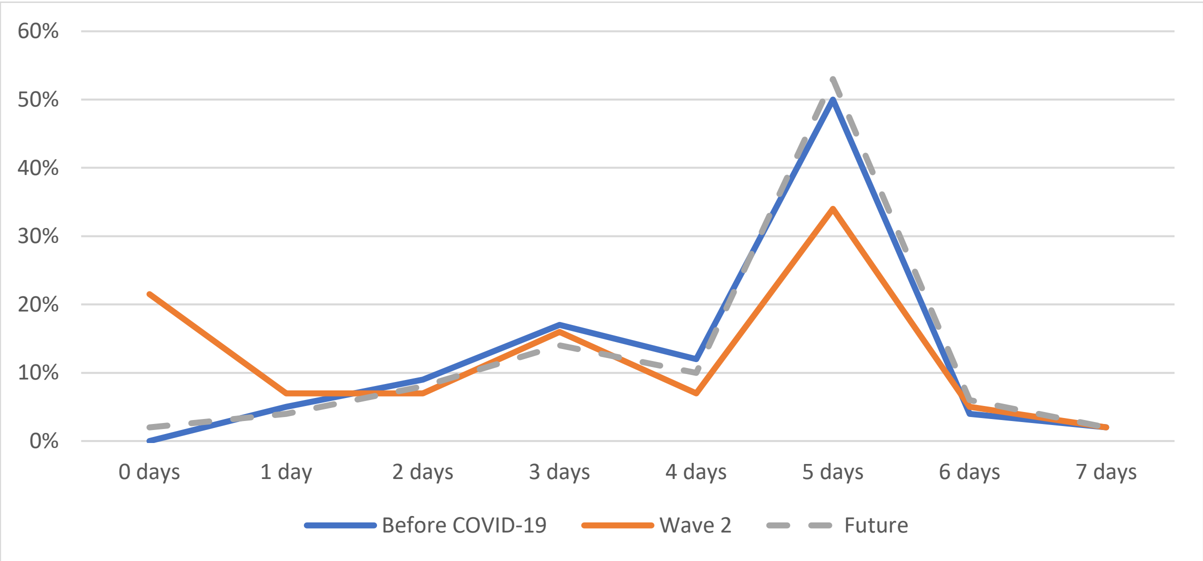


Figure 2: Comparing the number of days worked in a week

While Figure 2 shows the change to the volume of work, Figure 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.

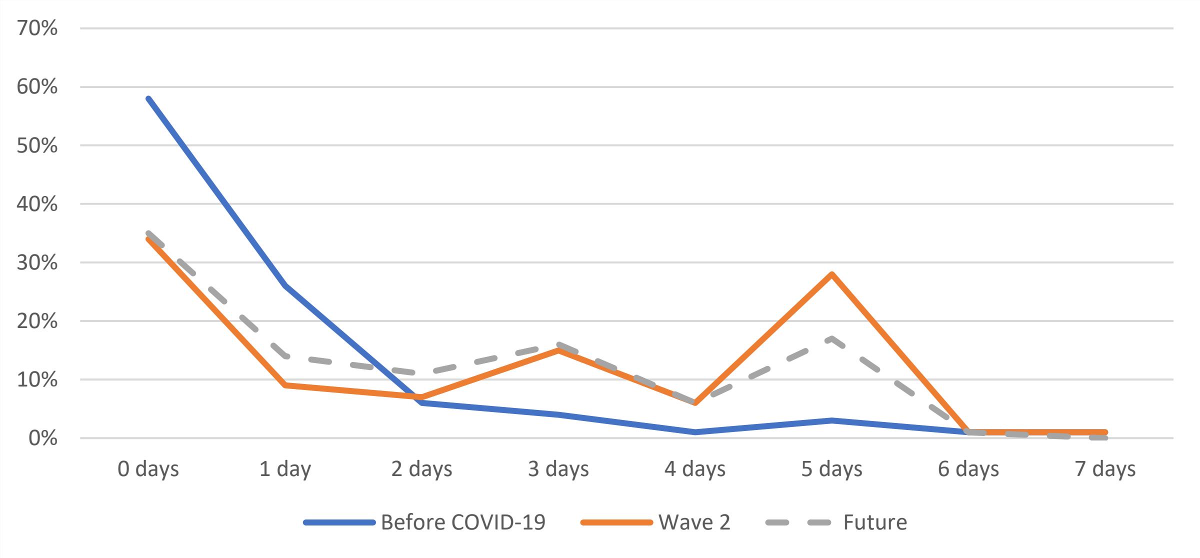


Figure 3: Comparing the number of days worked from home in a week

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 Figure 4. As shown in Figure 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.

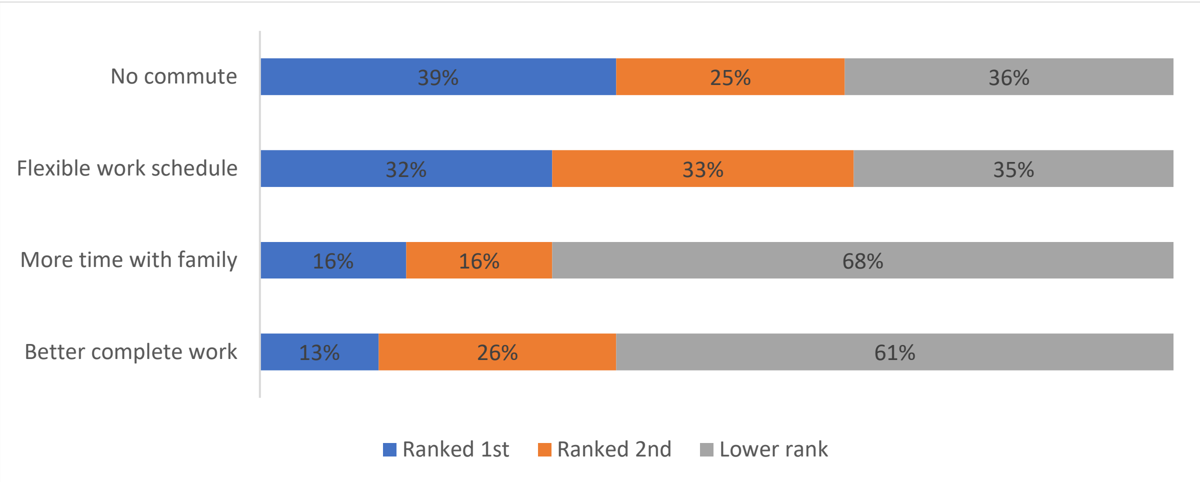


Figure 4: The benefits of working from home

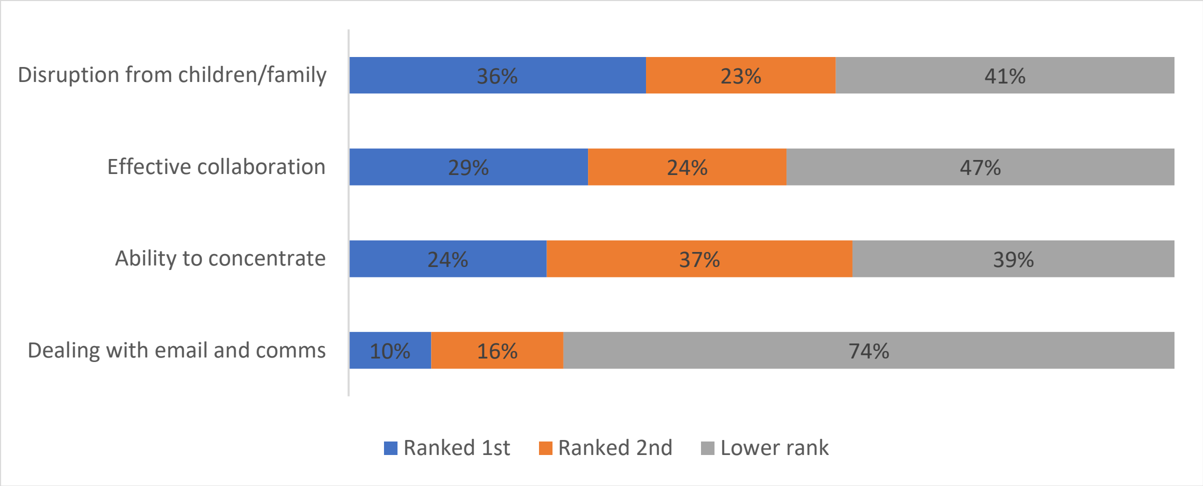


Figure 5: The barriers to working from home

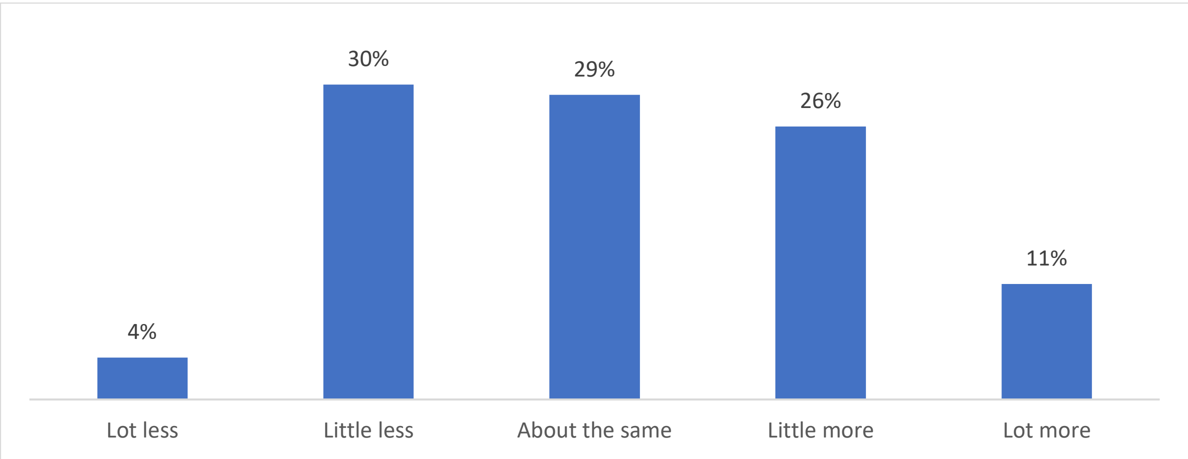


Figure 6: Productivity when working from home (employee perception)

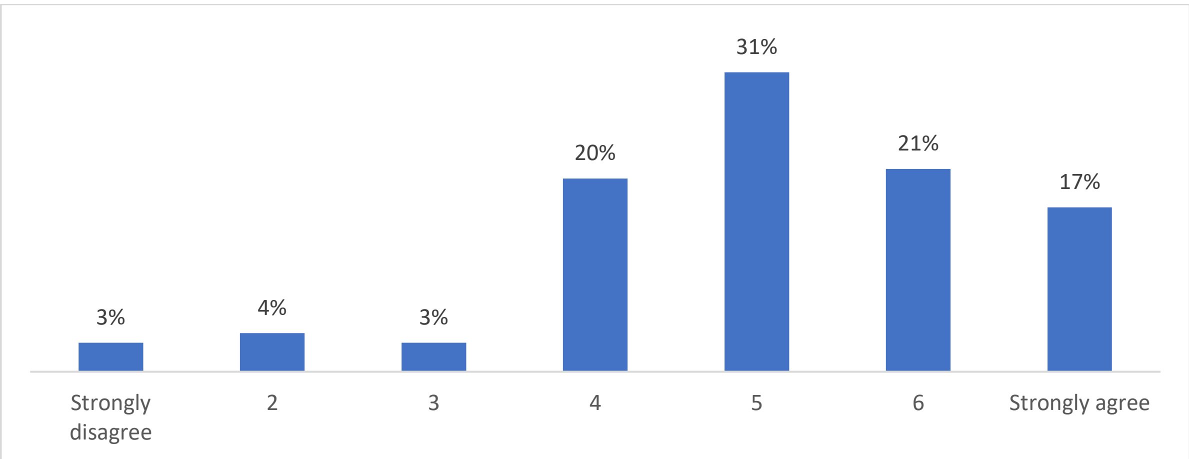


Figure 7: Overall working from home has been a positive experience

With respect to the productivity of the work from home experience, Figure 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, Figure 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. Figure 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.

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

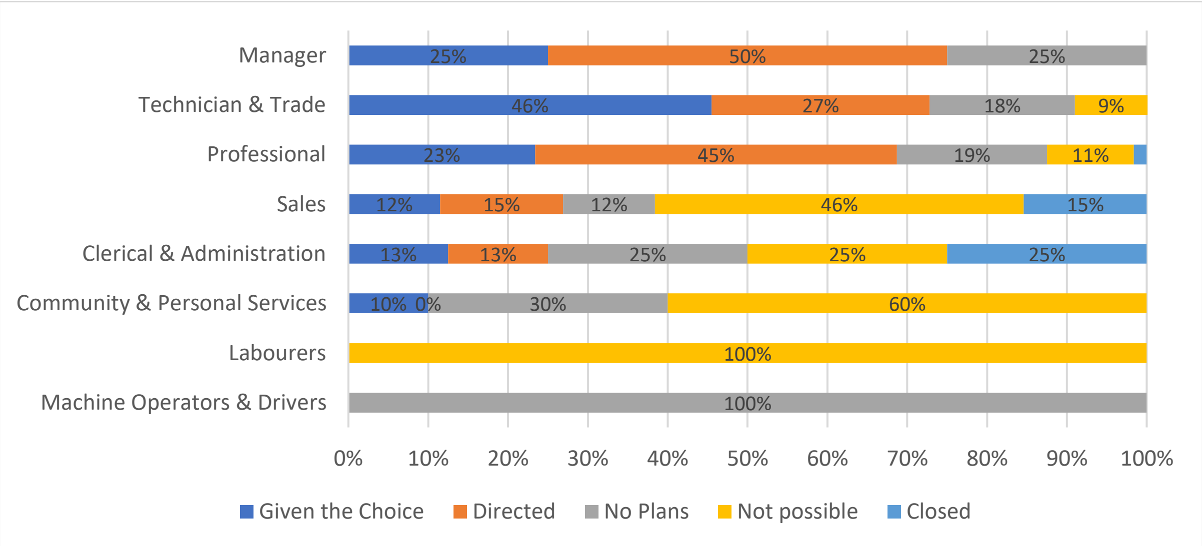


Figure 8: Work from home policy by Occupation

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.

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 to 10am and 3pm to 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, 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)[53] 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[54].

The monthly patronage figures for public transport for train and bus 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

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[53] 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%.

[54] 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.

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. Figures 9 and 10 summarise the findings from Tables 3 and 4.

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

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.

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%**

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%**

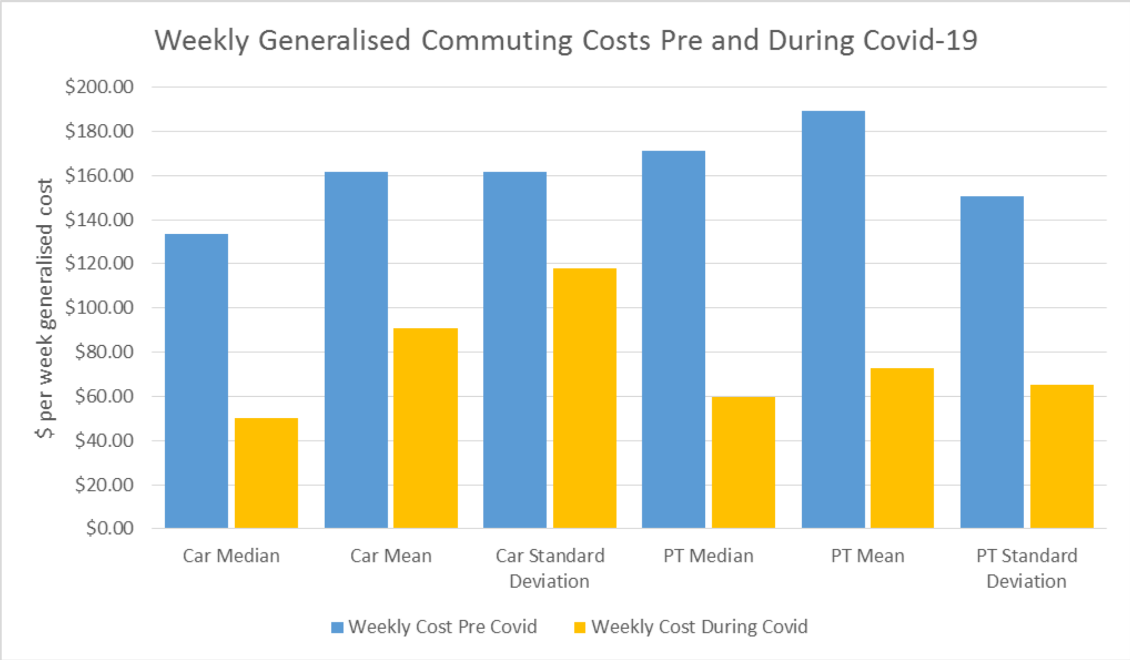

Figure 9. Comparison of commuter time and cost outlays in 2019 (Before COVID-19) and in late May 2020 (During COVID-19)

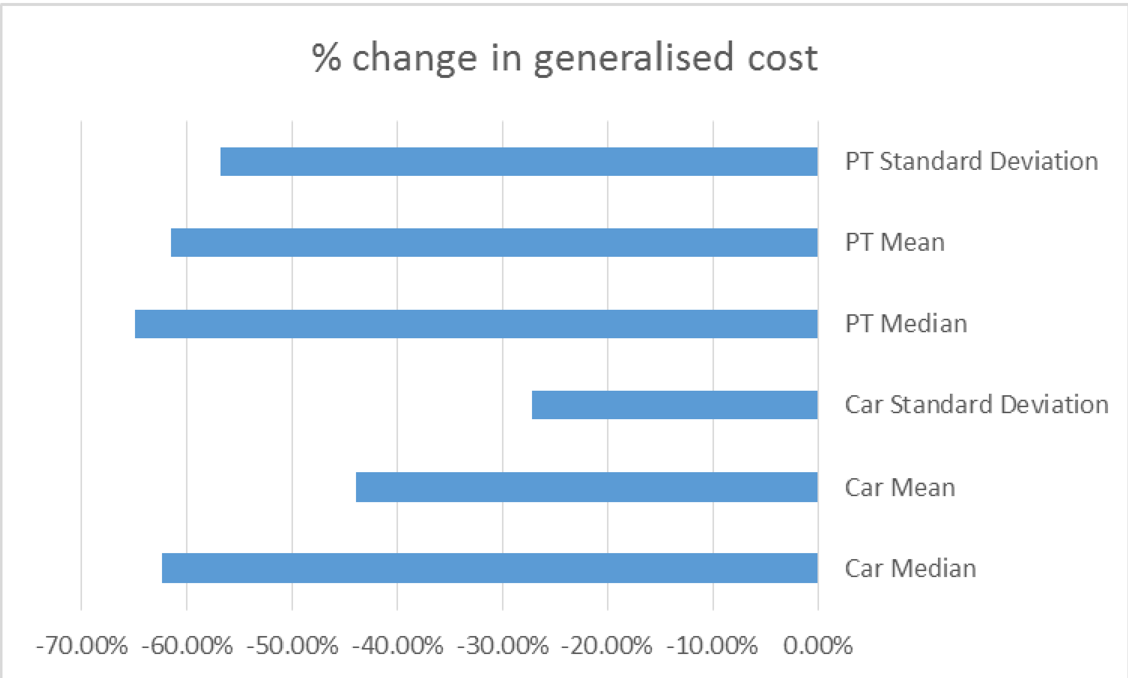

Figure 10. Comparison of percentage change in commuter time and cost outlays in 2019 (Before COVID-19) and in late May 2020 (During COVID-19)

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 Table 5 and 6. The average annual reduction in time costs for car travel is $2,312 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 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.

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

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.

Base: average per passenger before COVID-19	Car	Public Transport	Weighted average for both modes
Annual monetary costs before COVID-19	$1,950	$2,482	$2,105
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	$5,601.76	$6,421.93	$5,841
Annual time costs during COVID-19	$3,289.93	$1,219.24	$2,686
Annual time costs reduction	41.27%	81.01%	54.02%
Annual generalised costs before COVID-19	$7,551.70	$8,903.54	$7,946
Annual generalised costs during COVID-19	$3,666.36	$1,886.94	$3,147
Annual generalised costs reduction	51.45%	78.81%	60.40%

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 congestion costs[55]. During May 2020 we observed a significant reduction in commuting

[55] 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

activity (Beck and Hensher 2020). This is equivalent to a $8.485 billion reduction in overall generalised cost.

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***

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) / 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)[56]. 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.

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.

[56] It should be noted that the volume of work calculation encompasses the impact of JobKeeper, a $1,500 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

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 $3,447 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 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[57]. This is also backed by a range of wider studies; for example a survey of 6,000 Australian workers in the public sector has found 39 per cent of those surveyed would

[57] 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

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 (10 June 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[58] 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 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).

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

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 minute 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.

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 20kms 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	$1,950	$2,482	$2,105
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	$5,602	$6,422	$5,841
Annual time costs during COVID-19	$2,155	$1,288	$1,902
Annual time costs reduction	61.53%	79.94%	67.43%
Annual generalised costs before COVID-19	$7,552	$8,904	$7,947
Annual generalised costs during COVID-19	$3,109	$1,673	$2,690
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

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Appendix H. Paper #6: Characterising Public Transport Shifting to Active and Private Modes in South American Capitals during the COVID-19 Pandemic

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Abstract

During the year 2020, the COVID-19 pandemic affected mobility around the world, significantly reducing the number of trips by public transport. In this paper, we study its impact in five South American capitals (i.e., Bogotá, Buenos Aires, Lima, Quito and Santiago). A decline in public transport patronage could be very bad news for these cities in the long term, particularly if users change to less sustainable modes, such as cars or motorbikes. Notwithstanding, it could be even beneficial if users select more sustainable modes, such as active transport (e.g., bicycles and walking). To better understand this phenomenon in the short term, we conducted surveys in these five cities looking for the main explanation for changes from public transport to active and private modes in terms of user perceptions, their activity patterns and sociodemographic information. To forecast people's mode shifts in each city, we integrated both objective and subjective information collected in this study using a SEM-MIMIC model. We found five latent variables (i.e., *COVID-19 impact, Entities response*, *Health risk*, *Life related activities comfort* and *Subjective well-being),* two COVID-19 related attributes *(i.e., new cases* and *deaths*), two trip attributes (i.e., *cost savings* and *time*), and six socio-demographic attributes *(i.e., age, civil status, household characteristics, income level*, *occupation* and *sex*) influencing the shift from public transport to other modes. Furthermore, both the number of cases and the number deaths caused by COVID-19 increased the probability of moving from public transport to other modes but, in general, we found a smaller probability of moving to active modes than to private modes. The paper proposes a novel way for understanding geographical and contextual similarities in the pandemic scenario for these metropolises from a transportation perspective.

Keywords: Coronavirus; COVID-19; Public transport; Modal shift; Perception; Active modes

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1 Introduction and Background

COVID-19, considered as a global pandemic by the World Health Organization (WHO) in March 2020, had caused over 1.6 million deaths by December 2020 (WHO, 2021). South America was one of the regions most affected by the virus: according to Johns Hopkins University (2020), by December 2020 seven of the 12 independent nations in the region were among the 30 nations with highest mortality rate per 100,000 inhabitants in the world.

The impact of COVID-19 in travel behaviour has begun to be studied and analysed in various contexts (Abdullah et al., 2020; Neuburger and Egger, 2020; Tirachini and Cats, 2020), but the long-term impacts are still uncertain. Wearing masks is a crucial measure to minimize the spread of the virus (Matuschek et al., 2020; Rab et al., 2020), and allowing a certain amount of social distancing (Milne et al., 2020), keeping bus frequencies (De Vos, 2020) and sustaining hygiene measures inside vehicles and stations, are all relevant measures to combat the general perception that using public transport may be unhealthy (Tirachini and Cats, 2020). However, and although social distancing has been viewed as a threat to public transport use (Beck et al., 2020; De Vos, 2020), it has also been suggested as an opportunity to promote travel by active transport modes (Brooks et al., 2020).

COVID-19 transmission has been reported to increase with factors such as metropolitan area population (Hamidi et al., 2020), air pollution (Zhang et al., 2020), and population density (Rashed et al., 2020). We look at these and other factors in the case of five Spanish-speaking capitals in South America: Bogotá, Buenos Aires, Lima, Quito and Santiago, which were selected to provide a comparable sample in terms of geographical and cultural contexts. Basic information about these cities is provided in Table 1.

Table 1. Main information about COVID-19 for the selected cities (data from mid-November 2020)

City / Metropolitan Area[A]	Population	Confirmed cases	Confirmed deaths	Death rate / 100,000	City death rate / Country death rate[B]
Bogotá, Colombia	7.743.955[(1)]	356.711[(6)]	8.113[(6)]	104.80	1.53
Buenos Aires, Argentina	3.075.646[(2)]	153.670[(7)]	5.434[(7)]	176.70	2.22
Lima, Perú	10.804.609 [(3)]	428.412 [(8)]	16.229[(8)]	150.20	1.37
Quito, Ecuador	3.228.233[(4)]	63.555 [(9)]	2.099[(9)]	65.00	0.85
Santiago, Chile	8.125.072[(5)]	301.207 [(10)]	10.134[(10)]	124.70	1.58

[A] Data corresponding to: Bogotá – City; Buenos Aires – Inner City; Lima - City of Lima + El Callao Province; Quito - Pichincha Province; Santiago - Metropolitan Region. Data retrieved on November 16th, 2020.

[B] Country death rate/100,000 obtained from Johns Hopkins University (2020).

Data sources:

[1] DANE (2019) Proyecciones de Población Departamental para el Periodo 2018-2050 (in Spanish). https://www.dane.gov.co/index.php/estadisticas-por-tema/demografia-y-poblacion/proyecciones-de-poblacion

[2] INEC (2019) Proyecciones de Población por Sexo y Grupo de Edad 2010-2040, para cada Provincia (in Spanish). https://www.indec.gob.ar/indec/web/Nivel4-Tema-2-24-85.

[3] INEI (2019) Estimaciones y Proyecciones de Población por Departamento, Provincia y Distrito, 2018-2020 (in Spanish). https://www.inei.gob.pe/media/MenuRecursivo/publicaciones_digitales/Est/Lib1715/libro.pdf

[4] INEC (2019) Proyección de la Población Ecuatoriana, por años Calendario, según Regiones, Provincias y Sexo, Periodo 2010-2020 (in Spanish). https://www.ecuadorencifras.gob.ec/proyecciones-poblacionales/

[5] INE (2019) Estimaciones y Proyecciones de la Población de Chile 2002-2035 (in Spanish). https://www.ine.cl/estadisticas/sociales/demografia-y-vitales/proyecciones-de-poblacion

[6] Observatorio de Salud de Bogotá (2019) Saludata (in Spanish) http://saludata.saludcapital.gov.co/osb/index.php/datos-de-salud/enfermedades-trasmisibles/covid19/

[7] Gobierno Ciudad de Buenos Aires (2019) Parte Diario de Situación Sanitaria Covid-19 (in Spanish). https://www.buenosaires.gob.ar/coronavirus/noticias/actualizacion-de-los-casos-de-coronavirus-en-la-ciudad-buenos-aires (resident population only)

[8] Sala Situacional COVID-19 Perú (2019) https://covid19.minsa.gob.pe/sala_situacional.asp (in Spanish).

[9] Gobierno de la República de Ecuador (2019) Coronavirusecuador.com (in Spanish) https://www.coronavirusecuador.com/datos-provinciales/ ("deceased" + "probably deceased" included)

[10] Ministerio de Salud (2019) Casos confirmados en Chile COVID-19 (in Spanish). https://www.minsal.cl/nuevo-coronavirus-2019-ncov/casos-confirmados-en-chile-covid-19/

In particular, Table 1 shows that by mid-November 2020, Bogotá and Buenos Aires were the most affected cities in terms of mortality rates and also had the highest COVID-19 incidence rates, with around 1 confirmed case per 20 inhabitants (although antibody test studies suggested that the real rate was much higher, Buenos Aires Ciudad, 2020). On another hand, with the exception of Quito, all capitals had a higher mortality rate than their country average, and even though the global effects of the pandemic were comparable among them, the peak impacts occurred on different dates (WHO, 2021).

Most South American countries undertook several measures to contain or mitigate the spread of COVID-19, such as closing schools, forbidding mass gatherings and implementing lockdowns and/or night curfews. However, their effect was hampered by social inequalities and poor strategies to test and track for the virus (Benítez et al., 2020). Regarding transportation, the main measures adopted to mitigate the transmission of COVID-19 in the cities under study are presented in Table 2. These measures limited the possibility of using public transport and favoured the switch to other modes, particularly during the first months of the pandemic, when various benefits were even established for car drivers. As public transport is a mode with a naturally close contact between passengers, it was perceived as riskier than active and private motorised travel (Tirachini and Cats, 2020). The following paragraphs explain the changes from public transport to active modes and private motorised modes.

Table 2. Transport-related measures in the selected cities

City	Bogotá	Buenos Aires	Lima	Quito	Santiago
Public transport					
Mandatory face masks in public transport	✓	✓	✓	✓	✓
Public transport restricted to essential workers		✓			
Crowding restrictions	% of maximum vehicle capacity	seated only (trains) / up to 10 persons standing (buses)	seated only	% of maximum vehicle capacity	
App-based seat reservation		✓ (in trains)			
Other modes					

Temporary lanes for non-motorised transport	✓	✓	✓	✓	✓
Driver's license expiration extension		✓	✓	✓	✓
Temporary lift of on-street parking fares		✓		✓	
Temporary lift of car use restrictions	✓			✓	

COVID-19 significantly affected mobility in these five cities, particularly public transport patronage (Aloi et al., 2020; Jenelius et al., 2020). As an example, Figure 1 shows the variation in mobility in Buenos Aires, the whole of Colombia and Santiago during 2020.

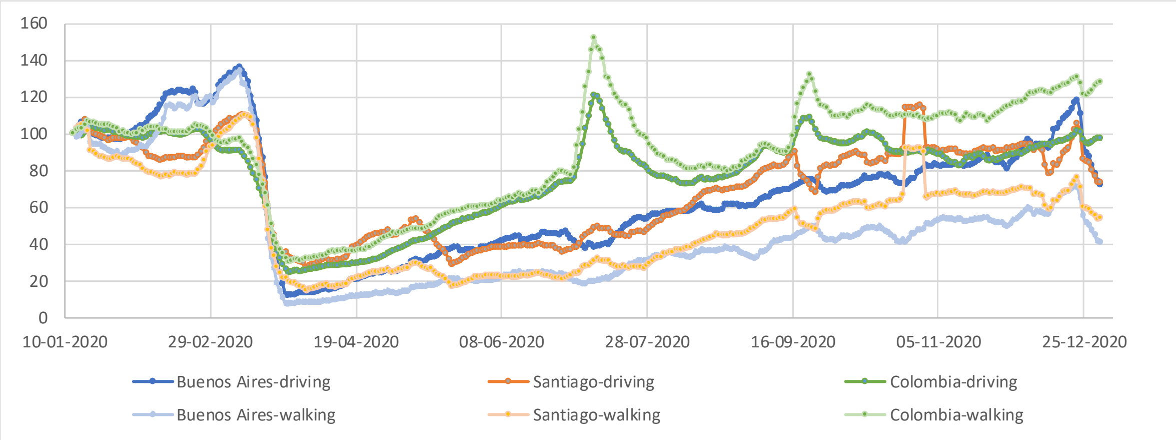


Figure 1. Mobility trends in certain cities during 2020

Data source: Apple Mobility Trends, 2021 (https://covid19.apple.com/mobility) 7-day moving average was applied to the original data.

A sharp drop in mobility is observed in all cases in March 2020, coinciding with the arrival of COVID-19 to South America. Recovery begins in the following months, faster in Colombia and slower in the capitals of Chile and Argentina, where mobility by car recovered faster than walking, contrary to what happened in Colombia. This difference may be due to the lower availability of cars and motorbikes in rural areas. Now, although there are no disaggregate data that allows observing the evolution of public transport ridership in all the cities considered in this study, the available information shows a sharp decline in public transport use during 2020. For example, ridership of the Buenos Aires Metro fell by 76.6 % in 2020 compared to 2019 (Metrovías SA, 2021), in the Santiago Metro the decrease was 62.6% (Santiago Metro, 2021) and in the Bogotá BRT system it was approximately 50% (Transmilenio SA, 2021). The larger decline in public transport use, compared to driving and walking, suggests that some of its former patronage shifted to these other options (i.e., active and private transport).

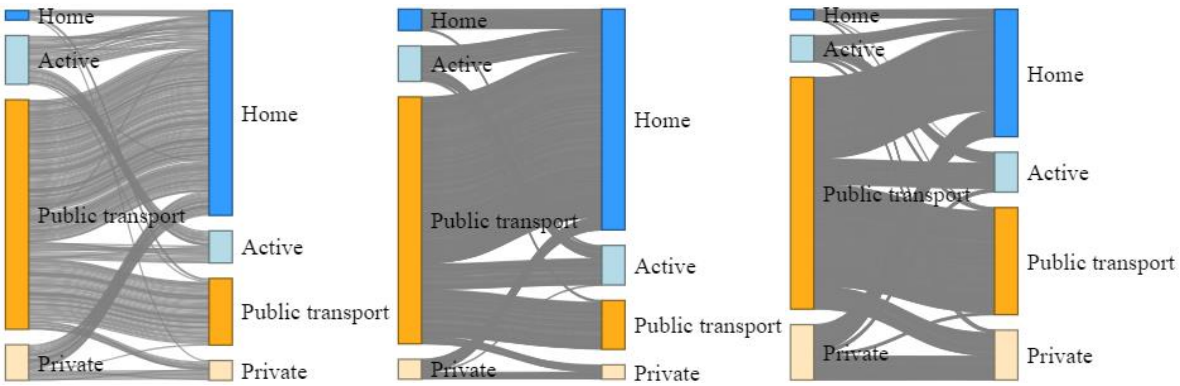
1.1 Shifting to active and private motorised modes

An increase in bicycle use worldwide had been observed prior to the coronavirus outbreak, but data indicates that the mode share of bicycles and other forms of non-motorised transport have grown more strongly during the pandemic in many cities throughout the world (Aloi et al., 2020; Bucsky, 2020; Meena, 2020). The advantages of cycling were, of course, known before the pandemic. Indeed, there is a wide range of literature promoting cycling and walking to foster benefits in health, the environment and energy (Aldred et al., 2017; Arellana et al., 2020b, 2020a; Deenihan and Caulfield, 2014; Götschi et al., 2016; Oja et al., 2011).

Projects undertaken during the COVID-19 pandemic in London (United Kingdom), Melbourne (Australia) and Rome (Italy), but also in Bogotá and other cities in Latin America, are also proof that the expansion of cycling infrastructure has been recurrent almost everywhere. As shown in Table 2, all the capital cities built temporary and/or permanent bike lanes during the pandemic. In Bogotá, in particular, 76 km of temporary bicycle lanes were quickly created on the main streets, and added to 550 km of permanent bicycle lanes.

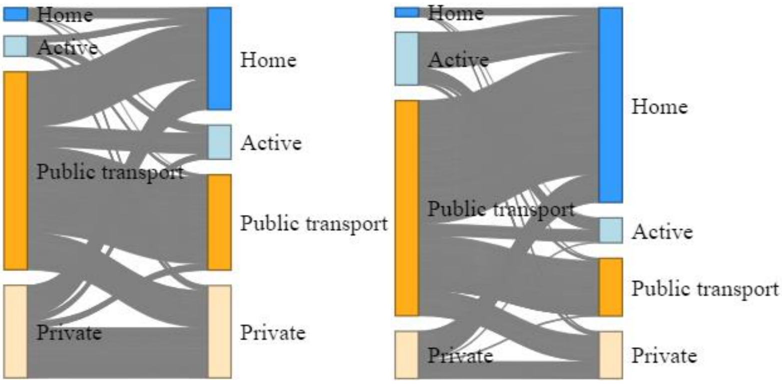
Notwithstanding, although the pandemic has been taken as an opportunity to promote the use of sustainable transport in the medium and long term, many users have shifted also from public transport to car. Beck et al. (2020) observed a rapid recovery in car travel during a phase when restrictions were relaxed in Australia, which could be explained by reasons of hygiene and perceived risk associated with the use of public transport. Given that various cities in South America adopted measures to reducing the cost of travelling by car, there may also be an economic incentive (hopefully unintended) towards greater use of private motorised transport in the region. Short-term spatial transformations, in immediate response to virus mitigation, have been recognised as an opportunity for initiating long-term radical transformation in cities, modifying not only the transport system but also land use planning (Honey-Roses et al., 2020). In this sense, it is relevant to know what types of users may be prone to modify their travel behaviour during a pandemic. To understand the users' decision process when both tangible and intangible (e.g., perceptions) elements enter into play, the use of latent variable models is recommended (Ortúzar and Willumsen, 2011).

Studies performed in different countries have found a decline in daily trips as a result of COVID-19, which affected particularly public transport (Aloi et al., 2020; Balbontin et al., 2021; Beck and Hensher, 2020; Bucsky, 2020). Indeed, for the five cities considered in our study, the most frequent shift corresponded to users who stopped travelling by public transport, as shown in Figure 2 and Table 3 below[59]. The largest falls in public transport use were observed in Bogotá, Buenos Aires and Santiago. In the latter case, there was a formal restriction on public transport use (see Table 2). These three cities also recorded the highest growth in *working from home* (i.e., Home in the diagrams).



(a) (b) (c)

[59] The Sankey diagrams were built using data from the surveys presented in section 2.2 and the R package "networkD3" (Allaire et al., 2017; R Core Team, 2020). The data were corrected with the R package "survey" (Lumley, 2020; R Core Team, 2020), using age and sex information from each city.



(d) (e)

Figure 2. Modal shifting for (a) Bogotá, (b) Buenos Aires, (c) Lima, (d) Quito, and (e) Santiago

Table 3. Modal shifting values for this study's sample

		Bogotá [%]	Buenos Aires [%]	Lima [%]	Quito [%]	Santiago [%]
Before COVID-19	Work from home	2.95	6.59	3.27	3.94	2.73
	Active	15.08	10.96	8.14	6.28	16.31
	Public transport	70.96	76.30	71.51	61.15	66.38
	Private	11.01	6.15	17.08	28.64	14.58
Wave 1	Work from home	63.33	68.22	39.30	31.47	60.00
	Active	9.94	12.23	12.31	10.54	7.69
	Public transport	20.61	15.11	33.01	29.45	17.81
	Private	6.12	4.45	15.38	28.53	14.50

We are interested in understanding the short-term mobility impacts of the coronavirus outbreak in a Latin American context. Specifically, the travel behaviour motivations that produce shifts from public transport to active modes and private motorised vehicles. In this quest, we estimated a Structural Equation - Multiple Indicator Multiple Cause (SEM-MIMIC) model to identify which kinds of users had a propensity to change from public transport to other modes. This could be useful to design public policies aimed at sustainable urban mobility. The paper focus on revising the short-term impacts of COVID-19, but we are also planning a second wave of surveys to study longer term effects.

The contributions of this study are: (i) a comparison of the COVID-19 effects in five capital cities in South America, showing the diversity of contexts in the region; these cities are comparable in geography and language and were strongly impacted by the pandemic; (ii) a discussion of the factors that influence subjective preferences towards mode shifts (i.e., public transport to active modes, and public transport to private motorised modes) in a South American context.

The rest of the paper is organised as follows. Section 2 discusses the methodology, explaining the model formulation and data collection process. Section 3 presents and discuss the estimated model, which seeks to explain the shifting decision from public transport to active and private modes. Section 4 presents the limitations and possible extensions of this study. Finally, section 6 summarises our main conclusions.

2 Methodology

A classic approach to explaining the shift from public transport to active and private motorised modes would consider objective attributes of the alternatives, such as travel times and cost, and user characteristics, such as gender, age and income. However, attitudes and perceptions have been recently incorporated to identify latent variables representing intangible elements (e.g., well-being) that can be used to improve our understanding of the cognitive process and the effects of objective information (e.g., sociodemographic attributes) in shaping individual choices (Bahamonde-Birke et al., 2017; Vij and Walker, 2016).

The COVID-19 outbreak has obviously impacted life and subjective well-being (Blasco-Belled et al., 2020; Möhring et al., 2020). Studies about subjective well-being have gained attention to explain travel behaviour and the impacts of using active transport in the last years (Dolan and White, 2007; Kahneman and Krueger, 2006). The measurement of well-being in transportation has been mainly explored through satisfaction with travel scales (Bergstad et al., 2011); however, more recent studies have shown that positive subjective well-being is also related to several other dimensions. For instance, active travel is associated with improvements in physical and mental health (Humphreys et al., 2013; Martin et al., 2014), happiness (Kroesen and De Vos, 2020), overall hedonic well-being (Singleton, 2019), satisfaction compared to travel by car or public transport (Ettema et al., 2011; Olsson et al., 2013), and even sociability (Wang and He, 2015).

People´s responses to the COVID-19 outbreak are influenced by different elements, where trust in institutions and governments plays a key role (Bavel et al., 2020). Public entities have taken action by limiting people's movements to face the virus, impacting their ability to perform activities, such as shopping and working (Güner et al., 2020). Besides, Benítez et al. (2020) have argued for the need to explore how the pandemic management, in terms of communication and coordination at different governmental or private levels and of diverse agents, has influenced not only the health system capacity and the contagion rate, but also travel behaviour and mode choice.

Community participation has also been crucial during the coronavirus pandemic (Marston et al., 2020), and collective responses to restrictions, lockdowns and measures have proved helpful in previous epidemics (Güner et al., 2020). Community, geographic location and epidemiological criteria must act together (Bispo Júnior and Brito Morais, 2020).

The intangible elements to explain shifting choice have to incorporate the elements mentioned above. To capture this information, we need to collect information that captures people's perceptions. In this case, we are interested in people´s perceptions about the impacts of COVID-19 on health, life and subjective well-being, and the general activities (e.g., leisure, shopping, work); we are also interested in peoples' perceptions about the entities and community response against COVID-19.

2.1 Data collection

An online survey was applied in Bogotá, Buenos Aires, Lima, Quito and Santiago. The questionnaire was based on one developed by Beck and Hensher (2020) and Beck et al. (2020). The design process included an initial translation of the original instrument to Spanish and a contextualization for each city (although everybody speaks Spanish, each country has different idioms and word usages). Before launching the survey, a pilot was applied in each city. The questionnaire included: (i) an initial section about travel activity and mode choice in a typical week both before and during the COVID-19 outbreak; (ii) employment information, including the ability to work from home and the respondent's role at work; (iii) potential impacts of COVID-19 in respondents' lives, including questions related to ordinary activity changes (e.g., go shopping); (iv) respondents working from home were asked about that experience; (v) attitudinal questions and perceptions about government, businesses, and people in general, related to facing the COVID-19 outbreak, and (vi) socio-demographic information.

We used the platform *SurveyMonkey* to make the questionnaire accessible online using a web link for each city. Participation was randomly solicited on social media platforms including *Facebook*, *Instagram*, *LinkedIn* and *Twitter*. Paid publicity was also hired in all the cities to increase participation, through *Facebook* and *Instagram*. To avoid multiple responses from the same respondent, we used cookies especially provided by *SurveyMonkey*.

We seek to explain the mode chosen before and during the COVID-19 outbreak through attitudinal questions, sociodemographic information, data on new cases and deaths, and time and cost savings indicators. Table 4 presents the different questions used to capture people's perceptions about the COVID-19 impact on respondents' health, life and subjective well-being, the entities and community response against COVID-19, and the comfort associated with doing general activities.

Table 4. List of indicators and corresponding questions

Indicator	Question (response labels)
Leisure and shopping comfort	
Going to pubs	How comfortable would you feel about completing these activities at the moment? (very uncomfortable, uncomfortable, neither, comfortable, very comfortable)
Going to the movies	
Eating in restaurants	
Watching live entertainment	
Working out in the gym	
Going to school	
Shopping	
Doctor's appointments	
Playing sports	
Entities response	
The national government response is appropriate	How much you agree or disagree with the following statements (totally disagree, disagree, neither disagree nor agree, agree, totally agree)
The Government COVID-19 strategy was adequate	
I trust the nation to confront COVID-19	
The municipal government response is appropriate	
Health risk	
For myself	
For people I know	

For other people	On a scale of 1 (extremely low risk) to 5 (extremely high risk), how much of a threat do you think COVID-19 is to the following?
Preoccupation about public transport's hygiene	What is your level of concern about hygiene on public transport today? (not at all concerned, slightly concerned, somewhat concerned, moderately concerned, extremely concerned)
Community actions	
Adequate social distance	People have been keeping appropriate social distancing as a measure to combat COVID-19 (totally disagree, disagree, neither disagree nor agree, agree, totally agree)
Adequate self-isolation	People have been appropriately self-isolating as a measure to combat COVID-19 (totally disagree, disagree, neither disagree nor agree, agree, totally agree)
Appropriate community response	The response of the wider community to COVID-19 has been appropriate (totally disagree, disagree, neither disagree nor agree, agree, totally agree)
Comfort with life related activities	
Meeting with friends	How comfortable do you feel about completing these activities at the moment? (very uncomfortable, uncomfortable, neither, comfortable, very comfortable)
Meeting with relatives	
Attending work functions	
COVID-19 impact	
COVID-19 is a serious public health concern	How much do you agree or disagree with the following statements (totally disagree, disagree, neither disagree nor agree, agree, totally agree)
COVID-19 requires drastic measures	
COVID-19 will affect travel	
Subjective well-being	
Life is worth it	To what extent do you feel that the things you do are worthwhile? (not at all worth it, not worth it, indifferent, worth it, completely worth it)
Happiness	How happy did you feel yesterday? (completely unhappy, unhappy, neither unhappy nor happy, happy, completely happy)
Life satisfaction	How satisfied are you with your life nowadays? (totally dissatisfied, dissatisfied, neither dissatisfied nor satisfied, satisfied, totally satisfied)

Table 5 presents the objectively measured information collected in the surveys. Three secondary variables were calculated based on the objectively measured attributes shown: *corrected equivalent income, time* and *cost savings*. The first was calculated following the guidelines of Departamento de Operaciones División de Focalización (2019), as the ratio of the reported *household income* and a *needs index* related with household size and the presence of children at home[60].

Table 5. Objectively measured attributes

Variable	Options/unit
Gender identity	Female, male*
Age	[years]
Occupation	Unemployed*, employer, employee, self-employed, student
Marital status	Single*, living together (married, domestic partnership), union dissolved (divorced, separated)
Household income level	Different ranges for each country depending on the minimum wage
Household size	[number]
Number of children at home	[number]
Travel duration prior to COVID-19	[min]
Travel duration during COVID-19	
Travel cost prior COVID-19	[in each country's currency]
Travel cost during COVID-19	

* Used as the base

Using this information, the level *low income* was as assigned to those with a corrected equivalent income lower than 80% of the minimum wage for each country, *middle income* to those with a corrected equivalent income between 0.8 and 4 minimum wages, and *high income* to those with a corrected equivalent income higher than 4 minimum wages for each country. On the other hand, *time saving* was taken as the difference between the trip duration prior to COVID-19 and during COVID-19. *Cost saving* was calculated similarly and corrected afterwards, by dividing it into the corrected equivalent income. Finally, we also included data about the new cases and deaths reported the day before the respondents answered the questionnaire[61].

Table 6 shows the socio-demographic data for each city survey. After data cleaning and validation, we obtained 282 valid responses for the study in Bogota, 779 in Buenos Aires (used as the base), 924 in Lima, 896 in Quito and 922 in Santiago. The surveys were conducted in September 2020 (except for Quito, where part of it was also taken in October and November); completion time took 12-14 min on average, and the completion rate varied from 45% in Bogotá to 56% in Santiago.

[60] Needs index = $N^{0.7}$ + 0.4 (Ch between 0 and 4) + 0.29 (Ch between 5 and 8) + 0.29 (Ch between 8 and 12) + 0.11 (Ch between 12 and 18) + 0.34 (Ch older than 18), where N is household size and Ch the number of children in the home.

[61] This information was obtained from the COVID-19 Data Repository by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University (https://github.com/CSSEGISandData/COVID-19).

Table 6. Basic socio-demographic data

Indicator	Bogota	Buenos Aires	Lima	Quito	Santiago	Total
Sex						
Female	42.14%	63.58%	49.78%	54.11%	65.65%	56.89%
Male*	57.86%	36.42%	50.22%	45.89%	34.35%	43.11%
Age						
18 – 25*	19.50%	5.26%	19.59%	9.71%	8.46%	11.62%
26 - 40	60.28%	64.06%	58.77%	71.09%	76.46%	67.16%
41 - 60	19.86%	24.90%	18.72%	18.42%	13.88%	18.83%
Older than 60	0.35%	5.78%	2.92%	0.78%	1.19%	2.39%
Income						
Low income*	57.09%	23.36%	50.65%	61.50%	26.90%	42.33%
Middle income	36.88%	62.64%	40.69%	35.83%	53.15%	46.78%
High income	6.03%	13.99%	8.66%	2.68%	19.96%	10.89%
Occupation						
Unemployed*	23.13%	10.29%	9.34%	19.95%	8.15%	12.76%
Employer	2.24%	1.67%	3.71%	2.95%	1.25%	2.41%
Employee	55.60%	72.6%	56.81%	51.24%	77.01%	63.51%
Self-employed	13.81%	12.38%	19.35%	18.65%	9.29%	14.92%
Student	5.22%	3.06%	10.80%	7.20%	4.30%	6.41%
Marital status						
Single*	55.76%	52.23%	61.88%	54.34%	65.83%	58.64%
Living together	40.65%	38.22%	34.06%	39.46%	29.68%	35.61%
Union dissolved	3.60%	9.55%	4.05%	6.20%	4.49%	5.75%

* Used as the base

2.2 Modelling approach

We initially conducted an exploratory factor analysis (EFA) using the indicators in Table 5, and a PROMAX oblique rotation method to allow correlations between the latent variables (Hair et al., 2014). The EFA results helped us identifying several latent variables, based on the groupings presented in Table 4 and confirmed using a screen test, but kept only those with eigenvalues greater than one. Then, we specified a SEM-MIMIC model to test the direct effects of the latent variables over the dependent variables, keeping only those effects with 90% or higher significance. If the direct effects were not significant, we tested the indirect effects of the latent variables over the dependent variables through other latent variables with statistically significant direct effects (Vallejo-Borda et al., 2020). Finally, the dependent variables and the latent variables with a significant relation over them were explained by objectively measured attributes (see Table 5), keeping only those significant over the 90% level.

We aimed to explain mode shifts from public transport modes (e.g., BRT) to active (e.g., walk, bicycle) and private modes (e.g., car, motorcycle), using people's perceptions and sociodemographic information. We compared the respondent's mode choices for a typical week both prior and during the COVID-19 outbreak to obtain each dependent variable. If the respondents' mode choice was public transport in the typical week prior to the COVID-19 outbreak and active or private transport during the outbreak, we assigned a value of 1 for the corresponding model; if there was no change, we assigned a value of 0. To forecast people's shifts from public transport to active and private modes in each city, we integrated the objective and subjective information using the SEM-MIMIC model, the generic structure of which is shown in Figure 3.

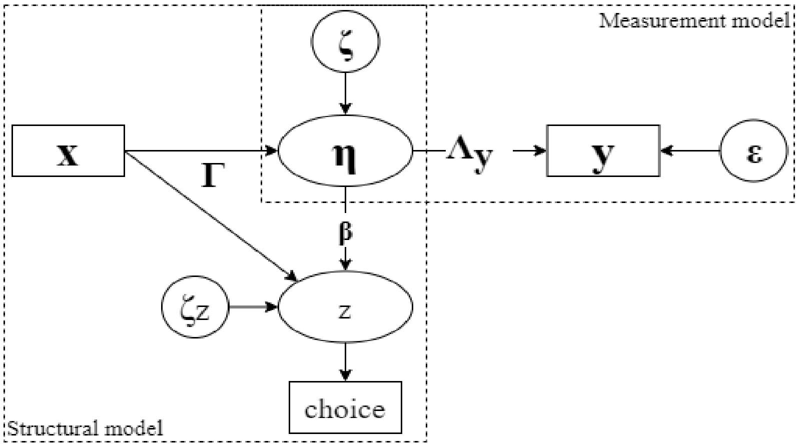


Figure 4. Generic SEM-MIMIC model

SEM-MIMIC models have latent variables ($\boldsymbol{\eta}$), indicators (**y**), and objectively measured attributes (**x**). As shown in Figure 3, the SEM-MIMIC structure can be divided into a *measurement model*, given by equation (1), and a *structural model*, given by equation (2):

$$\boldsymbol{y} = \boldsymbol{\Lambda}_y\boldsymbol{\eta} + \boldsymbol{\varepsilon} \quad \textbf{(1)}$$
$$\boldsymbol{\eta} = \boldsymbol{\Gamma}\boldsymbol{x} + \boldsymbol{\zeta} \quad \textbf{(2)}$$

where $\boldsymbol{y}$ represents the vector of indicators used to identify each latent variable (i.e., the subjective information presented in Table 4); $\boldsymbol{\Lambda}_y$ is a vector of coefficients weighing the change in the value of the indicators if there is a one-unit change in the latent variable; $\boldsymbol{\eta}$ is the vector of latent variables; $\boldsymbol{\varepsilon}$ is an error vector associated with each indicator; $\boldsymbol{\Gamma}$ is a row vector of structural parameters, indicating the change in the value of the latent variable if there is a one-unit change in the objectively measured attributes; $\boldsymbol{x}$ is the column vector of objectively measured attributes, and $\boldsymbol{\zeta}$ is an error vector associated with each latent variable. We assumed that the error terms ($\boldsymbol{\varepsilon}$ and $\boldsymbol{\zeta}$) distribute Normal with an expected value of 0 and unit variance.

The complete model was estimated using the function "sem" of the R package "lavaan" (R Core Team, 2020; Rosseel, 2012). Choice was defined as a binary variable, and we used a diagonally weighted least squares algorithm to estimate the model parameters. To forecast choices, we need to calculate an unobserved variable $\boldsymbol{z}$ using equation (3):

$$\boldsymbol{z} = \boldsymbol{\beta}\boldsymbol{\eta} + \boldsymbol{\Gamma}\boldsymbol{x} + \zeta_z \quad \textbf{(3)}$$

where $\boldsymbol{\beta}$ is a vector of parameters indicating the change in the value of $\boldsymbol{z}$ if there is a one-unit change in the latent variables $\boldsymbol{\eta}$, and ζ_z is the error associated with z, which is also assumed to distribute Normal with an expected value of 0 and unit variance. Then, to categorize the obtained value of **z**, it has to be compared with a threshold (μ) that is estimated jointly with the other model parameters. If z is lower or equal to μ the choice is considered as no shift from public transport to the other modes, and if z is higher than μ, the choice is a shift from public transport to either private or active modes, depending on the evaluation.

As the parameters related to the objectively measured attributes reflect these attributes' metrics, they cannot be directly compared. To make them comparable, we also calculated their standardized coefficients indicating the expected increase of the dependent variable in standard deviation units. Relationships with standardized coefficients close to 0.1 are usually considered *weak*, those with values close to 0.3 are usually considered *medium* effects, and those higher than 0.5 are considered *large* effects (Gana and Broc, 2019). Here, we assumed that standardized coefficients below 0.1 were weak effects, those between 0.1 and 0.5 were medium effects and those higher than 0.5 were considered large effects.

All the assumed relationships are considered simultaneously in the SEM-MIMIC model, and goodness-of-fit is evaluated using the indicators described in Appendix 1, which have been classified as *absolute*, *incremental* and *parsimonious*. We used three absolute indicators, normed χ^2, goodness-of-fit index (GFI) and standardized root mean residual (SRMR); two incremental indicators, Tucker Lewis index (TLI) and comparative fit index (CFI), and one parsimonious indicator, root mean square error of approximation (RMSEA). Note that the latter can also be found in the literature as an absolute indicator (Gana and Broc, 2019).

3 Results and Discussion

From seven potential latent variables, only five were finally considered: (i) *Subjective well-being*, *Entities response* and *Life-related activities comfort,* which represent "positive" constructs; (ii) *Health risk,* which represents a "negative" construct, given the indicators used to identify them, and (iii) *COVID-19 impact*, which may represent either a positive or a negative construct, as the indicators used to identify its impact may be perceived positively or negatively depending on the respondent´s perspective. Figure 4 shows the graphic representation of the estimated SEM-MIMIC model; the relationships with positive coefficients are represented in green, and those with negative coefficients in red. The model appears to fit the data well and we did not conduct *post-hoc* modifications given its good fit[62]. We will analyse each component of this figure in turn.

[62] The normed χ^2 is 2.992; GFI is 0.987; SRMR is 0.042; TLI is 0.997; CFI is 0.991; and RMSEA is 0.023.

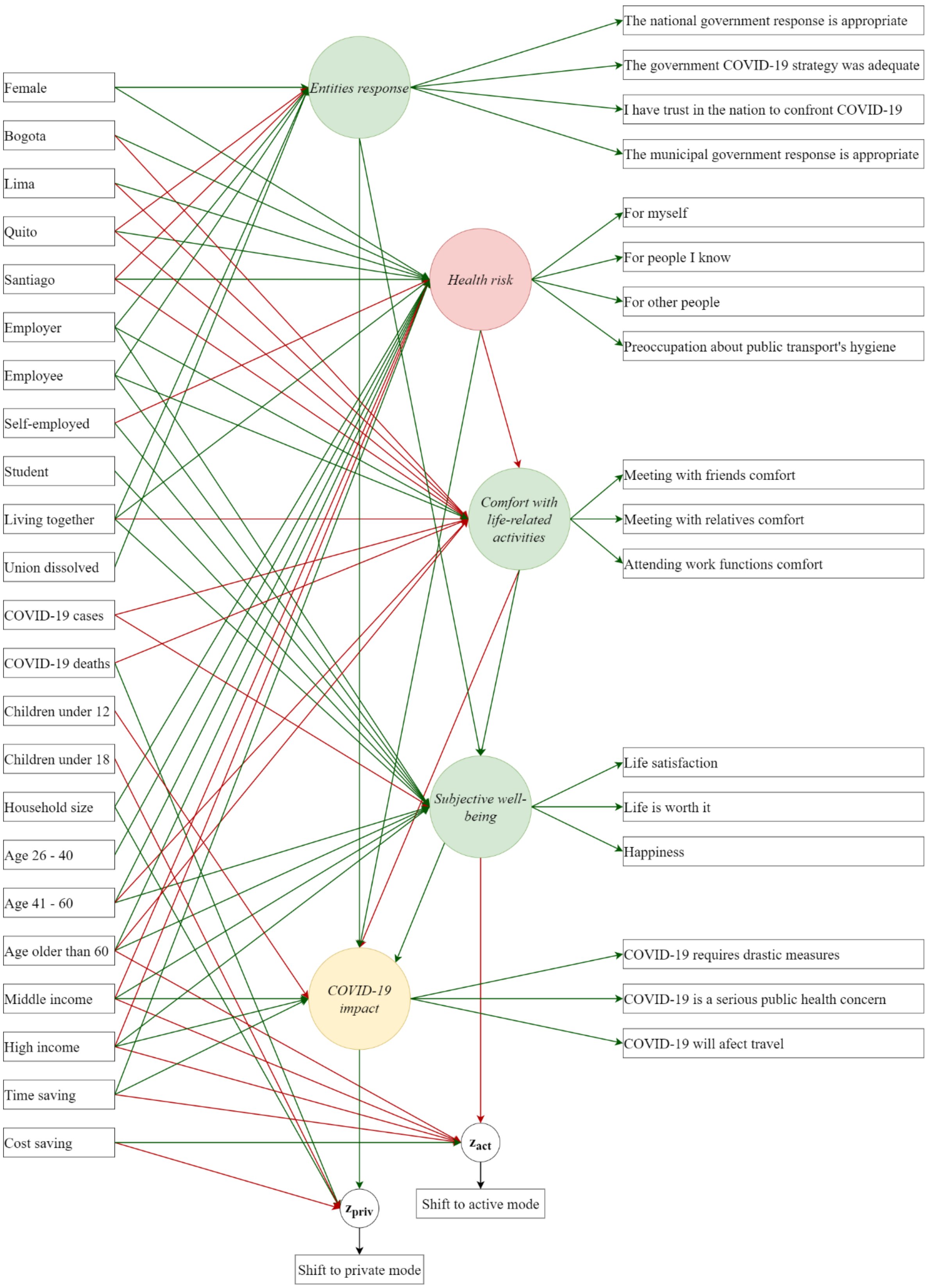


Figure 4. SEM-MIMIC model of shifting from public transport to private and active modes

3.1 Measurement model results

The *measurement model* component of our SEM-MIMIC model considers five latent variables explained by 17 indicators (measured through the online surveys in each city). The coefficients and t-test associated with the relationship between latent variables and indicators in this model are presented in Table 7. As can be seen all effects are highly significant, and can be considered either medium or strong.

Table 7. Parameters of the measurement model

Latent variable	Indicator	Coefficient (t-test)	Standardized coefficient
COVID-19 impact	COVID-19 requires drastic measures	1.000 (fixed)	-
	COVID-19 is a serious public health concern	0.985 (32.12)	0.827
	COVID-19 will affect travel	0.483 (19.85)	0.412
Subjective well-being	Life satisfaction	1.000 (fixed)	-
	Life is worth it	0.666 (20.01)	0.663
	Happiness	0.662 (19.68)	0.659
Entities response	Appropriate national government response	1.000 (fixed)	-
	The Government COVID-19 strategy was adequate	0.965 (146.36)	0.900
	I trust the nation to confront COVID-19	0.912 (132.60)	0.854
	Appropriate municipal government response	0.623 (54.15)	0.596
Health risk	For myself	1.000 (fixed)	-
	For people I know	0.980 (81.58)	0.867
	For other people	0.940 (77.79)	0.837
	Preoccupation about public transport's hygiene	0.597 (30.80)	0.554
Life-related activities comfort	Meeting with friends	1.000 (fixed)	-
	Meeting with relatives	0.887 (40.73)	0.832
	Attending work functions	0.508 (29.18)	0.484

3.2 Structural model results

Table 8 shows the estimated coefficients of the structural model depicted in Figure 4, where the medium and high effects are shown in bold. Note that this strength is not always associated with a higher significance of the estimated coefficient.

Table 8. Parameters of the structural model explaining the shift from public transport to private and active modes

Attribute	Unstandardized effect		Standardized effect
	Estimate	t-test	
Shift to private mode			
$\mu_{private}$	3.025		
COVID-19 deaths*	0.504	1.506	**0.260**
Children under 18	-0.347	-2.159	**-0.158**
Household size	0.066	2.557	0.100
Cost savings	-0.105	-7.675	**-0.191**
COVID-19 impact	0.169	3.677	**0.137**
Shift to active mode			
μ_{active}	0.755		
Age older than 60*	-0.851	-1.630	**-0.123**
Middle income*	-0.139	-1.562	-0.066

High income*	-0.227	-1.422	-0.067
Time savings	-0.009	-7.473	**-0.271**
Cost savings	0.039	2.769	0.072
Subjective well-being	-0.130	-3.449	**-0.127**
COVID-19 impact			
Children under 12	-0.114	-1.678	-0.061
Middle income	0.065	1.771	0.038
High income	0.115	1.916	0.042
Time savings	0.002	3.136	0.061
Entities response	0.088	4.850	0.100
Health risk	0.523	27.756	**0.583**
Comfort with life-related activities	-0.067	-3.892	-0.075
Subjective well-being	0.076	4.215	0.091
Subjective well-being			
Employer	0.564	4.741	0.082
Employee	0.517	10.313	**0.246**
Self-employed	0.464	7.187	**0.157**
Student	0.398	4.264	0.092
Living together	0.136	3.303	0.063
COVID-19 cases*	-0.905	-1.644	**-0.209**
Age 41 – 60	0.288	3.881	**0.110**
Age older than 60	0.484	3.473	0.072
Middle income*	0.375	8.640	**0.182**
High income*	0.641	8.918	**0.194**
*Entities response**	0.260	14.774	**0.247**
*Comfort with life-related activities **	0.055	2.642	0.052
Comfort with life-related activities			
Bogota	-0.669	-3.336	**-0.182**
Lima	-0.912	-4.501	**-0.407**
Quito	-0.726	-2.796	**-0.320**
Santiago	-0.731	-2.938	**-0.326**
Employer	0.229	1.911	0.036
Employee	0.136	2.669	0.069
Living together	-0.078	-2.063	-0.039
COVID-19 cases*	-0.974	-1.986	**-0.240**
COVID-19 deaths*	-0.267	-1.708	**-0.152**
Age 41 – 60	-0.135	-1.956	-0.055
Age older than 60	-0.418	-3.368	-0.066
*Health risk**	-0.400	-21.285	**-0.398**
Health risk			
Female	0.191	5.775	0.099
Bogota	0.654	3.036	**0.179**
Lima	0.784	3.576	**0.352**
Quito	1.071	3.870	**0.475**
Santiago	0.911	3.411	**0.408**
Self-employed	-0.128	-2.174	-0.047
Living together	0.071	1.919	0.036
Household size	0.028	2.367	0.047
Age 26 – 40*	0.112	2.009	0.055
Age 41 – 60*	0.170	2.517	0.070
Age older than 60*	0.192	1.493	0.031
Middle income*	-0.083	-2.190	-0.043
High income*	-0.234	-3.877	-0.076
Time savings	0.002	2.935	0.053
Entities response			
Female	0.081	2.405	0.041
Quito	-0.685	-2.447	**-0.298**
Santiago	-0.509	-1.897	**-0.223**
Employer	0.201	1.886	0.031
Employee	0.149	3.142	0.075
Living together	0.095	2.501	0.046
Union dissolved	0.176	2.332	0.042

* Relation significant at the 90% level considering a one-tailed test as the sign of the relationship is known (i.e., t-test higher than 1.282)

Note: medium and high effects are presented in bold

3.2.1 Analysis of the latent variables' effects

As mentioned in the introduction, the COVID-19 pandemic has brought drastic changes in daily life patterns, including reductions in the number of trips and changes in mode choice (De Vos, 2020; Guzman et al., 2021; Tirachini and Cats, 2020). Our results partially support this information by suggesting that although the perceived *COVID-19 impact* influences the decision to shift from public transport to private modes, it does not influence the change to more sustainable active transport modes. Besides, our findings indicate that the perceived *COVID-19 impact* also acts as a mediator to include the effect of other subjective attributes (i.e., *Subjective well-being*, *Entities response*, *Life-related activities comfort* and *Health risk*) in the decision to shift to private modes.

Considering *Subjective well-being*, it is interesting to note that the literature reports improvements in several well-being dimensions when using active modes (Ettema et al., 2011; Humphreys et al., 2013; Kroesen and De Vos, 2020; Martin et al., 2014; Olsson et al., 2013; Singleton, 2019; Wang and He, 2015), whilst our model suggests the opposite relation. In particular, people who reported higher *Subjective well-being* appear more likely to shift to private modes and less likely to shift to active modes. This finding could be related to the social stigma associated with bicycles (i.e., being mainly used by poor people) in certain countries of the region (Gómez et al., 2005; Rosas-Satizábal and Rodriguez-Valencia, 2019). Notwithstanding, our results also indicate a relevant role for *Subjective well-being* as a mediator to explain the shifting decision to active modes, and indirectly to private modes for the perceived *Entities response* and *Life-related activities comfort*. Also, given that *Subjective well-being* is explained by three indicators, among which *Life satisfaction* is the most relevant in terms of weight, and that the average income of individuals switching to private modes is significantly higher than for the rest, we could posit that the higher *Subjective well-being* reported by new car or motorcycle users is possibly explained by wealth rather than by their choice of mode.

The management of the COVID-19 outbreak by the government may also influence travel behaviour (Benítez et al., 2020), suggesting an interest in understanding how people's perception of the *Entities response* may influence their modal shift decisions. Our results establish an indirect relationship between the perceived government *Entities response* and modal shift with a similar effect to *Subjective well-being* in the shifting decision; in other words, people who reported higher perceived *Entities response* were more likely to shift to private modes and less likely to shift to active modes. This relationship can be explained by the positive influence of the perceived *Entities response* on the people's perceived *Subjective well-being* suggested by our model.

Blasco-Belled et al. (2020) reported that changes in daily life activities impact people's lives. Similarly, our model suggests that perceived *Life-related activities comfort* influences the shifting decision from public transport to private and active modes in a similar way. In other words, we found a decrease in the probability of shifting from public transport to the other modes for people who feel higher *Life-related activities comfort*. This finding can be explained by the positive relationship found between the perceived *Life-related activities comfort* and *Subjective well*-being, and the negative relationship between the perceived *Life-related activities comfort* and the perceived *COVID-19 impact* reported in our model.

Perceived health risks associated with COVID-19 have also been reported as motivators to reduce interactions between people, discourage commuting trips, and alter cities' usual daily activity patterns (De Vos, 2020; Guzman et al., 2021; Tirachini and Cats, 2020). Our results suggest that a higher perceived *Health risk* is associated with an increase in the probability to shift from public transport to other modes. This finding is consistent with reports stating that public transport is perceived as a risky mode in terms of contagion (Abdullah et al., 2020; Barbieri et al., 2021; Moslem et al., 2020). Higher levels of perceived *Health risk* increased the perceived *COVID-19 impact*, which is associated with an increase in the propensity to shift from public transport to private modes. In other words, higher levels of perceived *Health risk* may encourage the use of private modes, as has been reported in previous studies (Beck et al., 2020). Besides, the perceived *Health risk* also negatively influences the latent variable *Life-related activities comfort*, increasing it the propensity to shift from public transport to other modes.

The objectively measured attributes presented in Table 5 also influence the decision to shift from public transport to private and active modes, both directly and indirectly through the latent variables. Household information, COVID-19 numbers (in terms of new cases and deaths), and time and cost savings, directly influence the decision to shift to private modes. On the other hand, the age, income level, and time and cost savings, directly affect the decision to shift to active modes. Besides, the latent variable *COVID-19 impact* is identified as a mediator to include the influence of household information, income level, and time and cost savings. *Subjective well-being* is identified as a mediator of the effect that occupation, civil status, age, income level and COVID-19 numbers have in the shift to private and active modes. Also, *Life-related activities comfort* mediates the effect of occupation, civil status, age and COVID-19 numbers into the shifting decisions. Further, the perceived *Health risk* is also identified as a mediator of all categories of objectively measured attributes, except for the COVID-19 numbers. *Entities response* mediates the effect of sex, occupation and civil status in the decision to shift to private and active modes. Finally, we also found differences in the decision to shift to private and active modes in each city through the latent variables *Life-related activities comfort*, *Health risk* and *Entities response*.

3.3 Total effects

Table 8 referred to the different impact of the various independent variables (i.e., latent variables and objectively measured attributes) in the shift to private and active modes, as direct and indirect effects. However, we are also interested in quantifying the total influence (i.e., total effect) of the different independent variables on the shifting decision. These are presented in Table 9. A total effect is represented by the addition of each independent variable's direct and indirect effects. A direct effect is measured by the coefficient of the variable considered (Gana and Broc, 2019); the indirect effect is represented by the sum of all possible path coefficient chains products from one variable to another (Hoyle, 2014). For example, the *total effect* of being older than 60 in the shift to active modes (-0.910) in Table 9, is calculated as follows: first, the direct effect (-0.851) comes from Table 8; then, in Figure 4 we can observe three different paths from being older than 60 to the shift to active modes decision: (i) *Age older than 60 - Health risk – Comfort with life-related activities – Subjective well-being* - z_{act}; (ii) *Age older than 60 - Comfort with life-related activities – Subjective well-being* - z_{act}; and (iii) *Age older than 60 - Subjective well-being* - z_{act}. Thus, from the coefficients in Table 8 the product of coefficients in each path is as follows: (i) (0.192)·(-0.400)·(0.055)·(-0.130) = $5.49\text{x}10^{-4}$; (ii) (-0.418) ·(0.055)·(-0.130) = $2.99\text{x}10^{-3}$; and (iii) (0.484)·(-0.130) = -0.063. From these, the indirect effect of being older than 60 in the shift to active modes decision is simply the sum of the coefficients products for each path: $5.49\text{x}10^{-4}$ + $2.99\text{x}10^{-3}$ + (-0.063) = -0.059. Finally, the total effect is the sum of the direct and indirect effects: -0.851 + (-0.059) = -0.910. These findings are commented in the subsections below.

Table 9. Total effects on the decision to shift from public transport to private and active modes

Attribute	Unstandardized effect		Standardized effect	
	Shift to private	Shift to active	Shift to private	Shift to active
COVID-19 impact	0.169 (3.677)	0	**0.137**	0
Subjective well-being	0.013 (2.775)	-0.130 (-3.449)	0.013	**-0.127**
Comfort with life-related activities	-0.011 (-2.579)	-0.007 (-2.093)	-0.010	-0.007
*Health risk**	0.093 (3.662)	0.003 (2.096)	0.084	0.003
Entities response	0.018 (3.224)	-0.034 (-3.353)	0.017	-0.031
Female	0.019 (3.113)	-0.002 (-1.648)	0.009	-0.001
Bogota	0.068 (2.519)	0.007 (1.892)	0.017	0.002
Lima	0.083 (2.748)	0.009 (1.966)	0.033	0.004
Quito	0.095 (2.520)	0.031 (2.323)	0.038	0.013
Santiago	0.083 (2.384)	0.025 (2.092)	0.034	0.010
Employer	0.009 (2.175)	-0.082 (-2.893)	0.001	-0.012
Employee	0.008 (2.676)	-0.073 (-3.318)	0.004	-0.034
Self-employed	-0.006 (-0.978)	-0.061 (-3.132)	-0.002	-0.020
Student	0.005 (2.322)	-0.052 (-2.700)	0.001	-0.012
Living together	0.011 (2.326)	-0.020 (-2.519)	0.005	-0.009
Union dissolved	0.003 (1.893)	-0.006 (-1.897)	0.001	-0.001
COVID-19 cases*	-0.001 (-0.136)	0.124 (1.551)	-3.04×10^{-4}	0.028
COVID-19 deaths*	0.507 (1.514)	0.002 (1.313)	**0.262**	0.001
Children under 12	-0.019 (-1.526)	0	-0.008	0
Children under 18	-0.347 (-2.159)	0	**-0.158**	0
Household size	0.068 (2.650)	7.92×10^{-5} (1.587)	**0.104**	1.22×10^{-4}
Age 26 – 40*	0.010 (1.761)	3.21×10^{-4} (1.444)	0.005	1.43×10^{-4}
Age 41 – 60*	0.021 (2.453)	-0.036 (-2.542)	0.008	-0.013
Age older than 60*	0.029 (1.963)	-0.910 (-1.746)	0.004	**-0.132**
Middle income*	0.008 (1.155)	-0.188 (-2.146)	0.004	-0.089
High income*	0.006 (0.532)	-0.311 (-1.980)	0.002	-0.092
Time savings	4.25×10^{-4} (2.847)	-0.009 (-7.470)	0.013	**-0.270**
Cost savings	-0.105 (-7.675)	0.039 (2.769)	**-0.191**	0.072

* Relation significant at the 90% level considering a one-tailed test as the sign of the relationship is known (i.e., t-test higher than 1.282)
Note: medium and high effects are presented in bold

3.3.1 Effect of COVID-19 new cases and deaths

The numbers of COVID-19 new cases and deaths appear to have influenced the shifting decisions. In particular, the number of deaths per hundred thousand population has a medium effect in the shift from public transport to private modes. The values shown in Table suggest that, *ceteris paribus*, a growth in the number of deaths per hundred thousand population may indeed had increase the shift from public transport to private modes (Figure). This increase has a much higher a slope when the deaths are over 4.6 per hundred thousand population, revealing a threat not only to health but also to sustainable transport development. The number of reported deaths was also found to negatively impact the *Life-related activities comfort*, which, according to our results, may increase the propensity to shift from public transport to other modes.

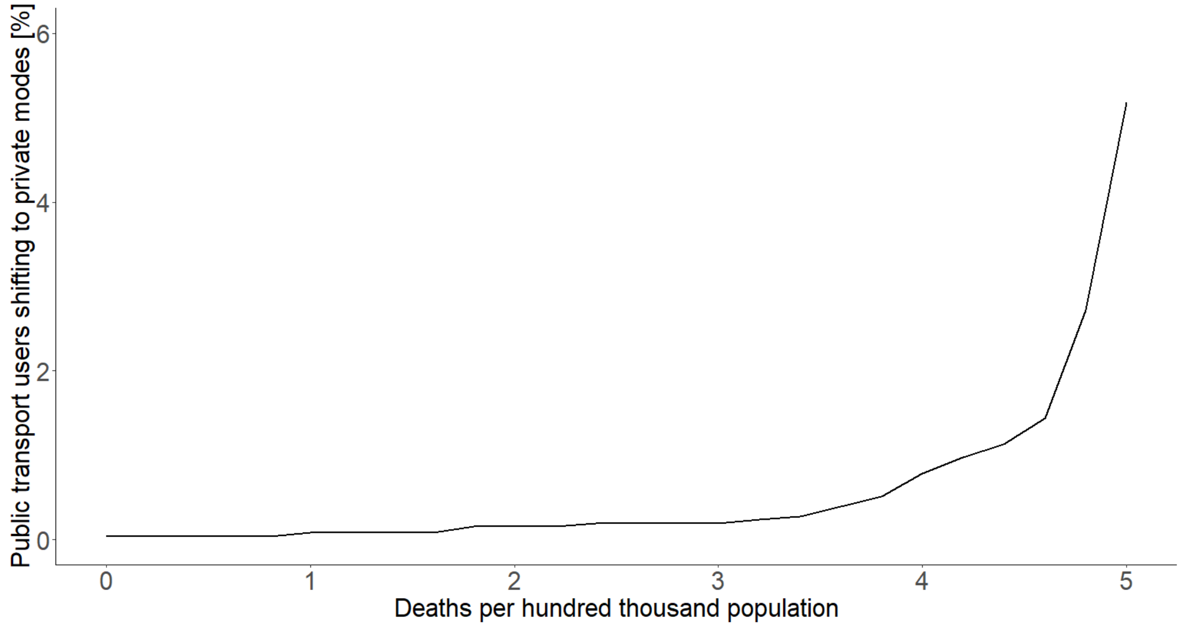


Figure 5. COVID-19 deaths influence on the shifting from public transport to private modes

The new cases of COVID-19 were also found to significantly explain the shifting decision from public transport to active modes through the perceived *Comfort with life-related activities* and *Subjective well-being*. The data in Table 9 suggest that, *ceteris paribus*, a growth in the number of cases per thousand population, may increase the shift from public transport to active modes (Figure 6) . This increase has a higher slope when the cases per thousand population are over 2.

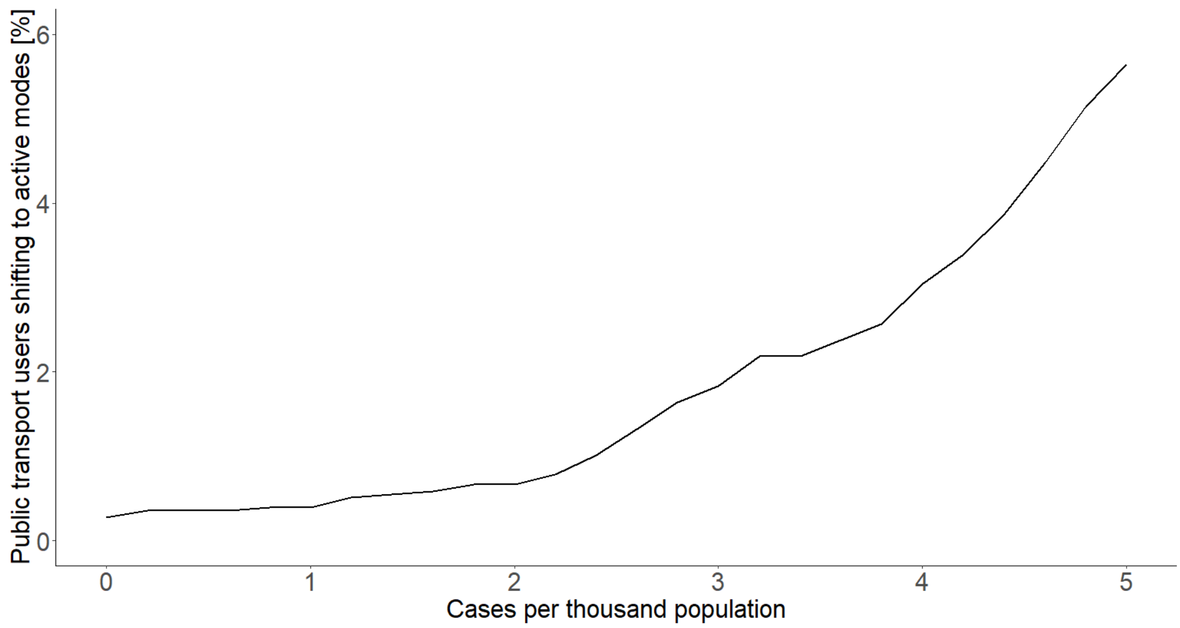


Figure 6. COVID-19 cases influence in the shifting from public transport to active modes

The slope of the curve in Figure 6 is smoother than the one representing the shift to private modes (Figure 5). For this reason, reducing the number of cases and deaths caused by COVID-19 seems to be a goal, not only for health reasons, but also to support the different plans to make cities sustainable from a transport planning perspective, reducing the public transport user's probability of shifting to other modes.

3.3.2 Travel-time and costs savings

A significant increase in travel costs was reported for those who switched from public transport to private modes, which was partially balanced by savings in travel time. On the contrary, a significant increase in travel times was observed (and also balanced by significant savings in travel costs) for those switching from public transport to active modes. Thus, trade-offs between time and cost savings are very evident in our data.

Time savings had a medium effect over the shift from public transport to active modes (and it is the attribute with more influence on this decision) and a weak effect over the change to private modes (see Table 9). The data in Table 9 suggests that public transport users may tolerate an increase of 20% in travel time before starting the process of shifting to active modes (see Figure 7). Besides, when time increases are higher than 60%, the slope of the curve increases. However, time increases on public transport trips represent a decrease in level-of-service (Lunke et al., 2021; Tiznado-Aitken et al., 2021), which is not a sustainable transportation goal.

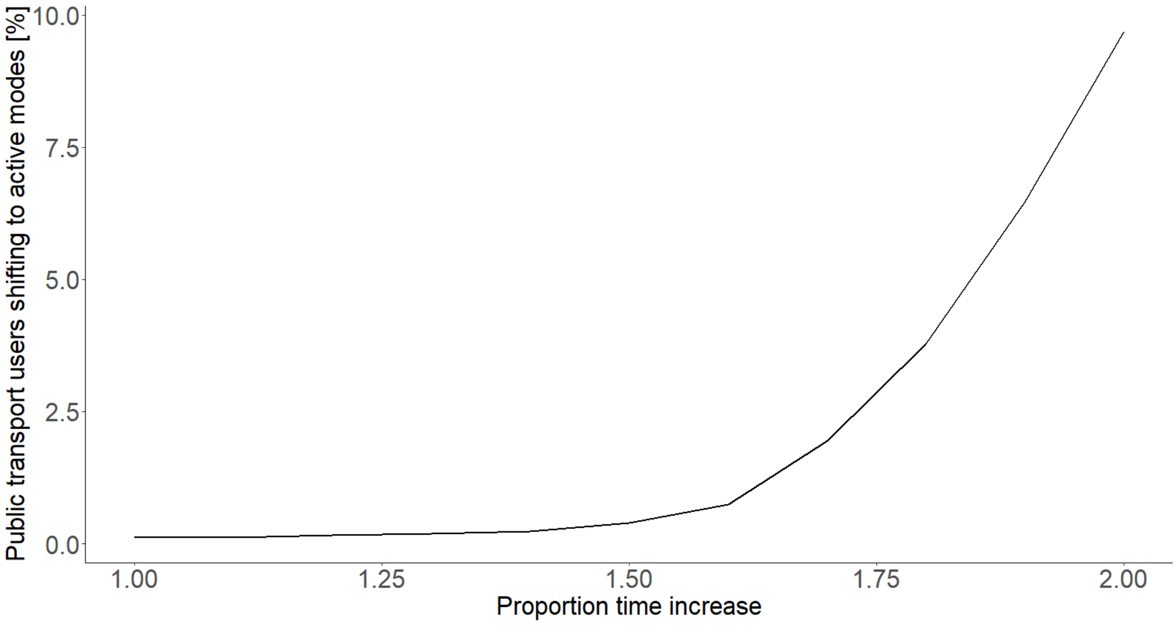


Figure 7. Time increase influence on shifting from public transport to active modes

On the other hand, corrected cost savings had a medium effect over the shift from public transport to private modes and a weak effect over the change to active modes (Table 9). In other words, a reduction in the corrected cost savings used for transportation may influence shifting from public transport to active modes. People can obtain such a reduction directly, from using active modes, and also from any incentives to using active modes by the public entities (e.g., tax reductions). The total effects in Table 9, suggest that public transport users may start moving to active modes when savings up to 7% of their corrected equivalent income are offered. Also, an increase in the rate of public transport users shifting to active modes can be observed from savings over 18% of their corrected equivalent income (see Figure 8).

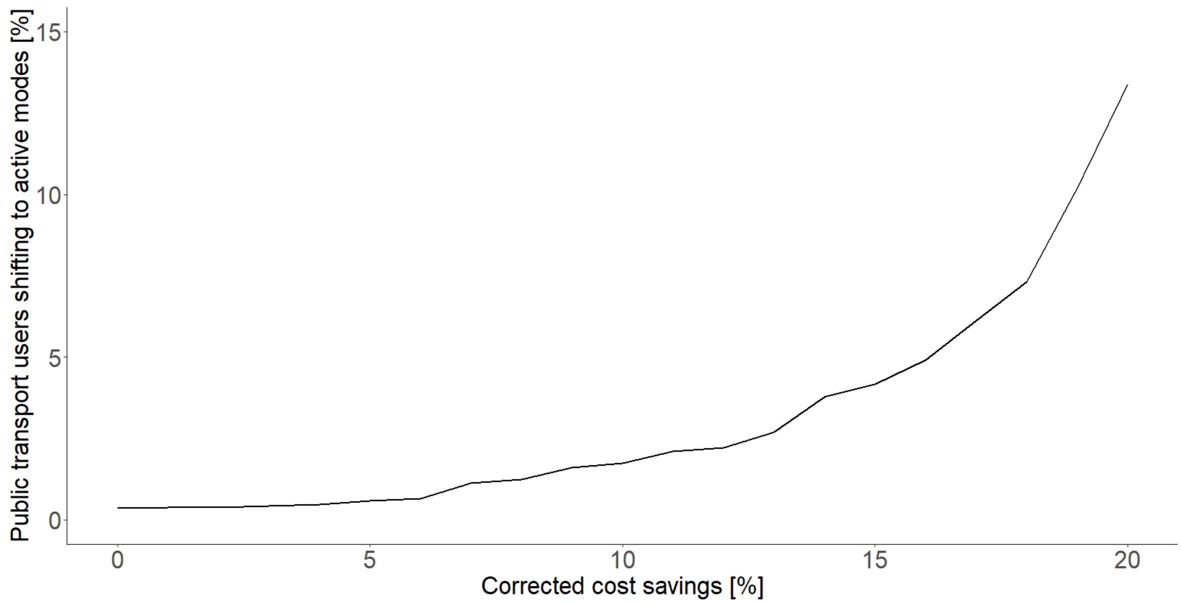


Figure 8. Corrected cost savings influence on shifting from public transport to active modes

Note that following the surge of COVID-19 contagions and deaths, travel times and costs are likely to become less relevant to explain mode choice. According to Abdullah et al. (2020), the proportion of respondents who give high importance to savings in travel time fell from 38% to 29%, while in the case of travel cost, this proportion decreased from 25% to 19%. Meanwhile, the risk of infection, safety, social distance and hygiene appeared as the highest priority factors. Although that research dealt mainly with respondents from Asia, it is likely that South Americans may have a comparable change in perceptions.

3.3.3 Socio-demographic characteristics

We found that women show a positive tendency to move to private modes and a negative tendency to shift to active modes. A potential explanation for this is that the latent variable *Entities response* is rated higher by women. This is a similar finding to Australia, where women tend to have more positive views on the state government response to COVID-19 (Beck and Hensher, 2020). Besides, the shift of women from public transport to private modes, is indirectly associated with *Health risk*. Both women and low-income individuals perceive a higher *Health risk* threat, contrary to Australia (Beck and Hensher, 2020), where no differences in terms of gender or income were observed.

Recent literature (Aldred et al., 2016; 2017; Lam, 2018) has explored the factors that contribute to increasing the use of bicycle for women. On the other hand, Sagaris and Tiznado-Aitken (2020) identified many barriers (e.g., safety) that limit the use of bicycles for women in a Latin American context. According to our model, the pandemic seems to be a new barrier for women to use active modes. In this sense, the existence of cycling lanes (and cycling infrastructure in general) are key to developing sustainable trends, especially considering the travel needs of women that tend to be different than for men (Sagaris and Tiznado-Aitken, 2020).

Regarding age, we found that the older the respondent, the higher the propensity to shift from public transport to private modes, and the lower the propensity to move to active modes. Physical effort is obviously a barrier for active mode use by older people, and this may explain the lower rate of older transport users shifting to active modes (Fernández-Heredia et al., 2014; Grudgings et al., 2021). Besides, the increase in the propensity to shift from public transport to private modes, is related to the higher perceived *Health risk* for older respondents, which is in line with reports regarding higher risks related to COVID-19 in older people (Beck and Hensher, 2020; Nimgaonkar et al., 2021; Sasson, 2021).

According to our model, employers, employees and students are more likely to shift to private motorised transport and less likely to change to active modes. On the other hand, self-employed are less likely to change mode when compared with the unemployed. Similarly, middle and high-income people are also more likely to shift to private modes and less likely to change to active modes. Given that car ownership increases with household income (de Jong et al., 2004) and that formal workers have higher average income than informal workers, it is expected that employees should have greater availability of private transport and therefore a greater probability of switching from public transport to car or motorcycle. Besides, the smaller propensity to change to active modes for middle and high-income people, can also be related to the aforementioned *bicycle use stigma* that associates bicycle use mostly with poor people (Rosas-Satizábal and Rodriguez-Valencia, 2019).

Regarding differences between the five cities studied, we found that Bogotá, Lima, Quito and Santiago showed a higher propensity to change from public transport to other modes compared with Buenos Aires. It is worthwhile noting that the sharpest reduction in public transport trips was observed precisely in Buenos Aires, the only city that imposed a formal limitation on public transport use to essential workers (see Table 2 and Figure 2). The fact that people from Buenos Aires reported the lowest *Health risk* and the highest *Life-related activities comfort*, suggests that at least part of the shift from public transport is explained by compliance to regulations rather than by risk perceptions. Unfortunately, our model does not allow to distinguish to what extent the mode shifting decision is influenced by health-related policy measures.

4 Limitations and Further Research

Different trade-offs need to be considered, in further research, to improve the understanding of the COVID-19 influences on transportation in South America. Applying online-based surveys is the fastest way to collect responses from people around the world (Dillman et al., 2014) and is the preferred option to collect information considering the pandemic nature. However, there are many limitations regarding this data collection method. Internet access is one of the most recognized limitations as it may generate a *coverage bias* by not reaching a, perhaps, not insignificant proportion of the population (Dillman et al., 2014). We collected a sample with responses from different groups of people in terms of gender, age, income, occupation, and marital status, to reduce the coverage bias as shown in Table 6. But our sample is, in a certain sense by design, not representative of the population; however, we do not consider this a serious problem given the study's objectives. On the other hand, as our survey was open to any visitor, obtaining multiple responses from the same person was a risk. To mitigate it, we used SurveyMonkey's cookies option to avoid having the same browser completing more than one survey.

Behaviours and attitudes during COVID-19 may change from day to day, considering the pandemic's natural state of flux and evolution. However, we need to develop research about sustainable transport in the future to understand how people's perceptions may influence changes in public transport use. In our case, the subjective information was collected for five capital cities of South America. It would enlarge the scope if we were able to bring together similar experiences around the world, as we have done in Australia. Both the research results and an updated version of the data collected would also benefit from other data collection waves, considering the changes in the development of the pandemic, as well as the governments and people's responses prior to the vaccination and decline of the contagions.

The team leading this paper has already started preparing further data collection waves for the coming years in an effort to comprehend better the short-, medium- and long-term effects of COVID-19 in transportation. A follow-up study should allow comparing the first period of the pandemic and the transitions after the lockdown scenarios in similar contexts.

Besides, as the main objective of this study was to explain the modal shifts from public transport to other modes based on people's perception, no information about the level of service of the various modes was collected. A more detailed analysis could be carried out in the future incorporating certain peculiarities of each city and its transport modes, which can certainly affect users' perceptions. Finally, future surveys should give a more detailed insight into which part of the mode choice change is driven by regulations and which one is driving by individual perceptions, such as health risk.

5 Conclusions

We adapted and collected information about travel patterns and telecommuting during the COVID-19 pandemic in five South American capitals, based on previous surveys performed in Australia by Beck and Hensher (2020) and Beck et al. (2020). The study collected information in Bogotá, Buenos Aires, Lima, Quito and Santiago through a survey carried out between August and November 2020. The approach has allowed us to improve our understanding of geographical and contextual similarities in the pandemic scenario. Since the pandemic's beginning, these five cities showed a decline in public transport use, which meant similar and significant challenges to keep public transport service standards.

The study proposed a model for understanding the profile of users that shifted from public transport to other modes during the COVID-19 outbreak. Having to perform face-to-face activities, public transport users tended to shift to other transport options (such as private and active modes). In contrast, users working at home shifted to immobility in their main productive activities. In general terms, our model implies a smaller probability of moving from public transport to active modes, than to private modes, suggesting difficulties in terms of encouraging active mode use as an alternative for public transport during the COVID-19 pandemic. This challenge can be added to the other barriers reported in the literature on the use of active modes in terms of safety (Manaugh et al., 2017; Sagaris and Tiznado-Aitken, 2020; Vallejo-Borda et al., 2020), security (Sagaris and Tiznado-Aitken, 2020; Vallejo-Borda et al., 2020) and even social stigma (Rosas-Satizábal and Rodriguez-Valencia, 2019). Confidence in the actions undertaken by both national and local authorities was essential to explain changes in commuting patterns. According to our findings, those who stopped travelling by public transport during the pandemic and switched to active modes, generally had less trust in public entities than those who changed to private modes. Besides, our findings also suggests that sustainable transport goals can be threatened by an increase in the number of deaths caused by COVID-19, giving the positive influence of this variable in the probability to shifting to private modes.

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Appendix: Goodness of fit indicators for the SEM-MIMIC model

Indicator	**Accepted threshold**	**Explanation**
Normed $\chi^2 = \frac{\chi^2_{model}}{df_{model}}$	< 3.0 (Bollen, 2014; Hair et al., 2014)	These indicators are based on the standardised comparison of the observed and reproduced variance-covariance matrices
$GFI = 1 - \frac{\chi^2_{model}}{\chi^2_{null}}$	> 0.95 (Hair et al., 2014; Hoyle, 2012; Schumacker and Lomax, 2016)	
$SRMR = \sqrt[2]{\left(\frac{1}{k}\right)(e'W_s e)}$	< 0.05 (Schumacker and Lomax, 2016)	
$TLI = \frac{\frac{\chi^2_{null}}{df_{null}} - \frac{\chi^2_{model}}{df_{model}}}{\frac{\chi^2_{null}}{df_{null}} - 1}$	> 0.95 (Gana and Broc, 2019; Hoyle, 2012)	These indicators are based on the comparison of the baseline and proposed models
$CFI = 1 - \frac{\chi^2_{model} - df_{model}}{\chi^2_{null} - df_{null}}$		
$RMSEA = \sqrt[2]{\frac{\chi^2_{model} - df_{model}}{(N-1)df_{model}}}$	< 0.05 (Gana and Broc, 2019; Schumacker and Lomax, 2016)	This indicator serves to estimate the parsimony of the model

Note: χ^2 = chi-square test statistic; df = degrees of freedom; k = number of unique distinct values in the observed variance-covariance matrix; e = vector of residuals from the observed and model-implied variance-covariance matrices; W_s = diagonal weight matrix to standardize the elements of the observed variance-covariance matrix; N = sample size (Hoyle, 2012; Schumacker and Lomax, 2016).

Appendix I. Paper #7: What might the changing incidence of Working from Home (WFH) tell us about Future Transport and Land Use Agendas

Matthew J. Beck
David A. Hensher

"Governments and employers working with employees can, and should, take advantage of the unintended positive consequences of COVID-19"

"Finally, we are truly in Liminal ("Threshold") Time – the gateway between two stages in life!"

This is a short think piece[63] that recognises that while the pandemic forced change without choice for almost all individuals and households, it has resulted in unintended consequences[64]. We are in the midst of a real-world experiment that has created positive outcomes in that it has been suggested that the pandemic has made us less selfish and more societal focused and caring for others through being, in general, better responsible members of the community. There are, however, negative outcomes associated with the challenging, if not traumatic, experience for some individuals and households associated with job loss, social isolation, and inter-personal pressures within the household. However, a notable and potentially lasting consequence with positive impact, is working from home (WFH) and how that might translate into many impacts through the supply chain of businesses, particularly those that depend heavily on workers at the office, or who work outside of the home.

Before discussing WFH and the impact it may have on future transport and land use agendas, it is worth highlighting the seismic impact of COVID-19 and associated policies on broad mobility patterns. Using Google Mobility Data (Google 2020) we can see that, in a small sample of 16 countries from different parts of the globe, the time spent in transit (Figure 1), at workplaces (Figure 2) and in the home (Figure 3) has changed dramatically almost everywhere. In particular, people have spent significantly less time in transit and workplaces, and more time inside the home which has in turn become the place of work (or study) for many. It stands to reason that the time spent at transit stations, workplaces and residences are intimately linked. Figure 4 highlights the degree to which these activities are related, with very strong positive correlations between the time spent at transit stations and work, and strong negative correlations between time spent at transit stations and home, and between time spent at work versus at home. It is interesting to note the differences in behaviour represented by South Korea and in particular Taiwan, suggesting that there are some differences in how these two countries are broadly responding to COVID-19.

[63] We thank our colleague, Professor John Nelson, and Sherri Fields of TfNSW for their comments.
[64] The opinions in this thought piece are those of the authors alone. The paper was prepared outside of two research projects which we are now engaged in, and we acknowledge the support from the iMOVE CRC (https://imoveaustralia.com/) and our industry partners (Transport and Main Roads (TMR) MR Queensland, Transport for NSW (TfNSW) and the Western Australia Department of Transport (WA DoT) in moving the WFH agenda forward in the next 18 months.

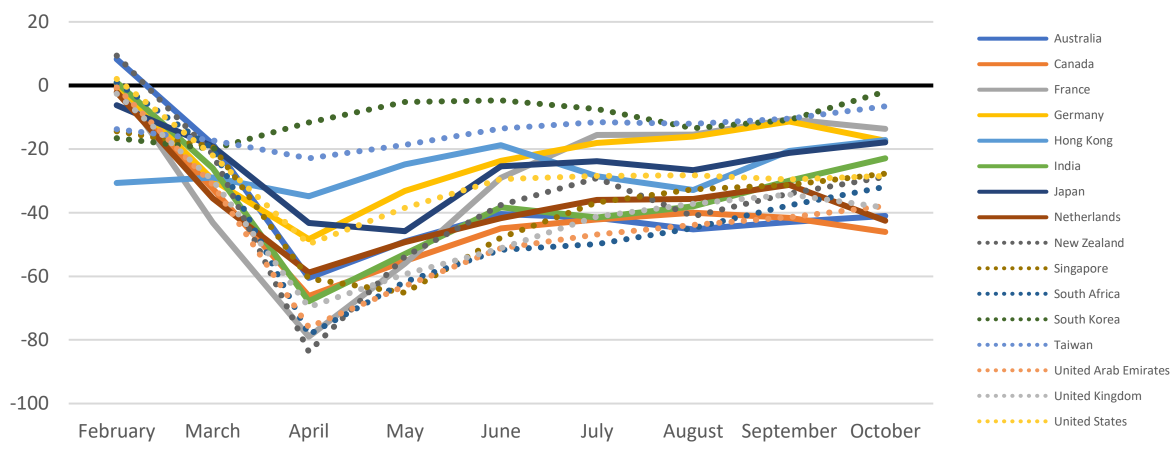

Figure 1: Google Mobility Data – Transit Stations

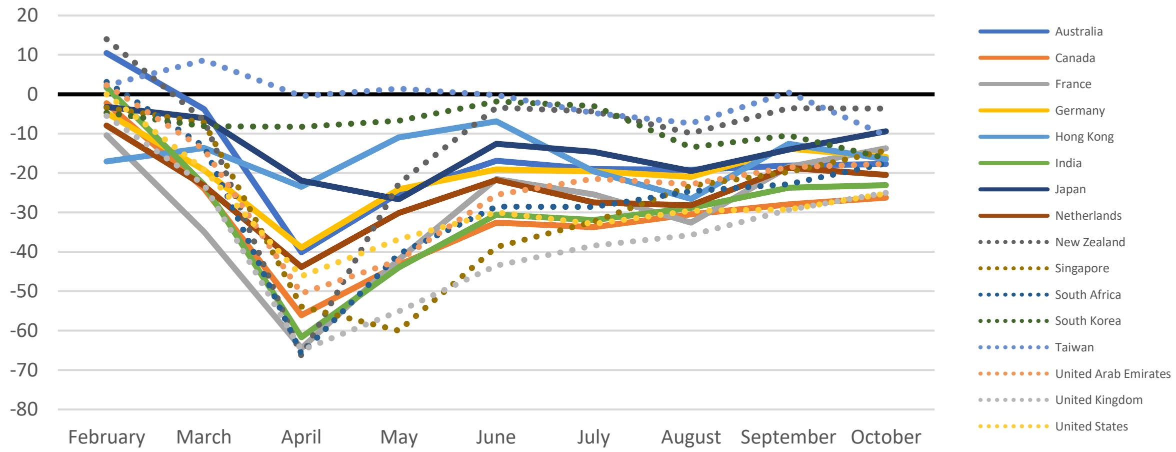

Figure 2: Google Mobility Data – Transit Stations

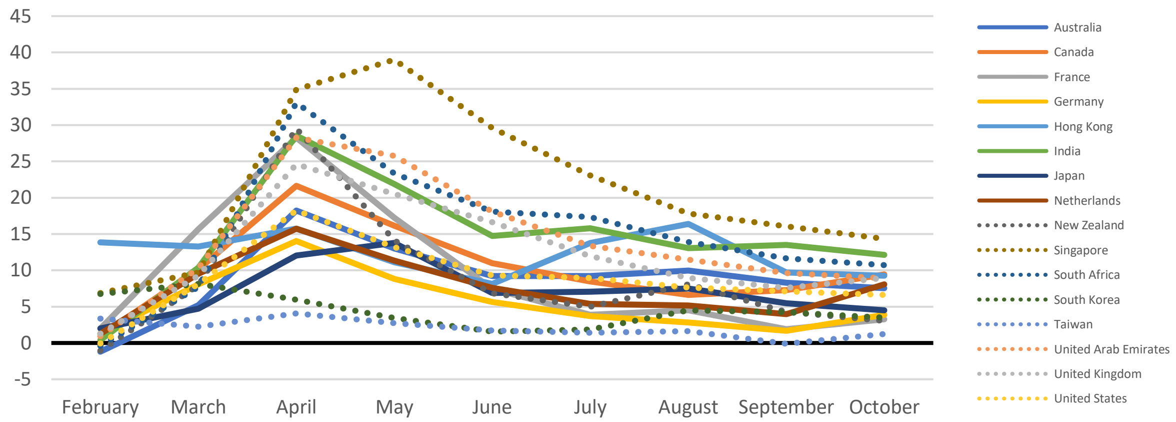

Figure 3: Google Mobility Data – Residential

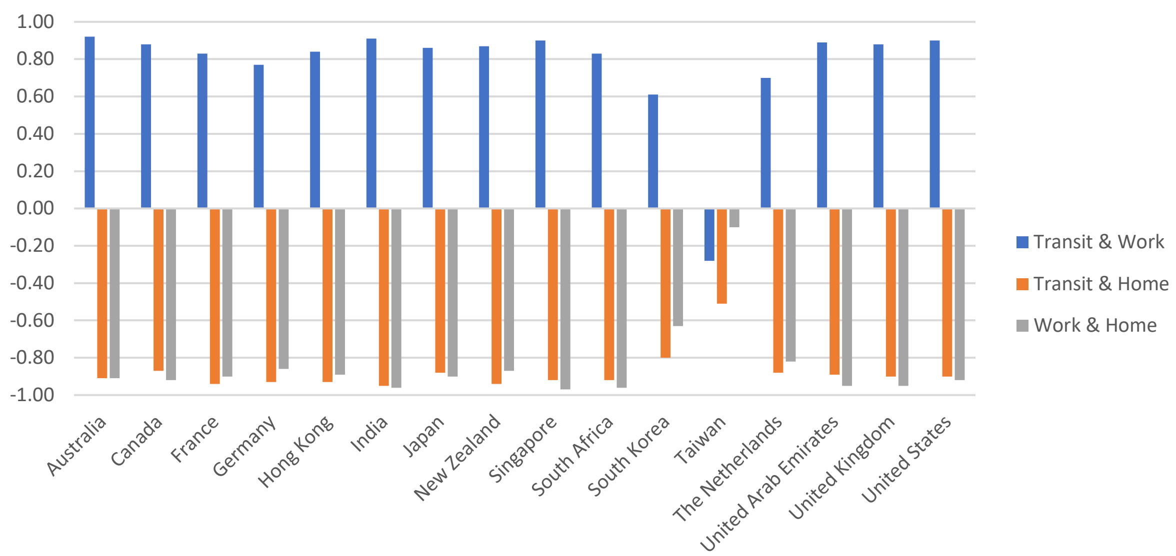

Figure 4: Correlations between Time Spent in Transit, Workplaces, and Homes[65]

A useful tool to measure the relative stringency of government policy across time is the Oxford COVID-19 Government Response Tracker (OxGRT 2020). OxGRT collect data on fourteen measures collected which are grouped into three over-arching dimensions, of which nine are used in the calculation of the Stringency Index:

$$Stringency\ Index = \frac{1}{k}\sum_{j=1}^{k} I_j \tag{1}$$

where *k* is the number of component indicators in an index and I_j is the sub-index score for an individual indicator (see Hale et al. 2020 for further information). The indicators used in the stringency index are as follows:

(i) Containment and Closure:

- School closing
- Workplace closing
- Cancel public events
- Restrictions on gathering size
- Close public transport
- Stay at home requirements
- Restrictions on internal movement
- Restrictions on international travel

(ii) Economic Response:

- Nil used in Stringency Index

(iii) Health Systems:

- Public information campaign

As can be seen, the biggest components in determining how stringent governments have been in responding to COVID-19 has been the limitations placed on the movement of people, which

[65] All correlation coefficients are statistically significant at the 1% level. Spearman's correlations were used for the Australian, German, New Zealand, Hong Kong, Japan and Taiwan, and within South Korea for correlations with "work" only, due to the data being non-normal.

largely explains the shifting patterns in mobility that are observed in Figures 1-3. Generally speaking, it is unsurprising that countries that have been more stringent in their response have been so because of higher rates of infection. This is highlighted by way of a simple comparison. Figure 5 shows the average rate of positive tests within each of the 16 countries sampled, plotted against the average stringency index within each country for the time periods in which OxGRT has collected data on each measure. The darker dashed lines represent the average positive test rate over the 16 samples countries (0.036) and the average of the stringency index over the sampled countries (47.0). While outliers exist, generally countries with higher levels of stringency are grappling with higher positive test rates for COVID-19.

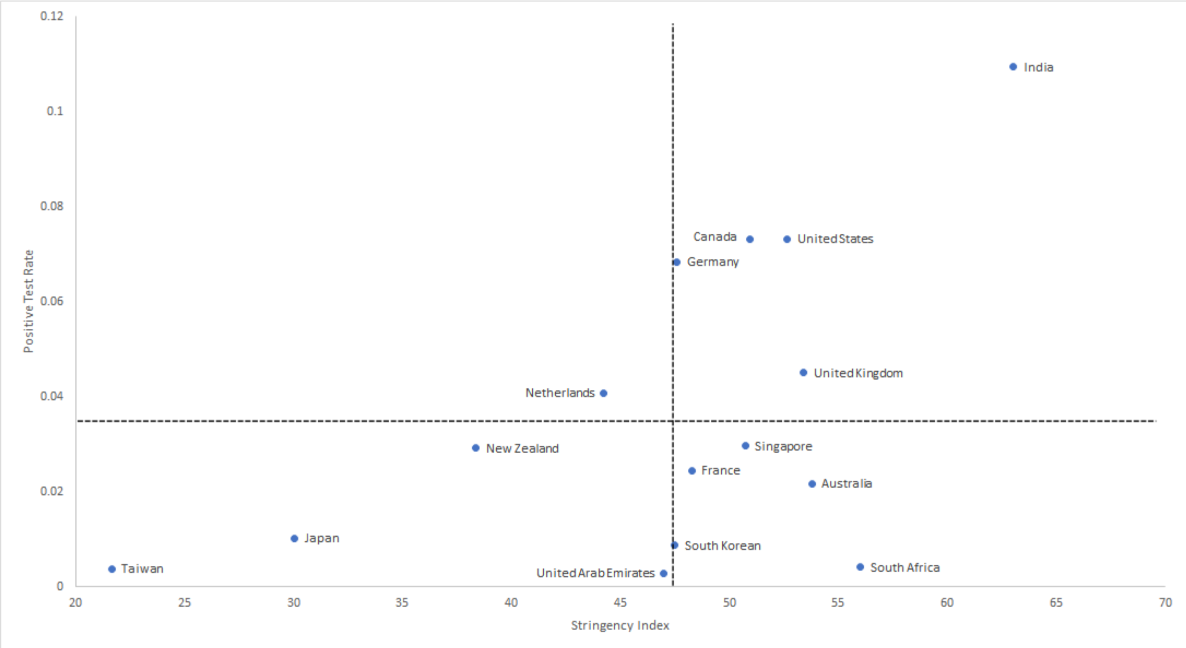

Figure 5: Positive COVID-19 Test Rates vs Stringency Index

To gain insight into the way in which the stringency of government policy impacts on travel behaviour, we employ cross-correlation analysis to help identify lags of the x-variable (Stringency Index) that might be useful predictors of the y-variable (time spent at transit stations). The cross-correlation is given by equation (2) where we are estimating the correlation between a variable y and a different time-shifted variable x_{t+k}, and σ_x and σ_y are the sample standard deviations of x_t and y_t respectively. Note that since time spent at transit stations is very strongly correlated with time spent either at work (positive correlation) or at home (negative correlation), analysing this one variable as a proxy for "movement" is sufficient.

$$g_k^{xy} = \frac{\frac{1}{n}\sum_{t=1}^{n-k}(y_t-\hat{y})(x_{t+k}-\hat{x})}{\sqrt{\sigma_x \sigma_y}} \quad (2)$$

Figure 6 provides the cross-correlation coefficients for lag periods +/- 20 days either side of when government policy was made more, or less stringent. The negative correlations indicate that an above average value of "stringency" is likely to lead to a below average value of "transit". In the majority of the sampled countries, the peak correlations (indicated by darker red) occur at a time lag around 0, indicating the changes in time spent in transit locations occur mainly on the day in which policy interventions are made. Some outliers exist, in particular

Hong Kong and Germany seem to have changes in mobility that occur before government policy is enacted (positive lag), and Japan has a negative lag of about 4 days which indicates that citizens respond more slowly to changes in stringency. Once again, Taiwan and South Korea also represent unusual cases.

It is clear that to restrict the spread of COVID-19, governments have deployed policies designed to curb the movement of people, which has in turn changed the nature of where time is spent and where work is done. It is undeniable that the change in work location is of considerable interest in many countries[66] and with people spending more time at home globally, many are now also having to work from this location (admittedly to varying degrees of success). This is resulting in work-related laws being revised. For example, Germany is drafting a new law to make working from home a legal right (Elliot 2020), large corporations in the technology sector were among to shift employees to WFH and have limited plans for them to return to the office (Lerman and Greene 2020), and the Office of National Statistics in the UK (ONS 2020) has noted a rise in the number of employees working exclusively from home (almost a quarter of those surveyed).

It is our belief that, a notable and potentially lasting consequence with positive impact, is working from home (WFH) and how that might translate into many impacts through the supply chain of businesses, particularly those that depend heavily on workers at the office, or who work outside of the home. In focussing on WFH[67], we emphasise that while the pandemic forced a cataclysmic change on our lives without much time to prepare, it has happened, and as we continue to respond to the pandemic by keeping our distance, evidence is building on the pros and cons of WFH and the extent to which WFH will continue at a level that is greater than pre-COVID-19.

There is plenty of evidence that this is a global trend. The software company Slack (channel-based messaging platform for fostering teamwork and collaboration within organisations) commissioned a survey of workers who identify as ‘skilled office workers’ in the US, the UK, France, Germany, Japan and Australia, fielded between June 30 and August 11, 2020. A key finding of this survey was the extent to which employees would prefer to work in the future in a hybrid way, mixing time working both from home and from the office, with only 11.6% wanting to return to the office full-time (Elliot 2020). Figure 7 shows the proportion of respondents in each country who would prefer a hybrid work model.

[66] Simple searches “work from home COVID” produces 789,816 results in ProQuest, 36,000 results in Google Scholar.

[67] Studying from home (SFH) has also occurred, and while this has subsided in Australia for primary and secondary education, it largely remains in place for tertiary education, and in many instances international students are now studying from their home country (though in considerably less numbers than before across the sector). The physical absence of tertiary students has had a significantly large and negative impact on local suppliers of student accommodation, and other support industries and services.

	-20	-19	-18	-17	-16	-15	-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Australia	-0.24	-0.28	-0.31	-0.35	-0.39	-0.43	-0.47	-0.51	-0.55	-0.59	-0.62	-0.65	-0.69	-0.72	-0.75	-0.78	-0.81	-0.83	-0.85	-0.87	-0.88	-0.87	-0.86	-0.84	-0.82	-0.80	-0.78	-0.76	-0.73	-0.71	-0.68	-0.65	-0.62	-0.59	-0.56	-0.53	-0.50	-0.47	-0.43	-0.40	-0.37
Canada	-0.14	-0.18	-0.22	-0.27	-0.31	-0.36	-0.40	-0.45	-0.49	-0.53	-0.57	-0.61	-0.65	-0.69	-0.72	-0.76	-0.79	-0.81	-0.82	-0.85	-0.87	-0.85	-0.84	-0.82	-0.80	-0.77	-0.75	-0.72	-0.69	-0.66	-0.63	-0.59	-0.56	-0.53	-0.50	-0.46	-0.43	-0.40	-0.37	-0.33	-0.30
France	-0.54	-0.58	-0.61	-0.64	-0.66	-0.69	-0.71	-0.73	-0.75	-0.76	-0.78	-0.79	-0.81	-0.83	-0.85	-0.87	-0.88	-0.89	-0.90	-0.91	-0.92	-0.91	-0.90	-0.88	-0.86	-0.84	-0.82	-0.80	-0.78	-0.76	-0.74	-0.72	-0.70	-0.67	-0.65	-0.63	-0.62	-0.60	-0.58	-0.57	-0.55
Germany	-0.08	-0.12	-0.16	-0.19	-0.23	-0.27	-0.31	-0.35	-0.38	-0.42	-0.45	-0.49	-0.53	-0.57	-0.60	-0.63	-0.67	-0.70	-0.72	-0.75	-0.79	-0.79	-0.79	-0.78	-0.77	-0.76	-0.74	-0.72	-0.70	-0.68	-0.65	-0.63	-0.61	-0.59	-0.56	-0.54	-0.52	-0.49	-0.47	-0.45	-0.43
Hong Kong	0.30	0.25	0.21	0.17	0.13	0.09	0.04	-0.01	-0.05	-0.08	-0.12	-0.14	-0.17	-0.22	-0.26	-0.30	-0.33	-0.35	-0.38	-0.40	-0.42	-0.45	-0.47	-0.48	-0.48	-0.48	-0.47	-0.47	-0.46	-0.46	-0.45	-0.44	-0.43	-0.41	-0.43	-0.41	-0.40	-0.39	-0.38	-0.37	-0.37
India	-0.25	-0.30	-0.34	-0.38	-0.42	-0.46	-0.50	-0.54	-0.58	-0.61	-0.65	-0.69	-0.72	-0.75	-0.77	-0.80	-0.83	-0.85	-0.86	-0.87	-0.88	-0.86	-0.83	-0.81	-0.78	-0.75	-0.72	-0.69	-0.66	-0.62	-0.59	-0.56	-0.53	-0.49	-0.46	-0.42	-0.39	-0.35	-0.31	-0.28	-0.25
Japan	-0.52	-0.53	-0.54	-0.55	-0.55	-0.55	-0.55	-0.55	-0.57	-0.58	-0.58	-0.57	-0.58	-0.59	-0.59	-0.59	-0.59	-0.59	-0.59	-0.58	-0.58	-0.55	-0.53	-0.50	-0.47	-0.44	-0.41	-0.39	-0.35	-0.31	-0.27	-0.25	-0.22	-0.20	-0.17	-0.14	-0.11	-0.09	-0.07	-0.05	-0.03
Netherlands	-0.21	-0.25	-0.30	-0.34	-0.39	-0.43	-0.47	-0.51	-0.55	-0.59	-0.63	-0.66	-0.70	-0.74	-0.78	-0.81	-0.84	-0.86	-0.88	-0.89	-0.90	-0.89	-0.87	-0.85	-0.83	-0.80	-0.77	-0.74	-0.72	-0.68	-0.65	-0.62	-0.59	-0.55	-0.52	-0.49	-0.45	-0.41	-0.38	-0.34	-0.30
New Zealand	-0.41	-0.44	-0.47	-0.50	-0.53	-0.56	-0.58	-0.61	-0.64	-0.67	-0.69	-0.72	-0.74	-0.76	-0.78	-0.80	-0.82	-0.84	-0.86	-0.86	-0.86	-0.84	-0.82	-0.79	-0.76	-0.73	-0.70	-0.66	-0.62	-0.59	-0.55	-0.52	-0.48	-0.44	-0.40	-0.36	-0.32	-0.28	-0.24	-0.19	-0.16
Singapore	-0.51	-0.54	-0.56	-0.59	-0.62	-0.64	-0.67	-0.70	-0.72	-0.74	-0.77	-0.79	-0.81	-0.83	-0.86	-0.88	-0.90	-0.91	-0.93	-0.94	-0.96	-0.95	-0.94	-0.93	-0.91	-0.90	-0.89	-0.87	-0.85	-0.84	-0.82	-0.81	-0.79	-0.76	-0.74	-0.72	-0.70	-0.68	-0.66	-0.63	-0.61
South Africa	-0.33	-0.37	-0.42	-0.46	-0.50	-0.54	-0.58	-0.62	-0.66	-0.70	-0.73	-0.75	-0.77	-0.79	-0.81	-0.83	-0.85	-0.86	-0.88	-0.90	-0.90	-0.88	-0.86	-0.84	-0.82	-0.80	-0.77	-0.75	-0.73	-0.70	-0.67	-0.65	-0.62	-0.59	-0.56	-0.53	-0.49	-0.46	-0.43	-0.40	-0.37
South Korea	0.05	0.07	0.05	0.05	0.03	0.04	0.02	0.01	-0.01	-0.02	-0.02	-0.05	-0.07	-0.09	-0.13	-0.16	-0.18	-0.19	-0.20	-0.21	-0.22	-0.21	-0.22	-0.20	-0.19	-0.19	-0.20	-0.22	-0.22	-0.22	-0.22	-0.23	-0.23	-0.25	-0.27	-0.28	-0.28	-0.29	-0.30	-0.30	-0.33
Taiwan	-0.56	-0.58	-0.56	-0.58	-0.60	-0.59	-0.59	-0.58	-0.56	-0.54	-0.54	-0.55	-0.54	-0.55	-0.54	-0.55	-0.54	-0.55	-0.59	-0.59	-0.60	-0.60	-0.59	-0.57	-0.57	-0.56	-0.55	-0.54	-0.52	-0.50	-0.50	-0.49	-0.47	-0.45	-0.44	-0.42	-0.40	-0.40	-0.39	-0.37	-0.35
United Arab Emirates	-0.43	-0.46	-0.50	-0.53	-0.57	-0.60	-0.63	-0.66	-0.69	-0.72	-0.75	-0.77	-0.79	-0.81	-0.83	-0.85	-0.87	-0.88	-0.90	-0.91	-0.92	-0.91	-0.89	-0.88	-0.85	-0.83	-0.81	-0.78	-0.75	-0.72	-0.69	-0.66	-0.63	-0.59	-0.56	-0.53	-0.49	-0.46	-0.43	-0.39	-0.36
United Kingdom	-0.16	-0.20	-0.24	-0.28	-0.32	-0.36	-0.40	-0.44	-0.48	-0.52	-0.56	-0.60	-0.64	-0.68	-0.72	-0.75	-0.78	-0.81	-0.84	-0.86	-0.87	-0.87	-0.86	-0.85	-0.84	-0.82	-0.80	-0.77	-0.75	-0.72	-0.70	-0.67	-0.64	-0.61	-0.58	-0.54	-0.51	-0.48	-0.45	-0.42	-0.39
United States	-0.16	-0.21	-0.25	-0.30	-0.34	-0.39	-0.44	-0.48	-0.53	-0.57	-0.60	-0.64	-0.67	-0.71	-0.74	-0.76	-0.79	-0.81	-0.82	-0.83	-0.85	-0.83	-0.81	-0.79	-0.77	-0.74	-0.71	-0.68	-0.65	-0.62	-0.58	-0.55	-0.52	-0.48	-0.45	-0.42	-0.38	-0.35	-0.32	-0.29	-0.26

Figure 6: Cross-Correlations of Stringency Index and Google Mobility Data (Transit Stations)

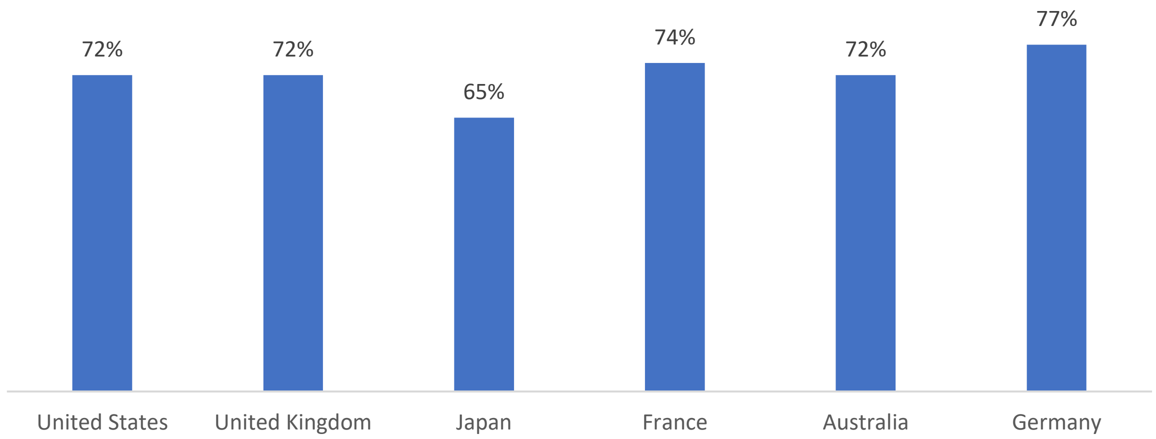

Figure 7: Workers Who Would Prefer Mix of Work from Home and Office

In focussing on WFH, we emphasise that while the pandemic forced a cataclysmic change on our lives without much time to prepare, it has happened, and as we continue to respond to the pandemic by keeping our distance, evidence is building on the pros and cons of WFH and the extent to which WFH will continue at a level that is greater than pre-COVID-19. At a high level, preliminary indications as of early September 2020, in Australia, are that we can expect to see a growing number of workers in some occupation classes (notably white collar but not exclusively) working from home for one to two days a week, and that this comes with the blessing of employers in particular, who believe there is generally no difference, on average, in productivity for employees who are currently working from home compared to before COVID-19 (Beck and Hensher 2020, 2020a). Studying from home (SFH) has also occurred, and while this has subsided in Australia for primary and secondary education, it largely remains in place for tertiary education, and in many instances international students are now studying from their home country (though in considerably less numbers than before across the sector). The physical absence of tertiary students has had a significantly large and negative impact on local suppliers of student accommodation, and other support industries and services.

While we have had disruption in the past, a key difference with COVID-19 compared to those such as SARS, MERS, the Global Financial Crisis and natural disasters, has been the duration, coverage and the extent to which disruption has occurred and continues to occur. Our evidence suggests that COVID-19 has also broken the back of significant business resistance to WFH, and at a time where many businesses are looking to reduce costs, many see WFH as an appealing and viable option to reduce the cost of office space provision where lease costs in the CBD in particular, are often sizeable. Ongoing levels of WFH would also be a prudent risk management strategy should the COVID-19 pandemic re-emerge or another replace it in the future. Significantly lowering the environmental impact of staff travelling every day can also allow big corporates to deliver on their sustainability charter which has generally alluded them to date.

Again, we acknowledge that not all can WFH as well as others and that occupation and the nature of work is a key determinant. For example, those with a face-to-face role in a service economy are facing unique difficulties in the face of a pandemic (in 2018 Deloitte produced a report about the rising importance of the service economy estimating that 70% of employment in the OECD is driven by this type of activity). Also, many workers face work/life balance concerns along with unequal distribution of non-paid labour in the home, and constraints on available space suitable for ongoing WFH. Technology access also plays a role, for example the availability, reliability and speed of an internet connection is pivotal. While these caveats remain, there are other considerable benefits that accrue to the employee who is able to WFH successfully such as being able to allocate their work hours in a more flexible way, or most importantly recovering time that is often lost to commuting. Employees (and/or their employers) have also likely made investments in the last six months to enable WFH (e.g., improved home office capability) and given the duration of the pandemic, new strategies and habits are likely being developed to make WFH work for them. While there does remain some hurdles to the ongoing levels of WFH such as social connectedness, team work, collaboration and creativity, the human desire for face-to-face interactions with others (many authors have explored the role of social capital in the workplace and how friendship and connection can improve productivity), many of these barriers can be addressed with innovation and a work environment where there is a mix of WFH and working in "the office".

The growth in WFH translates into some important positive changes in the performance of the transport network, particularly in the larger cities. Our research in Australia suggests that we might anticipate at least a 10 to 15 percent improvement in the metropolitan transport networks due to reduced traffic congestion on the roads and crowding on public transport. We suggest that WFH promises to be the greatest 'transport' lever for policy makers to reduce congestion and crowding that the sector has ever had. What we are seeing in our tracking surveys to date since March 2020 (Beck and Hensher 2020, 2020a) is that the increase in WFH in Australia is spread evenly throughout the five weekdays. This is important, since infrastructure and service capacity is typically determined by peak demand, and if this can be flattened as it suggests it might, then the implications for prioritising and deferring funds and planning in transport are potentially significant, even going forward over many years.

There are a growing number of structural responses that should be given serious consideration, and we now set out a number of likely futures post-COVID19.It will be useful to list a number of potential changes to the fabric of society that could occur due to increased WFH brought on by the pandemic and likely to continue well after the pandemic has subsided. These should, at a minimum, be part of any discussions by government in particular, but more generally, on future transport and land use agendas in all countries.

1. 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, around 80%, which will not only support reduced road traffic congestion but also manageable crowding on public transport compared to pre-COVID-19. Central areas of major metropolitan cities will continue to have a role, but as we discuss below, the idea of reinvigoration in suburbia should not be dismissed lightly in any attempt to protect and preserve the CBD as a matter of faith. Although this CBD impact is still a dent in the revenue sources for many businesses in the central city precincts that depend to a large extent on office trade, it is still enough activity to revitalise much of the business in the supply chain that is currently suffering. We must recognise that much of the loss in the supply chain is due to restrictions that are separate to restrictions on office workers and which are slowly being lifted. Furthermore, an increasing number of businesses have been moving to online trading and consequentially, one can expect a decline in traditional bricks and mortar trade. Restaurants and other food outlets will be the biggest winners as activity returns to some degree of normality in the CBD; however some structural change is likely, with new opportunities opening up in suburbia, and especially the locations that have already started to take on the appearance of a CBD or a small but growing business precinct.

2. 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 minute city, which remains a challenge given a strong radial and CBS focussed strategy in many cities throughout the world. We need to promote 'be local and buy local' to help capture the redistributive effect of increased

WFH where small business in suburban areas can benefit from increased economic activity that they would otherwise not participate in.

3. 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 (especially the reduced number of workers in the office at any one time), and while lower rents may attract a new class of small to medium sized businesses into (or back into) the CBD, we would suggest that this will be balanced against the benefits of a more local office plan, where rents will also be competitive and office space more convenient to where people live, again reducing the pressures of the commute and supporting more flexible working hours.

4. Although there is much talk in many countries about getting back to the pre-COVID-19 office versus continuing to WFH, 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. This has the advantage of supporting ‘working close to home’ (WCTH) (reduced time spent in travel), but not at home with all of its accompanying limitations such as lack of social interaction, and poor space to work effectively without interruptions from, or interrupting, other family members. It also significantly reduces the lease cost of office space and its associated overheads as well as creating connections locally, be they work or social, effectively reducing excess office capacity in this new world of connectivity through digital capability. What we have here is similar to efforts to reduce the fixed costs of private car ownership through mobility services such as Mobility as a Service (MaaS), with the prospect of growing demand for the lower cost ‘Office Location as a Service (OLaaS)’.

5. 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. As Mobility as a Service (MaaS) reboots after the pandemic (Hensher et al. 2020 Hensher 2020), there is a need to rethink monthly subscription plans to allow for subscriptions that have value when used for lesser number of days compared to the typical monthly pay plan. These might be repackaged for specific combinations of numbers of days per month. A greater focus on local shared mobility offerings, especially bicycles and e-scooters, should increasingly be built into the offered subscription bundles.

6. We should also reflect on long distance domestic travel as restrictions are lifted. Specifically, we are likely to see a significant reduction in domestic business air travel in many jurisdictions, replacing for example, the Sydney to Melbourne or the New York to Chicago and return flights (typically 4 hours out of the day) to attend a one hour meeting with an online meeting. This may translate into a growth in local non-commuting activity with time freed up.

7. With a greater focus on local activity, there will be a need to reprioritise improvements in local public transport, safer pedestrian walkways and precincts, and bicycle lanes, serving short distant trips throughout the day, with the added benefit of improving first and last mile connectivity to PT and (hopefully) contributing to improved health outcomes. Local road amenity and safety may also need to be revisited, with a greater focus on localised maintenance and traffic control measures to cope with a potential

change to localised traffic flow. Generally, we need a rethink where infrastructure funding should go, including deferring major infrastructure spend. We might even find that active travel strategies can become embedded within investment in key public infrastructure

8. The freight distribution sector, which has already shown significant growth with a noticeable increase in distribution to homes for online orders due to COVID-19, will continue to grow and investment to support freight networks with less "friction" will be crucial to the economy, even more so in the future.

9. Governments can lead the way in supporting WFH as a way of reducing pressure on the transport network, especially in metropolitan settings, but where this pressure is not of great consequence (e.g., many regional and rural contexts), they should encourage and support reduced travel and improvements in wellbeing associated with greater flexibility in work hours and days of the week working at home. Evidence through doing (leading by example) can flow through to the private sector to use WFH and WCTH to deliver on their sustainability charter.

10. Governments will also need to think creatively if they wish to reap the potential environmental benefits of increased work from home. Preliminary research has indicated that for people who commute by car, working from home is likely to reduce their carbon dioxide (CO_2) footprint if their journey to work is greater than about 6 kilometres[68]. However, for short car commutes or those done by public transport, working from home could increase CO_2 emissions due to extra residential energy consumption. Encouraging more thermally efficient buildings and sustainable energy sources such as solar could be considered.

In summary, the liminal threshold imposed on society by the COVID-19 pandemic provides an opportunity to allow decision-makers to take a hard look at the assumptions being used pre-COVID-19 that underlie many of the decisions made on transport and land use futures. Doing this may offer a real opportunity for sustained change that many have been seeking. COVID-19 has brought us all together and the future must be seen as an all of society commitment.

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Appendix J. Paper #7A: Australia 6 months After COVID-19 Restrictions- Part 1: Changes to Travel Activity and Attitude to Measures

Matthew J. Beck
David A. Hensher

Abstract

While many countries have experienced more than one wave of the pandemic throughout 2020, Australia has been able to contain the virus in a way that makes it a stand out (with New Zealand) in the way that it has been contained, with an exception in Victoria linked to failed quarantine procedures for travellers returning from overseas. Through descriptive analysis, this paper builds on earlier papers by the authors on the Australian response, with a focus on the changing dynamics of travel activity, concern with public transport, and attitudes surrounding activity given the perception of risk of COVID-19 and the level of public support for regulatory intervention and restrictions on movement. We find that Australia continues to suppress travel, particularly that for commuting, that comfort in completing day-to-day activities continues to rise (with the exception of Victoria where confidence feel significantly), and while support for intervention measures remains high, there has been an erosion in sentiment. As with previous work, we discuss what this might mean for future transport policy, and attempt to draw lessons from the Australian experience.

***Keywords**:* COVID-19, working from home, Australian experience, employer and employee support, implications on the performance of the transport network, longitudinal data

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1 Introduction

1.1 Literature Review

The impact of COVID-19 has been profound. It has changed the dynamics of people movement not only globally via international travel, but down to the unit of a household. Many individuals have severely curtailed their activity due to personal decisions about private and/or public health, or due to government regulatory intervention to stop rising case numbers. Many countries, Australia and New Zealand in particular, have found that restricting the movement of people is perhaps the best method to restrict the spread of the disease and facilitate the tracking community transmission.

While this paper will overview the ongoing experience in Australia, exploring disaggregate changes over time via the third wave of an ongoing series of national surveys, others have been doing similar work internationally. One such study is the MOBIS: COVID-19 work in Switzerland, who have been releasing close to weekly reports on mobility behaviour as tracked by GPS, relative to a baseline period of data September to November of 2019 . Recent insights from this valuable data collection effort (Molloy et al. 20221) reveal an ongoing acceptance of working from home and the modal shift in the recovery of the trip volumes and in the miles driven. They note that space-efficient large vehicles such as buses, trams and trains remain unpopular, and sustained increased in bicycle usage.

Similarly, in Sweden, who instead relied on behavioural guidelines rather than mandatory enforcement to limit human activity (Sabat et al. 2020), public transport ridership decreased in Stockholm by 60%, with travellers switching from 30-day period tickets to single tickets and travel funds and sales of short period tickets almost negligible (Jenelius and Cebecauer 2020). In explaining the propensity to stop travelling via public transport, education level, income, age, and work place were all significant (Almlof et al. 2020). In New York City it was found that subway use experienced a 90% fall, with evidence that some public transit users instead shifted to active modes such as bike sharing systems (Teixeira and Lopes 2020). The relatively larger move away from public transport can be explained by heightened concern about the risk of contagion on these modes (Scorrona and Danielis 2021, Qiu et al. 2020). Airplanes and buses are perceived to be the riskiest transport modes, while avoidance of public transport is consistently found across multiple countries, with income inequality the reported number of deaths due to COVID-19 aggravating this perception (Barbieri et al. 2021).

With respect to the impact on traffic, in South Korea there was a 23% to 26% reduction in traffic the weeks after the first confirmed COVID–19 case, with an increasing trend in traffic being observed as the number of COVID–19 cases started decreasing (Lee et al. 2020). Others have explored the potential positive externalities of this fall in traffic, for example in the city of Santander in Spain, overall mobility fell by 76% (public transport dropped by up to 93%), and as a result NO2 emissions were reduced as were the number of traffic accidents (Aloi et al. 2020). In Somerville USA it was it was found that a state-wide stay-at-home order in Massachusetts resulted in a 71% reduction in car traffic and 46% in trucks, contributing to an almost 70% reduction in ultrafine emission particles (Hudda et al 2020). In analysis of data across the USA, it has been found that such safer-at-home policies led to a 20% reduction in vehicular collisions entirely driven by less severe collisions, along with a 25% reduction in particulate matter concentration levels (Brodeur et al. 2021). Similarly, in the state of Qatar, while mobility restrictions did not change the hourly distribution of traffic over the day, they did reduce travel by 30%, resulting in total traffic crashes by about 37%, but the easing in movement restrictions did increase violations and fatalities (Muley et al. 2021).

While there have been some positive consequences of COVID-19 like those cited above, others have noted that the low production trend of greenhouse gas emission is expected to reverse once containment measures are lifted, and that the pandemic represents an opportunity to examine the role of public transit in a new green and public paradigm of mobility (Tardivo et al. 2021). Additionally, social distancing might result in social isolation and limited physical activity and as such walking and cycling can be important ways to maintain satisfactory levels of health and well-being (De Vos 2020). However, in the context of the immediate response to COVID-19, one study found that only 30% of transport experts worldwide reported guidelines and contingency plans for responding to the pandemic (Zhang et al. 2021).

Perhaps in light of this, research has also explored potential planning and operational responses, from identifying intervention measures that can support public transport service providers in planning their services in the post-shutdown phase and their respective modelling development requirement (Gkiotsalitis and Cats 2020) to the development of a new policymaking approach for battling the current COVID-19 and future pandemics (Zhang 2020). Highlighting the important role of movement and thus transport policy, it has been shown that social-based lockdown strictness will be sub-optimal and that policy makers need to intervene to impose this type of lockdown (Oum and Wang 2020). Indeed, optimisation models that can evaluate a modal-specific travel banning strategy and find a balance for the epidemic control as well as the negative impacts on regional economy have been developed (An et al. 2021). Finally, in a widespread study of government policy response across the EU, while citizens overall expressed satisfaction, this varied quite considerable from northern to southern countries, and was particularly pronounced for intrusive policy measures, such as mobile data use for movement tracking, economic concerns, and trust in the information from the national government (Sabat et al. 2020).

1.2 Scope and Structure of this Paper

In this paper, Part 1 of a joint overview, we will explore many of the themes addressed above, specifically reporting on the change in travel activity within Australia in the context of the majority of the country having very small to no new COVID-19 cases, while on the other hand the state of Victoria was in a very restrictive lockdown to combat a second wave of community transmission (peaking at just over 900 cases a day; a similar level to the national figures experienced in late March of 2020 after the initial outbreak). Part 1 explores not only describes changes to travel activity, but also provides an overview of the changing level of comfort in completing many day-to-day activities, support for COVID-19 policy measures and evolving perception of the risk of COVID-19. For international readers, an understanding of the overarching experience with COVID-19 in Australia might be instructive, as the country has had relatively low case numbers, but equally a relatively forceful regulatory approach to curb the spread of the pandemic.

The paper, where possible, compares the aggregate results from all three waves of the study to show the change over time, and continues to introduce new insights. In Part 2 of the paper series, we focus in detail on the rise of working from home. Note that we limit ourselves to aggregated analysis, given the desire to share timely information and the already large number of results discussed in this two-part work. We recognise that understanding the dynamics of changing behaviour at an individual level is crucial and as the panel nature of the data grows, ongoing work will seek to examine change and adaptation at an even more disaggregate level. This is part of ongoing work which complements the descriptive overview and interpretative policy analysis herein. This paper is structured as follows: section two provides an overview of the Australian experience; section three describes the sample collected for each survey wave and provides a note on hypothesis testing; section four discusses the results of overarching analysis; section five provides a discussion of the results and the potential policy implications that arise from the result found herein; and section six discusses limitations and provides the conclusion.

2 Overview of the Australian Experience

2.1 COVID-19 and the Community

This paper examines data collected in a third wave of an ongoing series of surveys designed to look at the changing impact of COVID-19 on travel, activities, and attitudes in Australia. We build on the findings of the second survey wave, which was conducted during a period of time where Australia had been relatively successful in combatting the first wave of COVID-19 infections through a series of regulations which were quickly implemented to halt the rise in transmissions. In discussing Wave 2, Beck and Hensher (2020a) note that the country had experienced a relatively low number of new daily infections almost exclusively restricted to what is now the largest risk factor in Australia; residents returning from abroad. Indeed, a key pillar in the strategy to combat the transmission of COVID-19 in Australia was to require all incoming international travellers to isolate in designated quarantine hotels for a period of two weeks after arriving in Australia, and at the time of writing the Wave 2 overview, it was not known what would happen in Victoria, where a breakdown in the hotel quarantine regime led to a sustained period of lockdown and restrictions.

Despite the relatively low number of positive COVID-19 cases in the Hotel Quarantine Program, breaches of containment in the program in May and June led to the second wave of COVID-19 cases in Victoria. In Victoria, private security contractors were used to maintain quarantine, and while this was also true elsewhere, other states made far more significant use of police and defence forces. A primary part of the breach was the result of four guests in quarantine in mid-May who tested positive to COVID-19, spreading the virus to a hotel staff member and two private security guards. By June 18, a further 17 people working at the hotel had tested positive. At the same time, community transmission outside of the hotel quarantine system was starting to spread, in particular a case that rose to attention on 2 May related to an outbreak in an abattoir in Victoria that saw eight confirmed cases grow to 90 over the course of just 12 days.

On 30 June, 10 Melbourne postcodes re-entered stage-three restrictions[69], and all international flights were diverted from Melbourne for the following two weeks. Four days later, lockdown expanded to include two more postcodes and nine public housing towers were placed under a controversial hard lockdown. On the 6th of July, the Victoria–NSW border was closed for the first time in a century. On 9th of July, stage-three restrictions would be extended to the whole of metropolitan Melbourne and the Mitchell Shire. On the 2nd of August, metropolitan Melbourne moved into stage-four lockdowns[70], being only allowed to shop for food and necessary supplies within 5 kilometres of their home, exercise for one hour once per day within 5km of home, and a stay-at-home curfew from 8:00pm to 5:00am each night. At approximately the same time, regional Victoria was placed in stage-three "stay at home" restrictions.

In other states, New South Wales continued to experience low levels of community transmissions, primarily linked to an outbreak in South-West Sydney that was the result of a

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[69] Key features of stage-three lockdown include: stay at home, except for four reasons: necessary goods or services; medical care or compassionate reasons; exercise, work and education if necessary; cannot enter metropolitan Melbourne unless having an exemption; no visitors to the house; work from home must occur wherever practicable; remote learning state-wide; sport of all kind closed / not permitted; and restaurants and cafes must have takeaway and delivery only.

[70] Key features above and beyond stage-four lockdown are the curfew, the requirement to cover the face outside of the home unless you have a lawful reason for not doing so, and that only one person per home is allowed leave per day for shopping with multiple trips not allowed.

function at a hotel/bar attended by a COVID-19 positive guest who had travelled up from Melbourne for the event. Elsewhere in Australia, COVID-19 had been all but eliminated save for returning travellers. The relative magnitude of the second wave of infection in Victoria, the community transmissions in New South Wales and what was occurring in other states can be seen in Figure 1. On this figure, we also highlight the periods in time where each of the three waves of surveying were conducted.

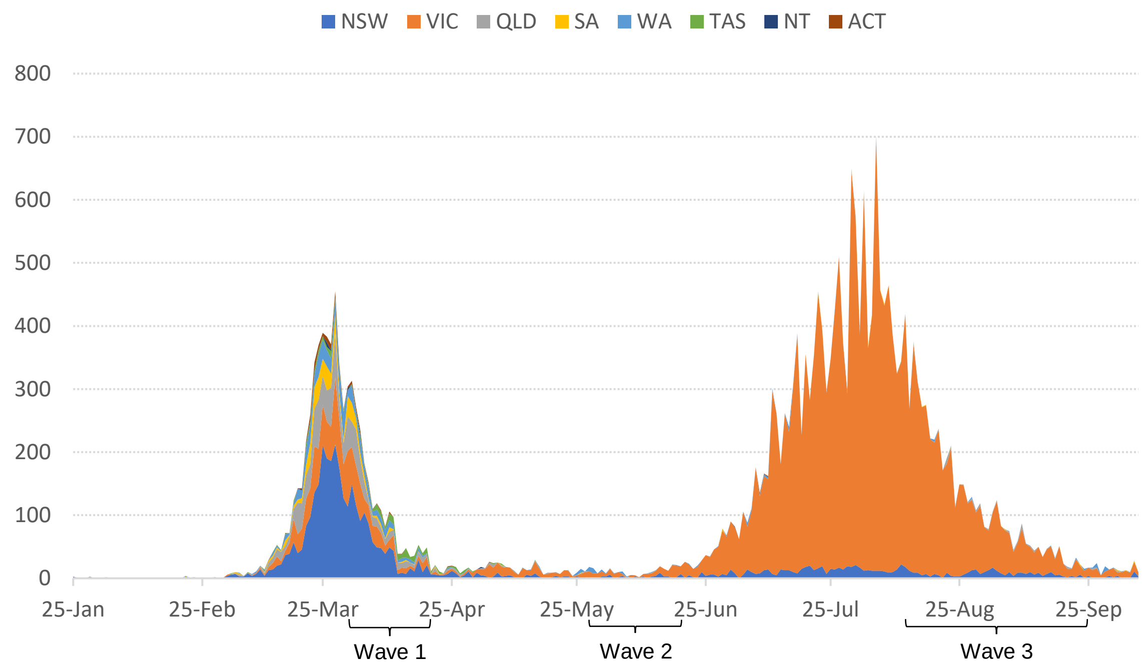

Figure 1: Daily Cases of COVID-19 by State

As we have been doing throughout the series of papers related to this survey, we include a summary overview of the key events over the time period or analysis (Figure 2 and Table 1), in this instance the period between Wave 2 and Wave 3. Unlike the timeframe between Wave 1 and Wave 2, the state borders remained mostly open; the exceptions being between New South Wales and Victoria, and Queensland for both New South Wales and Victoria. While the adoption of a tracking and tracing application (COVIDSafe) was thought to be a key prong in controlling COVID-19 at Wave 2, it has turned out that the application has been largely a white elephant. The ability of New South Wales to control and suppress COVID-19 community transmissions has instead been linked to a COVID tracking team of more than 300 people, who make over 2,000 calls a day to determine an infected person's hourly movements and who they potentially exposed, combined with testing of sewage, using photos, phone calendars, appointments and receipts to track movements (Cockburn 2020).

2.2 Aggregate Changes in Travel Activity

For the purposes of comparison to the disaggregate results discussed in this paper, we also provide aggregate measures of travel activity changes from external sources. It should be noted that, pleasingly, the travel patterns observed in our data mirror these external aggregate trends. In Figure 3 the aggregate data collected by the CityMapper Mobility Index (CityMapper 2020) is presented and shows that, relative to the baseline period (4 weeks between Jan 6th and Feb 2nd, 2020) mobility was trending upward at a slightly faster rate in Sydney than Melbourne, but also highlights the impact on mobility in Melbourne as a result of the severe restrictions placed on the city in an effort to curb the second wave of the pandemic.

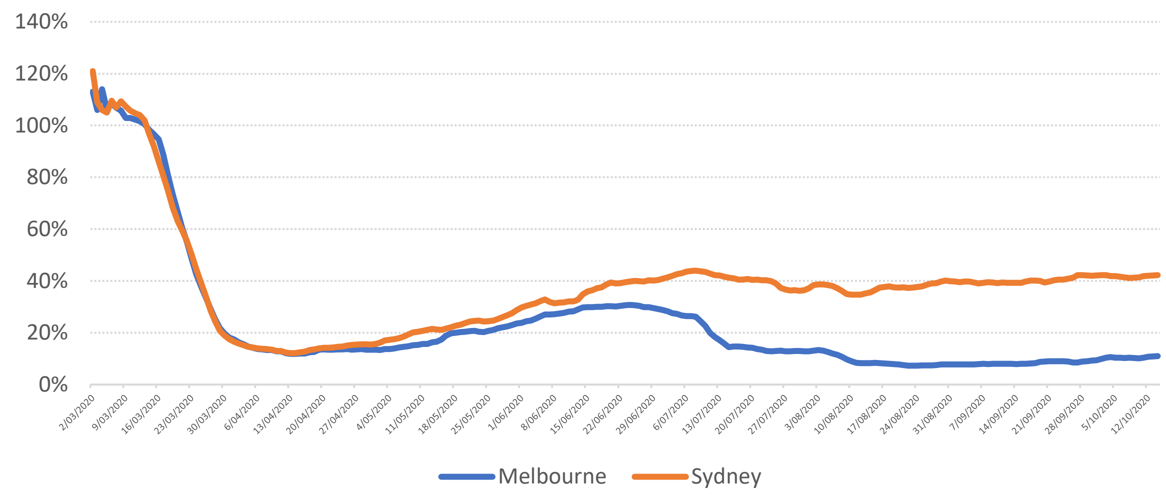

Figure 3: CityMapper Mobility Index Weekly Averages

Data from the Google Community Mobility Report is presented in Figure 4 (Google 2020: aggregates data across Australia and compares to the median value for the corresponding day of the week during the 5-week period Jan 3–Feb 6, 2020 as a baseline). The data shows a slow return to the parks such that activity now reflects the baseline period; however, the time spent at retail and recreational locations and workplaces appeared to plateau over the Wave 3 timeframe, at a level around 20% below what could be considered a pre-COVID “normal”. Likewise, time spent at public transit locations has also plateaued, but at a level considerably less than the baseline.

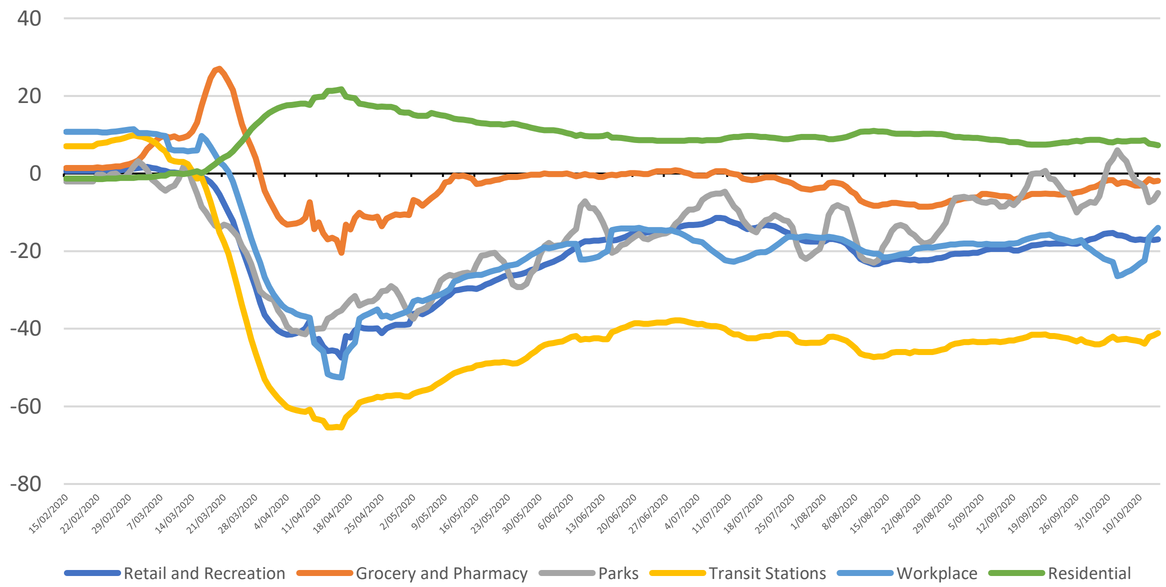

Figure 4: Google Mobility Index

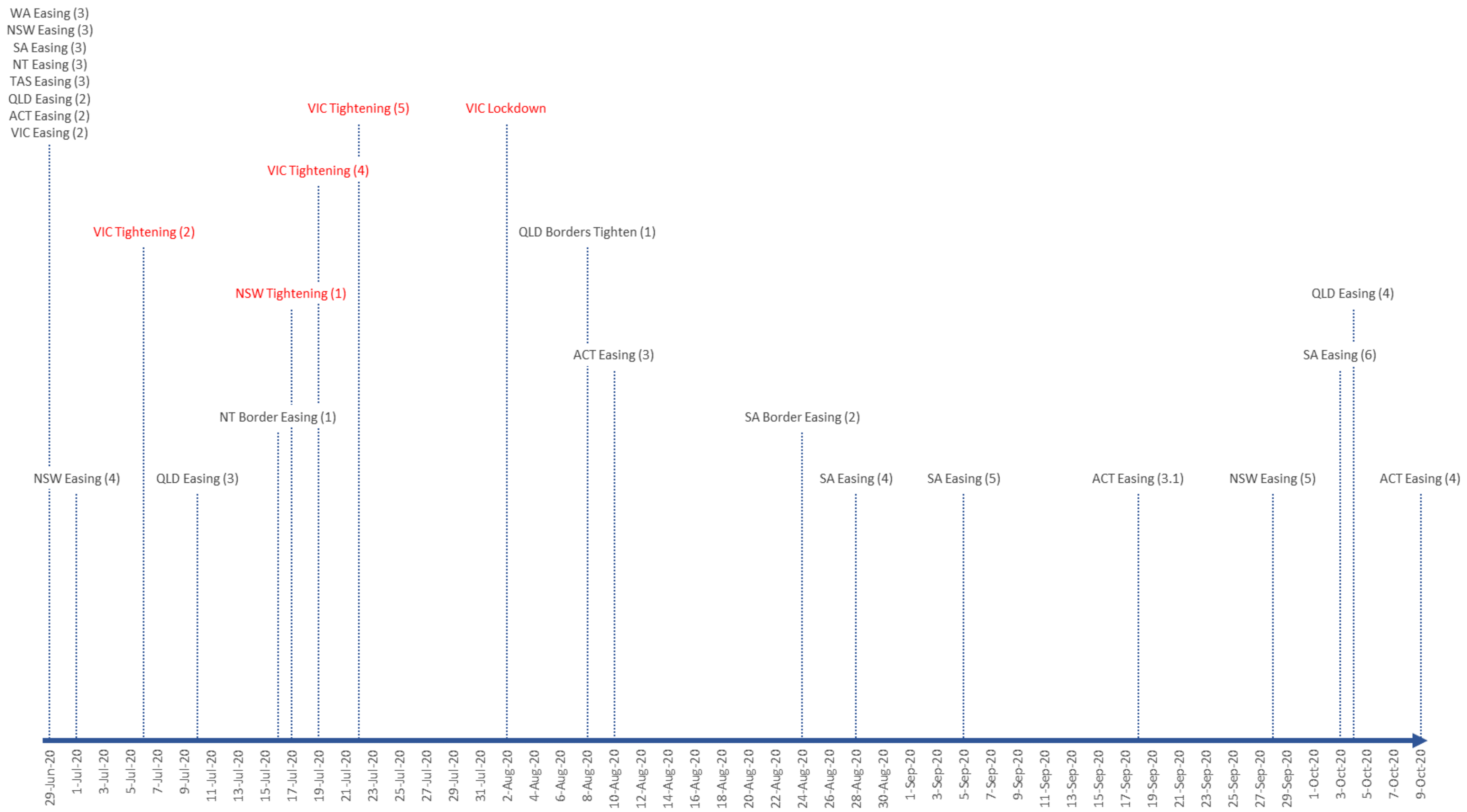

Figure 2: Ongoing Timeline of Key COVID-19 Events

Table 1: Summarising Key Events in an Ongoing COVID-19 Timeline

26/06/2020 (Current position for all states)	WA Easing (3)	Revision of spacing to 2sqm, non-work gatherings limited to 200 Venues with appropriate space limit of 300, gyms, cinemas and galleries reopen
	NSW Easing (3)	Pubs, clubs, cafes and restaurants limit of 50 customers
	SA Easing (3)	No limit on non-work gatherings other than 4sqm rule 2sqm rule may apply to smaller venues, nightclubs remain closed
	NT Easing (3)	All but 4sqm rule remains, some small venues allowed 2sqm per person
	TAS Easing (3)	Gatherings at households remain limited to up to 20 people Space require now 2sqm, upper limit of 250 indoors and 1000 outdoors
	QLD Easing (2)	Gatherings of up to 20 in homes and public spaces, gyms and non-contact sport allowed, Museums and galleries open, no limit on recreational travel
	ACT Easing (2)	Face to face higher education resumes, cinemas and movies open, theatres and galleries open, max of 100 people for indoor and outdoor with 4sqm rule
	VIC Easing (2)	Cafes, Restaurants, Pubs, Bars, museums, galleries have 50-person limit Cinemas, concert venues, theatres open with limit of 50 (with 4sqm rule)
30-Jun-20	VIC Tightening (1)	Re-enforced local lockdowns across 10 different Melbourne postcodes
1-Jul-20	NSW Easing (4)	All businesses, can reopen with exception night clubs No limit of numbers other than 4sqm rule being observed
2-Jul-20	WA Easing (4)	All existing gathering limits and the 100/300 rule removed All events permitted except for large scale, multi-stage music festivals
6-Jul-20	VIC Tightening (2)	additional two postcodes affected by the lockdown
8-Jul-20	NSW Borders Tighten (1)	NSW closes border to VIC due to Melbourne outbreak First time since the 1919 Spanish Flu epidemic
9-Jul-20	VIC Tightening (3)	Metro Melbourne and Mitchell Shire in lockdown 6 weeks
10-Jul-20	QLD Easing (3)	Gatherings 100 people permitted, community sport and fitness resumes, casinos, gaming and gambling venues and nightclubs open, 4sqm rule applies, visitors from all states and territories other than Victoria (border pass required)
16-Jul-20	NT Border Easing	NT opens borders with all states except for hotspots (Greater Sydney and VIC)
17-Jul-20	NSW Tightening (1)	Per-table seating reduced from 20 to 10, max of 300 in any venue
19-Jul-20	VIC Tightening (4)	Face coverings mandatory in metro Melbourne and Mitchell Shire outside of home
22-Jul-20	VIC Tightening (5)	Visit in aged/health care restricted to carers only and a limit of one hour per day
2-Aug-20	VIC Lockdown	State of disaster declared, curfew in Melbourne from 8pm to 5am enforced
2-Aug-20		**200 National Deaths**
8-Aug-20	QLD Borders Tighten (1)	Closure of border to New South Wales and the ACT
10-Aug-20	ACT Easing (3)	In and outdoor gatherings limited to 100 people, casinos and gambling venues, food courts, spas, gyms reopen
11-Aug-20		**300 National Deaths**
18-Aug-20		**400 National Deaths**
24-Aug-20		**500 National Deaths**
24-Aug-20	SA Border Easing (2)	Border with NSW reopens
28-Aug-20	SA Easing (4)	Residential gatherings allowed to have a max of 50 people
30-Aug-20		**600 National Deaths**
5-Sep-20		**700 National Deaths**
5-Sep-20	SA Easing (5)	Wedding or funeral increase to 150 people, food and alcohol service resumes for those seated at a bar
13-Sep-20		**800 National Deaths**
18-Sep-20	ACT Easing (3.1)	Small sized venues and facilities return to their pre-COVID capacity (25 max)
28-Sep-20	NSW Easing (5)	Theatres, cinemas and concert halls new capacity of 50%, to a max of 1000
3-Oct-20	SA Easing (6)	Private functions, weddings and funerals allowed 150 people, dancing permitted, standing consumption of food and beverages at both indoor or outdoor events
4-Oct-20	QLD Easing (4)	Standing eating and drinking permitted at indoor and outdoor venues, outdoor venues 2sqm rule, max of 1000 at outdoor event, stadium seated capacity to rise to 75%
9-Oct-20	ACT Easing (4)	Gatherings max of 200 people, cinemas and theatres 50% capacity, large indoor venues 50% (up to 1000)

3 Sample Description

3.1 Data Collection and Composition

This third wave of the ongoing COVID-19 Travel Survey was in field from the 4th of August to the 10th of October, with data being collected in three segments. Firstly, respondents who completed both Wave 1 and Wave 2 were recontacted, resulting in 269 respondents who have participated in all three waves; secondly respondents who completed either Wave 1 or Wave 2 were recruited resulting in a further 254 respondents who participated in two out of the three survey waves thus far; finally another 433 respondents who completed just Wave 3 alone were recruited. The online survey company PureProfile was used to sample respondents, and the survey was available across Australia in order to examine the widespread impact of COVID-19. Table 2 provides an overview of the sample collected in each wave[71].

Table 2: Overview of Survey Samples

	Wave 1	Wave 2	Wave 3	ABS
Total Sample	1074	1457	956	na
Female	52%	58%	58%	51%
Age	46.3 (σ = 17.5)	48.2 (σ = 16.2)	48.2 (σ = 16.2)	48.2
Median Income[72]	Household = $1682	Household = $1202	Personal = $960	Personal = $662 H'hold = $1438
Have children[73]	32%	35%	35%	25%
Number of children	1.8 (σ = 0.8)	1.7 (σ = 0.9)	1.8 (σ = 0.8)	1.8
Occupation for those working:				
Manager	1%	2%	14%	13%
Professional	38%	35%	28%	22%
Technician & Trade	5%	6%	6%	13%
Community & Personal Services	8%	10%	10%	11%
Clerical and Administration	17%	17%	22%	14%
Sales	23%	22%	11%	9%
Machine Operators / Drivers	2%	2%	4%	6%
Labourers	5%	5%	7%	10%
State				
New South Wales	22%	32%	31%	32%
Aust. Capital Territory	2%	2%	1%	2%
Victoria	28%	24%	24%	26%
Queensland	22%	18%	22%	20%
South Australia	11%	11%	9%	7%
Western Australia	11%	10%	10%	10%
Northern Territory	1%	1%	1%	2%
Tasmania	2%	3%	1%	1%

Comparing to census data (ABS), the samples are broadly representative of aggregate Australian characteristics, though the later waves oversample females. This is an artifact of the desire to try and build a valuable time-series panel data set (typically rare in transportation research), rather than achieving a specific quota. The impact of COVID-19 is, however, sufficiently widespread that no demographic can escape the disruption caused.

[71] For analysis of Wave 1 data refer to Beck and Hensher (2020a), and Beck and Hensher (2020b) for Wave 2.
[72] ABS reported income is for all individuals 15 years or older, whereas we sample 18 years or older, this may explain some of the discrepancy in personal income.
[73] Our survey reports whether a household has children or not, whereas the ABS only provides a definition of a family and includes households without children in that composition.

3.2 Analysis Methods

Consistent with the previous two papers examining the impact of COVID-19 on the travel and activity patterns exhibited within Australia (Beck and Hensher 2020a and 2020b) and given the already large number of results discussed in this two-part work, we limit ourselves to understanding differences at a disaggregated level across key socio-demographic groups. Specifically, differences are explored based on gender, age (younger (18 to 34, n=288); middle-age (35 to 54, n=359); older (55 or older, n=309)), and personal income (lower income ($40,000 or less, n=328); middle income ($40,001 to $80,000, n=307) and high income (more than $80,000, n=235). Additionally, we further explore differences in behaviours and attitudes based on whether a respondent is in a metropolitan (n = 499) or regional (n = 423) location; and we examine every question based on whether a respondent is located in Victoria (n = 229) or another state in Australia (n = 727).

All survey questions were examined for differences across these five socio-demographic characteristics. Depending on the nature of the data and the relevant hypotheses, a mix of t-testing, ANOVA, crosstabs, and correlations were used. Only differences in behaviours that are statistically significant are presented in the figures or discussed in the text. All testing conducted at the 5% level of significance and results can be provided upon request (given the volume of statistical testing done).

4 Results

4.1 Travel Activity

Figure 5 shows that the reported number of total one-way trips undertaken in the last week indicates a similar pattern to the aggregate data from sources such as Google Mobility (reported above). There is a stabilisation in the travel activity at around 15 trips per week on average, up from the lows of Wave 1 but still well below the amount of travel that was reported prior to COVID-19. The exception is Victoria who, under restrictions on movement that matched those observed in the early stages of action against COVID-19 in March, reverted to levels of travel activity observed in those early stages of responding to the threat of COVID-19 by restricting the movement of people in order to contain the spread of the disease. Younger respondents make, on average, five more trips per week than other respondents, and those on lower incomes have significantly less weekly trips on average than respondents in the middle to high income levels.

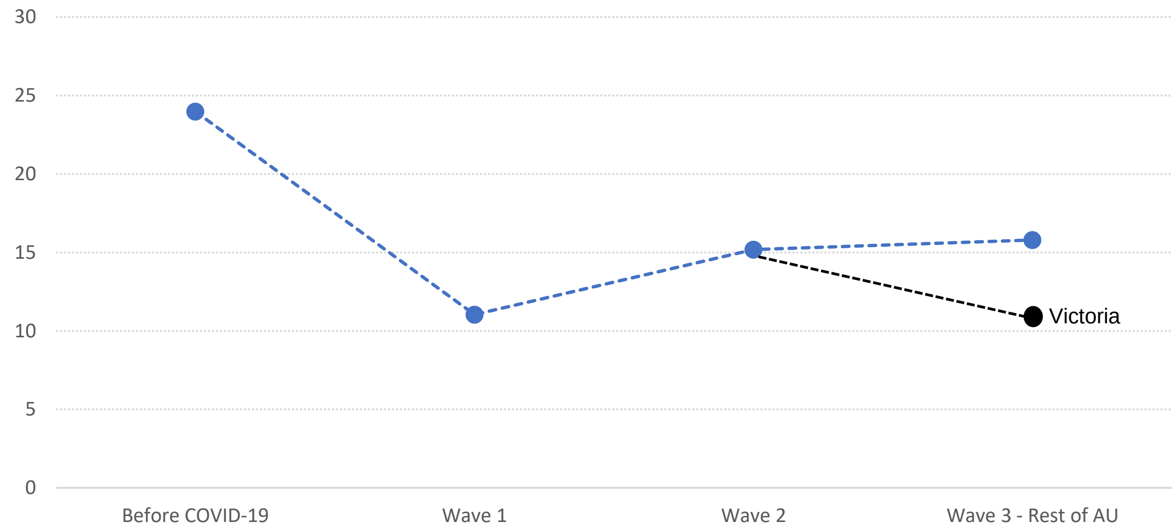

Figure 5: Impact of COVID-19 on Reported One-way Weekly Trips

While 8 out of 10 Australians outside of Victoria anticipate this level of travel to remain the same in the upcoming week and 16% plan to travel less (see Figure 6), one-third of Victorians are planning even less travel than the currently low levels of activity.

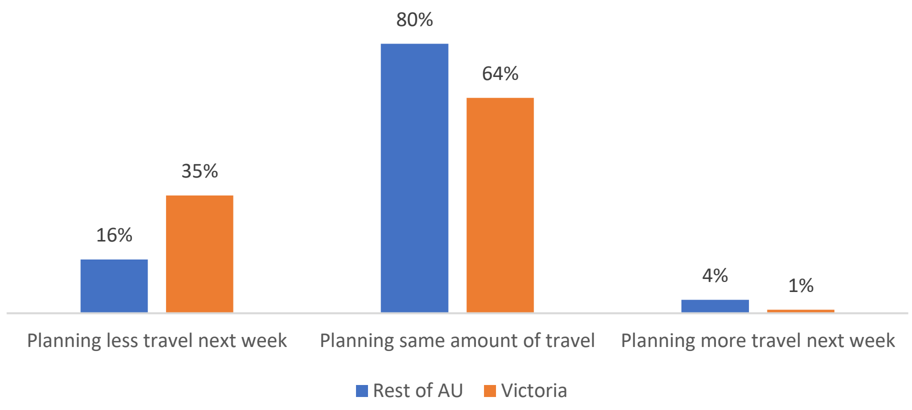

Figure 6: Planned Travel in the Upcoming Week (Wave 3)

Figure 7 shows the number of reported trips by mode, and we see that generally the private car continues its slow return to pre-COVID levels, the active modes of walking and cycling remain relatively constant but use of public transport remains relatively supressed. Older respondents and those on lower incomes use the car significantly less than other groups, younger respondents use taxis and ridesharing options more on average as well as buses, and older people use the train less. Those in metropolitan areas, unsurprisingly, make more trips by not only private car but bus and ferry, while use of trains and buses is significantly lower among females. Except for walking and cycling, Victorian residents use all other modes less than those in other parts of Australia.

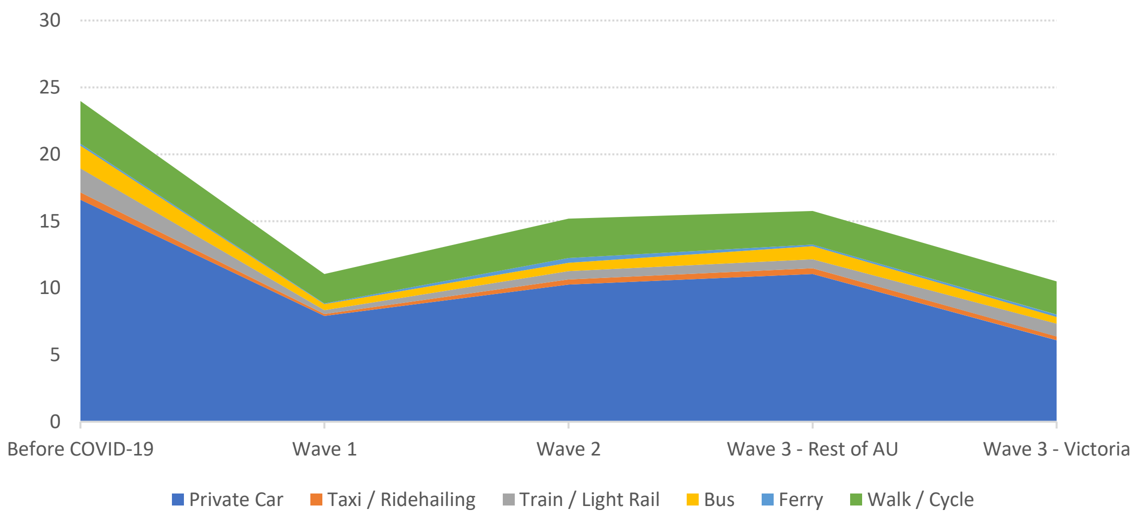

Figure 7: Number of Weekly Trips by Mode

Figure 8 shows the number of reported trips by purpose. Throughout the waves, shopping for food has been relatively stable which is unsurprising given the necessary nature of the travel and that supermarkets have remained open in Australia throughout the pandemic (including Victoria). We see an increase in trips for social and recreational purposes, which again is not surprising given the rolling back of restrictions in every state or territory jurisdiction outside of Victoria. Younger respondents report more commuting trips and more trips for general shopping, and lower income respondents report less trips for commuting and work-related business.

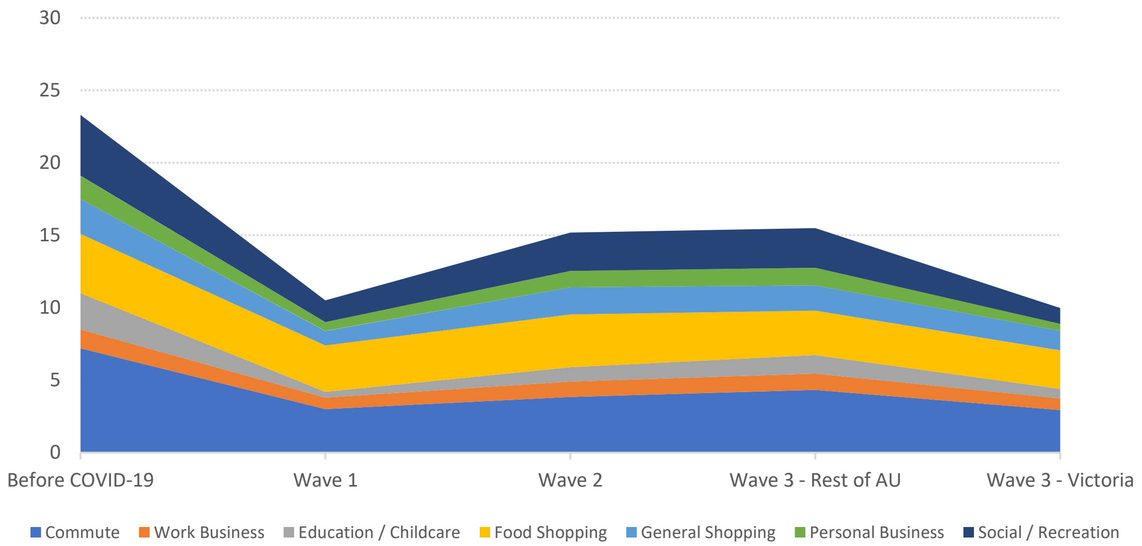

Figure 8: Number of Weekly Trips by Purpose

4.2 Travel Perceptions

Wave 3 explored how respondent perceived the changes in their level of use of different modes of transportation, with particular reference to active modes of transport (walking, running, cycling) given the large number of news media reports about large increases in exercise in outdoor places (ABC 2020) and significant increases in the sales of bicycles and cycling related equipment (Marks 2020), likely as substitute activity for gym closures but also because outdoor exercise was something that was also permitted throughout the pandemic.

While the majority of respondents outside of Victoria reported car use to be about the same in the last week as it has been overall since the start of the pandemic, almost half of Victorians (47%) reported decreased use of their car. Generally, this trend holds true for all of the modes of transport presented in Figure 9, though it is interesting to note that with respect to walking, more respondents reported an increased use of this activity than a decrease.

With regards to socio-demographics, respondents in metropolitan areas are more likely to have decreased their use of private car, trains, buses and taxis/ridesharing. Older respondents are more likely to have reduced car use, younger people more likely to have stated their use of the train has remained the same, lower income respondents more likely to not use taxis/ridesharing and females are more likely to state that they do not run or jog.

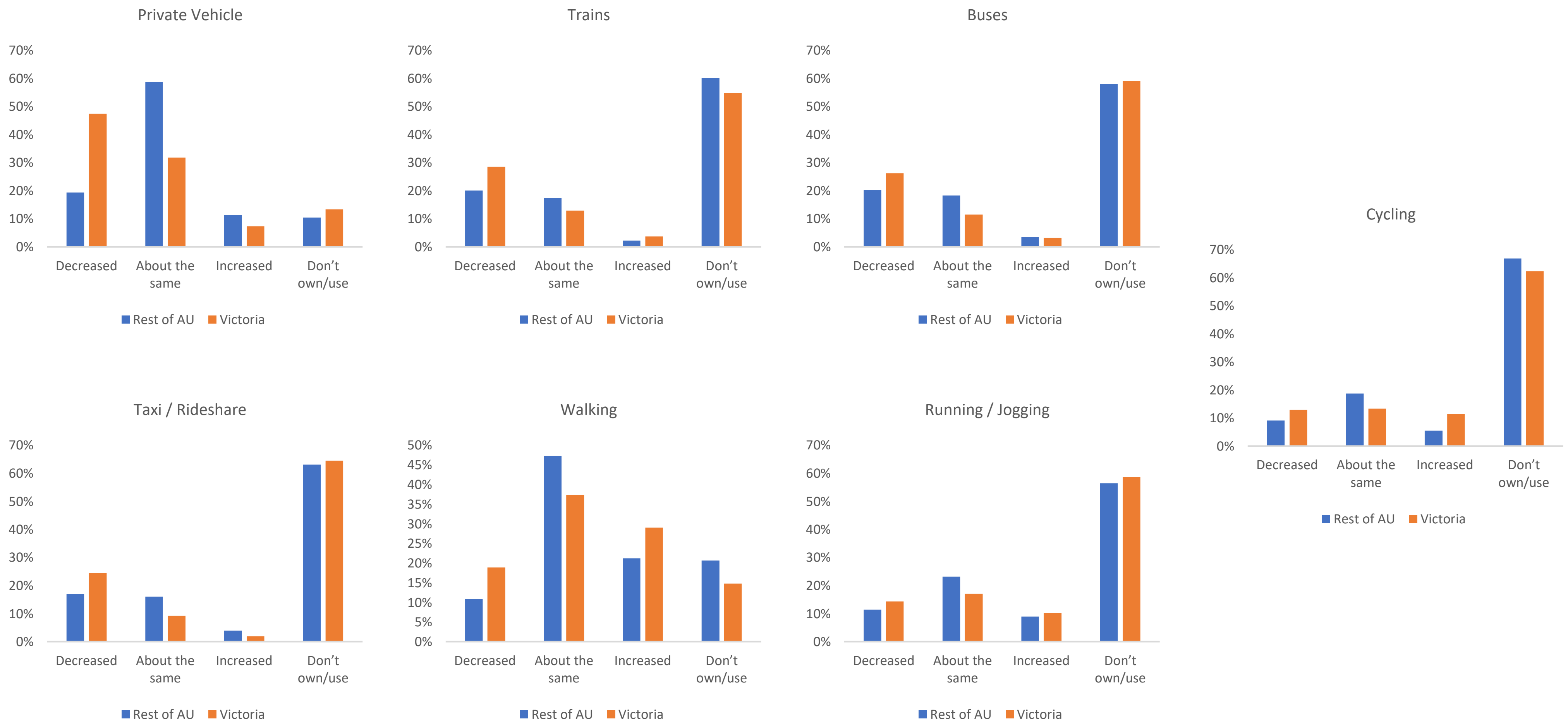

Figure 9: Perceptions of Changed Use of Modes (Wave 3)

As the pandemic progressed, we were increasingly interested in how localised travel patterns may have changed; with many now working from home or limiting non-essential travel over longer distances, there was anecdotal evidence that movements in local towns / suburbs was relatively more robust than travel in wider radii from home. Figure 10 shows that outside of Victoria, travel in the local area for many had returned to pre-COVID levels, was anticipated to remain unchanged both into the next three months and the future in general more broadly. Two-thirds of Victorians, on the other hand, reported decreased travel activity (unsurprising given the re-introduction of restrictions on movement), and only 17% expected that travel to increase again in the next three months.

Differences were observed between metropolitan and regional areas; metropolitan respondents were more likely to report a decrease in local travel relative to before COVID-19, and more likely to state that their travel would decrease in the next three months relative to their travel now. Those on higher incomes were more likely to state their local travel had increased relative to pre-COVID levels, and older respondents were more likely to expect the travel to be the same over the next three months.

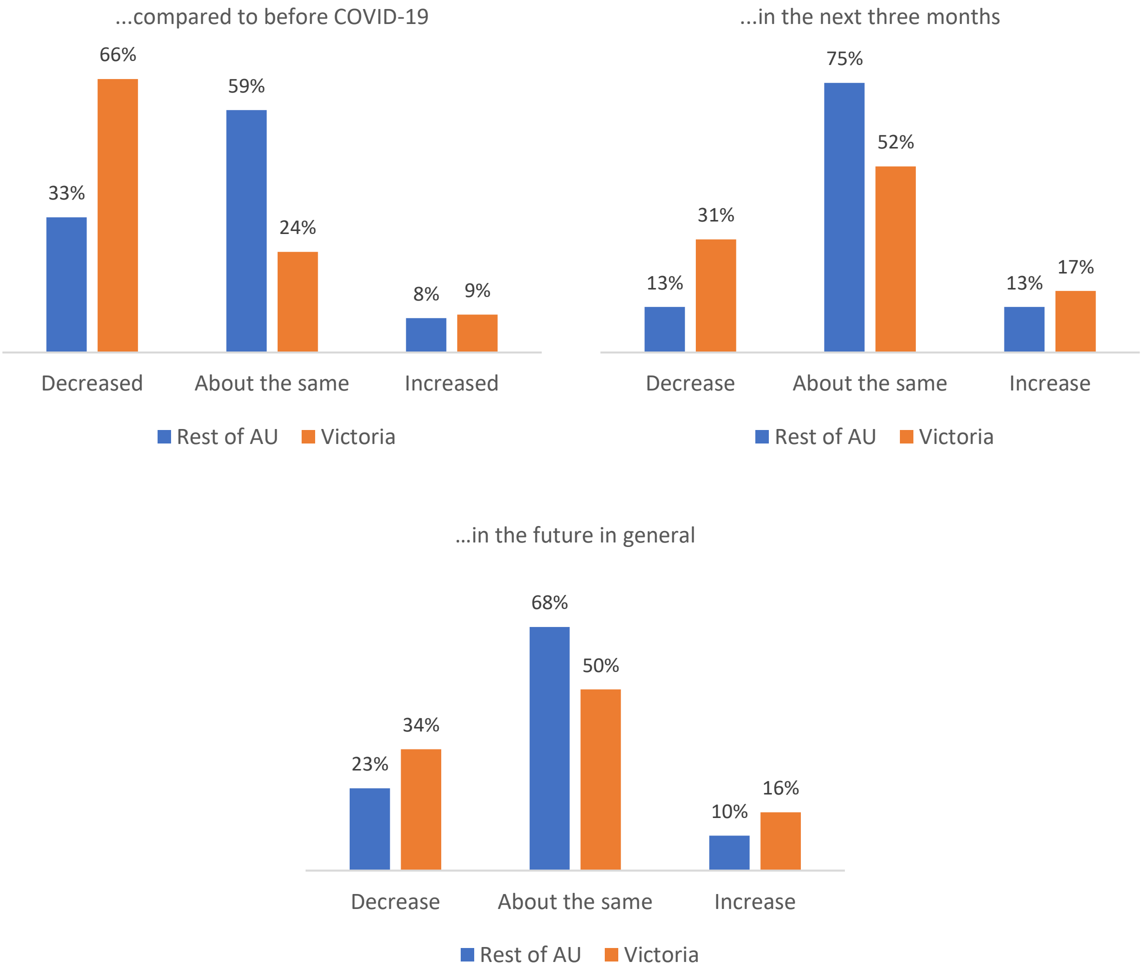

Figure 10: Travel in the Local Area (Wave 3)…

4.3 Preliminary Insights into Location Choices

Another spatial insight that the research explored was whether or not respondents were moving away from city locations, something that has subsequently emerged as a potential trend with some data showing certain property markets were experiencing growth on the back of COVID-19 and increased working from home (Collett 2020). Figure 11 shows the broad results of this preliminary investigation: 4% of respondents are thinking of moving and 2% have changed where they live; and 2% respondents reporting that their workplace is considering a location shift, and 1% of workplaces having done so already, although some of this may be related to changes that were already planned irrespective of COVID-19.

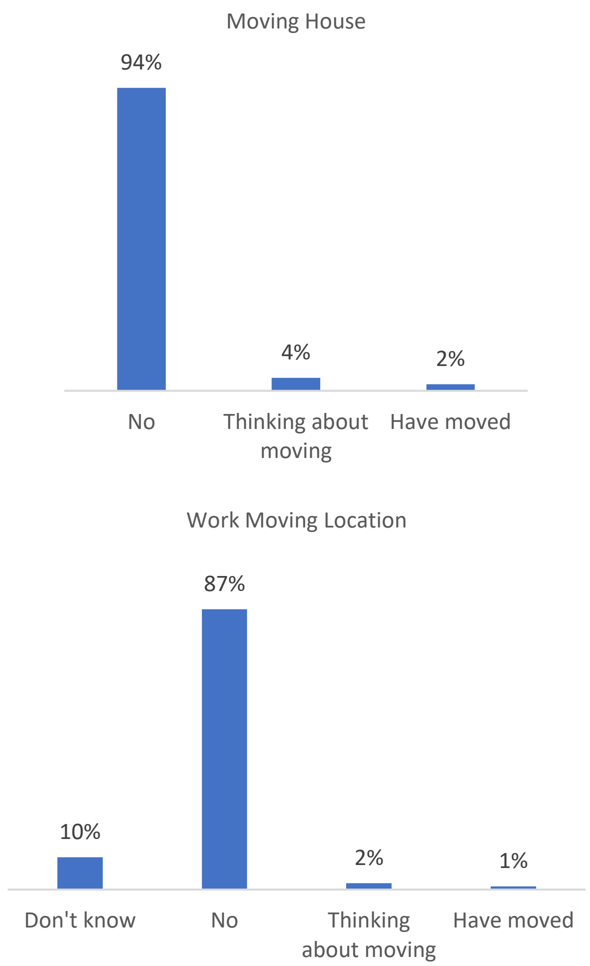

Figure 11: Changes to Home and Work Location (Wave 3)

4.4 Concerns about Public Transport

The research has been tracking community concerns with COVID-19 and public transport hygiene since the early stages of the pandemic in March 2020. Wave 3 results are presented in Figure 12. Outside of Victoria, the level of concern continues to fall; albeit while the change between Wave 2 and Wave 3 is significant, the difference is small. In Victoria, it is not surprising that concern is significantly higher than it was in Wave 2, but it is also interesting to note that concern did not increase to the “peak” of concern that was observed after the initial outbreak (Wave 1). Perhaps respondents are more tempered because of the ongoing exposure, and better prepared this time around than in the early stages of the pandemic.

Given that in many places in Australia the rates of community transmission of COVID-19 were low and that people were beginning to increase travel activity, in Wave 3 we asked an additional question about the level of concern with the number of other people catching public transport, if a respondent was forced to do so themselves. Figure 13 displays the distribution of concern about the volume of people using public transport, which was significantly higher in Victoria than the rest of Australia. Additionally, older people were, on average, more concerned about the number of people using public transport. Overall, the general lack of socio-demographic differences in concern about hygiene and the number of people using public transport shows that concern is widespread. However, it should also be noted that concern about hygiene on public transport and concern regarding the numbers of people using public transport are very strongly correlated ($r = 0.832$), as is expected.

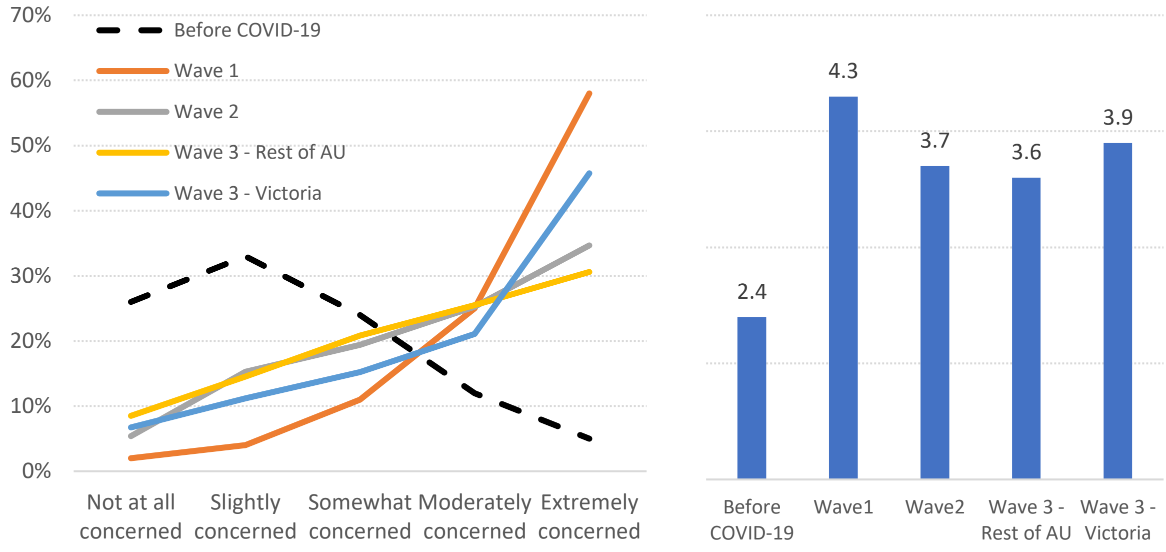

Figure 12: Concern about Public Transport Hygiene

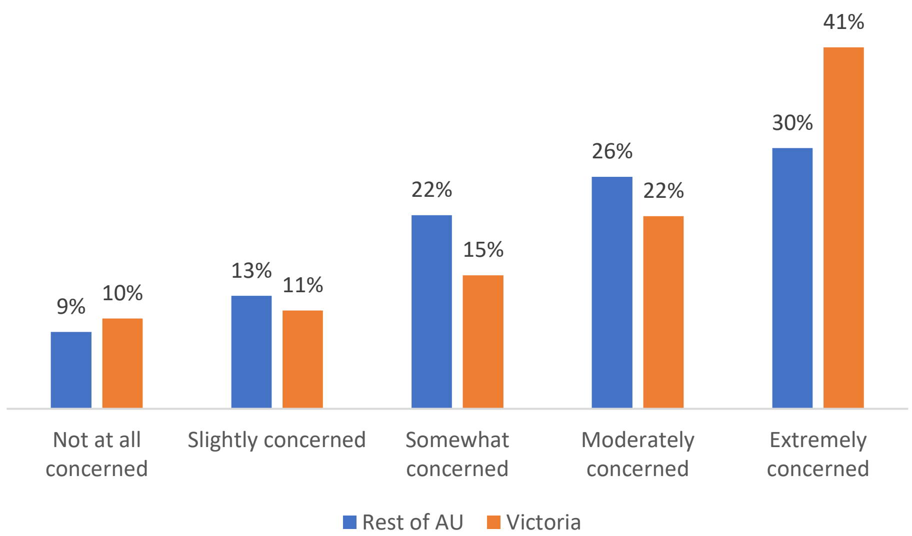

Figure 13: Concern about Number of People on Public Transport (Wave 3)

With respect to use of public transport, we examined if people had to wait longer for public transport services given the requirement for social distancing. The vast majority who had recently used public transport indicated that they boarded the service they had planned to use (89%), with a small number having to wait longer than normal (9%), and an even smaller number waiting too long and giving up (2%). For those that had to wait longer than normal, the average wait time was 14 minutes, and for those who eventually gave up, the average wait was 29 minutes. For the small number who gave up, most ended up driving to work (60%), or working from home (20%).

4.5 A Short Note on Work

As with many jurisdictions globally, COVID-19 has had a large impact on the nature of work. In the most recent data, almost two thirds of respondents report that either themselves, someone in their household, or someone they know has had reduced work as a result of restrictions. We do see, however, that for states outside of Victoria, the number of days working is slowly reverting towards the pre-COVID level. Additionally, we also observe that the number of days worked from home slowly diminishes over the waves as restrictions are eased, however the number of people who work at least one day from home remains close to 20% higher than before COVID-19. People remain concerned about the threat of COVID-19 in the workplace, with an increasing number of employers instigating staggered working times to spread the number of employees in the office at any one time. While acknowledging that working from home does not suit all people, the overall experience with working from home remains, on average, a positive one for employees and there is a strong desire among employees and employers for work from home to continue into well into the future. *For a detailed analysis of the work from home experience please refer to Part 2 of this paper series*.

4.6 Comfort in Day-to-Day Activities

From the analysis conducted during Wave 1 (Beck and Hensher 2020a), almost all day-to-day activities were interrupted by the initial response to COVID-19 by National Cabinet, placing restrictions on movement and how businesses could operate. In Wave 3 (excluding Victoria) we see a general uplift in the level of comfort expressed by respondents, above that which was stated in Wave 2. In particular, Figure 14 highlights larger increases in general comfort visiting restaurants, going to the movies, pubs and bars, and attending gyms and exercise groups. That said, respondents still only express average overall comfort for visiting restaurants, doctor's appointments, going to the shops and meeting friends. Given the second wave of infection in Victoria, it is unsurprising to see that on average respondents express significant discomfort with all activities other than doctor's appointments.

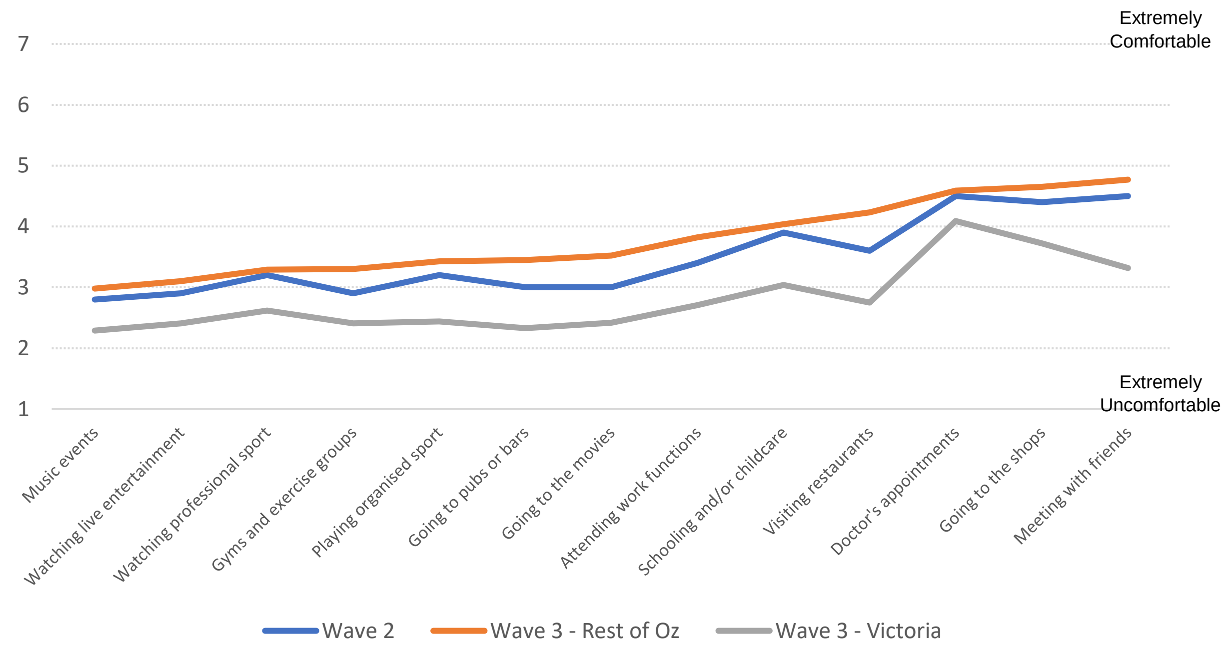

Figure 14: Level of Comfort with Day-to-Day Activities

There are a number of sociodemographic differences. *Metropolitan* respondents express significantly *less* comfort for all activities except attending music events, watching live entertainment, and attending work functions. *Females* express significantly *higher* levels of comfort visiting restaurants, going to the movies, going to pubs or bars, and school/childcare activities. *Younger* respondents are *more* comfortable visiting restaurants, going to the movies, going to pubs and bars, attending gyms and group exercise, watching professional sport, attending music events, watching live entertainment, and attending work functions. *Lower income* respondents also report *less* comfort with all activities except meeting with friends, going to the movies, doctor's appointments, music events, and watching live entertainment.

4.7 Attitudes toward COVID-19 Measures and Wellbeing

Figure A1 shows the average level of agreement with attitudinal statements associated with investigating the response to COVID-19. As with Wave 1 and Wave 2, there is agreement that the response to COVID-19 has been appropriate and was needed. Respondents continue to agree that COVID-19 is a serious public health concern that will affect the way people travel and will require drastic measures to be taken. An important finding in Wave 3, however, is that there is a significant fall in sentiment for almost all attitudinal statements, but in particular agreement that the State and Federal government responses have been appropriate (although the average still indicates that the majority of respondents agree the Victorian state government response has been appropriate, the fall in this measure is particularly notable). Additionally, there is a significant fall in the level of trust expressed by respondents about how governments and business will respond in the future.

With respect to sociodemographic differences, *metropolitan* areas agree *more* strongly that COVID-19 will affect the way people travel, that people have been appropriately self-isolating, and that they trust other people to respond in the future. *Females* agree *more* strongly that COVID-19 is a serious public health concern, will require drastic measures to be taken, that the business, State and Federal government responses have been appropriate, and that business can be trusted to respond in the future. *Higher income* respondents express *less* agreement that COVID-19 is a serious public health concern and that combatting COVID-19 requires drastic measures to be taken.

Figure A2 shows that after a significant fall from Wave 1 to Wave 2, attitudes towards the risk of COVID-19 have stabilised in Wave 3. Respondents still perceive COVID-19 to be a significantly higher risk to someone they know or the general public than themselves, and perceive the biggest risk of the virus to be to the economy. Females perceive COVID-19 to be a bigger risk to someone they know, the health of the general public and the economy. Older respondents perceive COVID-19 to be a bigger risk to themselves, the health of the general public and the economy.

Figure A3 shows how long respondents think it will take for things will return to what they used to be prior to COVID-19, with the general anticipation being that things will take another year to return to "normal". Interestingly, metropolitan based respondents tend to think things will return to the pre-COVID situation more quickly, and older respondents believe that things will take longer to recover. Figure A4 shows how prepared respondents think Australia is to combat future pandemics. While on average respondents feel that Australia is prepared ($\mu = 6.2$, $\sigma = 2.0$), the response indicates that this attitude is not strong. Older respondents believe Australia is more prepared than other respondents.

Figure A5 provides the results of a short series of subjective wellbeing questions that were first asked in Wave 2. These questions come from the United Kingdom's personal well-being questions used in their annual population survey and adopted by the Department for Transport in the household travel survey (ONS 2020). From Wave 2 to Wave 3 we see a significant erosion in the measures of wellbeing, which is particularly true in Victoria. Metropolitan areas report significantly lower scores for how worthwhile the things they do are, and higher levels of anxiety. Females report a higher level of anxiousness. Interestingly, older respondents have an overall higher level of wellbeing (significantly higher worthwhile, happiness and satisfaction scores and significantly lower levels of anxiousness). Higher income respondents also report being more satisfied with their lives and higher levels of happiness.

5 Discussion and Policy Implications

The overall experience of Australia is unique. The country has been successful in combatting COVID-19 following the initial wave of infection in March, and Victoria has managed to overcome a second wave of infection in August thru October. At the time of writing, Victoria has recorded more than 28 consecutive days without community transmission, meeting the common definition for elimination of COVID-19. The aggressive suppression of COVID-19 has been achieved, in the main, by curtailing the movement of people and thus the virus. In turn, this has underlined the pivotal role that transport plays in both human and economic activity. Indeed, as restrictions across Australia are eased (combined with significant fiscal support from Federal and State governments), there has been a rebound in confidence and employment. According to forecasts released in early December 2020, while the Australian economy is expected to contract by 3.8 percent in 2020, it is predicted to grow by 3.2 per cent in 2021 (OECD 2020).

Over the Wave 2 to Wave 3 time period, travel activity patterns remained stable, with very little change to total travel, travel purpose or travel mode. These current travel patterns seem to have also reached a potential short-term equilibrium, with the majority of respondents anticipating no future changes to this level of travel. The ongoing lower than normal level of travel is not only in response to restrictions that were in place over that time period (though over Wave 3 those restrictions were less than during Wave 2), but also likely a function of some degree of self-moderation given the second wave observed in Victoria, the ongoing albeit low levels of community transmission in New South Wales, and that COVID-19 is still perceived as a risk, something still drastic action to combat combined with an understanding that travel will be affected in doing so. There is also a general lack of comfort with completing most day-to-day activities which is also tempering increases in activity.

If there is one change of note, it is the relatively strong rebound in car use. Through Wave 1 and Wave 2, working from home has resulted in a dramatic change to the numbers of commuters on the transport network and in turn has resulted in significant improvements to traffic flow. It is also important to note that while diminishing, concern about public transport still exists both in terms of hygiene and the perceived number of people using the mode given the desire for social distancing is still high. Combined with the amount of working from home decreasing from the highs seen in Wave 1, this means that the aforementioned benefits associated with reduced travel demand could quickly erode should Australians en masse prefer to travel by private car as they also return to work. To that end, and as commented on in the discussion of Part 2, work from home and greater work flexibility represents potentially the largest policy level governments have ever had to reduce congestion, which has significant time and cost savings for society.

To that end, resuscitating confidence in public transport remains an important, though challenging, outcome to achieve coming out of COVID-19. Policies coming out of our research in Wave 1 still apply; overt and regular deep cleaning including with something as simple sanitiser that has a strong “antiseptic” smell; the enforcing the wearing of masks while on board, on platforms and at public transport terminals; and COVID-19 Marshalls similar to those required in bars and hotels patrolling services to ensure distancing and cleanliness; the creation of a service created where public transport users can receive alerts about when a good time to travel is or when is a bad time, via a simple “green” or “red” indicator in a phone app; and the provision of hand sanitiser at stations and onboard services. The purpose of these demonstrable actions is to reduce the level of concern with the overall cleanliness of each public transport mode. There may be the requirement to think in a novel fashion about the role of pricing as a mechanism to attract users back to public transport. While related to the public perception of public transport, innovative operators could consider how they might use their current spare capacity to assist in the day-to-day freight task as a potential way to offset revenue losses from lower patronage.

While the concern towards the hygiene and crowds on public transport remain high, transit operators and authorities should also begin to reconsider the messaging used around public transport. Particularly in the context of Australia where case numbers continue to remain low, the “stay away” message regarding public transport that was sent earlier in the pandemic and often re-iterated in later periods, needs to be reframed to increase public trust in the mode. Perhaps as argued by Barbieri et al. (2021), there is scope to use messaging about public transport as being a catalyst for change (Budd and Ison 2020) or a hallmark for recovery (Kuzemko et al. 2020), given that the perceived effectiveness of curbing COVID-19 for transport modes plays a role in determining frequency of use.

One thing governments and policy makers need to pay attention to, is the level of support expressed by the public for COVID-19 related measures. For example, in the case of Japan it was found that poor communication with the public may have been closely related to the spread of COVID-19 (Zhang 2021). In Australia, a key determinant of the early response was coherence in policy enacted by the formation of a National Cabinet, and the resulting unification of messaging and approach that brought about an “in it together” mentality. Interestingly, Australians may portray a “larrikin” image on a world stage, but our evidence indicates that the vast majority of citizens have not only been supportive, but compliant with policy measures that might seem drastic given the relatively low case numbers compared to other countries.

While support towards the response of governments and business to COVID-19 remain high, support appears to be slowly falling. Those in positions of authority will need to continue to make sure that communication is clear, encouragement is given, and validation of behaviour reinforced in order to ensure compliance, particularly as changes to behaviour continue and pandemic fatigue becomes a significant concern, mixed with a tentative but nonetheless growing desire and level of comfort with day-today activities, particular the more high COVID transmission risk activities of visiting restaurants, meeting friends, going to bars and gyms where restraint is often hard to maintain. Given that Australians by and large are expecting the current conditions to continue for another year, and wellbeing is also trending downwards, encouragement and validation for action will be increasingly important. This is particularly true for metropolitan areas where in many of the results outline in this paper, the impact on these respondents has been significantly more profound.

As highlighted in Beck and Hensher (2020a) however, the bigger challenge for policy makers is the way in which restrictions are removed rather than enforced. In Wave 3 we have seen a slight but significant erosion in the level of support for the COVID-19 response, in particular a slip in the trust respondents have for government to response in the future. Maintaining policy consistency may be important in maintaining trust, as there have been numerous ongoing public disagreements between state (and Federal) governments about the response to

COVID-19, and varying state border closures and travel restrictions that have made it harder for individuals to plan travel into the future.

6 Conclusion

The impact of COVID-19 has been profound, and admittedly while benefiting from being an island nation with a much better capability to control international borders, the Australian experience of swift and decisive action to restrict the travel and movement of people has shown to be relatively successful in controlling the spread of the disease. The biggest risk to community transmission in Australia remains breaches to hotel quarantine for inbound Australian citizens, but the severe lockdown in Victoria bought the uncontained spread under control with 112 days and a more recent cluster totalling 150 cases in the Northern Beaches of Sydney was contained and brought under control in 22 days by locking down just that area of the metropolitan area. Our results show general support for the actions of policy makers at both state and Federal levels, as well as support for the way in which business has responded. The reader is encouraged to move to Part 2 of this paper, where impact of and experience with working from home is discussed in greater detail.

Despite the relative global success Australia has had in combatting COVID-19, there is a general expectation from our surveys that it will take a year to 1.5 years to return to 'normal' or at least a well-defined future, and while respondents agree that Australia is much better prepared for a future pandemic, the attitude is not particularly strong. This is an interesting juxtaposition for governments and regulators given the success of Australia on a global scale in combatting COVID-19. We acknowledge that the analysis completed in this paper is descriptive in nature, but nonetheless it provides a substantial number of insights as to the changing impact of COVID-19 and how policy might be formed accordingly. Future work will seek to quantify many of the results herein. In future work we will seek to examine in more detail the direct link between attitudes, experience, policy intervention and travel behaviour changes, using more complex methodologies.

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Graphical Appendix

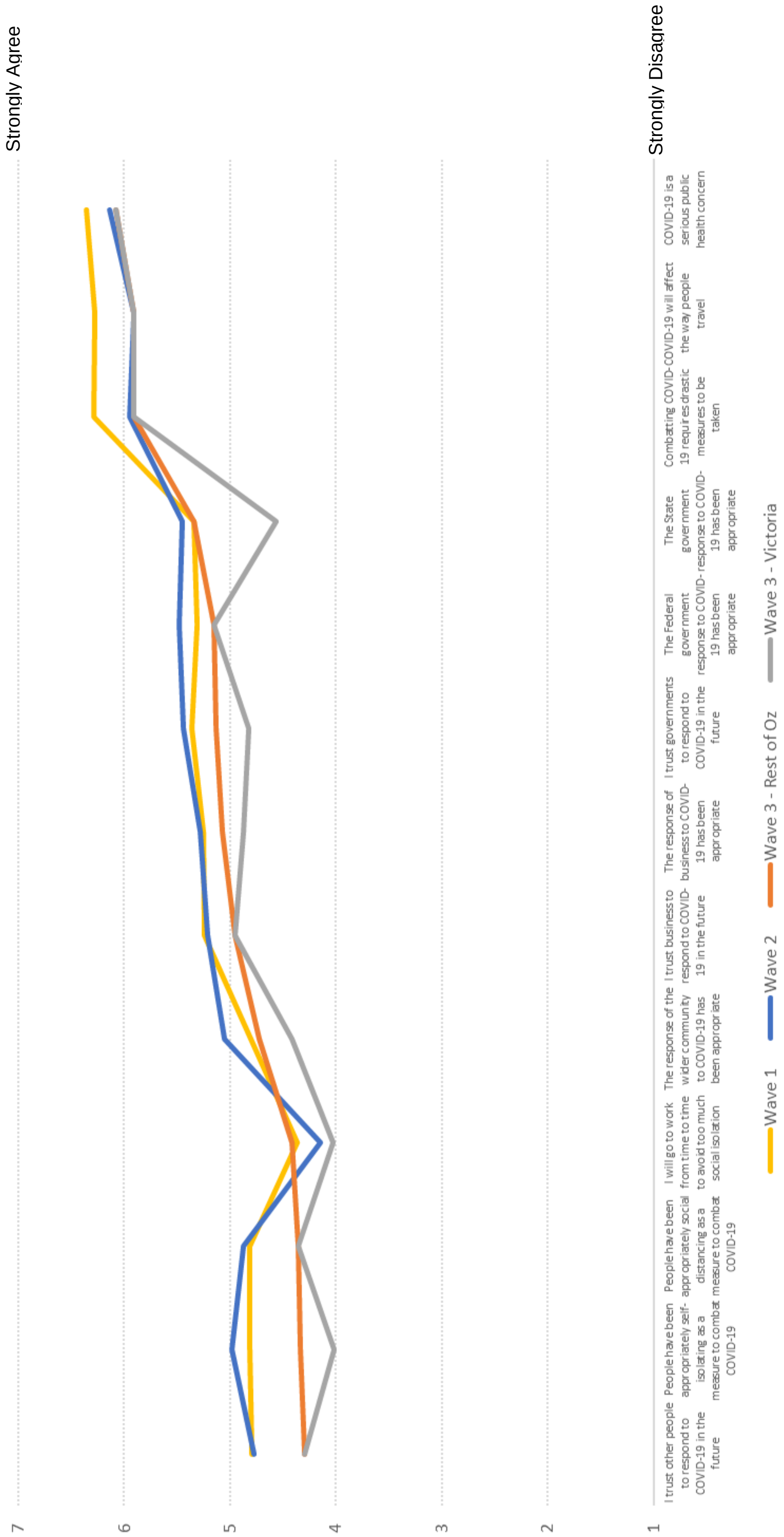

Figure A1: Attitudes toward COVID-19 Response

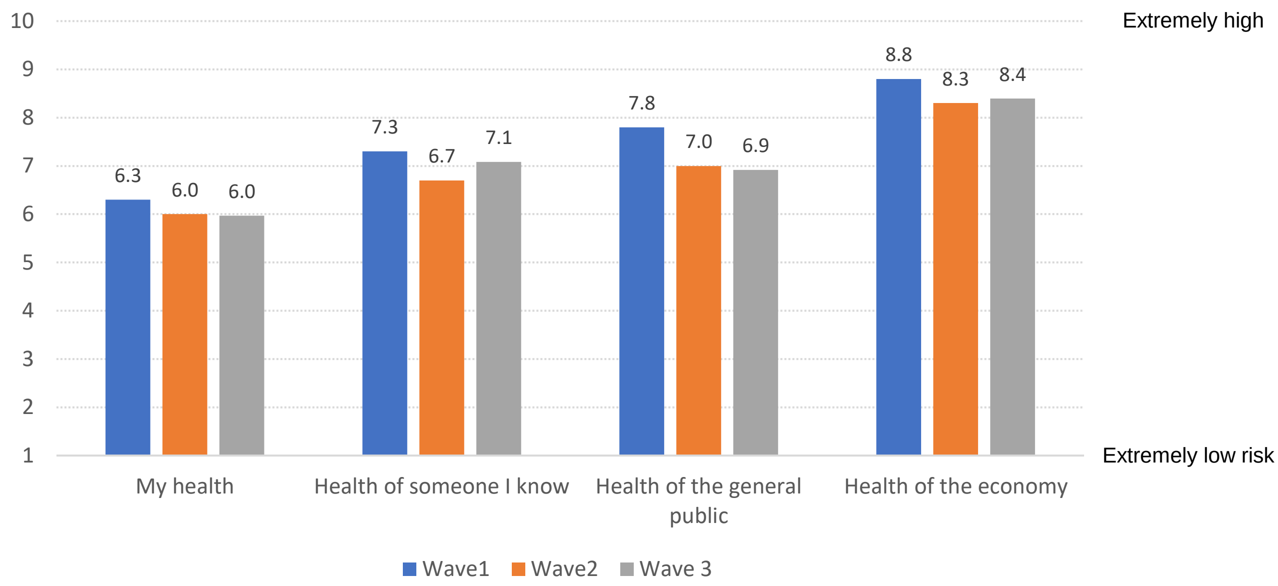

Figure A2: Perceived Risk of COVID-19

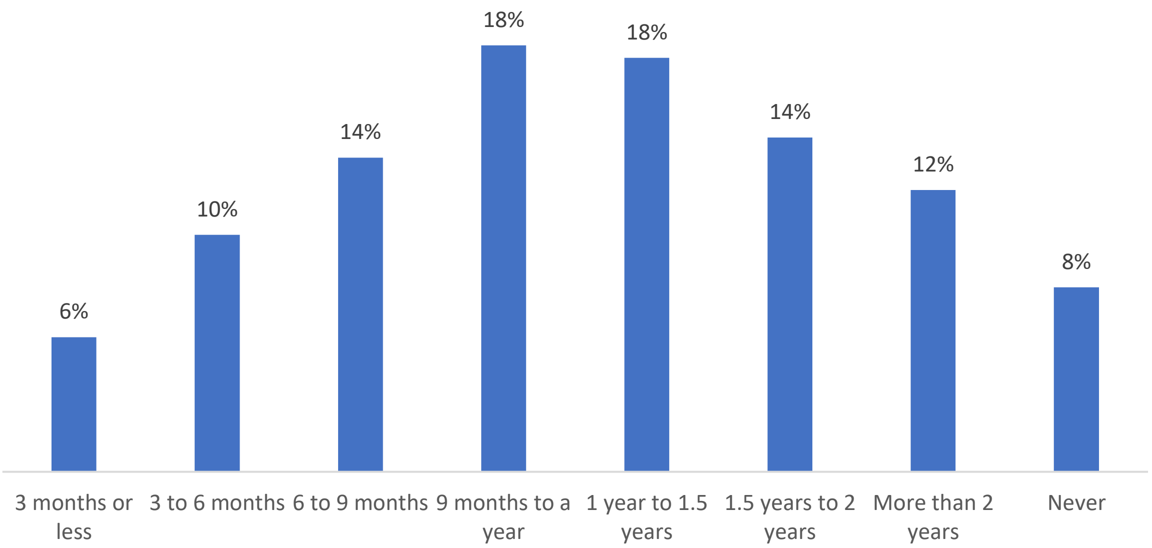

Figure A3: How Long till Thing Return to pre-COVID “Normal”?

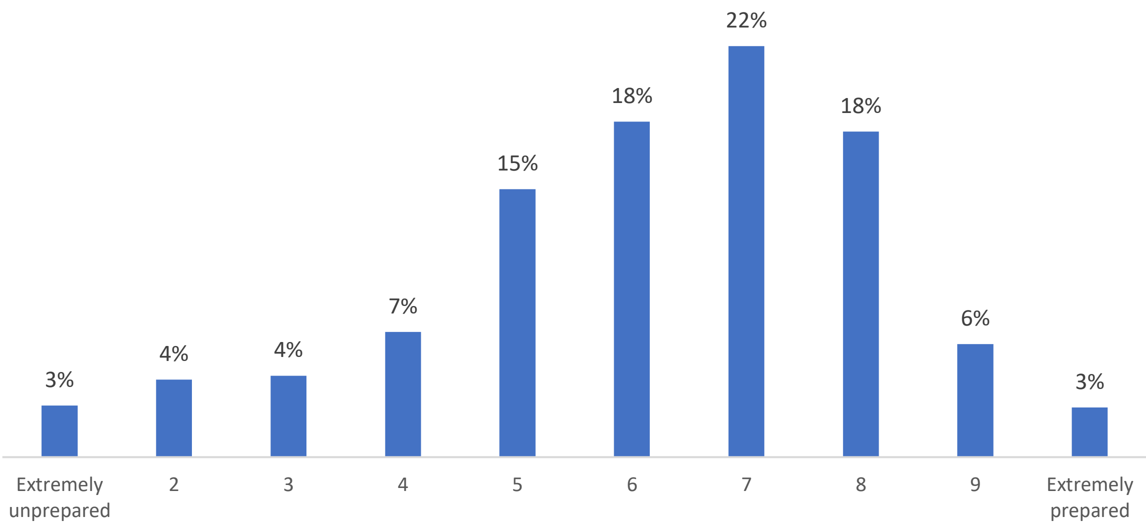

Figure A4: How Prepared is Australia to Combat a Future Pandemic?

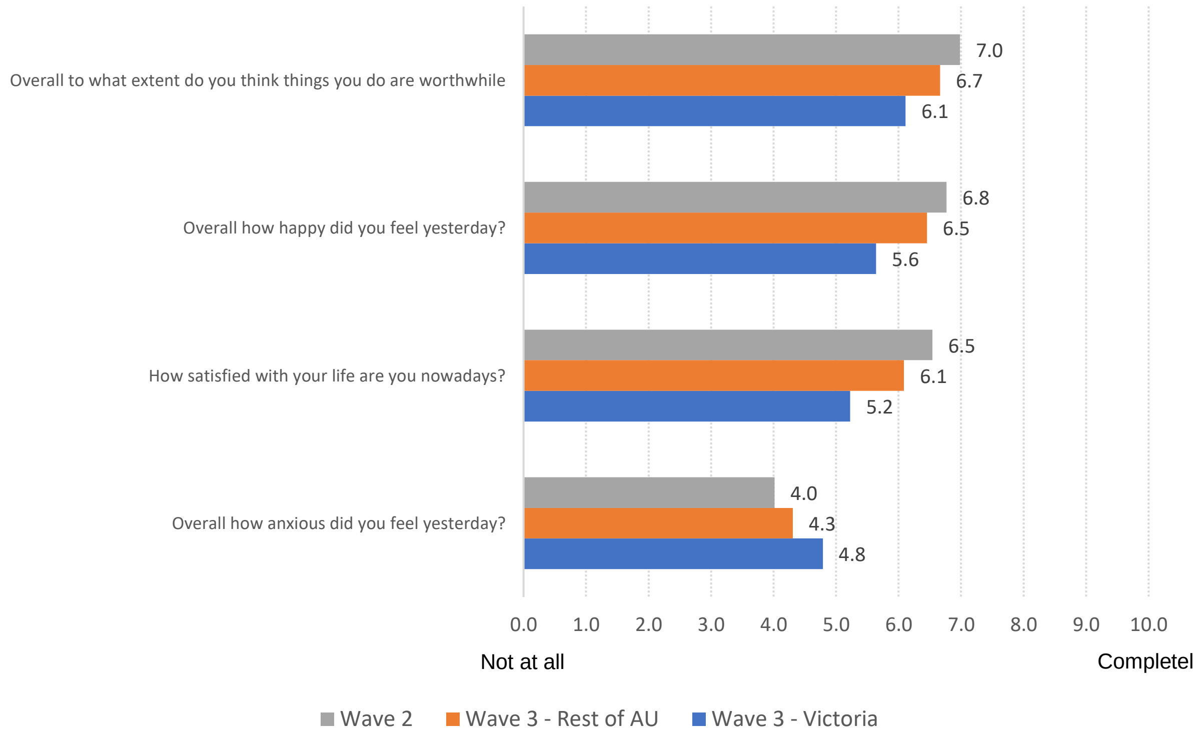

Figure A5: Overview of Subjective Wellbeing

Appendix K. Paper #7B: Australia 6 months After COVID-19 Restrictions Part 2: The Impact of Working from Home

Matthew J. Beck
David A. Hensher

Abstract

This paper (Part 2 in the paper series), building on earlier studies examining the Australian response, extends on findings related to travel activity, commuting, and attitudes towards COVID-19 measures (Part 1 in the paper series). In this paper we focus in detail on the impact of, and experiences with, working from home (WFH), perhaps the largest of the positive unintended consequence of the pandemic, with respect to transport, and a key lens through which the changing patterns in travel activity and attitudes discussed in Part 1 need to be understood. We conclude that through the widespread adoption of WFH as a result of nationwide public health orders, there is evidence emerging that WFH is now seen as an appealing instrument of change by employees and employers, there is growing support to continue to support WFH into the future. This represents a significant potential contribution to the future management of the transport network, especially in larger metropolitan areas. We also discuss policy implications of this result and what the international community may take from the Australian experience.

Keywords: COVID-19, working from home, Australian experience, employer and employee support, implications on the performance of the transport network, longitudinal data

Acknowledgments. This research is part of iMOVE Cooperative Research Centre (CRC) research projects 1-031 and 1-034 with Transport and Main Roads, Queensland (TMR), Transport for News South Wales (TfNSW) and WA Department of Transport (WADoT) on Working for Home and Implications for Revision of Metropolitan Strategic Transport Models.

1 Introduction

1.1 Literature Review

Previous papers (Beck and Hensher 2020a and 2020b) have reviewed the transportation literature on the impact of telecommuting including Nilles (1973), Salomon and Salomon (1984), Mokhtarian (1991), Yen and Mahmassani (1997), thru to Nash and Churchill (2020). Common among these studies is the discussion that working from home may be an important instrumental lever in reducing commuting activity if widely adopted, albeit some conjecture of whether working from home is a complement or substitute for travel activity, but a general finding that telecommuting, or working from home continued to be a niche alternative in the work and commuting mix.

COVID-19 however, brought about rapid and widespread adoption of working from home (WFH) either as a function of an individual's concern about their own risk of contraction or more typically in response to employer or regulatory measures that made the work from home choice binding for those that could. In Australia, a public health order was issued in all states and territories actively encouraging all businesses to, wherever reasonably practicable, allow staff to work from home. As highlighted in Beck and Hensher (2020a, 2020b), the adoption of WFH has been widespread and in the immediate to short-term aftermath of the first outbreak in Australia, largely positive. This experience has also been extreme in other jurisdictions that have taken a relatively less forceful approach than Australia; for example it has been found that in May 2020, 35.2 percent of the US workforce worked entirely from home, with 71.7 percent of workers that could work from home effectively doing so (Bick et al. 2020).

In examining the changing nature of work, with reference to WFH, as a result of COVID-19many people have found experiences and attitudes to be favourable. For example, de Haas et al. (2020) found that in the Netherlands, 44% of workers started to or increased the number of hours working from home and 30% have more remote meetings and while 90% of people who reduced their outdoor activities are not expecting to continue to do so in the future, 27% of home-workers expect to work from home more often moving forward. Meta-analysis of global social media data between 15th March and 15th April 2020 found that the emotions associated with most of the tweets were of trust and anticipation indicating that this concept is being welcomed by the people (Dubey and Tripathi 2020). Lai et al. (2020) argue that work-from-home routines can boost both performance efficiency and individual wellbeing, outlining various ways in which home design might need to be rethought to facilitate more flexible space in the home to accommodate future changed behaviour.

While working from home has been widely adopted, some have noted that increased amounts of WFH has the potential for negative health outcomes (De Vos 2020); for example, it has been found that for those who were formally using public transport, an additional 21 minutes of extra activity per day would be needed to offset lost physical activity associated with walking to and from interchanges (Laverty et al. 2020). In a pre-pandemic study Ozbilen et al. (2021) find that all else being equal, respondents with higher durations of telework tend to spend less time on auto and transit, however those with higher durations of online shopping spend more time walking and bicycling. Increased work from home might result in a similar stronger update of walking and cycling.

The COVID-19 pandemic has also resulted in loneliness, particularly among younger people and those with mental health symptoms (Groarke et al. 2020), and the workplace is often an environment where people can interact socially. The impact of COVID-19 may also be unbalanced across gender. Craig and Churchill (2020) find that women shouldered most of the extra unpaid workload, and while the childcare duty gap narrowed, the relative gap in housework remained, with ultimately the dissatisfaction with balance of paid and unpaid work rising markedly and from a much higher base for women. It has also been found that mothers have scaled back their work hours to a far greater extent than fathers (Ladivar et al. 2020). Additionally, not all jobs are those that can be completed from home. Baker (2020) states that in the U.S. the majority of workers employed in occupations that cannot be done at home, put 108.4 million individuals at increased risk from adverse health outcomes related to working during a public health emergency.

There are also potential changes that might arise from future uptakes in working from home rather than a central place of work. Given that individuals are attracted to work environments that mirror their own beliefs and values (Kristof-Brown & Guay, 2011), working from the home might lead to an increased incongruence between the self and place of work. Working out of the home has also meant a redefining of work and family roles, thus making it more difficult than ever to maintain adequate work-family-life dynamics (Giurge & Bohns, 2020). The rise of working from home may also create job-market segmentation which allocates workers to “good jobs” and “bad jobs” and thus further occupational segmentation and inequality (Kramer and Kramer 2020). Trust and management style also play a significant role in worker wellbeing and effectiveness (Grant et al. 2013), in particular managers who cannot “see” their direct reports sometimes struggle to trust that their employees are indeed working. When such doubts creep in, managers can start to develop an unreasonable expectation that those team members be available at all times, ultimately disrupting their work-home balance and causing more job stress (Parker et al. 2020).

However, in aggregate the uptake of working from home among those who are able to do so has been significant and likely a disruptive event with longer term implications for where work is completed. Perhaps more importantly, as the impact of the pandemic continues, it has been found that working from home is very effective in reducing infection risk (Fadinger and Schymik 2020), and there is support for the continuation of work from home policies (to reduce public transport use) and strategies that mitigate the risk associated with re-opening of social venues as a result of the second wave of infection witnessed in Victoria (Scott et al. 2020).

1.2 Scope and Structure of This Paper

In this paper, part two of the analysis of Wave 3 data, we present an overview of the findings on working from home; perhaps one of the most positive unintended consequences of the COVID-19 pandemic. Working from home has been an instrumental part in restricting the movement of people and the wider spread movement of the disease and has been widely adopted within Australia over what is now an extended period of time. We examine the extent to which working from home has prevailed over multiple waves of data collection, how experiences with and attitudes towards working from home have evolved, and how flexible work may also facilitate reduced travel in the peak through greater ability to peak-spread when the choice is made to actually commute. We extract policy implications for both the short-term and long-term facilitation of work from home and discuss how it might influence transport policy into the future. The paper is structured as follows: section three provides an overview of the sample collected for Wave 3; section four discusses the results of overarching analysis; section five provides a discussion of the results and the potential policy implications that arise from the result found herein; and section five discusses limitations together with the conclusion.

2 Sample Description

2.1 Brief Overview

This third wave of the ongoing COVID-19 Travel Survey was in field from the 4th of August to the 10th of October 2020. In total, the Wave 3 data analysed herein is comprised of 956 respondents from all states and territories in Australia. The online survey company PureProfile was used to sample respondents, and the survey was available across Australia in order to examine the widespread impact of COVID-19. A summary of the Wave 3 sample is provided in Table 1. While Wave 1 was collected in March 2020 to ensure as complete a replication of Australian socio-demographics as possible, the focus of Wave 2 (in May 2020) and Wave 3 was to create a valuable time-series panel data set (typically rare in transportation research), as such quotas were not introduced on those completing the survey, other than ensuring representation from all states and territories. The impact of COVID-19 is, however, sufficiently widespread that no demographic can escape the disruption caused.

Table 1: Overview of Survey Sample for Wave 3

Female	58%
Age	48.2 (σ = 16.2)
Personal Income	\$62,551 (σ = \$46,964)
Have children	35%
Number of children	1.8 (σ = 0.8)

New South Wales	31%
Australian Capital Territory	1%
Victoria	24%
Queensland	22%
South Australia	9%
Western Australia	10%
Northern Territory	1%
Tasmania	1%

2.2 A Note on Analysis Methods

When exploring socio-demographic differences, categories consistent with previous published research were used, specifically gender, three age-groups (younger (18 to 34, n=288); middle-age (35 to 54, n=359); older (55 or older, n=309)), three personal income groups (lower income (\$40,000 or less, n=328); middle income (\$40,001 to \$80,000, n=307) and high income (more than \$80,000, n=235), metropolitan versus regional location (n = 499 and 423 respectively), and lastly Victoria versus the rest of Australia (during which time n = 229 Victorians were in lockdown during July through to November 2020 and the remaining 727 from elsewhere were largely free to move within their state).

It should be noted that all relevant working from home questions, the results of which are discussed herein, were examined for differences across these five socio-demographic characteristics outlined above. Depending on the nature of the data and the relevant hypotheses, a mix of t-testing, ANOVA, crosstabs, and correlations were used. Only differences in behaviours that are statistically significant are presented in the figures or discussed in the text. All testing conducted at the 5% level of significance and results can be provided upon request (given the volume of statistical testing done).

3 Results

3.1 Changes in Work and Work from Home

As with many jurisdictions globally, COVID-19 has had a significant impact on the nature of work. Figure 1 shows the changing way in which COVID-19 restrictions have impacted the availability of work (being stood down or having significantly reduced number of shifts). The small growth in neither the respondent nor someone known to them being impacted by measures indicates the small increases in economic activity that are occurring as restrictions are eased in many states given the sustained run of low community transmission. Older respondents are more likely to state that they or someone they know have not been affected, younger respondents and those on lower incomes are more likely to state that they have been impacted, while higher income respondents are more likely to state that they know someone who has been affected.

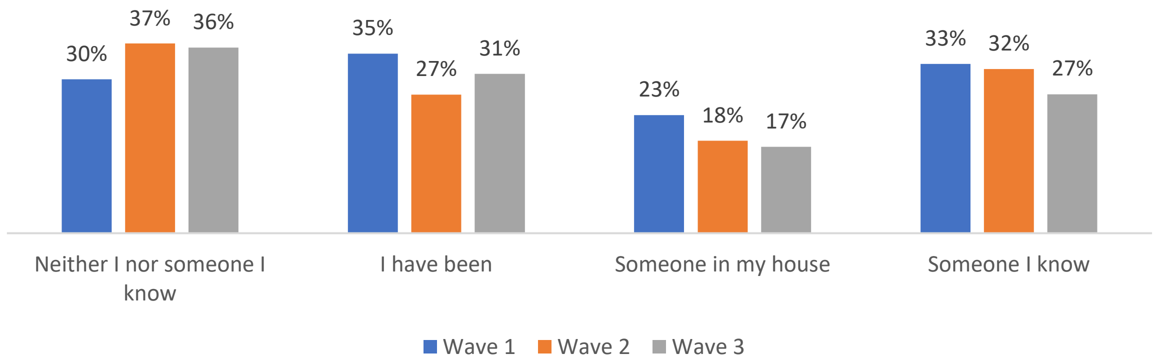

Figure 1: Have COVID-19 Restrictions Had an Impact on Availability of Work?

Whether or not respondents have been asked to work for reduced pay as businesses attempt to cope with decreased activity was also examined and is shown in Figure 2. The results are relatively consistent over Wave 2 and Wave 3, with approximately two-thirds of respondents not having been asked to work for lower pay. Those in regional areas are more likely to state they have not been asked, as are older respondents or those on lower incomes. Those in metropolitan areas are more likely to have been asked, as are younger respondents.

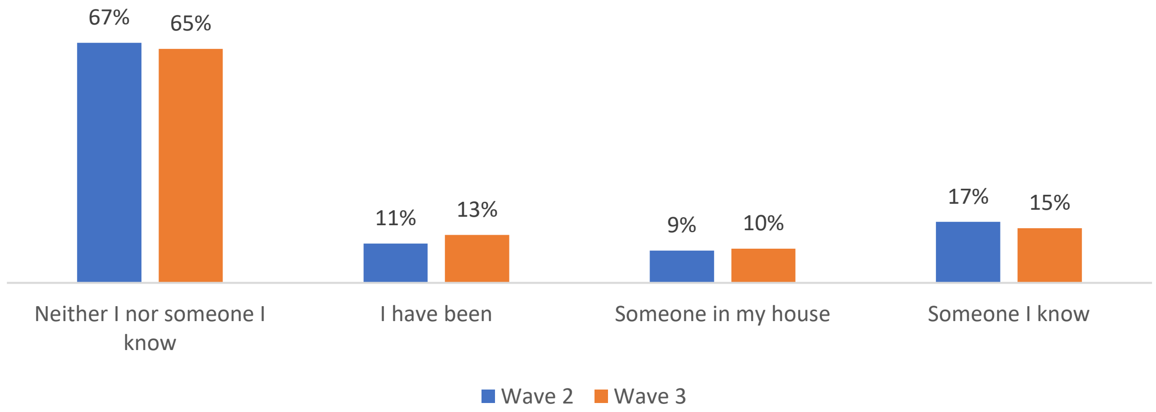

Figure 2: Have COVID-19 Restrictions Meant You Are Working for Less Pay?

Figure 3 displays the distribution of days worked in a week (among those who were working prior to COVID-19), while the average number of days worked in Wave 3 (3.8) remains significantly below the average number worked prior to COVID-19 (4.5), we do see that for states outside of Victoria the number of days working is slowly reverting towards the pre-COVID level. Within Victoria though, the stringent restrictions on movement have resulted in the level of work (average number of days worked in Wave 3 for Victoria = 3.1) regressing back to that observed during Wave 1. The only broad socio-demographic different identifiable is that older respondents on average work less days per week in Wave 3, but also worked less days per week prior to COVID-19.

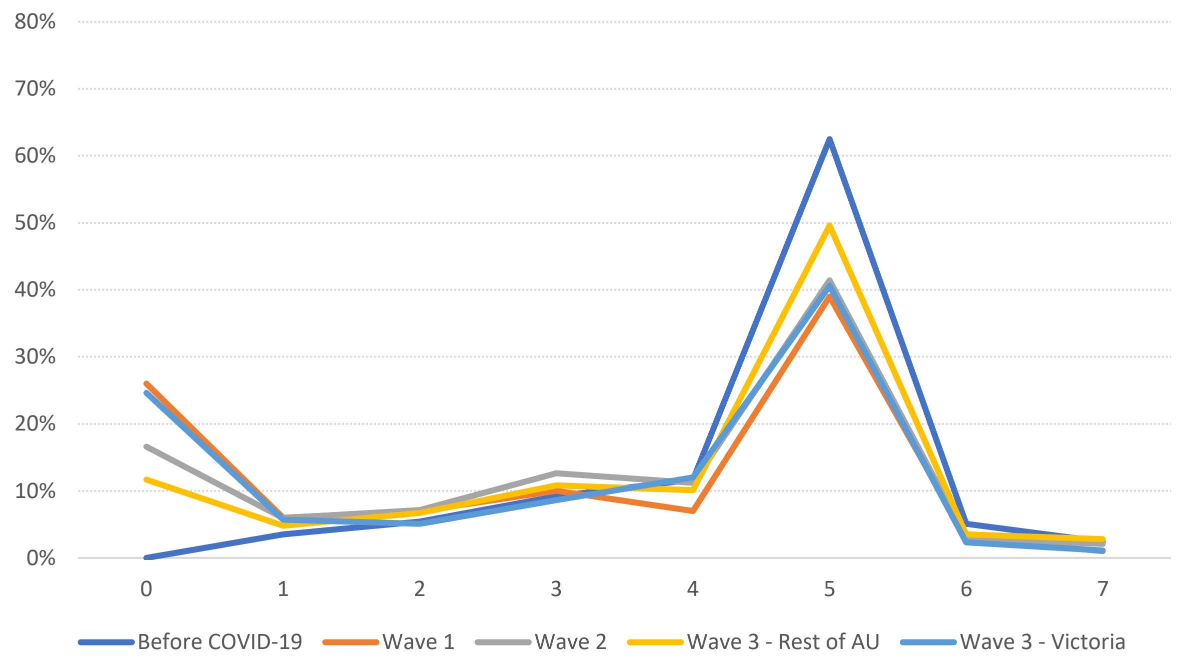

Figure 3: Days Worked in the Last Week

As was the case with the number of days worked, we see the number of days worked from home slowly diminishing over the waves as restrictions are eased. This is shown in Figure 4. However, and excluding Victoria, we do see some stability in the number of respondents working zero days from home between Wave 3 at around 55% (compared to 71% prior to COVID-19), and the reduction in work from home being those working five days week from home, falling from 21% to 14%. In Victoria, unsurprising the level of work from home in Wave 3 again returns to the same levels seen in the immediate response to the pandemic in Wave 1. In aggregate, those in metropolitan regions, those who are in the middle age group, those on higher incomes, and males all report higher average number of days worked from home during Wave 3.

Figure 5 shows the aggregate change in the volume of work for respondents relative to their level of employment prior to COVID-19. Outside of Victoria, just over half of respondents (57%) report that they are working the same number of days/hours as before the pandemic, almost a third (29%) are working less, and a small number (13%) are working more days or hours now than before COVID-19. Once again the differences in Victoria are stark, roughly the same number of respondents (44%) reporting less work, as the number who are working the same amount now relative to before COVID-19 (43%). Those on higher incomes are more likely to report that they are working more now, while older respondents as well as those on lower incomes are more likely to report they are working relatively less now compared to before.

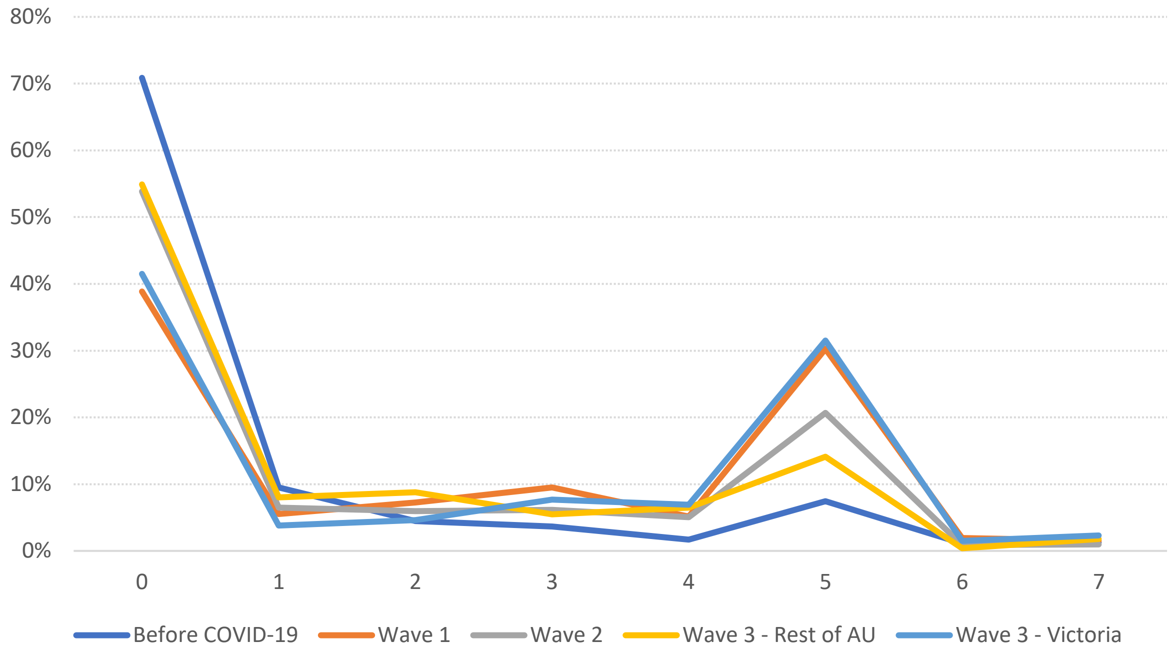

Figure 4: Days Worked from Home in the Last Week

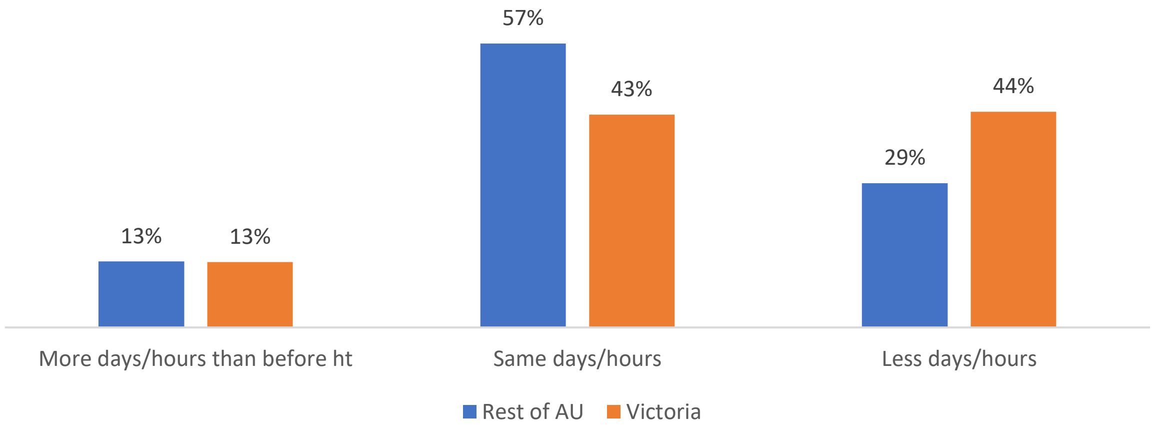

Figure 5: Overall Change in Level of Employment Relative to Before COVID-19

We also sought to gain insight into the expectation that respondents might have about the level of employment in the immediate to short term (Figure 6). While the majority of respondents in Victoria (67%) and the rest of Australia (81%) expected their level of employment to be the same in the next week, in Victoria around one-quarter of respondents (27%) expected to be working less days or hours, compared to 13% elsewhere. In the short-term over the next 3 months the dominant expectation is that the level of employment will remain unchanged, however rather than being positive there is on overall sense of pessimism with slightly more respondents (particularly in Victoria) expecting levels of employment to fall rather than increase, relative to the last week of work. Those on lower incomes are more likely to expect less work over the next week, and less work three months from now.

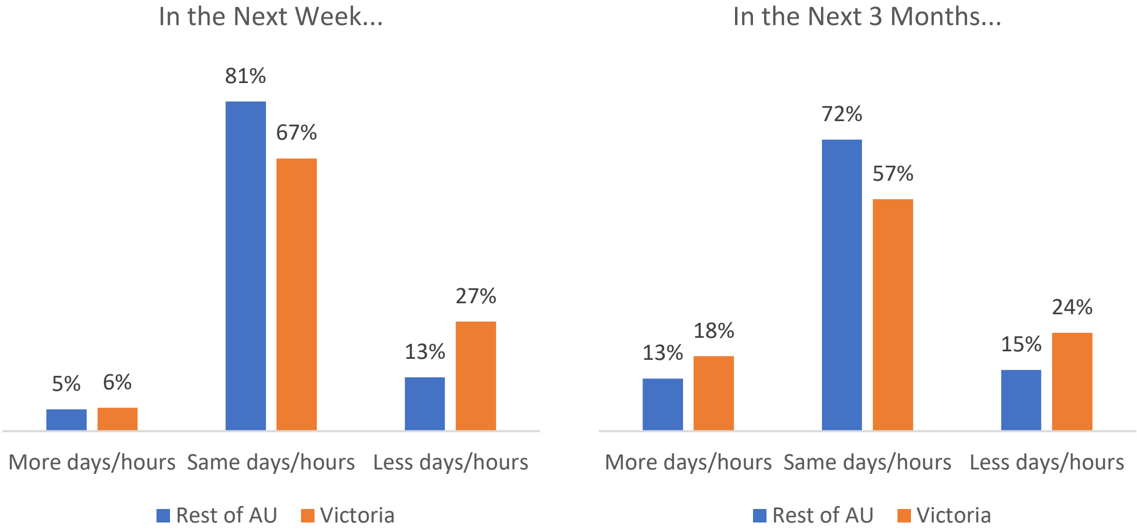

Figure 6: Expected Changes to Employment Relative to the Last Week

With regards to the main mode respondents reported using to get to work, Figure 7 shows a slight increase in private car driving as the reported main mode now compared to before COVID-19, along with a rise in walking. We see that the main public transport modes of train, bus and light-rail have all fallen. Older respondents are more likely to report the car as their main mode and younger respondents are relatively more likely to use the train as a main mode than other age groups. While there are large differences in what is nominated as the main mode in metropolitan and regional areas (for example public transport alternatives are more likely to be available and thus are seen to be more often nominated as the main mode in metropolitan areas), the proportional changes to each mode are very similar to the aggregate changes presented.

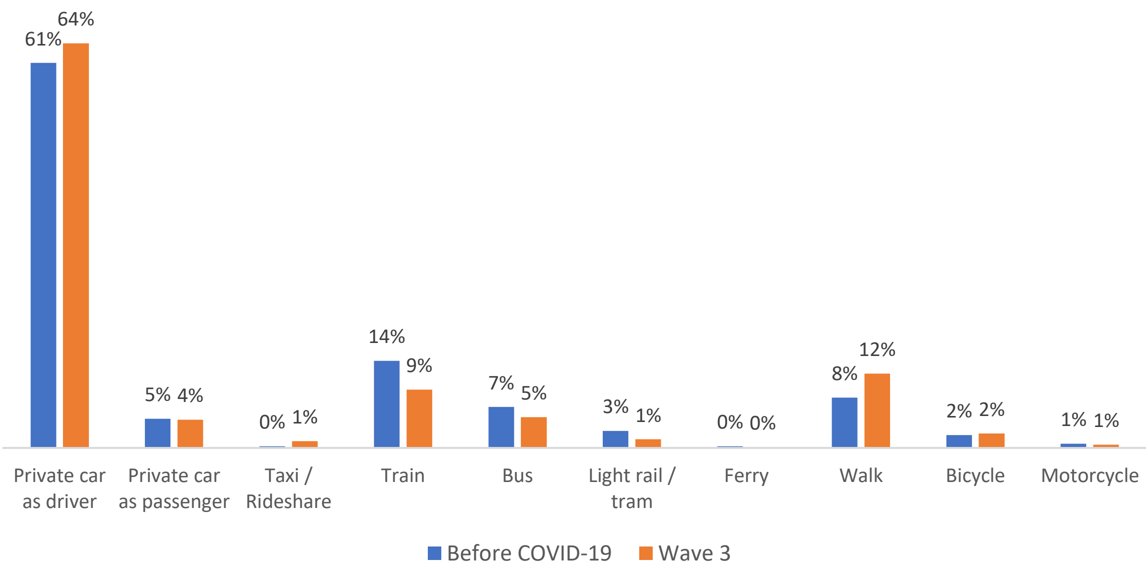

Figure 7: Nominated Main Mode for Travelling to Work

Figure 8 presents insights into how stable employment levels and subsequent commuting behaviour might be, given respondent assessment of what their work might look like over the next several weeks relative to what it is now. The vast majority of respondents either agreed or strongly agreed that over the next several weeks, the days they work per week, how often they work from home, the way they travel to work and the number of times they travelled to work would remain very similar to the last week. Victorians agreed less, on average, that the way the travel to work and the number of times they did so would be similar coming up. Females agreed more strongly to all four statements. Those in metropolitan areas agreed significantly less to the travel modes and number of trips to work being similar. Older people, on average, expressed higher agreement that the number of days worked, and subsequent travel modes and number of trips would remain unchanged.

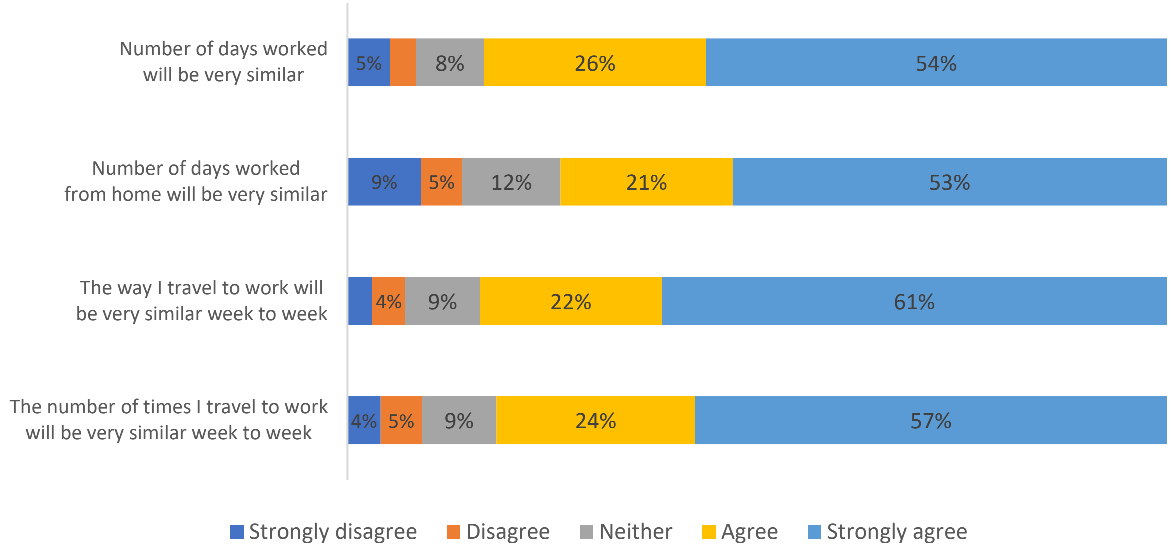

Figure 8: Nominated Main Mode for Travelling to Work

Figure 9 shows the level of concern that respondents have over the risk of COVID-19 at their place of work. On average there is mild concern about COVID-19 and the workplace, with concern being significantly higher on average in Victoria. Metropolitan respondents also report significantly higher average levels of concern. Concern about COVID-19 and the workplace also has a strong and significant positive correlation with concern about hygiene and public transport and concern about the number of people using public transport. There is also a significant positive correlation between concern and the number of days worked from home, but the correlation is weak (r = 0.096). Finally, those in sales, community and personal services, managers, and professionals all report significantly higher average concern about COVID-19 and the work place than other occupations.

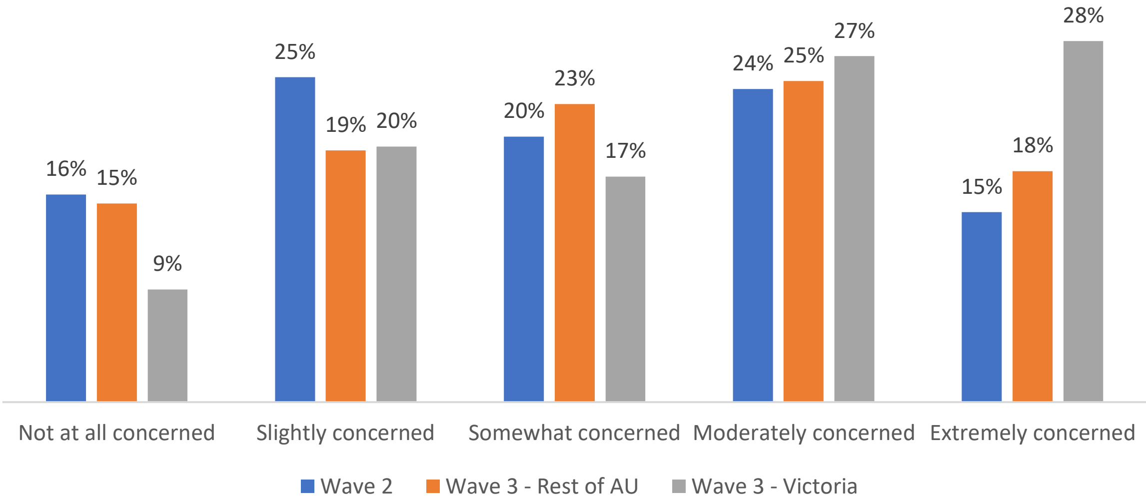

Figure 9: Concern about COVID-10 and the Workplace

3.2 Number of Days Worked from Home

Holding everything else constant, males, those in metropolitan areas, on higher incomes and in older age groups report significantly higher average number of days worked from home. In terms of differences across occupations, Figure 10 shows that those who are employed in white collar professions report a higher average number of days worked from home compared to blue collar occupations or those who are in service delivery roles.

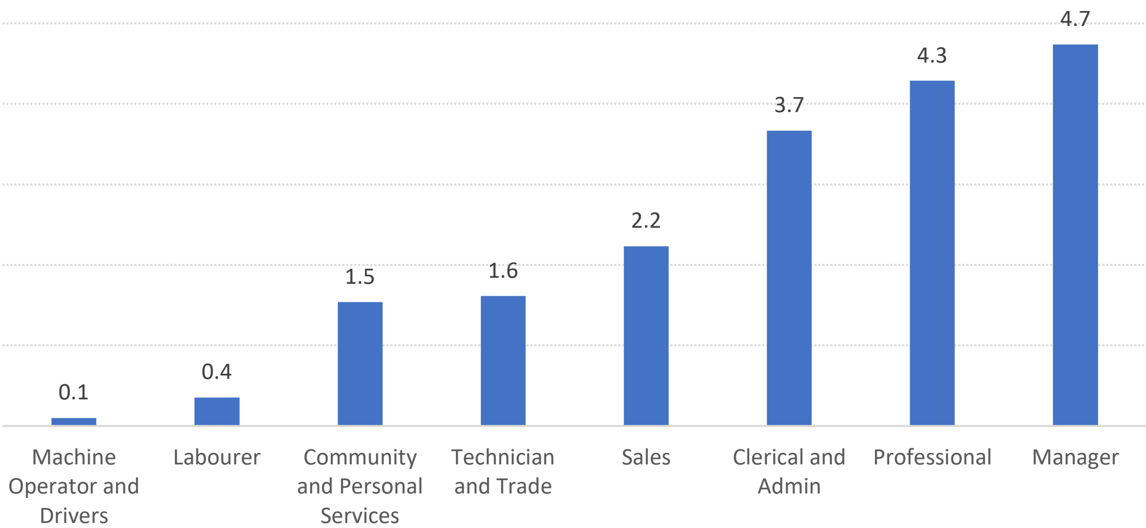

Figure 10: Average Days Worked from Home by Occupation

The size of the organisation (sole traders or firms with 1 to 4 employees, 5 to 19, 20 to 199, or workplaces with 200 or more employees) for which a respondent works plays no significant role in differences in the average number of days worked from home. Figure 11 shows the distribution of the average number of days worked from home by industry. It should be noted that within an industry there are many occupations or roles that have lesser or greater ability to have work completed from home. Figure 12 shows the distribution of working from home over each day of the week, showing that from Monday to Friday approximately one-third of those working are currently doing so from home.

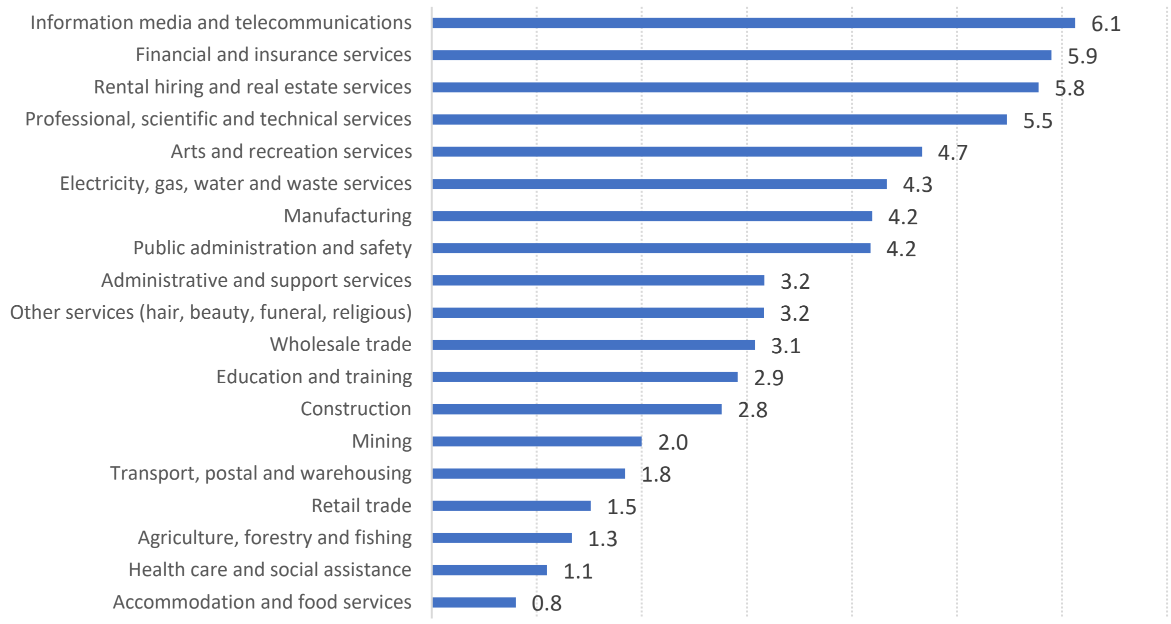

Figure 11: Average Days Worked from Home by Industry

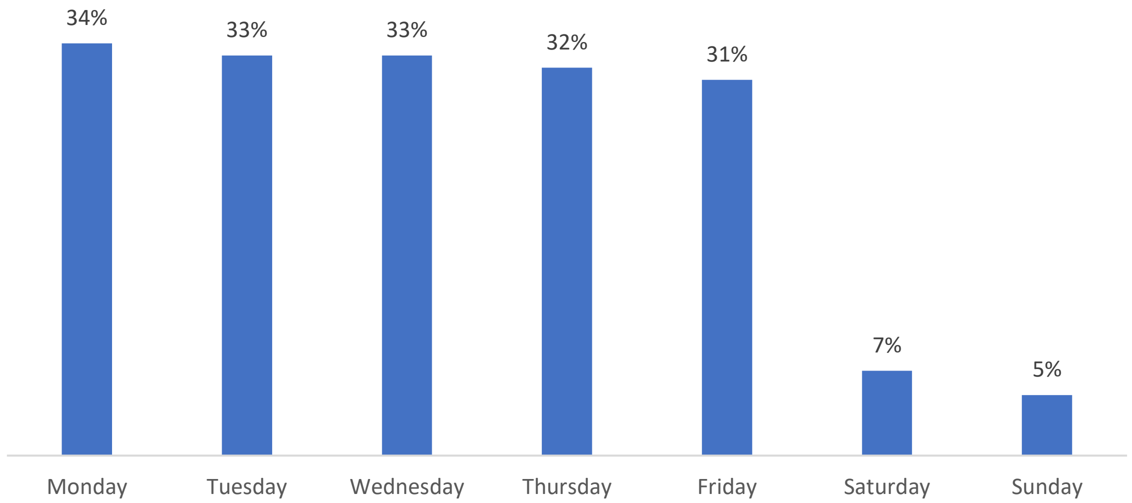

Figure 12: Current Incidence of Working from Home by Day of Week

With regards to the policy within an organisation towards working from home, as shown in Figure 13, 43% of respondents outside of Victoria are either directed or given the choice to work from home. This percentage is approximately the same as Wave 2 (39%), but down from the 57% observed in Wave 1. In Victoria, however, we once again see a result that mirrors that from Wave 1, with 44% being directed to work from home and 16% being given the choice. The differences are also significant between metropolitan and regional areas with 36% of regional employees in workplaces that have no plans to work from home (compared to 28%) and 24% in a role that cannot be undertaken from home (compared to 17%). Younger respondents are more likely to be in work places that offer the choice to work from home, males more likely to be directed to work from home, and those on higher incomes more likely to be given the choice or directed.

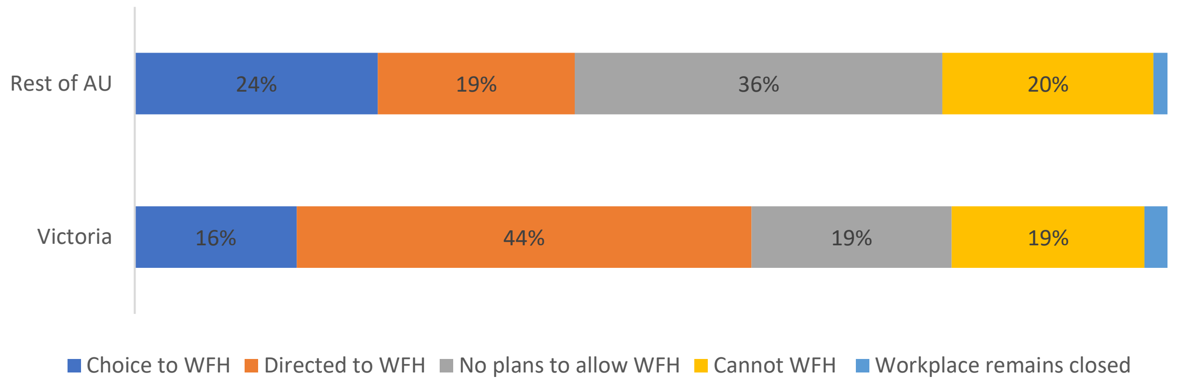

Figure 13: Workplace Policy toward Work from Home

Respondents also reported the change in work from home policy compared to before COVID-19, which is shown in Figure 14. While there is no significant difference between Victoria and the rest of Australia with regards to the shift in work from home policy, metropolitan respondents are more likely to WFH more now than before compared to those in regional areas, and regional area employees more likely to be in a workplace where working from home is not possible/allowed both before and after COVID-19. Higher income respondents are more likely to be able to work from home more now than before.

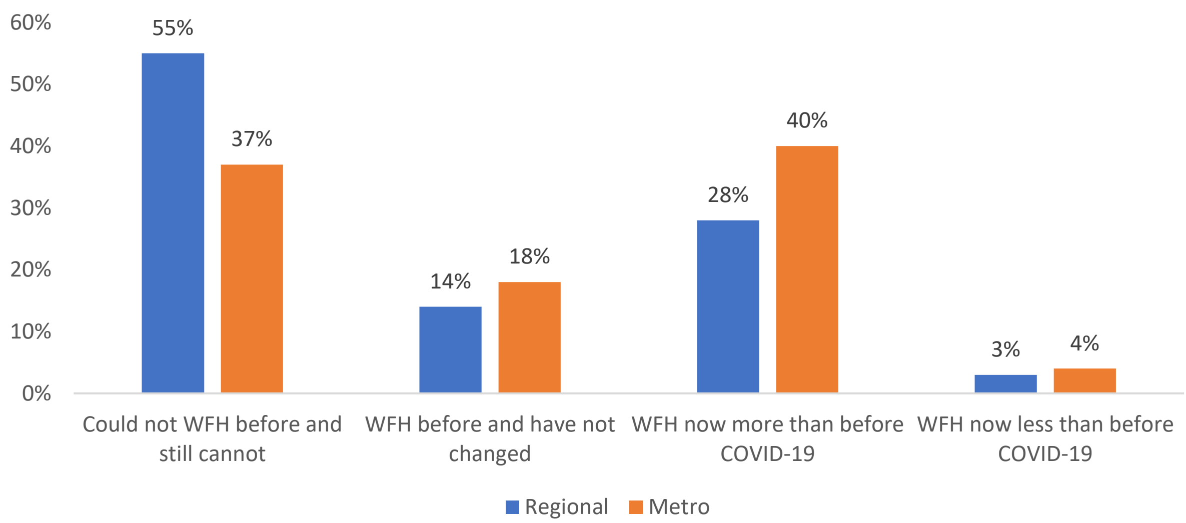

Figure 14: Change in Workplace Policy toward Work from Home

Respondents were also asked to assess how well the work from home policy had been communicated to them (Figure 15) and overall, respondents found that the policy had been communicated clearly. Victorians on average felt the policy was more clearly communicated than respondents in other parts of Australia, as did those in metropolitan regions. Males, older respondents, and those on higher incomes also found that the communication from their workplace was clearer.

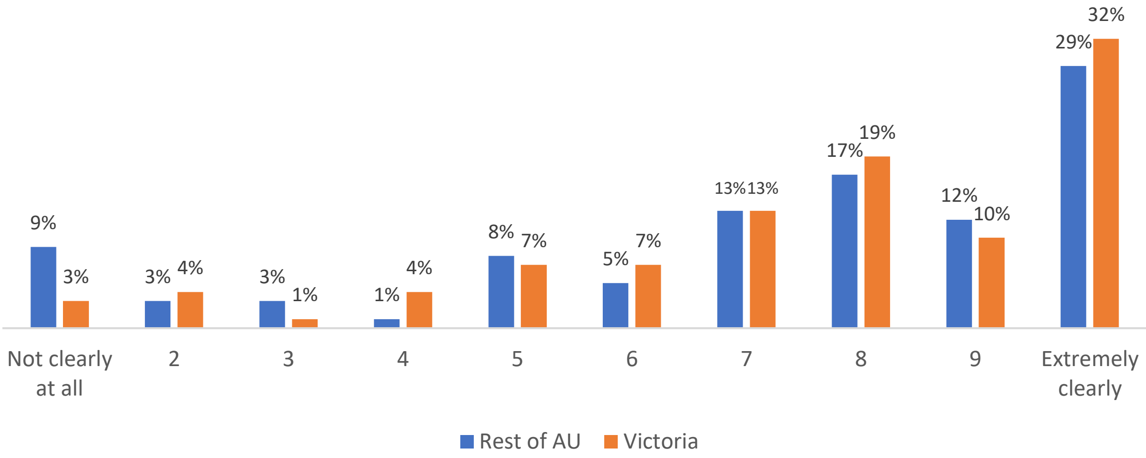

Figure 15: Change in Workplace Policy toward Work from Home

3.3 The Experiences of Working from Home

While acknowledging that working from home does not suit all people, the overall experience with working from home remains, on average, a positive one for employees. Indeed, despite the ongoing pandemic and the now significant period of time over which working from home has become widespread, there is very little change in attitude and experiences from that found in Wave 2; in fact the distribution of responses for each statement is statistically identical, as shown in Figure 16[74].

While respondents perhaps still need more equipment to work from home as well as they would like (males on average agreeing more strongly that they would like more equipment), the majority of respondents agree they have everything they need to work from home successfully and that they have the appropriate space to work from home (though agreement in the metropolitan regions is significantly less, and older respondents are more likely to agree that they have an appropriate space). Respondents agree that they are able to find a balance between work and unpaid work (more likely for older respondents and less for those in metropolitan areas), and can balance the time spent working and not working whilst doing so from home (older respondents also agree more strongly on average to this statement). As a result of the aggregate ability to manage work from home successfully, and the overall positive experience as a result, respondents also indicate that they would like to work from home more often in the future, would like more flexible work times and would also like to commute at less busy times in the future if it were possible. Interestingly for this study, females agree more strongly to these three statements.

[74] The two questions "I have everything I need to work from home successfully" and "I still require equipment to work from home as well as I would like" were introduced in Wave 3 to gain insight into whether respondents believed they could work from home well (Yes), and if there was room for further improvements (no).

Figure 16: Experiences with Working from Home

We further examined the kind of space a respondent works from when doing so from home. 74% reported that they have their own room/space, while 26% stated that they shared a room/space. It should also be noted that those respondents who have their own space agreed more strongly that they can balance their time between work and not working, between paid work and unpaid work (e.g. housework, childcare, yard work) and that they have everything they need to work from home successfully. However, there was no difference in how positive the overall experience has been nor whether a respondent would like to work from home more in the future. With regards to the expense of setting up an environment to be able to work from home, Figure 17 shows that only 15% of respondents had everything they needed prior to COVID-19. In acquiring what was needed, 42% paid for it themselves. Older respondents are more likely to have paid for equipment themselves, with middle aged more likely to have expenses shared between themselves and their employer, and younger more like to have paid for it but been reimbursed by their employer.

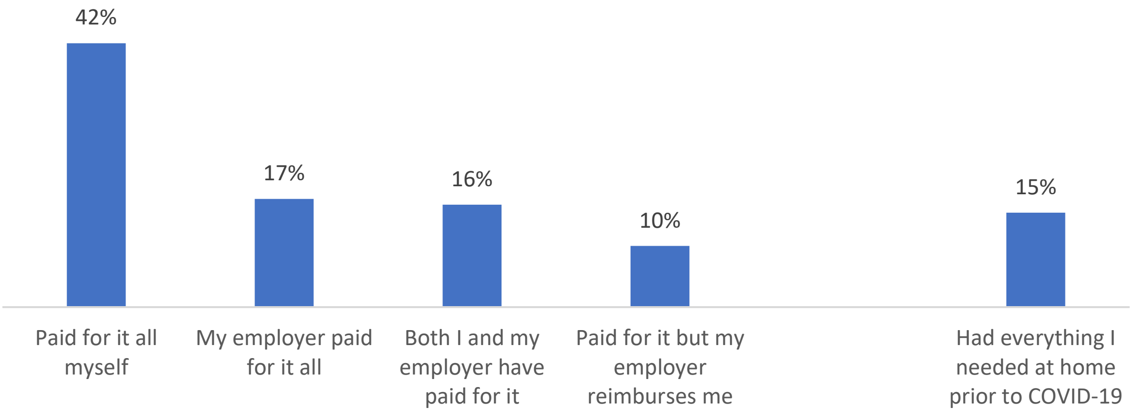

Figure 17: Who Paid for Equipment / Technology Required to Work from Home

Respondents were also asked to assess their level of productivity when working from home (Figure 18). The sample average of 3.2 ($\sigma = 1.1$) indicates that in aggregate those working from home perceive little difference in productivity relative to before COVID-19. The relative perception remains virtually unchanged from Wave 2 and is not even different in Victoria compared to the rest of Australia. Interestingly, metropolitan residents report a lower average level of productivity compared to regional workers. Unlike in Wave 2, however, there are no longer differences in productivity based on age or income. It should also be noted that productivity does not vary based on whether a respondent works in their own space/room or shares space with another while working from home. The perspective of managers and employers was also explored (n = 106 in Wave 2 and 126 in Wave 3), and much like the assessment of a respondent's own productivity, on average, managers/employers have found staff to be just as productive working from home as they were prior to COVID-19 and that evaluation has also remained unchanged from Wave 2 to Wave 3. While prior to COVID-19 many, especially employers and managers, might have been tempted to think that working from home resulted in employees working less, these results indicate that there has been no change in productivity despite the wholesale shift towards working from home.

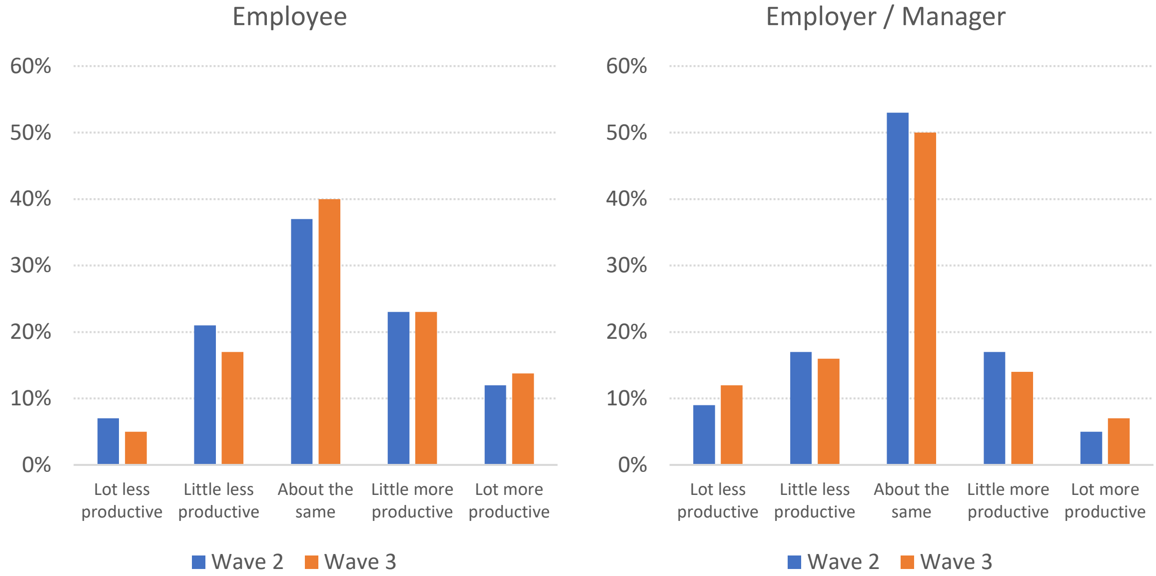

Figure 18: Productivity of Work from Home Relative to Before COVID-19

3.4 Expectations of Future Working from Home

Two-thirds of respondents (66%) indicated that they have had conversations around working from home (or staggering work hours). As shown in Figure 19, among employees around half believe that their work cannot be done from home, while 31% believe that their employer would support working from home either as often as they would like or in some balance with working in the office. Younger respondents are more likely to state that their work cannot be done from home, while older individuals are more likely to believe a balance between work from home and the office would be likely, and those on higher incomes are more likely to state their employer would support working from home as often as they would like. The difference between metropolitan and regional areas is quite pronounced, with 38% of metropolitan respondents stating that their employer will support work from home as often as they would like or some balance between home and the office, compared to 23% in the regions.

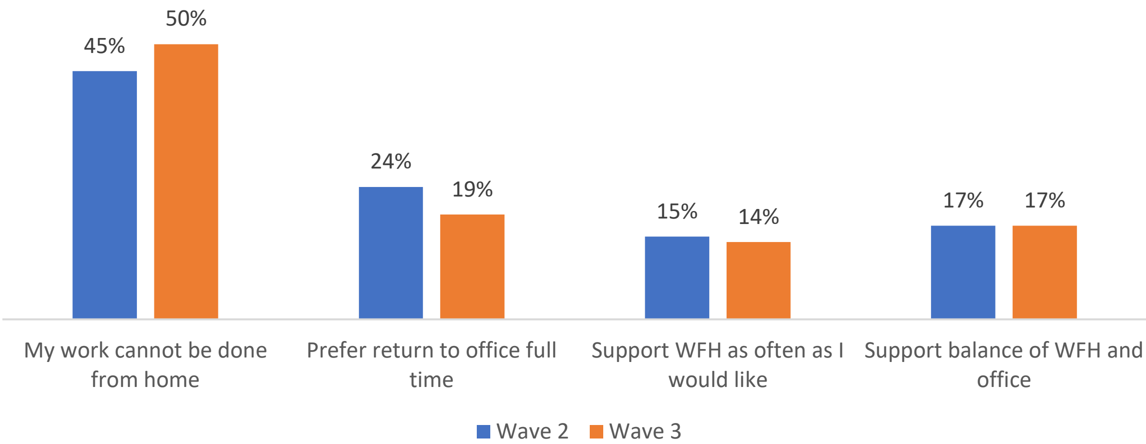

Figure 19: Employee View on Employers Support for Work from Home in the Future

Employers and managers were also asked how working from home would be supported in the future, as shown in Figure 20. Comparing these results with those in Figure 41, it would seem that there is potentially a disconnect between employees and employers/managers, with the latter being more supportive of working from home than potentially expected. Additionally, we see a growth in the support for working from home overall from Wave 2 to Wave 3. Among those managers and employers sampled, 78% have input into work from home decisions entirely or through providing recommendations to the company, with only 22% having no authority in the matter.

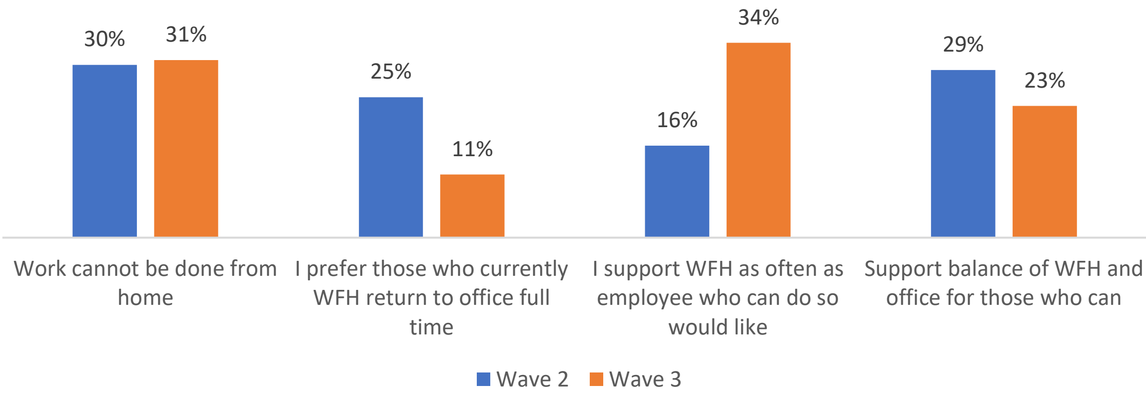

Figure 20: Employer/Manager Support for Work from Home in the Future

Respondents were also asked to state if they would like to work from home for each of the days of the week they normally work. While 51% of respondents indicated they would not like to work from home at all (with regional locations, females, older respondents and those on lower incomes being more likely to provide this response), as shown in Figure 21 the distribution of working from home is uniform over the days of the week (Mon-Fri). This is very similar to the pattern of working home over the week that we currently observe during Wave 3 (as shown previously in Figure 12).

Respondents were also asked to state how supportive they think their employer would be for each of the days they would like to work from home. As can be seen in Figure 22, employees generally feel that their employer would provide support or be extremely supportive of their desire to work from home for any given day of the week (Mon-Fri). Interestingly, Wednesday is the day where there is slightly less perceived support. For all days of the week respondents in metropolitan areas believed their employer to be significantly more supportive, and those on lower incomes felt their employer would be significantly less supportive of working from home on any day Monday thru Friday.

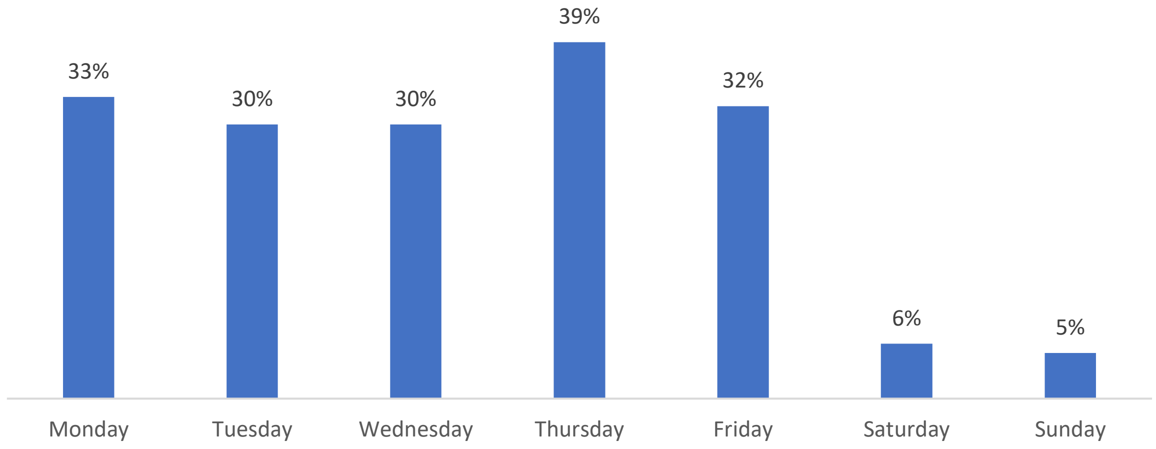

Figure 21: Day of the Week Respondent Would Like to Work from Home

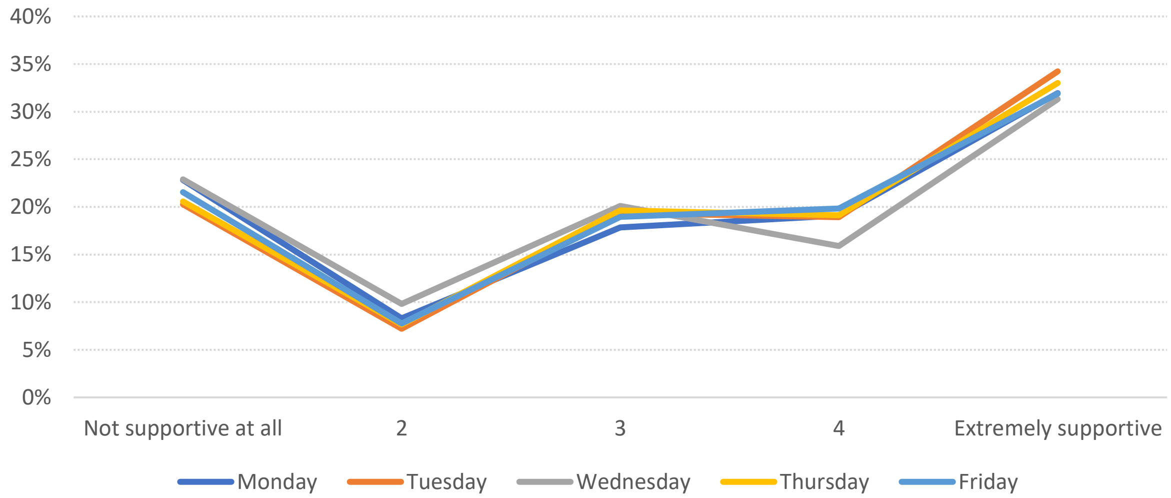

Figure 22: Perceived Support for Working from Home on Each Day

In terms of the actual number of days that an employee would like to work from home, Figure 23 shows this distribution and contrasts it against the number of days that an employer or manager feels is appropriate for a member of staff to work from home. The average number of days an employee would like to work from home has fallen slightly from an average of 1.9 in Wave 2 (σ = 1.9) to 1.7 in Wave 3 (σ = 2.1). While the average number of days an employer or manager feels is appropriate is higher than what employees in the sample have expressed, it has also decreased from 2.6 (σ = 1.8) in Wave 2 to 2.4 (σ = 1.8) in Wave 3. Employees in metropolitan areas, females, older respondents and those on middle and high incomes all express significantly higher average number of days they would like to work from home in the future.

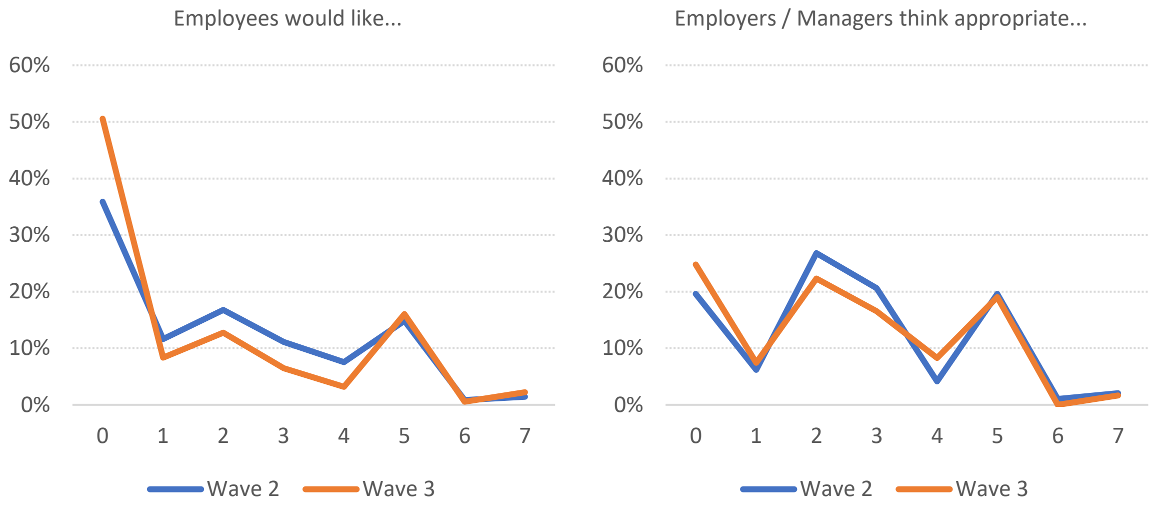

Figure 23: Number of Days of Work from Home in the Future

3.5 Staggering of Work Hours (Peak Spreading)

A series of questions introduced in Wave 3 explored the propensity for workers to stagger the times that they work, as a strategy to reduce capacity in peak times in light of capacity constraints brought about by the requirement for social distancing; true of both the office, public transport, and even to create space on the road. Figure 24 shows how willing a respondent is to stagger their work hours to help with congestion and capacity constraints due to COVID-19: 40% of respondents in regional areas cannot stagger their work hours, compared to 28% in metropolitan regions who state they cannot. Conversely, those from metropolitan areas are more likely to be happy to stagger their work hours (27% compared to 18%), which is important as metro areas are more likely to have capacity concerns. Females are more likely to be in employment where hours cannot be staggered, and males more likely to state that they do not want to stagger their work hours. Younger respondents are more likely to be happy to stagger their work hours, and lower income to be in roles where hours cannot be staggered, or where they are staggered already.

Preferences of commuters were also explored, to determine what policy would be most preferable if respondents were forced to stagger their working hours (Figure 25). Around half would prefer a new set of starting and finishing times that could remain unchanged until restrictions end. There is also a preference that if forced, they would like to leave for work earlier than is currently the case. For those who expressed a preference to leave for work earlier, on average that would be 45 minutes earlier than is currently the case ($\sigma = 39$) and those who prefer a later departure than normal would prefer to do so 46 minutes later ($\sigma = 39$). Unsurprisingly, both distributions of departure times are bimodal around 30 and 60 minutes.

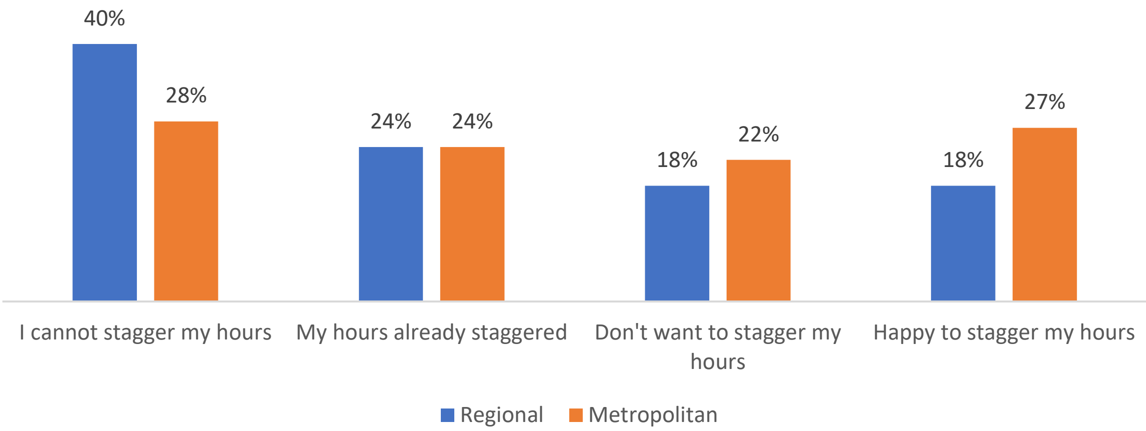

Figure 24: Willingness to Stagger Working Hours

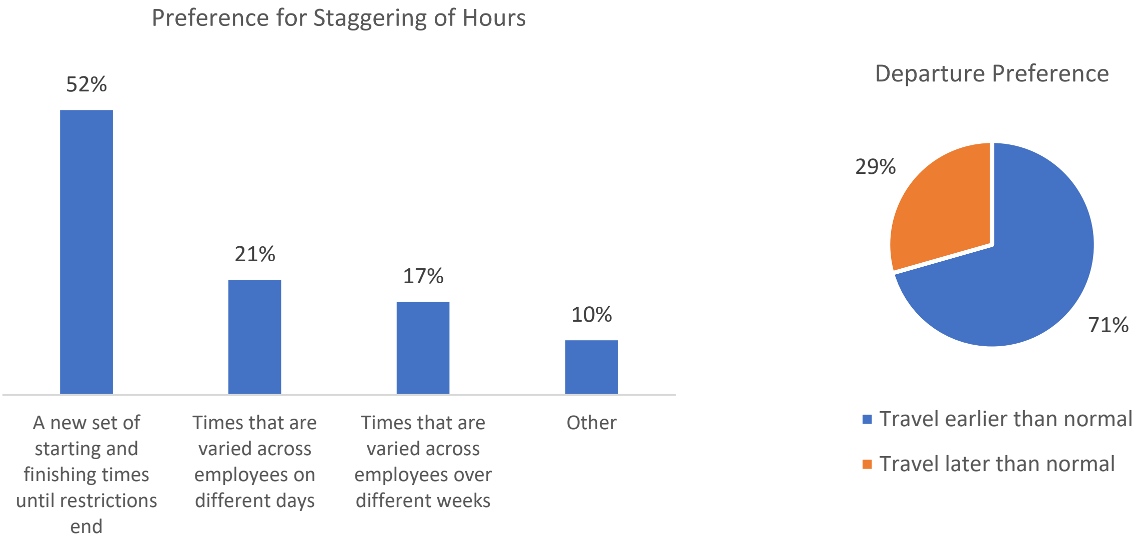

Figure 25: Preferences if Forced to Stagger Hours

Given the relationship between the ability to stagger work hours and the previously discussed finding that employees would like more flexible working hours in the future and would also like to be able to commute at less busy times if possible, the survey also explored the likelihood that employee would stagger work hours, as well as the position of employers and managers with regards to staggering; the results summarised in Figure 26. The majority of employees believe that hours cannot be staggered or will not be staggered (total of 62%); however just less than half of managers or employers believe this to be the case (46%). Again, it would seem that there is a potential mismatch between the support that employees expect from their workplace, versus that which might be given by managers or employers (even accounting for the fact that the employers/managers in this sample are not the managers or employers of the employees sampled).

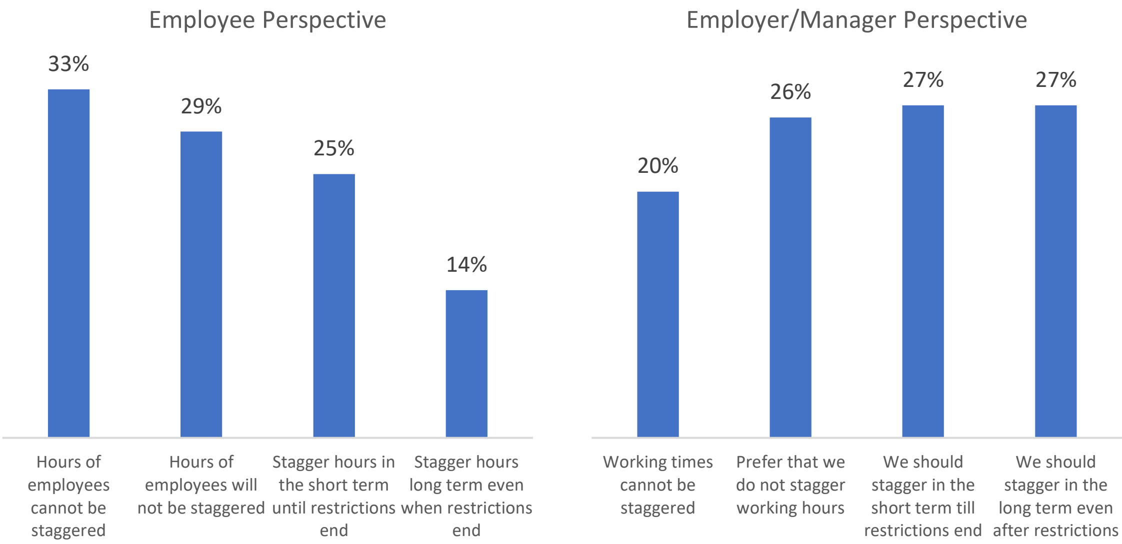

Figure 26: Future of Staggered Working Hours

4 Discussion and Policy Implications

While widespread significant increases in working from home has been one way to curb the movement of people and thus the spread of COVID-19, it has been a more viable option for some members of the community than others. For example, in addition to the findings in Wave 2 (Beck and Hensher 2020b), in Wave 3 we still find that males, those in metropolitan areas, on higher incomes and in older age groups report significantly higher average number of days worked from home. For those working from home, there exists gender inequality in remote work arrangements; for example studies have found that females spend significantly more time performing housework when they work from home than males, and also spend more time doing their jobs with children present (Lyttelton 2020). There is also inequality in access to appropriate technology and space within the home to work successfully, and there are also consequences with regards to social isolation for some working solely from home. Additionally, we find that the impact on work itself is larger for those on lower incomes both in the present (availability of work in the last week) and also the availability of work in the short-term (next week and three months from now).

While working from home remains strong in all states, we do see a decrease from the highs observed during Wave 1 of data collection. However, the experience in Victoria, where the rapidly growing outbreak leading to severe lockdown measures to battle the spread, saw a rise in working from home to similar levels during the early stages of the initial pandemic response in late March 2020. The Victorian experience serves to highlight that in the context of an ever-changing and unpredictable pandemic, the ability for business (and this employees) to be able to switch to working from home or rapidly increase the volume of work done from the house is a crucial component to organisational and economic resilience. Greater levels of working from home also enable public transport systems to significantly reduce crowding and creating a more viable transport option for those whose travel by public modes is to be encouraged. To that end, working from home should continue to be a part of the work mix even if the pandemic is thought to come under some level of control – as easing restrictions can increase rates of infection (Scott et al. 2020), even off low levels of community transmission as witnessed in Australia.

Additionally, and as highlighted in Part 1 of this paper series, we have seen public transport use remain relatively suppressed, and concern about the hygiene and crowds on public transport remain relatively high compared to pre-COVID-19. While car use and thus congestion has been lower during the pandemic, and travel times significantly improved for all road users (including those unable to work from home benefitting from the improvement), the benefits associated with reduced travel demand could quickly erode should Australians en masse prefer to travel by private car as they also return to work. We have already seen that motor vehicle use is rebounding more strongly than all other modes, and while there is no expectation that working from home would or should continue at levels seen during the peak periods when responding forcefully to COVID-19, even a marginal increase in working from home will effectively create more capacity in transport supply, subject to any continuing requirements for social distancing that may results in a capacity shortage.

Thus, as a society we have a choice to make: we can continue to return to pre-COVID levels of car use (or even greater use), which will result in congestion that is worse than before COVID-19; or adopt a model where people are encouraged to work flexibly by either doing so at home or varying the times they commute for work, which have massive time and cost savings for society. The Australian context seems to suggest that the (effectively) nationwide mandate to allow staff to work from home has created the impetus needed for employees and perhaps more importantly employers, to see that working from home is an eminently viable option for many and work can be completed successfully and with minimal change to productivity. The desire for flexibility in choice has emerged as a major product of the pandemic. In the absence of a regulatory change that forces working from home to occur, transport authorities should work closely with industry (particularly in centres where white-collar employment is high) to create incentives for business to experiment with changes to working from home. The Australian experience seems to indicate that an extended experience will create positive outcomes, a greater uptake than historically the case, with the dividend of reducing strain on travel networks by a not insignificant amount. In our data; more than 50% of respondents feel some or all of their work can be done from home.

There is anecdotal evidence in Sydney that many large organisations are planning to make more extensive use of working from home than previously (for a variety of reasons including those discussed in Beck and Hensher 2020b: financial advantages, risk management, the wellbeing of staff, and the increased attractiveness of employment offers due to more flexible work); the employers and managers in our sample are in general more supportive than the employees think they would be. The dividends to business of more flexible work are potentially large. Now is the time for transport policy makers to point to these potential organisation dividends and encourage organisations to have conversations internally about the role working from home might have moving forward. Our research indicates that when outlining why respondents would be needed in the office, the biggest needs are not for day-to-day work, but for reasons of building social connections, sense of team and community, solving more difficult or complex problems, and training. These are tasks that can still occur at a central location, and will not be eliminated in a world with increased work from home. This is especially the case for young staff who are in the early days of building networks where face to face contact is an important element.

Wave 3 was collected some six months after the initial outbreak in Australia, and it is admittedly still unclear as to what direction will ultimately be taken with regards to working from home, particularly in the context of the habitual nature of human behaviour. However, the duration and scope of the disruption caused by COVID-19 is unlike anything we have seen before and in the face of such a shock, there is potential for new habits and processes to have been developed over that six-month time period. Our results show that many respondents have made significant investments in technology and equipment to work from home and many agree that they have what they need to work from home successfully. It is likely that respondents will want to see a return on their investments. Our data also indicates that on the whole, working from home has been a positive experience for those that been able to do so, and if anything the attitudes towards working from home have become more positive from Wave 2 to Wave 3. Similarly, there is a strong desire for the ability to work from home to continue, and strong evidence from both employees and employers that productivity whilst working from home has been maintained.

For the benefits to be maximised, the incidence of working from home needs to be spread evenly over the working week. This is currently occurring and the future preferences for working from home expressed also indicated that no one day (Monday thru Friday) is preferred to any other when it comes to wanting to work from home. It is again important that transport authorities liaise with businesses, or provide communication around the importance of evenly apportioning working from home over the week in order to maximise system benefits, effectively flattening the peaks. Additionally, while some also argue that increased activity is needed in urban areas to stimulate economic activity, this argument ignores the redistributive effect that working from home has had on local small businesses and non-CBD economies.

While there has been much attention on working from home as a policy measure, staggering work hours is a complementary and perhaps under-discussed policy instrument. A large percentage of respondents are open to having their work hours staggered; and again if businesses are able to take a coordinated approach to staggering hours such that true peak-spreading can be achieved in the system (there could be a role for governments to play a coordinative function in this process), greater benefits will accrue. Perhaps in an expression of the desire for habit, if work hours were to be staggered, the majority prefer one change to their hours that they can adapt to, preferably leaving earlier for work than normal.

5 Conclusion

The impact of COVID-19 has been profound, and while the vast majority of the outcomes have been negative, there have been a number of unintended positive consequences. The natural experiment of COVID-19 has shown work from home to be a viable well-being option and has the potential to take a large amount of pressure off transport networks. While understanding that work from home is a more viable alternative for some than others, if those people who are able to work from home do so, then the benefits of their absence in the transport network will also be transferred to those that are not able to work from home via relatively less congested transport networks and thus better traffic flow and commute times. Additionally, we are finding that behaviour and attitudes within regards to working from home in Wave 3 are remarkable consistent with Wave 2 *and* the future working from home that respondents would like to engage in. This suggests that, with the support of employers and governments, we may be beginning to see glimpses of a ‘future equilibrium’ wherein on any given day, approximately 30% of those working may be doing so from home, a huge boon to the transport system. Moreover, the evidence that working from home is evenly distributed over the week, means that the ability to plan without peaks varying through the week enables some new thinking on transport priorities that include deferring investment where there is more capacity that thought pre-COVID-19, or alternative investment to support better working from home as a complement to transport expenditure.

At no point have we argued that working from home should or will continue at the rates observed after Wave 1 or in Victoria during Wave 3, but rather an increased use of flexible work practices as a low public cost approach to reducing significant lost productivity that arises due to congestion. It is still demonstrably the largest transport lever to reducing travel demand on any given day, outside of road pricing reform which may be required should people continue to favour the car above all else. Change in thinking among managers and employers is already occurring and we should seize the momentum to create a flexible workplace that works better for employees and employers. Clearly more research, and research over a longer time horizon, is required to understand the role of working from home within different organisations, and the mix of processes and procedures that make working from home a more successful and long-term viable option. There are a growing number of studies that are delving more deeply into the relationship between specific work activity and the flexibility of where this work can be undertaken (including the remote or satellite office in lieu of the home location) (see Jacoby et al. 2019 and Mak et al. 2019).

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Appendix L. Paper #8: The Impact of Working from Home on Modal Commuting Choice Response during COVID-19: Implications for Two Metropolitan Areas in Australia

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Edward Wei

Abstract

The need to recognise and account for the influence of working from home on commuting activity has never been so real as a result of the COVID-19 pandemic. Not only does this change the performance of the transport network, it also means that the way in which transport modellers and planners use models estimated on a typical weekday of travel and expand it up to the week and the year must be questioned and appropriately revised to adjust for the quantum of working from home. Although teleworking is not a new phenomenon, what is new is the ferocity by which it has been imposed on individuals throughout the world, and the expectation that working from home is no longer a temporary phenomenon but one that is likely to continue to some non-marginal extent given its acceptance and revealed preferences from both many employees and employers where working from home makes good sense. This paper formalises the relationship between working from home and commuting by day of the week and time of day for two large metropolitan areas in Australia, Brisbane and Sydney, using a mixed logit choice model, identifying the influences on such choices together with a mapping model between the probability of working from home and socioeconomic and other contextual influences that are commonly used in strategic transport models to predict demand for various modes by location. The findings, based on Wave 3 (approximately 6 months from the initial outbreak of the pandemic) of an ongoing data collection exercise, provide the first formal evidence for Australia in enabling transport planners to adjust their predicted modal shares and overall modal travel activity for the presence of working from home.

Keywords: COVID-19, working from home, Australian experience, mixed logit model, commuter mode choice, value of time, elasticities, segment mapping for WFH propensity

Acknowledgments*.* This research is part of iMOVE Cooperative Research Centre (CRC) research projects 1-031 and 1-034 with Transport and Main Roads, Queensland (TMR), Transport for New South Wales (TfNSW) and WA Department of Transport (WADoT) on Working for Home and Implications for Revision of Metropolitan Strategic Transport Models. The findings reported are those of the authors and are not the positions of TfNSW or TMR; but approval to present these findings is appreciated. We also thank Andre Pinto of ITLS for his role in the iMOVE projects. We thank two referees and the guest editors, Hani Mahmassani and Patricia Mohktarian, for very insightful and constructive comments and suggestions.

1 Introduction

Working from Home (WFH) is evolving into a popular and potentially significant alternative to commuting to a regular office location. We have described it as the most influential transport policy lever that we have seen since World War II (Hensher et al. 2020), with evidence from many jurisdictions suggesting a preference for WFH at least 1 or 2 days a week (Beck and Hensher 2020a, Barralo et al. 2021). To the surprise of many commentators, both employees and employers have adapted extremely well to forced WFH with many advantages (and some disadvantages) being revealed. Most notable has been the amount of trust demonstrated by employers for employees to WFH (at least to some extent going forward) linked to increased productivity, and employees seeing WFH as an opportunity to reduce the stress of commuting and opening up greater quality time with family and friends, especially when aligned with more flexible working hours (Beck and Hensher 2020, 2020a, 2021).

Given the growing evidence that WFH is unlikely to be a temporary phenomenon[75], the need to review current transport models that are used to obtain predictions of commuter modal choice and aggregate modal shares becomes of paramount importance. With reduced commuting activity each day of the week and a move to greater flexibility in the time of day and day of week that employees work (extending beyond weekdays to include weekends and evenings throughout the week), as well as a growing preference for staggered working hours, there is a need to reconsider (at least) commuter mode choice models. A reconsideration of the commuter mode choice model must now allow for the real possibility of replacing a regular commuting trip (for a fixed number of days per week in most cases), with working from home, as well as not working at all at particular times of the day, across days of the week, while attaining the agreed number of weekly working hours. Crucially, we suggest that a commuter mode choice model must recognise the role of WFH and No-Work in establishing the probability of commuting on a particular day and at a particular time of day by a specific mode from the full set of modes including walking and bicycle, given that the latter two active modes have grown in relevance (Beck and Hensher 2020a).

In developing new empirical models of commuter mode choice in the context of WFH, this paper draws on data collected in the third wave, called Wave 3, of an ongoing COVID-19 Travel Survey which went into field from the 4th of August the 10th of October, approximately 6 months after the beginning of the pandemic).[76] We focus on two metropolitan areas in South East Queensland (including Brisbane) (SEQ), and the Greater Sydney Metropolitan Area (GSMA), presenting formal discrete choice models of commuting versus working from home or not working at all for specific days of the week and times of day. Details of the data collected for all of Australia in Wave 3 as well as the previous waves has been presented in detail in Beck and Hensher (2020, 2020a, 2021), Beck et al. (2020), and Hensher et al. (2020,

[75] Unlike the influence of previous pandemics and natural disasters which, in the main, have been very localised and had limited impact on work activity.

[76] The data collected to date since early 2020 has three waves. While Wave 1 was collected to ensure as complete a replication of Australian socio-demographics as possible, the focus of Wave 2 and Wave 3 was to create a valuable time-series of cross-sections 'panel' data set (typically rare in transportation research), where a percentage of the repeated sample was the same individuals, designed to ensure representation from all states and territories. The impact of COVID-19 is, however, sufficiently widespread that no demographic can escape the disruption caused. The ongoing plan is to analyse Waves 2 and 3 with subsequent waves, with Wave 4 having been collected in June 2021. We will be estimating models along the exact same lines as the Wave 3 models developed in this paper where we see the current paper as the first representation of a new model form that provides an appealing framework within which to condition out the probability of working from home and non-working over a 7 day week in order to adjust for the future incidence of commuting activity.

2020a)[77]. The data collected is extensive, but in this paper we focus on summarising only the descriptive evidence relating to working from home in Wave 3 as a prelude to the presentation of the model forms used and the sampled profile of commuter mode choice and available modes.

The paper is organised as follows. In the next section we provide a brief literature review given that much of the material has been summarised and commented on in Beck and Hensher (2020, 2020a) and Beck et al. (2020) which list many of the main contributions by other authors. We then provide a descriptive profile of the context within which we are modelling the choice between WFH and commuting. We then set out the mixed logit model form together with the definitions used for the alternatives in the commute mode choice versus WFH and No-Work model. A descriptive profile of the relevant data is presented followed by the model results for each of SEQ and GSMA. The next section sets out the mapping model between the probability of WFH and a number of socio-demographic variables and contextual characteristics as a way of providing a practical tool to predict the incidence of WFH in various population and location segments; with a number of simulated applications presented. The paper concludes with a summary and suggested ongoing research activity.

2 Literature Review on Working from Home in the Commuting Context

Working from home has long been of interest to transport researchers. In early work the focus was mainly on white collar workers in the information technology sector (Salomon and Salomon 1984), and many looked barriers which might exist to working from home such as lack of social interaction, inability to separate home from work, and feeling that there was a need to be seen in order to advance (Salomon 1986, Hall 1989). Nonetheless, the concept of working from home gained traction in the transport literature as a relatively fast and inexpensive way to overcome several problems associated with congestion and it was argued that the impact of telecommuting on traditional transport demand models needed to be considered (Mokhtarian 1991).

Ben-Akiva et al. (1996) proposed a travel demand modelling framework for the information era. They outline a three-stage approach to incrementally updating the forecasting process through understanding how lifestyle decisions impact on mobility choices and how both impact on daily activity patterns. While Ben-Akiva et al. (1996) include sampling of both employees and employers, Yen and Mahmassani (1997) include both from the same organisation. The role of social influence and social contact on telecommuting has also been explored (Wilton et al. 2011). 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).

In terms of the effect of telecommuting on travel behaviour, Mokhtarian et al. (1995) found that both commute and non-commute travel (measured in person-miles) decreased as a result of telecommuting. Mokhtarian et al. (2004) found that one-way commute distances were longer for telecommuters than for non-telecommuters, but average commute miles overall were less than non-telecommuters due to trip infrequency. Hensher and Golob (2002) updated the current thinking on the role of the interaction between telecommunications and travel which at the time was described as ‘the opportunity to appraise the potential for telecommunications to facilitate and/or enhance the exchange of information with/without travel’. Zhu (2012), however, found that telecommuting generated longer one-way commute trips but also longer and more frequent daily total work trips and total non-work trips, arguing that there is in fact a

[77] We also used the Wave 2 survey instrument to undertake surveys in South America and South Africa. See Vallejo-Borda et al. (2021) for the South American study and Balbontin et al. (2021) for both South America and South Africa.

significant complementary effect of telecommuting on personal travel. Research by Kim et al. (2015) also found that telecommuting can indeed be a complement, particularly when it releases the household vehicle from mandatory work travel, to be used for non-commute trips.

However, in Australia the incidence of working from home remained persistently low, the Australian Household Income and Labour Dynamics survey (DSS 2020) shows that over the duration of the survey, which first commenced in 2001, approximately 25% of respondents worked from home regularly at an average of 11 hours per week. In exploring barriers to working from home, Hopkins and McKay (2019) find that it was a managerial decision rather than a function of the type of work that suppressed uptake. Such barriers are also prevalent in precarious and unskilled areas of the economy which have restricted access to flexible work practices (van den Broek and Keating 2011). There are other inequities in working from home, such as differences in outcomes for employed women and men with children, particularly in the areas of job satisfaction and satisfaction with the distribution of childcare tasks (Troup and Rose 2012); whereas other have found some evidence that working from home contributes to better relationships and a more equitable division of household responsibilities for couples with children (Dockery and Bawa 2019). With regards to COVID-19 it has been found that the impact has been disproportionately large on women (Nash and Churchill 2020, Craig and Churchill 2020, Lister 2020).

In April 2020, Linkedin developed the Workforce Confidence Index (Anders 2020), which shows that in Australia almost a quarter of respondents stated they felt safer at home, and another quarter would not want to go back to back to full-time office based employment. As a result of COVID-19, it may be possible that we will see the rise in working from home that was anticipated in the early work as far back as the 1970's. Should this indeed be the case, then there are significant ramifications for future travel demand and the model systems on which demand forecasts are made. For example, in the context of Sydney, the Strategic Transport Model (STM) is the primary tool used to test alternative settlement and employment scenarios; and determine the travel demand impacts from proposed transport policies, transport infrastructure or services. Many of these tools do not consider working from home in any significant way, as prior to COVID-19 working from home was not systematic.

3 Descriptive Overview of Working from Home in Wave 3 (August-September 2020)

We provide a brief assessment of the reported evidence on the impact of working from home on travel activity in the SEQ and GSMA areas for workers in Wave 3, excluding all non-workers from the analysis. We refer the reader to a more extensive discussion in Beck and Hensher (2020a,b) and Beck et al. (2021)[78]. Vallejo-Borda et al. (2021) and Balbontin et al. (2021) have recently reported on the evidence from five South American Cities. The evidence presented in this section uses the sample that is the basis of the estimation of the mixed logit model in a following section.

With regards to the number of days worked, the dashed line in Figure 1 indicates that there has been a slight downturn in Wave 3 compared to before COVID-19 in both the GSMA and

[78] Beck and Hensher (2021, 2021a) summarise the status of the pandemic at the time of the Wave 3 survey in Australia. On the 2nd of August, metropolitan Melbourne moved into stage-four lockdowns, being only allowed to shop for food and necessary supplies within 5 kilometres of their home, exercise for one hour once per day within 5km of home, and a stay-at-home curfew from 8:00pm to 5:00am each night. At approximately the same time, regional Victoria was placed in stage-three "stay at home" restrictions. In other states, New South Wales continued to experience low levels of community transmissions, primarily linked to an outbreak in South-West Sydney that was the result of a function at a hotel/bar attended by a COVID-19 positive guest who had travelled up from Melbourne for the event. Elsewhere in Australia, COVID-19 had been all but eliminated save for returning travellers.

SEQ. Prior to COVID-19 there were no reported differences in the average number of days worked by males and females, however in Wave 3 females reported a significantly lower number of days worked in the last week. Older and lower income respondents worked less days in an average week both prior to COVID-19 and in Wave 3. Conversely, as shown in Figure 2, we see across the board growth in working from home in both the GSMA and SEQ; from an average of 0.9 days before COVID-19 to 1.6 during Wave 3. However, the average number of days worked from home in the GSMA (1.8 days) is significantly higher than the number in the SEQ (1.4 days). Males in the GSMA work more days from home on average than others, as do higher income respondents in both the GSMA and SEQ.

As highlighted in Figure 3, the growth in work from home is due to workplaces either giving employees the choice to work from home or directing them to do so (50% in the GMSA and 45% in SEQ). In the GSMA, males are more likely to be directed to work from home whereas females are more likely to be in employment where work cannot be done from home. In both the GSMA and SEQ, higher income respondents are more likely to be given the choice or directed to work from home whereas lower income respondents are typically less able to work from home due to the nature of their work. With regards to any shift in the workplace policy around working from home, Figure 4 shows that the growth in working from home is also likely coming from respondents who had the ability to work from home prior to COVID-19 but are doing so more often during Wave 3 than they did before. Again, higher income respondents are more likely to belong to this group.

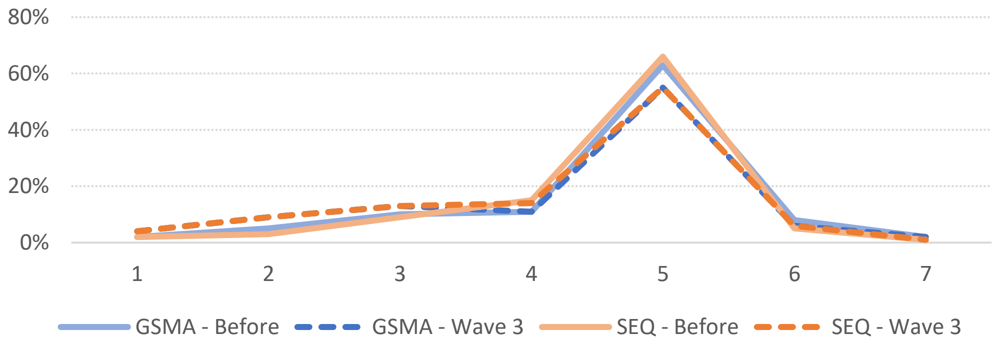


Figure 1: Days Worked in the Last Week and Before COVID-19

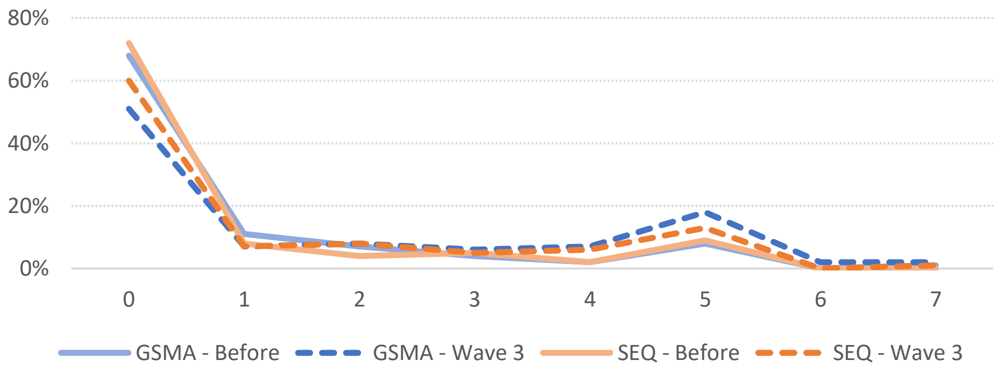


Figure 2: Days Worked from Home in the Last Week and Before COVID-19

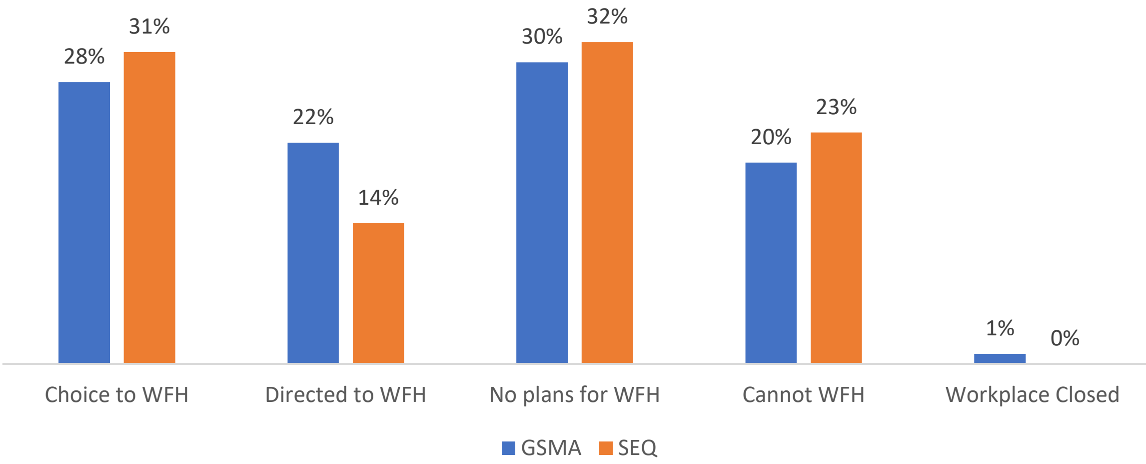


Figure 3: Current Workplace Policy toward Working from Home

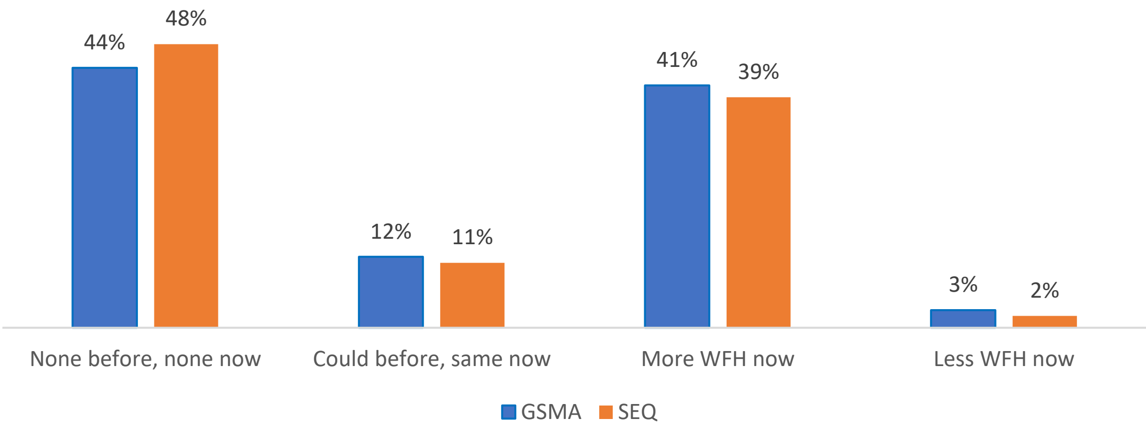


Figure 4: Comparison of Workplace Policy toward Working from Home before and during COVID-19

With regards to the day of the week that respondents work from home, Figure 5 shows a relatively even spread over the course of the typical working week in both the GSMA and SEQ, albeit at a higher rate in the GSMA. This is a non-trivial point; for the benefits of reduced commuting behaviour to be maximised, demand needs to be reduced by some margin on each day to improve traffic flow, rather than having all of the benefits of a reduction limited to one or two days (and likely a case where the reduction on these days is large but fails to add any additional marginal benefit than that which would accrue at a smaller fall in commuting).

When asked about the days a respondent would like to work from home in the future once COVID-19 restrictions cease, a similarly uniform distribution is observed (Figure 6). Interestingly, the number of days an employee would like to work from home in the future in the GSMA is the same as the current levels observed during Wave 3; but for SEQ the average number of days an employee would like to work from home in the future is significantly higher than is currently the case in the Wave 3 collection period. Younger and middle-aged respondents, along with those on middle to higher incomes, would like to work from home significantly more than others.

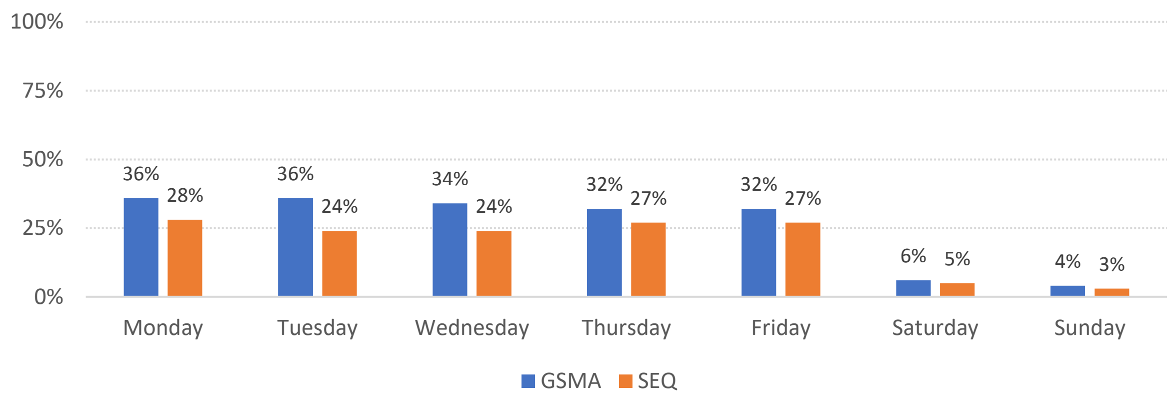


Figure 5: Working from Home by Day of Week

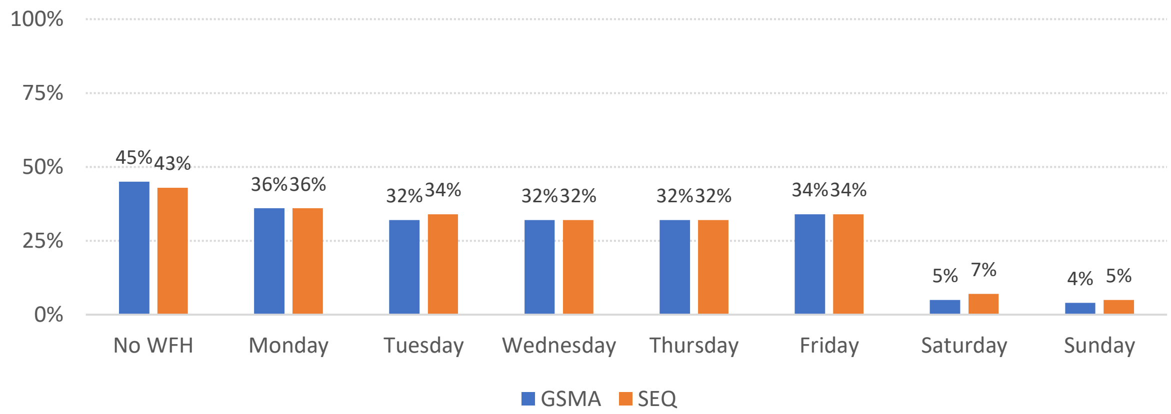


Figure 6: Days Like to Work from Home in the Future

It comes as no surprise that working from home is more of an option for different occupations and is more prevalent in certain industries. Figure 7 shows that the white-collar occupations of managers, professionals, technicians and trades, and clerical and administration all exhibit a higher average number of days worked from home[79]. Figure 8 shows that working from home is lower in occupations that require some focal point service delivery and retail[80].

[79] Occupations are coded as per the ABS Australian and New Zealand Standard Classification of Occupations https://www.abs.gov.au/ausstats/abs@.nsf/mf/1220.0

[80] Industries are coded as per the ABS Australian and New Zealand Standard Industrial Classification https://www.abs.gov.au/ausstats/abs@.nsf/mf/1292.0. In the analysis industries are further grouped into broad categorisations that are used within transport authority modelling, specifically: Retail (wholesale trade, retail trade, accommodation and food services); Service (education and training, health care and social assistance, arts and recreation services, other services); Professional (financial and insurance services, rental hiring and real estate services, professional, scientific and technical services, administrative and support services, public administration and safety); Industry (manufacturing, construction, transport, postal and warehousing, information media and telecommunications); and Other (agriculture, forestry and fishing, mining, electricity, gas, water and waste services).

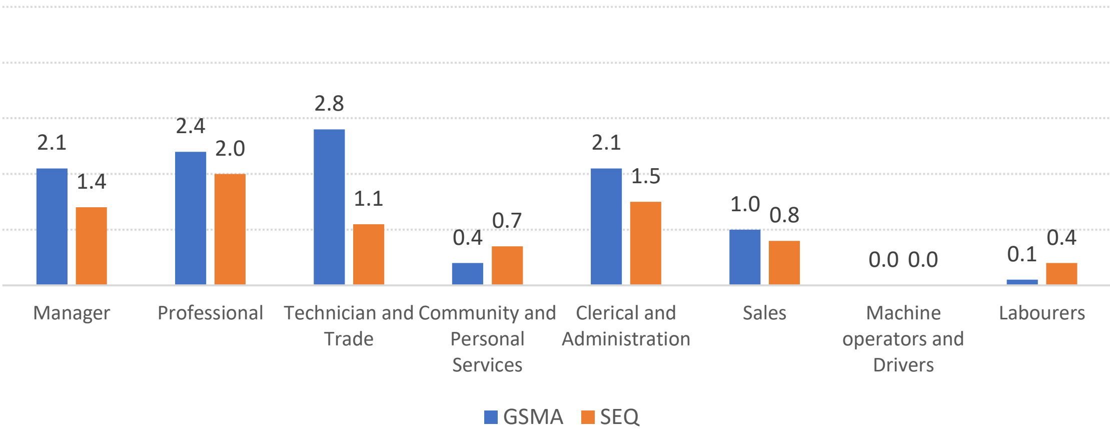


Figure 7: Average Days Worked from Home by Occupation

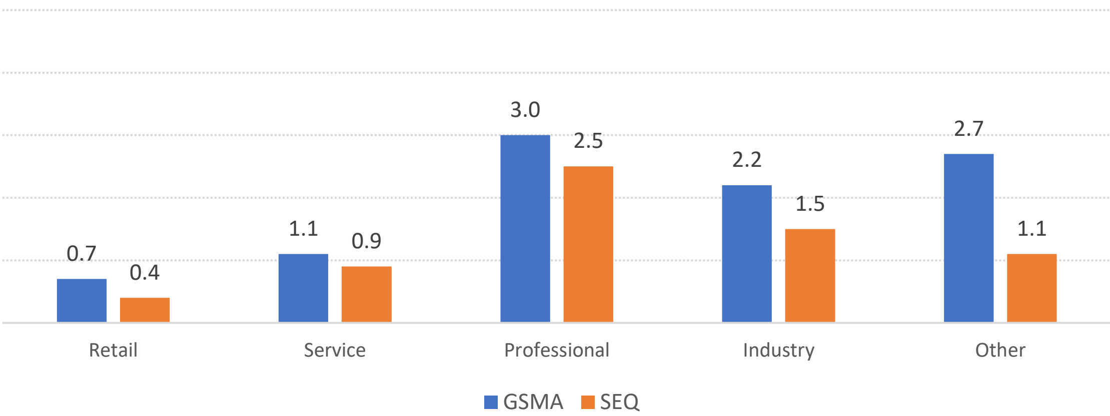


Figure 8: Average Days Worked from Home by Industry

With regards to how respondents travel to work, the majority of respondents indicated that the car (as driver) was their main mode for commuting before COVID-19 (see Figure 9). The dominance of car has increased as in both the GSMA and SEQ the number of respondents reporting the car as the main mode has increased in Wave 3. On the other hand, we see a decline in the train as the reported main mode (particularly in the GSMA) and slight decreases in the bus.

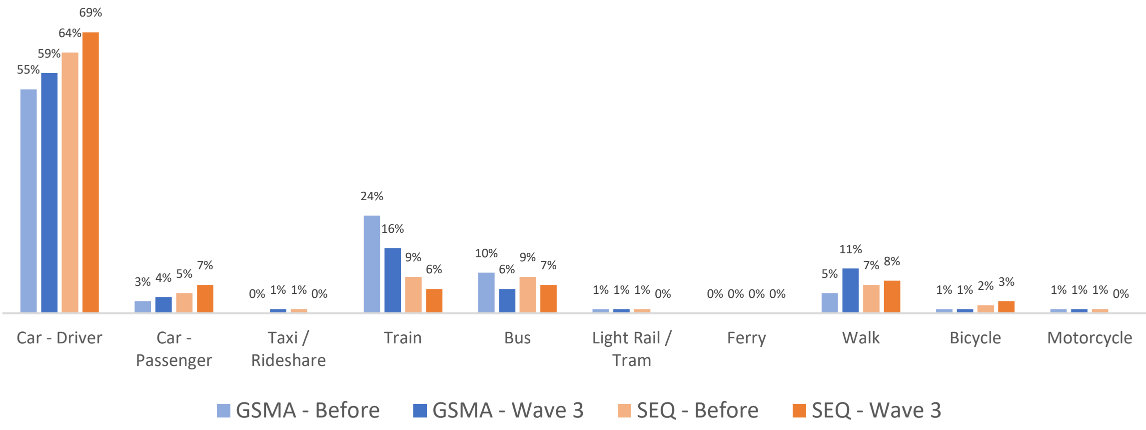


Figure 9: Modes Chosen for the Commuting Trip and Before and During COVID-19

The downturn in public transport use and the increase in the car as the main mode for commuting is likely attributable to the concern that people have about biosecurity in public transport and overcrowding in the context of the requirement to social distance. In Wave 3, the concern around both issues continues to remain very high, as shown in Figure 10, with more than half of respondents in the GSMA and SEQ reporting moderate to extreme concern about the hygiene of public transport and numbers of other people using public transport. Concern is significantly higher on average in the GSMA across both dimensions. Females also express significantly higher concern in both the GSMA and SEQ, as do older respondents in SEQ, with both hygiene and numbers of people using public transport.

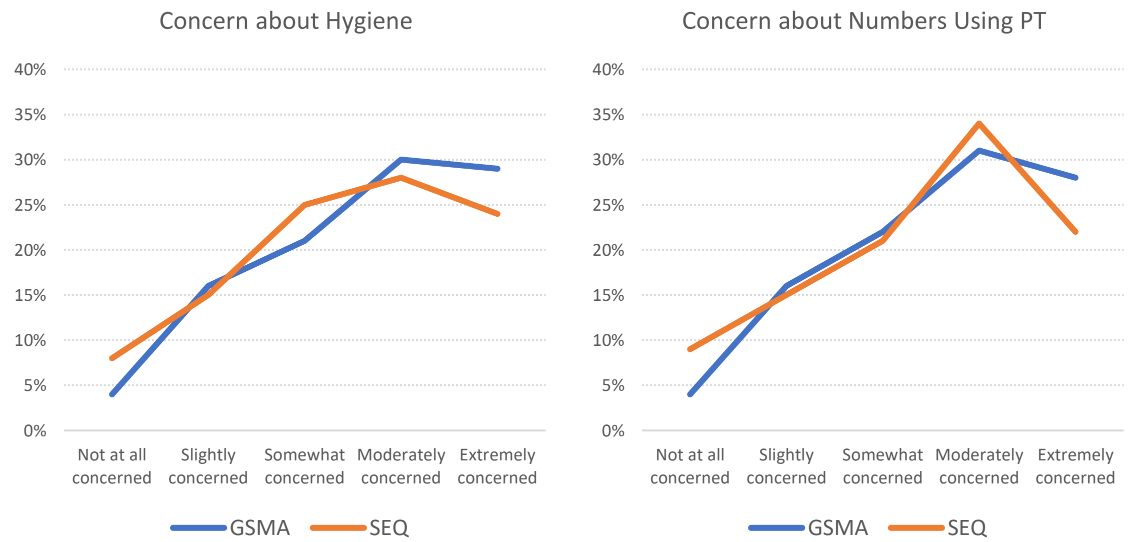


Figure 10: Concern about Using Public Transport

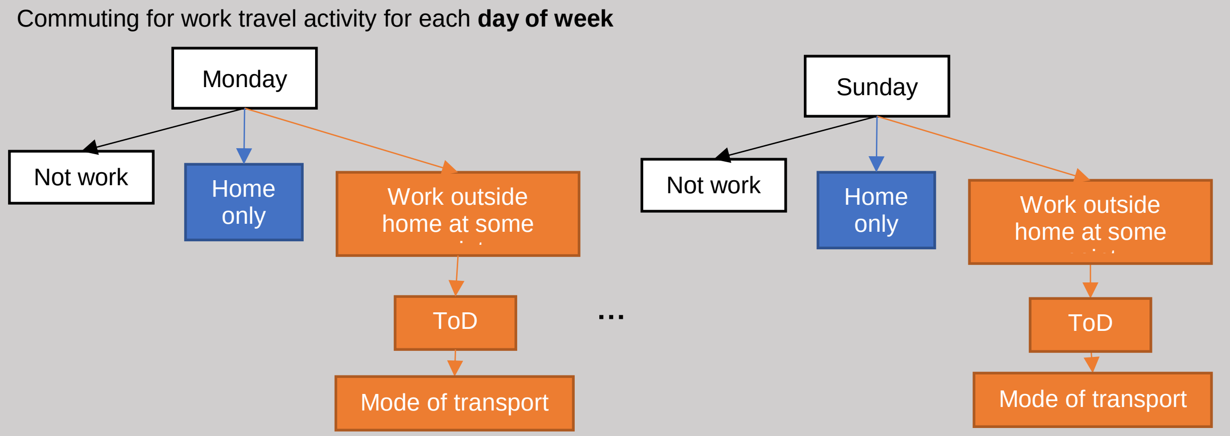
Overall, these results indicate that even six months after the initial outbreak of COVID-19 in Australia (around mid-March 2020), working from home continues to exist in a significant way at levels much higher than before COVID-19. Given that working from home remains a viable tool for authorities to reduce movement and thus potential contagion, along with helping to alleviate potential congestion particularly in the increasing dominance of the private vehicle (something that many jurisdictions globally have fought hard to erode), encouraging working from home to continue would be desirable outcome for authorities and society. The descriptive analysis herein indicates that respondents would like to continue to do so, at levels that are higher than before COVID-19. It should be noted that neither we nor any authority should expect working from home to be an all or nothing proposition, rather simply *more* working from home than was the case before COVID-19 would have positive dividends.

There is broad evidence that increased levels of working from home is likely to continue into the future. A recent report from KPMG (KPMG 2020) finds that flexible working is quickly becoming a key element of the employee value proposition and will contribute to an organisation's ability to attract and retain talent. Others find that as a result of experiences during COVID-19, a majority of workers want more flexibility when it comes to remote work and interest is actually higher among managers than general employees (Hennessy 2020). A large study of 6, 000 respondents within the community and public sector found that 90% of managers reported staff productivity to be the same or higher whilst working from home and nearly two-thirds saying they intended to be more supportive of working from home in the future (Colley and Williamson 2020).

The Australian evidence aligns well with a recent USA study by Barrero (2021) who surveyed more than 30,000 USA residents over multiple waves in 2020 to investigate whether WFH will stick, and why. That found that 20 percent of full workdays will be supplied from home after the pandemic ends, compared with just 5 percent before [COVID-19], of which 2 days a week is not uncommon. They provide five reasons for this large shift: better-than-expected WFH experiences, new investments in physical and human capital that enable WFH, greatly diminished stigma associated with WFH, lingering concerns about crowds and contagion risks, and a pandemic-driven surge in technological innovations that support WFH. The consequences are that employees will enjoy large benefits from greater remote work, especially those with higher earnings; the shift to WFH will directly reduce spending in major city centres by at least 5-10 percent relative to the pre-pandemic situation; data on employer plans and the relative productivity of WFH imply a 5 percent productivity boost in the post-pandemic economy due to re-optimized working arrangements; and only one-fifth of this productivity gain will show up in conventional productivity measures, because they do not capture the time savings from less commuting. Contrasts with Developing economies have been studied in Balbontin et al. (2021) who investigated the relationship between WFH and commuting activity in South Africa, and five South American capital cities (i.e., Buenos Aires, Bogotá, Lima, Quito and Santiago) in August-December 2020, using questions derived from the Australian study (Beck and Hensher 2020,2020a and Beck et al. 2020). The number of days working from home has more variation across countries, where the lowest is in Australia with 1.63 average days WFH, followed by South Africa with 2.31 days; and the highest is Argentina with 3.43 days WFH followed by Chile with 3.19 days.

4 Methodology

The model structure used in this study is presented in Figure 11. Respondents were asked, for each day of the week, where they worked from and, if they went outside the home to work, at what time of day and what mode of transport they used. There were three main alternatives for each day: not work, work from home (WFH) only, work outside home at some point (even if they did work from home as well during that same day). Including ‘No work’ for particular times of day and days of the (7-day) week is important under COVID-19 since we find that individuals work from home throughout the 7-day period in contrast to the more typical 5 day week cycle pre-COVID-19, and that failure to account for periods of No Work risks confounding it with WFH. If they did work outside the home at some point during the day, the possible alternatives are defined by four different times of day (ToD) and ten modes of transport available: car driver, car passenger, taxi/rideshare, train, bus, light rail, ferry, walk, bicycle, and motorcycle. This model structure includes 42 alternatives that are presented in Table 1, and the ToDs for QLD and NSW are defined in Table 2. Different ToD specifications were considered for each state (NSW and QLD) so that they are aligned with the definitions used by the relevant transport authorities (Transport for NSW (TfNSW) and Transport and Main Roads Queensland (TMR), respectively), which are different across states.



*Four ToDs will be considered for each day:
QLD = 7am-8.59am; 9am-3.59pm; 4pm to 5.59pm; 6pm to 6.59am.
NSW = 7am-8.59am; 9am-2.59pm; 3pm to 5.59pm; 6pm to 6.59am.

*The participants that WFH **and** went to the office on a given DoW, will be considered as 'work outside home at some point'; and the hours that he/she WFH will be treated as an exogenous variable.

Figure 11: Model structure

Table 1: Alternative numbers per DoW

	Monday - Sunday		Monday - Sunday
Alternative	**Description**	**Alternative**	**Description**
1	Not work	**22**	Work outside home ToD 2 - motorcycle
2	Work from home only	**23**	Work outside home ToD 3 - car driver
3	Work outside home ToD 1 - car driver	**24**	Work outside home ToD 3 - car passenger
4	Work outside home ToD 1 - car passenger	**25**	Work outside home ToD 3 - taxi/rideshare
5	Work outside home ToD 1 - taxi/rideshare	**26**	Work outside home ToD 3 - train
6	Work outside home ToD 1 - train	**27**	Work outside home ToD 3 - bus
7	Work outside home ToD 1 - bus	**28**	Work outside home ToD 3 - light rail
8	Work outside home ToD 1 - light rail	**29**	Work outside home ToD 3 - ferry
9	Work outside home ToD 1 - ferry	**30**	Work outside home ToD 3 - walk
10	Work outside home ToD 1 - walk	**31**	Work outside home ToD 3 - bicycle
11	Work outside home ToD 1 - bicycle	**32**	Work outside home ToD 3 - motorcycle
12	Work outside home ToD 1 - motorcycle	**33**	Work outside home ToD 4 - car driver
13	Work outside home ToD 2 - car driver	**34**	Work outside home ToD 4 - car passenger
14	Work outside home ToD 2 - car passenger	**35**	Work outside home ToD 4 - taxi/rideshare
15	Work outside home ToD 2 - taxi/rideshare	**36**	Work outside home ToD 4 - train
16	Work outside home ToD 2 - train	**37**	Work outside home ToD 4 - bus
17	Work outside home ToD 2 - bus	**38**	Work outside home ToD 4 - light rail
18	Work outside home ToD 2 - light rail	**39**	Work outside home ToD 4 - ferry
19	Work outside home ToD 2 - ferry	**40**	Work outside home ToD 4 - walk
20	Work outside home ToD 2 - walk	**41**	Work outside home ToD 4 - bicycle
21	Work outside home ToD 2 - bicycle	**42**	Work outside home ToD 4 - motorcycle

Table 2: QLD and NSW ToD combinations available

ToD	QLD time frames	NSW time frames
1	7am to 8.59am	7am to 8.59am
2	9am to 3.59pm	9am to 2.59pm
3	4pm to 5.59pm	3pm to 5.59pm
4	6pm to 6.69am	6pm to 6.69am

The alternative of no work (alternative 1) is described by the alternative specific constant ASC and by respondents' socioeconomics z_n. The working from home alternative (alternative 2) is described by its alternative specific constant; respondents' socioeconomics; by dummy variables that represent each different day *d* of the week day_d; if the respondent works in the central business district area CBD_{work}; and by the distance from their home to their office $Dist_{Home-work}$. The utility functions are defined as follows:

$$U_{NoWork} = ASC_{NoWork} + \sum_n \beta_{NoWork,n} \cdot z_n \quad (1)$$

$$U_{WFH} = ASC_{WFH} + \sum_n \beta_{WFH,n} \cdot z_n + \sum_n \beta_{WFH,d} \cdot day_d + \beta_{WFH,CBD} \cdot CBD_{work} + \beta_{WFH,Dist} \cdot Dist_{Home-work} \quad (2)$$

where β represents the estimated parameters associated with the different attributes or characteristics. The utility functions for the modal alternatives (alternatives 3 to 42) are described by two alternative specific constants: one that refers to mode *m*, and one that refers to the time of day *t*. The utility function for the public transport modes is defined by travel time TT_{Mode_m}; access time AcT_{Mode_m}; egress time EgT_{Mode_m}; waiting time WT_{Mode_m} and fare $Fare_{Mode_m}$, as shown in equation (3). Note that the parameter estimate β for access, egress and waiting times is generic[81].

$$U^{PT}_{Mode_m,ToD_t} = ASC_{Mode_m} + ASC_{ToD_t} + \beta_{Mode_m,TT} \cdot TT_{Mode_m} + \beta_{Mode_m,Cost} \cdot Fare_{Mode_m} + \beta_{Mode_m,AEWT} \cdot \left(AcT_{Mode_m} + EgT_{Mode_m} + WT_{Mode_m} \right) \quad (3)$$

The utility function for the car driver and motorcycle alternatives is described by travel time, fuel cost $Fuel_{Mode_m}$, parking cost $Park_{Mode_m}$, and toll costs $Toll_{Mode_m}$; as well as some socioeconomic characteristics[82], as presented in equation (4). Note that the parameter estimate β for fuel, toll and parking was estimated in the preferred model as generic[83].

$$U^{Car/moto}_{Mode_m,ToD_t} = ASC_{Mode_m} + ASC_{ToD_t} + \beta_{Mode_m,TT} \cdot TT_{Mode_m} + \beta_{Mode_m,Cost} \cdot \left(Fuel_{Mode_m} + Park_{Mode_m} + Toll_{Mode_m} \right) + \sum_n \beta_{Mode_m,n} \cdot z_n \quad (4)$$

The active modes and car passenger[84] alternatives are described only by the travel time, as presented in equation (5).

81 They were estimated as specific first and the results suggested that they were not statistically different.

82 The respondents' socioeconomics were tested in different modes of transport, but they were statistically significant only in the car driver mode.

83 They were estimated as specific first and the results suggested that they were not statistically different.

84 We tested the option of including the costs associated with a car trip but they were always not significant, suggesting that car passengers do not usually pay for these costs and, therefore, are not part of their decision.

$$U^{Active}_{Mode_m,ToD_t} = ASC_{Mode_m} + ASC_{ToD_t} + \beta_{Mode_m,TT} \cdot TT_{Mode_m} \quad (5)$$

Looking ahead to the results, we find that the role of travel time and travel cost changes quite noticeably when WFH and not working are allowed for. With a significant number of days WFH in particular (see Figure 2), typically 1 to 2 days per week, the incidence of commuting declined noticeably (especially for public transport), and as a consequence the sensitivity to daily travel time and cost is expected to change. We suggest there is likely to be less sensitivity to travel time and cost given that the weekly outlays are reduced, resulting in the value of travel time savings (VoT) that could be higher or lower than before COVID-19. We hypothesise a higher VoT if one is prepared to pay more per trip since there are less outlays required per week given the time and money budgets; but lower with relatively less congestion on the roads and also willing to put up with any delays when they occur given it is associated with fewer days per week of commuting.

5 Descriptive Profile

The profile of respondents' characteristics included in the models, as well as the descriptive profile of the alternative's attribute levels are presented in Table 3. For the GSMA (metropolitan area of New South Wales, NSW)[85] we have 409 observations (after data cleaning), which for the commuter mode choice model is a total of 40,735 observations that represent the different available alternatives for each DoW-respondent (plus commuting alternative). For the SEQ (metropolitan area of Queensland, QLD) we have 247 respondents' observations representing for the modelling 24,393 observations for different available alternatives for each DoW and ToD-respondent and commuting alternative.

The GSMA[86] and the SEQ[87] data have a similar age, number of people in the same household, and number of modes available. However, the average personal annual income in the GSMA area is higher, the number of cars in the household is slightly smaller, and there are slightly more children per household.

Table 3: Descriptive profile of respondents - mean (standard deviation)

Variables	SEQ	GSMA
Age	38.49 (12.7)	39.18 (12.2)
Average personal annual income (AUD$000)	81.34(47.3)	90.21(60.4)
Number of people in the same house	2.67 (1.3)	2.83 (1.3)
Number of cars in your household	1.09 (1.5)	1.53 (0.9)
Number of children in household	1.61 (0.9)	1.77 (1.0)
Number of modes available	2.92 (1.4)	2.92 (1.4)
Proportion who used car as driver to commute prior to COVID-19	0.619	0.510
Distance from home to regular workplace location (kms)	18.72 (16.7)	22.28 (29.5)
Proportion of sample who are blue collar workers	0.081	0.078
Proportion of workers who have a high level of concern about using PT	0.542	0.575
Occupation professional (1,0)	0.375	0.375
Occupation manager (1,0)	0.141	0.176
Occupation sales (1,0)	0.080	0.072
Occupation clerical and administration (1,0)	0.259	0.236

85 The GSMA includes Newcastle, Sydney, Central Coast, Illawarra, Nowra-Bomaderry, St Georges Basin- Sanctuary Point, Milton-Ulladulla, and Kangaroo Valley-Southern Highlands.
86 The GSMA includes Newcastle, Sydney, Central Coast, Illawarra, Nowra-Bomaderry, St Georges Basin- Sanctuary Point, Milton-Ulladulla, and Kangaroo Valley-Southern Highlands.
87 SEQ includes Brisbane, Gold Coast, Sunshine Coast, Ipswich and Gympie.

Variables	SEQ	GSMA
Occupation community and personal services (1,0)	0.064	0.072
Occupation technology (1,0)	0.049	0.053
Occupation machine operators (1,0)	0.006	0.007
Occupation labourers (1,0)	0.031	0,0180
NSW - Wollongong residential location (1,0)	-	0.097
NSW - Newcastle residential location (1,0)	-	0.101
NSW – Central Coast residential location (1,0)	-	0.109
QLD – Gold Coast residential location (1,0)	0.215	-
QLD – Sunshine Coast residential location (1,0)	0.129	-
Work located in CBD (1,0) (SEQ=4000, 4006 postcodes; GSMA = 2000, 2007, 2009 and 2011 postcodes)	0.210	0.245
Number of respondents	**247**	**409**
Number of observations (respondents-day of week)	**1,718**	**2,825**

The modes' characteristics are presented in Table 4. The main differences in travel times are by bus, ferry and bicycle which are much higher in the GSMA area. These variables are included in the models presented in the following subsection.

Table 4: Mode characteristics - mean (standard deviation)

Variables	SEQ	GSMA
Travel time car driver (min)	27.26 (32.0)	29.73 (28.3)
Travel time car pax (min)	27.77 (41.3)	28.48 (23.3)
Travel time taxi/ride share (min)	23.12 (13.8)	26.44 (26.5)
Travel time train (min)	38.11 (28.0)	37.20 (37.8)
Travel time bus (min)	32.88 (21.4)	47.21 (41.7)
Travel time light rail (min)	30.21 (20.0)	28.64 (21.1)
Travel time ferry (min)	19.63 (12.8)	33.00 (23.7)
Travel time walk (min)	56.83 (38.6)	52.71 (38.9)
Travel time bicycle (min)	33.88 (25.4)	50.68 (62.6)
Travel time motorcycle (min)	26.31 (14.5)	26.50 (20.1)
Fuel car driver (AUD$)	2.80 (5.3)	2.61 (3.4)
Fuel car pax (AUD$)	3.01 (7.0)	2.48 (2.6)
Fuel motorcycle (AUD$)	2.91 (2.0)	2.91 (3.0)
Parking car driver (AUD$)	3.81 (20.0)	4.60 (13.7)
Parking car pax (AUD$)	0.85 (5.1)	2.49 (11.6)
Parking motorcycle (AUD$)	0.00 (0.0)	3.00 (7.1)
Toll car driver (AUD$)	1.10 (7.3)	1.46 (4.6)
Toll car pax (AUD$)	0.18 (0.9)	0.98 (3.8)
Toll motorcycle (AUD$)	0.69 (1.7)	1.38 (3.6)
Waiting time taxi/ride share (min)	10.07 (8.0)	10.35 (8.2)
Waiting time train (min)	9.56 (7.1)	8.68 (6.5)
Waiting time bus (min)	11.25 (11.2)	10.69 (8.0)
Waiting time light rail (min)	8.79 (7.3)	6.43 (4.6)
Waiting time ferry (min)	8.13 (9.2)	16.10 (12.1)
Egress time taxi/ride share (min)	2.60 (7.6)	3.34 (8.2)
Egress time train (min)	13.61 (15.9)	13.47 (14.9)
Egress time bus (min)	8.97 (11.4)	10.19 (12.9)
Egress time light rail (min)	13.57 (17.0)	9.57 (10.7)
Egress time ferry (min)	11.13 (7.0)	14.30 (17.2)
Access time taxi/ride share (min)	7.92 (13.2)	9.94 (16.5)
Access time train (min)	21.69 (25.1)	22.04 (24.7)
Access time bus (min)	15.19 (16.9)	21.40 (30.1)
Access time light rail (min)	26.93 (24.0)	19.71 (19.0)

Variables	SEQ	GSMA
Access time ferry (min)	18.88 (12.8)	23.10 (12.8)
Ride Share fare ($)	36.39 (26.3)	40.54 (69.8)
Train Fare ($)	5.76 (4.0)	5.56 (5.2)
Bus Fare ($)	4.11 (2.8)	4.40 (3.4)
Light Rail Fare ($)	3.87 (1.4)	4.13 (2.7)
Ferry Fare ($)	3.03 (0.9)	4.14 (2.4)

The shares of commuting mode, No Work and WFH for SEQ and GSMA are shown in Table 5. As expected, many times of day and days of the 7-day week involve no formal paid work; in contrast we see that of the 42 ToD/DoW periods, 19.6 and 26% percent involved working from home, with 46% and 39% respectively for SEQ and GSMA involving a commuting trip to a location outside of the home. This has significant implications on the quantum of commuting activity on any one day of the week and time of day, and if maintained post-COVID-19 will have a massive impact on the performance of the transport network. While there has been a greater decline in public transport trips compared to car travel linked to the biosecurity risk, real or otherwise in using public transport, and hence the dominance of the car is the commuter modal share.

Table 5: Modal availability and Shares in the presence of WFH and No Work

		SEQ %	GSMA area %
Availability	No Work	100.0%	100.0%
	WFH	66.0%	68.9%
	Car driver	83.0%	71.6%
	Car passenger	42.9%	34.5%
	Taxi/ride share	34.4%	29.8%
	Train	32.4%	46.9%
	Bus	48.2%	52.3%
	Light rail	5.7%	6.8%
	Ferry	3.2%	2.4%
	Walking	20.2%	25.7%
	Bicycle	13.4%	15.9%
	Motorcycle	5.3%	6.4%
Number of respondents		***247***	***409***
Choices	No Work	35.4%	35.1%
	WFH	19.6%	26.0%
	Car driver	31.3%	26.5%
	Car passenger	3.4%	2.2%
	Taxi/ride share	0.2%	0.2%
	Train	2.2%	4.2%
	Bus	3.6%	2.4%
	Light rail	0.3%	0.4%
	Ferry	0.1%	0.1%
	Walking	3.1%	1.9%
	Bicycle	0.8%	0.6%
	Motorcycle	0.0%	0.6%
Number of respondents-DoW		***1,718***	***2,825***

6 Mixed Logit Model Results

The model results for mixed logit models for SEQ and GSMA are presented in Table 6.[88] Account is taken in estimation for observations associated with the same respondents (i.e., the data on each of the 7 days of the week). The overall fit of the models is impressive with a McFadden Pseudo R^2 of 0.52 and 0.55, respectively for the SEQ and GSMA models[89]. Most of the parameter estimates are significant at a 90% confidence level or better, except for travel time for all modes, except active modes, in the SEQ model which is statistically significant at an 80% confidence level and, since it is one of the main variables of interest, it is included in the models. While we cannot be certain, we hypothesise that the role and influence of travel time and cost has dissipated significantly as a result of the reduced weekly commuting activity with WFH occurring frequently at 2 to 3 days a week for many respondents. Individuals are now far less sensitive to travel times and costs leading to its role being reduced compared to pre-COVID-19.

Two parameters in each model were estimated as random to test and account for preference heterogeneity: travel time for all modes except the active modes, and cost. Different parameter distributions were tested (e.g., normal, lognormal, triangular)[90], and the results show that the time and cost of the SEQ model follow a constrained triangular distribution, where the spread of the travel time is 5% of the mean; and the spread of the cost parameters is equal to the mean. We used 100 Halton intelligent draw, noting that we increased this to 1000 and the results were almost identical. The constraint assumption was varied to investigate the extent of preference heterogeneity around the mean and as is shown, the degree of preference heterogeneity for travel time is best described as slight. In the GSMA model, both parameters follow a constrained normal distribution, with a standard deviation equal to the mean.

Table 6: Model results SEQ and GSMA, Wave 3 (September 2020)

Parameters	Acronym	Alternatives	SEQ Mean (t value)	GSMA Mean (t value)
ASC no work	ASC_NoWork	1	-	-
ASC work from home	ASC_WFH	2	-2.239 (5.94)	-
ASC car driver/motorcycle	ASC_CarMoto	3, 12, 13, 22, 23, 32, 33, 42	-0.889 (4.30)	-0.203 (1.01)
ASC car passenger	ASC_CarP	4, 13, 24, 34	-2.086 (9.78)	-1.654 (7.75)
ASC taxi/ridesharing	ASC_Taxi	5, 15, 25, 35	-4.233 (6.79)	-3.600 (6.69)
ASC public transport	ASC_PT	6-9, 16-19, 26-29, 36-39	-1.761 (7.27)	-1.410 (7.86)
ASC active modes	ASC_Act	10, 11, 20, 21, 30, 31, 40, 41	-0.426 (1.67)	-0.877 (3.44)
ASC ToD 1 and 3	ASC_T13	3-12, 23-32	0.513 (5.23)	0.391 (4.94)
ASC ToD 2	ASC_T2	13-22	-	-

88 This is a relevant model using Wave 3 data of an ongoing study which will be estimating new models as we add additional waves of data over the 2021-22 period.

89 We estimated a series of nested logit models as well as error components models, distinguishing time of day of commuting vs WFH and No-Work. Best (in terms of goodness of fit and inclusion value parameters consistent with generalised extreme vale utility maximisation (i.e., the 0-1 bound on parameter estimates). The best Nested logit models for the GSMA were (i) WFH and No-Work compared to commuting in peak periods (Tods 1 and 3) vs off peak and (ii) WFH and No-Work compared to commuting by car modes (car driver, car passenger, ride share) versus but other models Public transport, walk, bicycle). However, the overall fit was 0.391 and 0.323 respectively, considerably lower than mixed logit. The error components model was not very good with all error component not statistically significant different from unity. For the GSMA we could not found an appropriate nested structure.

90 We ran the same functional forms for the random parameters for both the SEQ and GSMA but did not find statistically significant parameters across both data sets to enable us to adopt the same distributions for preference heterogeneity. In a sense this should not *a priori* be expected since we are dealing with geographical settings in which the levels of congestion on the roads and crowding on public transport is quite different as is the incidence of WFH.

Parameters	Acronym	Alternatives	SEQ Mean (t value)	GSMA Mean (t value)
ASC ToD 4	ASC_T4	33-42	0.408 (3.68)	0.217 (2.36)
No Work - Age	Age_NW	1	0.026 (7.74)	0.027 (10.36)
No Work - Male (1,0)	Male_NW	1	-	-0.326 (3.55)
WFH - Distance from home to work	DistHW_WFH	2	0.011 (2.50)	-
WFH - Age	Age_WFH	2	0.018 (2.96)	-
WFH - Number of people in household	HPers_WFH	2	0.105 (1.88)	-
WFH - Income	Inc_WFH	2	0.006 (3.80)	-
WFH - Proportion of workers who have a high level of concern about using PT	ConcPT_WFH	2	0.482 (3.27)	0.477 (4.39)
WFH - Professional (industry category) (1,0)	Prof_WFH	2	0.957 (5.70)	-
WFH - Industry (industry category) (1,0)	Ind_WFH	2	0.494 (2.46)	-
WFH - Occupation professional (1,0)	OcProf_WFH	2	-	5.184 (12.50)
WFH - Occupation manager (1,0)	OcMng_WFH	2	-	5.235 (12.25)
WFH - Occupation sales (1,0)	OcSale_WFH	2	-	4.507 (10.03)
WFH - Occupation clerical and administration (1,0)	OcAdm_WFH	2	-	5.071 (12.04)
WFH - Occupation community and personal services (1,0)	OcCom_WFH	2	-	3.849 (7.47)
WFH - Occupation blue collar worker (1,0)	OcBlCl_WFH	2	-	5.058 (11.34)
WFH - Monday dummy variable (1,0)	DMon_WFH	2	1.366 (6.49)	-1.325 (8.17)
WFH - Tuesday dummy variable (1,0)	DTue_WFH	2	1.135 (5.34)	-1.333 (8.18)
WFH - Wednesday dummy variable (1,0)	DWed_WFH	2	1.126 (5.27)	-
WFH - Thursday dummy variable (1,0)	DThu_WFH	2	1.316 (6.24)	-1.044 (6.44)
WFH - Friday dummy variable (1,0)	DFri_WFH	2	-	-0.975 (6.07)
WFH NSW - Wollongong residential location (1,0)	Woll_WFH	2	-	-0.571 (2.76)
WFH NSW - Newcastle residential location (1,0)	Newc_WFH	2	-	-0.855 (4.24)
WFH QLD - work located in CBD (1,0)	CBD_WFH	2	0.309 (1.98)	-
Car driver - Income	Inc_CarD	3, 13, 23, 33	0.005 (3.16)	0.002 (1.97)
Car driver - Number of cars in household	NCar_CarD	3, 13, 23, 33	-	0.339 (5.33)
Car driver - Number of cars per person in household	NCar_CarD	3, 13, 23, 33	0.149 (3.23)	-
Travel time all modes except active *- mean*	TT_CarPT	3-9, 12-19, 22-29, 32-39, 42	-0.003 (1.35)	-0.029 (4.98)
- standard deviation			0.00015 (1.35)	0.029 (4.98)
Travel time walking	TT_Walk	10, 20, 30, 40	-0.028 (4.95)	-0.029 (4.70)
Travel time bicycle	TT_Bike	11, 21, 31, 41	-0.029 (3.02)	-0.043 (3.30)
Cost all modes except car pax and active *- mean*	Cost_CarPT	3, 5-9, 12, 13, 15-19, 22, 23, 25-29, 32, 33, 35-39, 42	-0.019 (2.52)	-0.068 (4.34)
- standard deviation			0.019 (2.52)	0.068 (4.34)
Access + egress + waiting time taxi/PT modes	TTAEW	5-9, 15-19, 25-29, 35-39	-0.012 (2.44)	-
Number of parameters estimated			30	30
Sample size			1,718	2,825
Log Likelihood at convergence			- 3,094.11	- 4,775.84
Log likelihood at zero			- 6,421.32	- 10,558.92
McFadden Pseudo R squared			0.52	0.55
AIC/n			3.64	3.40

We investigated every variable presented in Table 6 for both SEQ and the GSMA as well as many other variables, and have not included those that were not statistically significant at the 95 percent level of better, the exception being travel time in SEQ. The most interesting results relate to the distance of the commuting trip and the biosecurity concern associated with using regular public transport. We see that when the distance of the commuting trip increases, there is a heightened probability of working from home for the SEQ; however, it was not significant for the GSMA (reinforced below by a flat probability of WFH in Figure 12 and Appendix Table A2). For the SEQ, those who spend more days WFH tend, on average, to have a longer commute (Figure 12 and Appendix Table A1). As the number of days WFH increases, we see a reduction, on average, in the number of weekly commuting trips, as expected (Figure 12). As the number of days WFH increases, we see on average what appears to be a U-shaped relationship (for weekdays) with the average number of weekly non-commuting trips, being at its greatest for 2 and 3 days WFH per week and at its lowest when WFH occurs on 4 or 5 days per week (see Figure 12). This is the first time we have observed this and reported it.

For the GSMA, we investigated this further and found that occupation was a statistically significant surrogate for distance to the regular work office in the GSMA (i.e., if we removed the occupation dummy variables, the commute distance became statistically significant and positive). There is an expected significant industry and occupation influence on the willingness to WFH; where industry grouping is statistically significant in the SEQ and occupation is statistically significant for the GSMA.

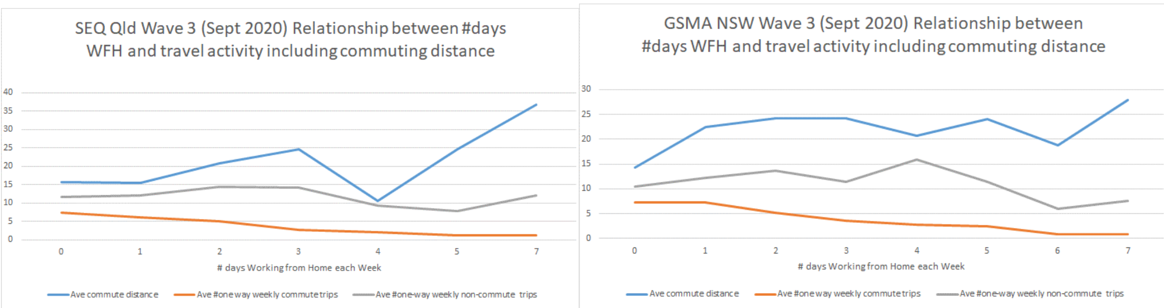


Figure 12: The relationship between # days WFH and weekly commuting and non-commuting trip activity and distance

A number of dummy variables were included to test for differences in the probability of WFH compared to the modal and No-Work alternatives. For SEQ, we find that the Brisbane CBD (postcodes 4000 and 4006) has a statistically significant and positive effect suggesting that workers in the Brisbane CBD have a higher probability of WFH after controlling for other influences more generally such as industry affiliation, socioeconomic influences (income, age, household size, car ownership), and concerns are bio-security of public transport use. We did not find a statistically significant difference between the Gold Coast, Sunshine Coast and Greater Brisbane area. For the GSMA we see a statistically significant and negative influence of residing in Newcastle and Wollongong compared the Sydney Metropolitan area after controlling for influences such as occupation and other socio-demographics effects.

We also investigated the role that the day of the week plays and found for the SEQ that Monday through to Thursday dummy variables have a positive and statistically significant influence on the probability of WFH compared to Friday and the weekend; however, for the GSMA we find that Monday, Tuesday, Thursday and Friday dummy variables have a negative and statistically significant effect on the probability of WFH compared to Wednesday and weekend days. It is important to identify and control for these day of week effects since it is necessary to establish the extent of peakedness of commuting activity across the week since this has serious implications on the capacity requirements of the road and public transport network. The descriptive data supports a somewhat flat profile throughout the week which is an important result (see Figure 5 and 6 in Section 3). Finally, we included a series of time of day dummy variables in the utility expressions for all of the modes, finding that for SEQ and the GSMA, a single dummy variable for the morning and afternoon peaks and evening dummy variables, compared to the period between the peaks (set to zero), were positive and statistically significant.

The value of travel time savings for these models is presented in Table 7. The results suggest that the VoT is significantly higher in the GSMA than in the SEQ area. This is in part due, we suggest, to personal incomes being higher (mean and standard deviation) in the GSMA (Table 3) as well as a greater percent of respondents in the professional occupation class; but also that congestion remains higher (even if less than pre-COVID-19) in the GSMA. However, the mean estimate for the GSMA is higher than the recommended guidelines in NSW of $17.72/person hour, suggesting that individuals are willing to pay more to save travel times in the presence of a high incidence of WFH, due essentially to reduced commuting activity, and hence less travel expense outlaid. This is the opposite to that recommended for the SEQ which uses a slightly lower mean estimate than NSW. We remain open as to whether the mean estimate of commuting VoT is likely to be higher or lower than pre-COVID-19 as a result of reduced commuting activity. A lower estimate might relate to an hypothesis that individuals who tend to commute more due to the essential nature of their work, tend to have lower incomes and hence represent the population of commuters who generally have a lower mean estimate of VoT. To investigate this, we ran a simple model of the relationship between the number of days WFH and personal income and obtained a direct elasticity of 0.298 (standard error of 0.0059) for the SEQ and 0.282 (standard error of 0.0055) for the GSMA. What this indicates is that there is indeed a relationship between those who commute more and personal income, indicating that a 1 percent increase in income results, ceteris paribus, in a 0.298 (SEQ) or 0.282 (GSMA) percent increase in the number of days WFH. This relationship has to be weighed against a hypothesis that reduced commuting activity means that an individual is willing to pay more to save time simply because they commute less and hence have more travel budget to spend to maximise the utility of commuting. This is a theme worthy of further research, and one we plan to investigate with data from future Waves.

Table 7: Value of travel time SEQ and GSMA models (AUD$)

	Mean (AUD$)	95% Confidence interval	
SEQ	15.64	6.23	45.16
GSMA	26.02	9.17	42.85

We also calculated, for the GSMA, the reduction in time and money costs from commuting during the period of the Wave 3 survey (Table 8)[91], and found that close to 50% of the pre-COVID-19 time outlays were ‘saved’. On average, each commuter saved $2,949 per annum in the SEQ and $3,546 in the GSMA, of which $779 and $906 respectively is out of pocket costs.

[91] All the assumptions are presented in Hensher et al. (2021), but unlike that paper where we used Wave 2 data in the current paper we have used Wave 3 data.

Table 8: The change in annualised commuting time and out-of-pocket costs

	SEQ	GSMA
1) How many days they worked per week before COVID? - days	4.69	4.64
2) How many days they WFH before COVID? - days	1.31	1.16
3) How many days they worked last week?- days	4.33	4.4
4) How many days they WFH last week? - days	3.35	3.65
5) How many minutes it takes to get to work via their main mode? (one-way) - minutes	31.9	34.1
Outputs		
Total commuting time spent before COVID per week (both ways in mins)	216	237
Total commuting time spent last week (both ways in mins)	63	51
Time and Cost Saving due to COVID/WFH		
Weekly time saving in commuting time (mins)	153	186
Annual time saving in commuting time (hours)	122.5	148.9
Total annual cost saving on travel time ($)	$2,171	$2,639
Other annual costs saving (e.g., car fuel, fare, and toll etc)	$779	$906
Total annual cost saving ($)	$2,949	$3,546

We derived the direct and cross point share elasticities for travel time and fare as summarised in Table 9. These results align quite well with ranges typically reported in the broader literature, even though these travel time and fare elasticities are at the lower end suggesting that there is less sensitivity to travel times given the reduced amount of commuting trips. Note that the access, egress and wait time for public transport is statistically significant for SEQ but not for the GSMA. The lack of significance for the GSMA, even after assessing each of the three service level attributes separately may be because of both the significantly reduced use of public transport (7.3% of the sample); however, for the SEQ is it also low (at 6.2%) (Table 5), and the mean service levels are also very similar.

Table 9: Illustrative Direct and cross share elasticities for travel time (all modes) and fares (public transport and ride share), probability weighted by the probability of a mode being chosen

9a GSMA Travel Time and Fare for Morning Peak

Travel Time	No Work	WFH	Car Driver	Car Pax	Ride Share	Train
Car Driver	0.0120	0.0117	-0.1690	0.0123	0.0097	0.0090
Car Pax	0.0011	0.0011	0.0011	-0.1829	0.0009	0.0010
Ride Share	0.0001	0.0001	0.0001	0.0001	0.1659	0.0000
Train	0.0028	0.0030	0.0015	0.0018	0.0025	-0.2230
Bus	0.0021	0.0019	0.0015	0.0013	0.0026	0.0020
LRT	0.0003	0.0004	0.0001	0.0002	0.0005	0.0000
Ferry	0.0001	0.0001	0.0001	0.0001	0.0002	0.0000
Walk	0.0049	0.0024	0.0035	0.0042	0.0051	0.0030

Travel Time	Bus	LRT	Ferry	Walk	Bike	Moto
Car Driver	0.0087	0.0051	0.0092	0.0039	0.0035	0.0097
Car Pax	0.0008	0.0007	0.0012	0.0005	0.0005	0.0011
Ride Share	0.0002	0.0002	0.0003	0.0001	0.0001	0.0002
Train	0.0031	0.0038	0.0030	0.0009	0.0006	0.0012
Bus	0.2827	0.0023	0.0028	0.0008	0.0010	0.0018
LRT	0.0005	-0.2040	0.0032	0.0001	0.0002	0.0006
Ferry	0.0001	0.0011	-0.2487	0.0000	0.0001	0.0005
Walk	0.0051	0.0039	0.0022	-0.7369	0.0103	0.0029

Fare	No Work	WFH	Car Driver	Car Pax	Ride Share	Train
Train	0.0003	0.0003	0.0001	0.0002	0.0002	-0.0210
Bus	0.0001	0.0001	0.0001	0.0001	0.0002	0.0000
LRT	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ferry	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Fare	Bus	LRT	Ferry	Walk	Bike	Moto
Train	0.0003	0.0004	0.0004	0.0002	0.0001	0.0001
Bus	0.0192	0.0002	0.0002	0.0001	0.0001	0.0001
LRT	0.0000	-0.0190	0.0003	0.0000	0.0000	0.0000
Ferry	0.0000	0.0001	-0.0275	0.0000	0.0000	0.0000

9b SEQ Travel Time and Fare for Morning Peak

Travel Time	No Work	WFH	Car Driver	Car Pax	Ride Share	Train
Car Driver	0.0067	0.0061	-0.0698	0.0070	0.0051	0.0050
Car Pax	0.0010	0.0005	0.0008	-0.0782	0.0006	0.0000
Ride Share	0.0000	0.0000	0.0000	0.0000	0.0602	0.0000
Train	0.0007	0.0006	0.0004	0.0002	0.0004	-0.0990
Bus	0.0011	0.0009	0.0006	0.0008	0.0014	0.0020
LRT	0.0001	0.0001	0.0001	0.0001	0.0002	0.0000
Ferry	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000
Walk	0.0070	0.0043	0.0044	0.0075	0.0146	0.0020

Travel Time	Bus	LRT	Ferry	Walk	Bike	Moto
Car Driver	0.0036	0.0074	0.0026	0.0016	0.0028	0.0070
Car Pax	0.0005	0.0006	0.0004	0.0004	0.0001	0.0005
Ride Share	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000
Train	0.0012	0.0005	0.0014	0.0001	0.0003	0.0005
Bus	0.0920	0.0008	0.0020	0.0006	0.0009	0.0010
LRT	0.0001	-0.0876	0.0005	0.0000	0.0000	0.0000
Ferry	0.0001	0.0002	-0.0629	0.0001	0.0001	0.0000
Walk	0.0109	0.0138	0.0134	-0.8755	0.0201	0.0029

Fare	No Work	WFH	Car Driver	Car Pax	Ride Share	Train
Train	0.0005	0.0005	0.0004	0.0002	0.0003	-0.0800
Bus	0.0007	0.0005	0.0004	0.0005	0.0009	0.0010
LRT	0.0001	0.0000	0.0001	0.0001	0.0001	0.0000
Ferry	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000

Fare	Bus	LRT	Ferry	Walk	Bike	Moto
Train	0.0008	0.0004	0.0007	0.0001	0.0003	0.0004
Bus	0.0574	0.0007	0.0009	0.0006	0.0007	0.0007
LRT	0.0001	-0.0551	0.0003	0.0001	0.0001	0.0000
Ferry	0.0001	0.0002	-0.0448	0.0001	0.0001	0.0000

The model formulation for the SEQ and GSMA data provides an understanding on the incidence of the probabilities of no work, work from home and commuting. The results are presented in Table 10. This is an important finding which can be used to adjust the pre-COVID-19 commuting modal probabilities used to obtain modal shares. On average we can see that as of September 2020, 6 months into the pandemic, that the mean probability of WFH is 0.196 for SEQ and 0.260 for GSMA. However, if we focus only on WFH versus commuting (assuming the respondent already decided to work), the average probability of WFH is 0.30 for the SEQ and 0.39 for the GSMA. What this suggests is that on any ToD and DoW when the individual works (regardless of location), that if there are, for example, 100 individuals who work, 30 are predicted to WFH in SEQ. When translated into the Days of the Week, subject to variability across the days in WFH, which is relatively flat (see Figure 5), we predict that the average days working from home per week, including weekends is 2.1; or if we exclude weekends it is 1.5 days per week, resulting in 3.5 days per week of commuting. Given two one-way commuting trips per day, this is equivalent to 7 one-way weekly commuting trips, down from a typical 10 such trips. The equivalent evidence for the GSMA suggest that average days working from home per week, including weekends is 2.73; or if we exclude weekends it is 1.95 days per week, resulting in 3.05 days per week of commuting. Given two one-way commuting trips per day, this is equivalent to 6.1 one-way weekly commuting trips. Even allowing for the pre-COVID-19 incidence of WFH at 4.6%[92], this is a substantial change.

The overall predictive performance of the SEQ and GSMA models is summarised in Table 10. The ability to reproduce the aggregate number of No-Work and WFH periods (ToD by DoW) as well as the quantum of overall commuting activity is impressive. Within the specific models by the four time of day, there are varying degrees of predictive reproduction of actual numbers for each mode. This can be corrected through calibration on known modal shares for each time of day in a real world application where time of day effects need to be accounted for.

Table 10: Predicted versus actual choice numbers for WFH, no work and commute in SEQ and GSMA models

SEQ	NOWORK	WFH	Commute	CarD	CarP	RShr	Train	Bus	LR	Ferry	Walk	Bike	MotorB		PT	Total
Actual	588	337	793	521	59	4	35	62	7	4	45	42	17		108	2514
Predicted	608	337	773	538	59	3	37	62	6	1	54	13	0		106	2491
GSMA	NOWORK	WFH	Commute	CarD	CarP	RShr	Train	Bus	LR	Ferry	Walk	Bike	MotorB		PT	Total
Actual	952	725	1148	734	59	10	90	94	13	4	57	59	28		201	3973
Predicted	987	735	1103	749	61	7	120	67	11	2	54	16	16		200	3928

In addition, we wanted to set out a mapping between the probability of WFH compared to the probability of commuting and contextual influences. To do this we adjusted the probabilities at a respondent level to remove the probability of no work. The kernel density distributions for the probability of WFH and Commuting, summing to 1.0, at a respondent level and 100% at a sample level are shown in Figure 13 and Figure 14 for the SEQ and GSMA models, respectively.

[92] Source: Australian Bureau of Statistics, 2016 Census Journey to Work

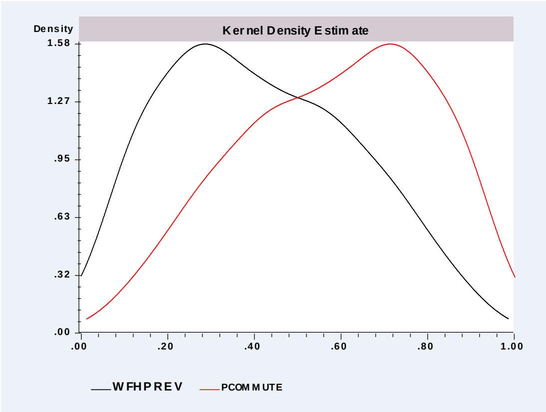


Figure 13: Probability distributions for WFH (WFHPrev) and commute (PCommute) SEQ model

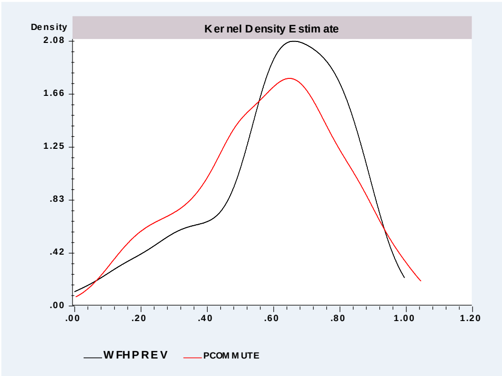


Figure 14: Probability distributions for WFH (WFHPrev) and commute (PCommute) GSMA model

7 Mapping the Probability of Working from Home with Socioeconomic and Contextual Influences

A linear regression model was estimated with the probability of WFH as the dependent variable (considering that the respondent already decided to work that day, i.e., excluding the no work alternative), and several socio-economic and contextual influences as explanatory variables. To ensure that the probability of working from home satisfies the 0-1 bound we imposed a non-linear constraint so as to satisfy this condition. The results of this regression are presented in Table 11. The overall explanatory power for the disaggregated data is 0.86 and 0.82 respectively for SEQ and the GSMA, which is an impressive capturing of sources of systematic variation in the probability of WFH (or conversely of commuting). Such a mapping model is very useful for identifying adjustments in the probability of commuting as a result of the incidence of WFH, and within the setting of strategic transport models, the segments based of a rich array of socioeconomic and contextual profiles can be used to create a distribution of WFH incidence that is typically useful at an origin-destination level. For example, if the transport analyst responsible for a strategic transport model system obtains the mean values for each of the relevant explanatory variables in Table 11 for a given origin-destination pair, they can then obtain an estimate of the probability of WFH, and hence adjust the incidence of commuting on particular days of the week and weekend. Friday was not statistically significant for SEQ and Wednesday for the GSMA as was a separate dummy variable for the weekend; hence these are combined with the weekend where the dummy variable is set to zero as the comparator with the estimated parameters for the other days of the week.

Table 11: WFH probability mapping model results (linear regression with 0-1 constraint)
Note: confidence intervals are available on request

Parameters	SEQ Mean (t value)	GSMA Mean (t value)
Constant	-0.022 (1.52)	1.015 (29.9))
Age	0.004 (16.5)	-
Income	0.001 (9.02)	-
Distance from home to work	0.004 (25.4)	0.002 (7.1)
Number of people in household	0.026 (14.4)	-
Number of cars per person in household	-0.018 (10.7)	-0.019 (5.97)
Children in primary school (1,0)	-	0.022 (4.41)
Children in secondary school (1,0)	-0.019(3.03)	-0.029 (3.11)
Children in tertiary school (1,0=	-0.045 (5.84)	-
Number of modes available	-0.036 (21.4)	-0.045 (33.8)
Prior to Covid-19, main mode of transport car driver	-0.066 (9.46)	-0.125 (21.9)
High level of concern number of people in PT	0.082 (14.8)	0.078 (17.2)
Professional (industry category) (1,0)	0.221 (30.1)	-
Industry (industry category) (1,0)	0.096 (12.8)	-
Services (industry category) (1,0)	0.045 (5.34)	-
Occupation professional (1,0)	-0.033 (5.45)	0.421 (13.6)
Occupation manager (1,0)	-	0.413 (13.1)
Occupation sales (1,0)	-	0.323 (10.0)
Occupation clerical and administration (1,0)	-0.042 (6.06)	0.406 (13.1)
Occupation community and personal services (1,0)	-0.031 (2.88	0.157 (4.87)
Occupation labourer (1,0)	-	-0.086 (5.22)
Occupation blue collar worker (1,0)	-	0.391 (12.4)
Work located in GSMA CBD (1,0)	-	0.069 (12.9)
Work located in SEQ CBD (1,0)	0.137 (15.5)	-
GSMA Newcastle location (1,0)	-	-0.190 (26.2)
GSMA Illawarra location (1,0)	-	-0.118 (13.5)
GSMA Central Coast location (1,0)	-	-0.026 (2.55)
SEQ Gold Coast location (1,0)	-0.033 (5.78)	-
SEQ Sunshine Coast location (1,0)	-0.038 (5.25)	-
Monday (1,0)	0.274 (38.1)	-0.243 (37.7)
Tuesday (1,00	0.225 (31.0)	-0.245 (38.00
Wednesday (1,0)	0.224 (30.9)	-
Thursday (1,0)	0.263 (36.4)	-0.194 (29.2)
Friday (1,0)	-	-0.182 (27.3)
Number of parameters estimated	24	23
Sample size[93]	1,133	1,943
Adjusted R squared	0.86	0.82

To give an example of how the probability of WFH varies by the levels of statistically significant influences, we present the findings for a few socioeconomics and locational influences for the SEQ and GSMA, one at a time, in Figure 15 and Figure 16, respectively. Analysts using this mapping device in real applications should use the mean values for each explanatory variable for the spatial context if interest, as discussed above. The results show that as distance from home to work increases between 1 to 40 kilometres, the probability of WFH increases, between 0.38 and 0.510 in the SEQ model, and between 0.28 and 0.40 in the GSMA model. As the personal income in the SEQ area increases, the probability of work from home increases from 0.40 for respondents with an income below $10,000 p.a., to 0.60 for respondents with an income of $400,000 p.a. or more. The industry categories in the SEQ

[93] The sample size for the WFH probability models is different than the previous models, because it only includes respondents that could WFH, which was available for 66-69% of respondents, presented in Table 5.

model have a significant influence over the probability to work from home, where respondents that work in professional industry categories have a WFH probability of 0.55, and respondents that work in retail have a WFH probability of 0.32. In the GSMA model, the occupations of respondents are found to have a significant influence on the WFH probability, where the highest WFH probability is for professional workers (0.41) and the lowest for community and personal service workers (0.14).

Figure 15: WFH probability changes by location/socioeconomic changes in SEQ model

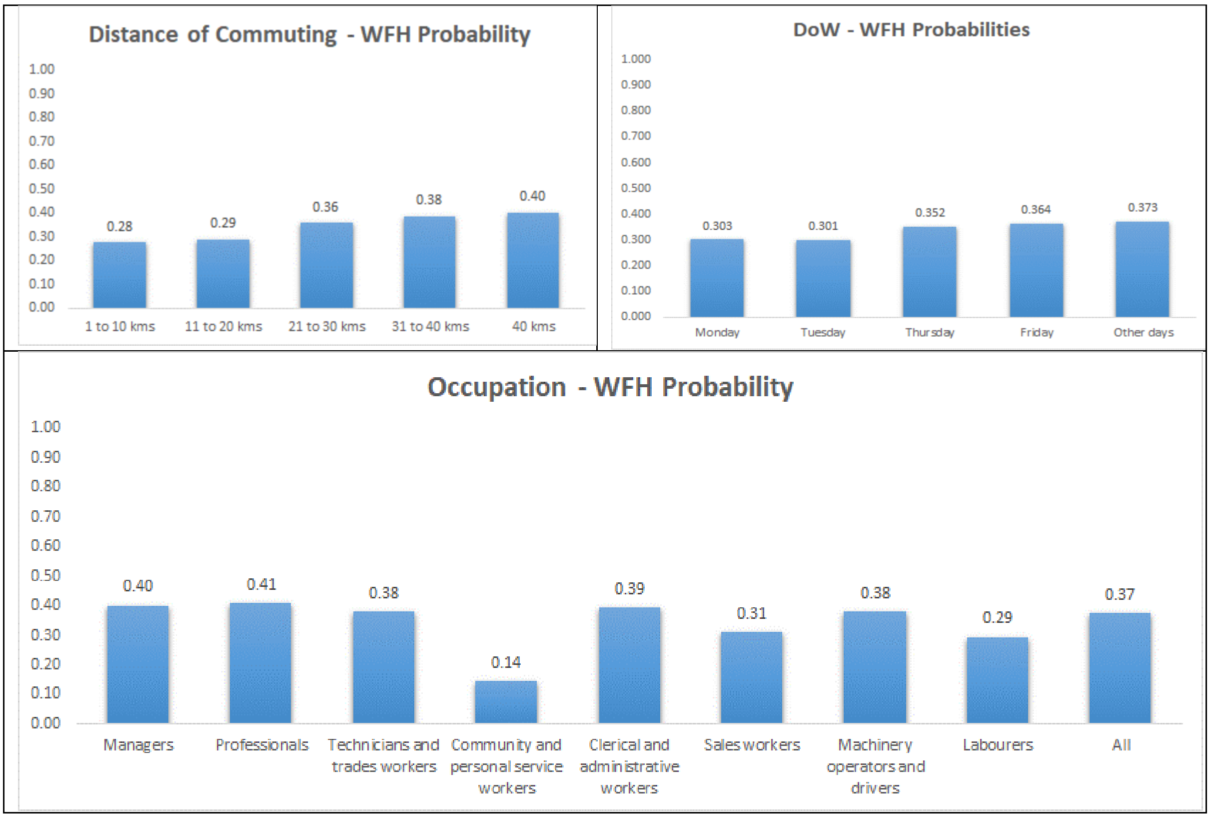


Figure 16: WFH probability changes by location/socioeconomic changes in GSMA model

8 Conclusions

With working from home likely to remain to some extent after COVID-19 has dissipated in the presence or otherwise of a vaccine, it becomes imperative to find a way to integrate the probability of working from home into current transport model systems, be they at the metropolitan area level or at other geographical jurisdictions[94]. Although the focus in this paper is on commuter mode choice and how it is expected to be impacted by the incidence of working from home, we have also developed and estimated Poisson regression models[95] to identify the systematic sources of influence on the number of one-way weekly trips by each mode and trip purpose. We wanted to establish the extent to which working from home changes the amount of such weekly travel activity and we were able to show that for most trip purposes that there was a change, often an increase, in the quantum of non-commuting trips[96].

Together with the commuter mode choice model, transport analysts and planners now have a suggested way to revise the current set of mode choice and trip generation models to account for the probability of working from home by socioeconomic and geographical segments. We have considered a number of ways of building the new models into existing strategic transport models and while it is possible to replace existing models with appropriate calibration, it is also feasible and indeed attractive for practitioners who have invested heavily in integrated transport and land use model systems to append these new models as a mechanism to adjust the probabilities (including logsums) of commuting by various modes for specific segments to account for working from home. At a very high aggregate level, the adjustments are likely to be in the vicinity of 0.3 to 0.4 (Table 10) if the evidence from September 2020 is maintained

[94] We have developed similar models for regional towns in Queensland and New South Wales.
[95] Given that the dependent variable is count data and hence not continuous, regression-based methods are not appropriate. Earlier models were developed for Wave 2 (Hensher et al. 2020).
[96] This research will be reported in a subsequent paper.

going forward. This adjustment can be done either prior to forecasting or after application. There is one caveat to this approach; namely that we assume that all parameters estimated prior to COVID-19 are appropriate for the post-COVID-19 setting and if not, this will require re-estimation. The particular parameters at risk, as a minimum, are crowding on public transport, the mix of congested and free flow time for a particular trip and reliability of travel time (i.e., travel time variability) for repeated trips on the road network. We will be re-assessing the changes in such attributes in a series of surveys in 2021 (Waves 4 to 7) to understand the stability or otherwise of the parameter evidence used in this paper, from Wave 3.

In ongoing research, in addition to re-estimating the models presented in this paper to look for signs of settling down of the behavioural responses post-COVID-19, we will be calibrating the models into a strategic model system to assess the likely traffic predictions in the presence and absence of the anticipated levels of working from home post-COVID-19. With three waves of data and an additional one recently collected in June 2021, we can start thinking about a longitudinal assessment. There are caveats however. Wave 1 is a standalone convenience sample, with Wave 2 the beginning of systematic sampling throughout Australia, but with greater sample sizes in NSW and Queensland given the sources of funding. Some of the participants in Wave 2 were in Wave 3 but a relatively small number, with Wave 3 having a high proportion of first time respondents. This means that although the panel nature of the data is limited, we are still able to consider a longitudinal assessment through a formal modelling framework

Contributions: David Hensher undertook all model estimation and interpretation and drafted the initial versions of the paper as well as contributed to final editing; Camila Balbontin prepared and cleaned the data for modelling as well as contributed to preparation of the paper and final editing; Matthew Beck designed the survey instrument and prepared the descriptive profile as well as writing various sections and editing the final version; Edward Wei designed the decision support system used to create the graphs for various socioeconomic and context variables associated with the probability of working from home

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Appendix Paper #8

Table A1: The relationship between # days WFH and weekly commuting and non-commuting trip activity for the SEQ (linked to Figure 13)

#WFH days	Ave commute distance	Ave #one way weekly commute trips	Ave #one-way weekly non-commute trips
0	15.63	7.42	11.71
1	15.4	6.15	12.05
2	20.84	5	14.47
3	24.64	2.73	14.09
4	10.62	2	9.25
5	24.58	1.18	7.89
7	36.67	1.33	12

Table A2: The relationship between # days WFH and weekly commuting and non-commuting trip activity for the GSMA (linked to Figure 14)

#WFH days	Ave commute distance	Ave #one way weekly commute trips	Ave #one-way weekly non-commute trips
0	14.33	7.33	10.44
1	22.49	7.25	12.29
2	24.28	5.13	13.7
3	24.17	3.59	11.48
4	20.64	2.79	15.89
5	24.12	2.4	11.43
6	18.71	0.86	6
7	27.83	0.83	7.6

Appendix M. Paper #9: Public transport trends in Australia during the COVID-19 pandemic: an investigation of the influence of bio-security concerns on trip behaviour

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Abstract

This paper draws on findings from an Australia-wide survey with data collected in three waves throughout 2020 to explore the impact of COVID-19 on public transport trends in metropolitan areas of Australia. Following consideration of the public transport sector response to the pandemic and the emerging literature context, we explore three principal questions: (i) How has weekly travel composition changed across the waves? (ii) How has level of concern with using public transport changed over the course of the pandemic given new bio-security concerns? and (iii) How has attitudes to risk been associated with the changes in PT use? A key finding is that concerns over bio-security issues around public transport are enduring, that concern about hygiene is significantly negatively related to public transport use and that those with higher concern about the hygiene of public transport also held higher concern about COVID-19 at work. Even as COVID-19 restrictions are eased, both concern about crowds and hygiene have a significant and negative correlation with public transport use. Concluding remarks are offered on what might need to happen for public transport patronage to start returning.

Keywords*:* COVID-19, public transport, bio-security, working from home, Australian evidence; patronage, concern.

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1 Introduction

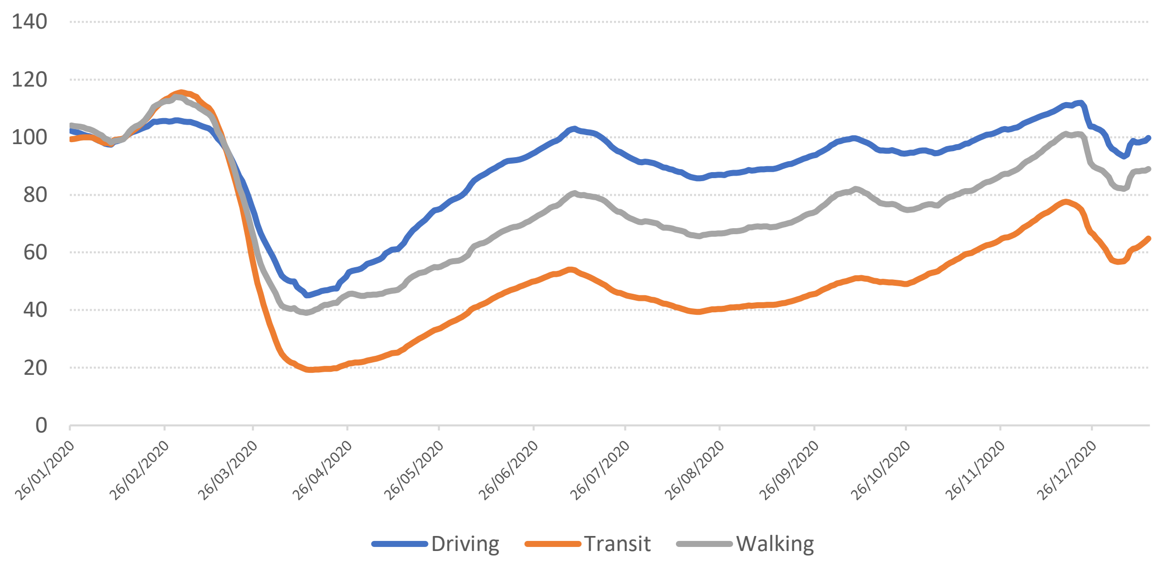
This paper reports on an analysis of changing patterns of use and attitudes towards public transport, following the incidence of COVID-19. It has particular reference to bio-security concerns associated with public transport use among other factors, such as the tendency to work from home (WFH). The analysis is based primarily on data from a survey of household travel, working, and other activities such as shopping in Australia collected during the COVID-19 pandemic. We look at public transport trends during the pandemic with a focus on experience in the Metro regions of Australia. Data are drawn from three waves of data collection in 2020: Wave 1 (March); Wave 2 (June); and Wave 3 (September).

1.1 An Overview of COVID-19 in Australia

Whilst Australia has recently been ranked number 8 in the world in terms of how COVID-19 has been handled based on a methodology that tracked COVID-19 case numbers in each country, as well as confirmed deaths and testing rates[97], there have been unprecedented impacts on public transport patronage. Figure 1 shows the aggregate mobility trends for Australia during 2020 derived from Apple mobility data. In aggregate we can see the sudden collapse in trip making by all modes from early to mid-March 2020 onwards as stay at home orders were implemented. Public transport use in Australia fell by about 80% (in some other locations the fall was greater still with New York reporting a 97% decrease in bus ridership by the end of April). Subsequently, the now familiar trend of car use rebounding much more quickly than public transport is apparent. In the case of Australia, from April to June public transport activity rebounded commensurate with the easing of restrictions, but a plateau was reached where from June to October use generally levelled out. This corresponds with the extended lockdown associated with the second wave of COVID-19 in Victoria from early July to late October. Public transport patronage growth continued again from the end of October but was impacted by the emergence of a new COVID-19 outbreak in Sydney in December 2020. The December outbreak in Sydney perfectly exhibits the vulnerability of public transport to public health concerns. Data provided by TfNSW shows that in Sydney, patronage in early December 2020 was at the highest levels since March's lockdowns having returned to around 150,000 trips / day. However, only about 80,000 to 100,000 trips were taken during the peak morning and afternoon periods in Sydney on Monday 11th Jan 2021, when people would be expected to return to work after the summer break, which is less than half of the 200,000 to 250,000 trips on the corresponding day one year earlier.

The pattern of quick cessation in overall travel activity, followed by growth, and then a steady state for an extended period, exhibited by the aggregate Apple Mobility data (Apple 2020) shown in Figure 1 is reflected in the disaggregate data we have collected over Wave 1 to Wave 3 (described in the section below on survey method).

[97] https://interactives.lowyinstitute.org/features/covid-performance/#region



Data source: https://covid19.apple.com/mobility

Figure 1: Aggregate mobility trends: Australia during 2020

2 Structure of the Paper

Given the background of Australian experience with COVID-19 during 2020, this paper seeks to address three principal questions: (i) how has weekly travel composition changed across three survey waves? (ii) how has level of concern with using public transport changed over the course of the pandemic given new bio-security concerns? and (iii) how has attitudes to risk been associated with the changes in public transport use?

The paper is organised as follows: the next section provides an overview of the relevant literature, followed by a description of the survey tool and overview of the sample used in this paper. Following this the results are presented. The impact on trip making is considered through examination of changes in weekly travel composition. This is followed by investigation of concern about public transport which includes consideration of the relationship between concern about public transport and the use of public transport. Poisson regression is conducted to examine the role that bio-security concerns may have determining patronage. Finally, concluding remarks are offered on what might need to happen for public transport patronage to start returning.

3 Literature context

There is an emerging literature on COVID-19 and public transport. Several studies have taken a country-specific context. Eisenmann et al (2021) in their analysis of experience in Germany during 2020, describe how public transport lost ground during times of greatest restriction while individual modes of transport became more important. They suggest that the long-term effects of increased concern about public transport (much of it explained by changed perceptions of “comfort”) and the new individual routines that citizens have adopted, now car-based in many cases, confirms the importance of health risk in re-shaping transport demand.

The case of public transport in Poland is documented by Wielechowski et al. (2020) covering the first five months of the pandemic. Poland was one of the last European Union countries to experience the outbreak of COVID-19 and to date the experience has been relatively mild. Restrictions imposed by the government have however been severe. A key conclusion drawn, and one that resonates with the experience in Australia, is that government action (e.g., the implementation of forced lockdown) reduces public transport use more so than the perception of risk of the disease. In contrast to the Polish analysis Shibayama et al. (2021) adopt a multi-country approach in their analysis of changes in commuting patterns as a result of lockdown experiences in 14 countries. They find that amongst those who changed their commuting travel modes from public transport to other modes in response to COVID-19, avoiding risk of infection on public transport was their main reason for the change.

Many cities worldwide responded to their first lockdown by reducing service levels, particularly during peak hours (as an example DeWeese et al (2020) report that public transport agencies across North America made significant adjustments to their services in the early months of the pandemic), this was much less prevalent in Australia, except for Perth which instituted a weekend timetable on its rail services. The decision to maintain services for essential workers and people without access to a car has served to emphasise the essential role of public transport for some citizens. To encourage a return to public transport discounted off-peak fares were introduced in Sydney from 6th July 2020 (a 50% discount for 3 months, reducing to a 30% discount thereafter), accompanied by slightly extended peak hours. A 30% off-peak discount has been introduced in Melbourne from January 2021 as part of a policy to encourage people to return to the workplace which may involve staggered start and finish times.

Measuring customer attitudes towards level of service has traditionally been a fertile area for research. Beck and Rose (2016), reiterating that the measurement of attitudes is relied on by public transport authorities' the world over, proposed a dual version of best–worst scaling as an alternative measure of satisfaction. Such an approach is ideal for handling the comparative evaluation of a large number of attributes. Beck and Rose (2016) conducted a survey of bus users in Sydney, and it is interesting to note (and especially because this work was completed in a pre-COVID-19 context) that they found that the level of crowding and cleanliness of the bus stops at both ends of the journey, as well as having shelter at the end of the trip, all exhibited large positive correlations between satisfaction and importance. Somewhat presciently, given the context of the pandemic, Beck and Rose (2016, p121) suggest that the implications of "crowding may be something that needs to be emphasised by operators and that perhaps further research may be needed into what constitutes crowding and why those who find it important are satisfied with the level of crowding".

Dong et al. (2021), based on their cross-sectional study of eight Chinese cities, note that there is limited detailed understanding of how passengers' perception of safety, as perceived in a public health crisis is influencing feelings of satisfaction toward public transport. They find that an individual's state anxiety (a transient response that can cause feelings of apprehension) influences perception of public transport safety and may linger for months. The role of traveller information is thus an important measure in reassuring passengers and information about on-board crowding conditions has become increasingly available during the pandemic. Passenger reluctance to ride a crowded vehicle has been shown to be much higher in the pandemic than previously reported (Tirachini and Cats, 2020).

Whilst the link between public transport and the spread of COVID-19 is uncertain (Shibayama et al, 2021) there is evidence from Australia that the level of risk from public transport depends on the number of cases circulating in the community (Barrett, 2020). In their multi-country survey, Shibayama et al. (2021) report that 70 to 80% of respondents from Austria, Bulgaria, Germany, Hungary and Japan who changed their commuting travel modes from public transport to other modes referred to risk avoidance as their main reason for the change. Dzisi and Dei (2020) note there is evidence from an operator perspective that policy on using masks in public transport has been more difficult to enforce (a contrast with policy on physical distancing). The compliance level associated with mask wearing has not been helped by conflicting official "messaging" around safety across jurisdictions (Nelson, 2021). Masks have been mandatory for public transport users in Melbourne in July 2020 (and in London from June 2020) but were only "strongly recommended" in Sydney until they became mandatory on 4th January 2021. Greater clarification would be helpful for commuters particularly as concerns around transmission of the virus continue (Dong et al. 2021). Recent experience from Switzerland[98], though, suggests that there is not a strong relationship between mask use and public transport patronage.

Other safety-related measures include increased cleaning measures, a shift to rear door boarding on buses and marshalling of queues of intending public transport passengers to maintain physical distancing and on-board vehicles. In Sydney "No dot, no spot" was introduced to indicate the safest places to sit and stand although Australian cities did not institute temperature checks for public transport users. In many locations across the world, journey planners have been modified to help travellers plan their journeys more safely by showing whether physical distancing can be observed (e.g., TfLGo has been introduced to help main physical distancing and help "get London moving again, safely and sustainably"); and COVID-19 travel advice web pages have become readily available.

A justification of the analysis of the effect of risk upon public transport utilisation lies in its relevance to managing future crises. Tardivo et al (2021) propose an agenda based around five ''R''s—resilience, return, re-imagination, reform, and research. Dong et al. (2021) argue that a better understanding of factors affecting passenger satisfaction, and particularly the perception of safety, can aid future disaster emergency management. Overall, it is clear is that public transport users are concerned about the health risks associated with public transport and this motivates the exploration of the trends in level of concern with public transport and its impact on use in this paper.

4 Survey Method and Sample

Figure 2 provides the 7-day rolling average of new COVID-19 cases in Australia from January 2020 through to the start of December 2020, covering the key time periods where survey data was collected. Additionally, the Oxford Government Stringency Index is also charted (OxCGRT 2021), to highlight the government response in Australia in dealing with COVID-19.

By mid-March 2020, it had become apparent that the COVID-19 disease, the result of the SARS-CoV-2 virus, was unlike any flu-like epidemic seen previously. In response to the rising threat, the Australian Federal Government began instituting a series of public health measures to curb COVID-19 infections, chief amongst which included closing the national borders to travel from 17th March, through to instituting a series of lockdown style measures on 23rd March, which reached a peak on 29th March with health orders issued by states restricting all movement with the exception of shopping for essentials; medical or compassionate needs; exercise in compliance with the public gathering restriction of two people; and for work or education purposes. Wave 1 of the survey entered the field at this point in time, gathering insight into the behaviour of respondents in the context of the first spike in COVID-19 cases in Australia.

Following four weeks of this lockdown, state governments in Australia began to ease restrictions (at a differing pace), following the decline in the average number of new cases to less than 20 a day nation-wide. After an approximately two-month period of low case numbers, with large parts of the country having all but eliminated COVID-19 (to a large extent the disease was only circulating in Sydney and Melbourne), Wave 2 was collected from late May to early June following this relatively settled period where freedoms of movement were starting

98 Personal communication from Kay Axhausen of ETH.

to return and many social activities were allowed. Importantly, during this time in many jurisdictions, the public health order that firms must allow those who can work from home to do so wherever practicable was still in effect.

By the end of June, not long after Wave 2 came out of field, it became apparent that COVID-19 was beginning to spread at an alarming rate in the city of Melbourne as a result of the disease escaping hotel quarantine. On 2nd August a state of disaster was declared, and metropolitan Melbourne was placed into a curfew from 8 pm to 5 am, in addition to an order that people must not travel beyond a 5km radius of their home, with a permit required for those that still needed to travel to work outside of their 5km radius. Wave 3 went into the field on 7th August and data collection was maintained up until the first week of September 2020.

The profile of each wave of data collection is shown in Table 1. The sample is broadly representative of the Australian population, though Wave 2 and Wave 3 have a relatively higher proportion of females. It should be noted that the Australian Bureau of Statistics (ABS) calculation of income is for all individuals 15 years or older, however the data collected by this project only includes individuals who are 18 years or older, which may explain some of the discrepancy in personal income. Additionally, where we define having children the ABS rather define a family, which includes any of the following categories: couple family without children; couple family with children; one parent family; other family. For the purposes of this paper examining the impact of COVID-19 on public transport, only respondents who live in a metropolitan area are used (as meaningful public transport alternatives only exist in such areas in Australia). An overview of findings is reported in Beck and Hensher (2020a) for Wave 1 and Beck and Hensher (2020b) for Wave 2.

It should be noted that each survey was conducted online making use of an online consumer research panel. The sampling strategy was such that respondents from previous waves were extended invitations to complete subsequent waves of the survey a few days in advance of main recruitment when new respondents were also invited to complete the survey. In this analysis, however, we treat the data as repeated cross-sectional data.

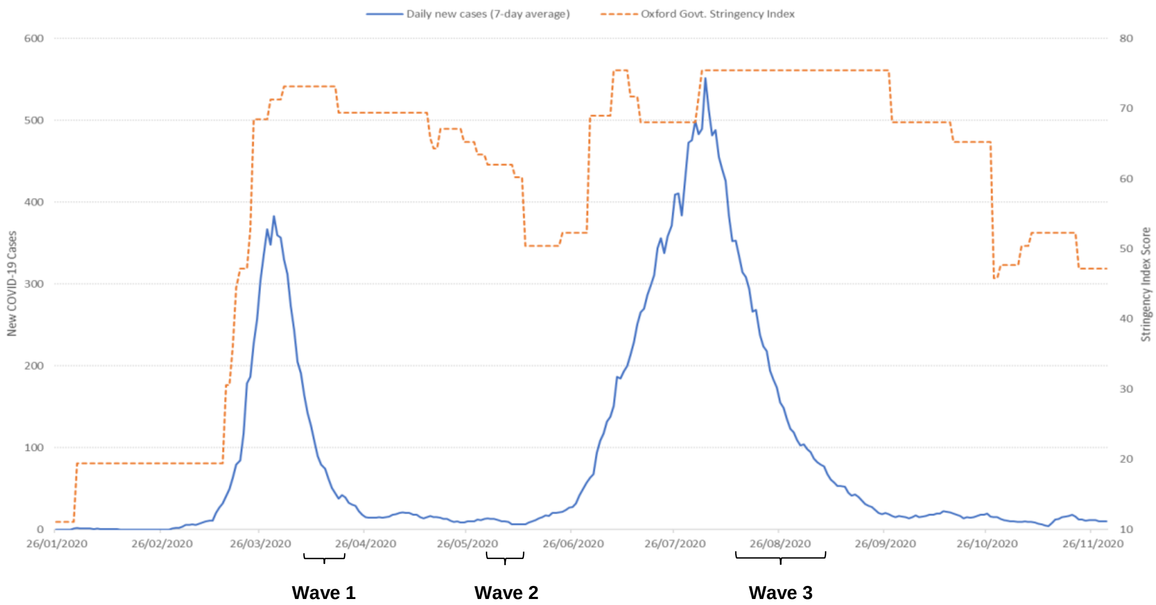


Figure 2: New COVID-19 Cases in Australia vs. Level of Government Response

Table 1: Profile of Samples

	Wave 1	Wave 2	Wave 3	ABS
Time Period	Late March 2020	Late May 2020	August 2020	2016
Total Sample	1074	1457	956	na
Female	52%	58%	58%	51%
Age	46.3 (σ = 17.5)	48.2 (σ = 16.2)	48.2 (σ = 16.2)	48.2
Median Income	H'hold = $1682	H'hold = $1202	Pers. = $960	Pers. = $662 H'hold = $1438
Have children?	32%	35%	35%	25%
Number of children	1.8 (σ = 0.8)	1.7 (σ = 0.9)	1.8 (σ = 0.8)	1.8
Occupation (those working)				
Manager	1%	2%	14%	13%
Professional	38%	35%	28%	22%
Technician & Trade	5%	6%	6%	13%
Community & Personal Services	8%	10%	10%	11%
Clerical and Administration	17%	17%	22%	14%
Sales	23%	22%	11%	9%
Machine Operators / Drivers	2%	2%	4%	6%
Labourers	5%	5%	7%	10%
Distribution by State				
New South Wales	22%	32%	31%	32%
Aust. Capital Territory	2%	2%	1%	2%
Victoria	28%	24%	24%	26%
Queensland	22%	18%	22%	20%
South Australia	11%	11%	9%	7%
Western Australia	11%	10%	10%	10%
Northern Territory	1%	1%	1%	2%
Tasmania	2%	3%	1%	1%

5 Results

5.1 Impact on Trip-Making

In this section we briefly look at disaggregate trends from the survey data to see how weekly travel composition changed across the three waves of the survey. Figure 3 shows the average trips by mode (private car versus total public transport trips made), for respondents living in metropolitan regions of Australia. The slow return to use of public transport as seen in Figure 1 is replicated: among all respondents, an average of 5.4 trips / week by all public transport (train, bus and ferry) was reported before the pandemic, a figure which has recovered to only 2.7 trips / week during Wave 3. The stronger recovery of active modes was also exhibited in Figure 1 and this has been widely encouraged in many jurisdictions through provision of measures to support active travel (ITF, 2020, Shibayama et al., 2021).

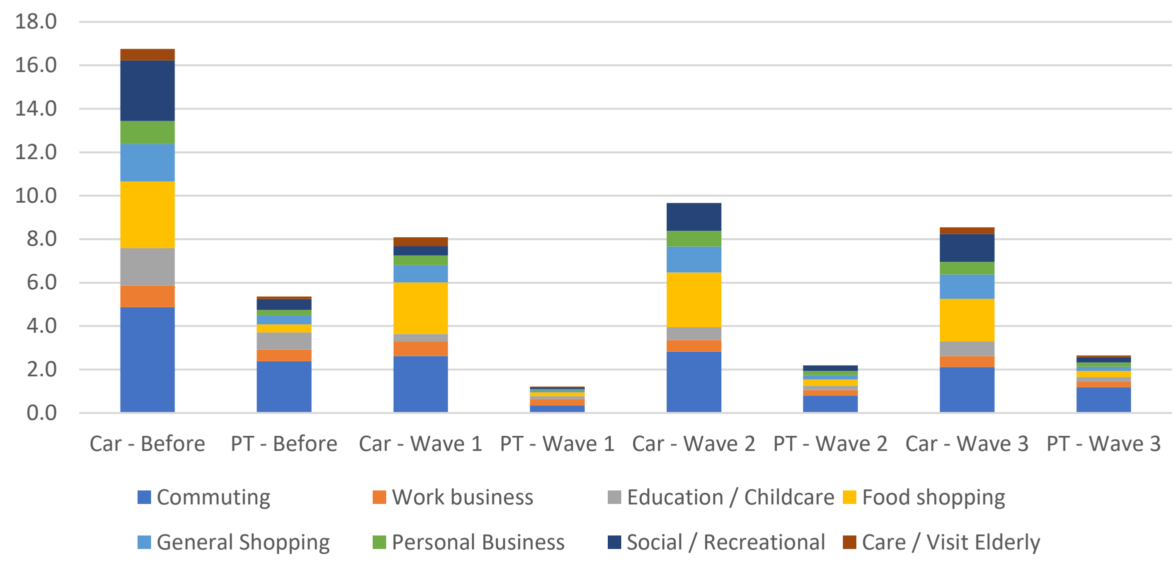


Figure 3: Average trips by mode and purpose

With respect to trip purpose, while commuting is still suppressed (up until late 2020 the health order requiring those staff who are able to work from home be allowed to do so was still in effect for the largest two metropolitan centres of Sydney and Melbourne), there are signs that commuting is a trip-making activity returning more strongly, especially in Wave 3 where it was 50% of the before COVID-19 levels. Work business trips by public transport have returned to 60% of before COVID-19 levels but for most other trip purposes the recovery is slower. A steady return to the use of public transport for food shopping demonstrates the essential nature of public transport for some travellers. By way of background, respondents who list public transport as their main mode for commuting are more likely to be those who work for large businesses (200+ employees), have the ability to work more days from home, have a positive attitude towards more flexible work in the future, have greater concern about COVID-19 in the workplace, are less concerned about COVID-19 as a risk to health, have lower incomes, are younger, and live further away from work.

5.2 Bio-Security Concern about Public Transport

In this study, an attitude to risk is incorporated via passenger concerns about the hygiene of public transport modes in two ways. First, in Wave 1, 2 and 3 a proxy measure, relating to the fear of infection is used, while in Wave 3 the volume of people currently using public transport is used also as a proxy for the difficulty of maintaining physical distance from fellow travellers. Both measures emerged as a clear concern for public transport travellers during the pandemic as can be seen in Figure 4 which charts responses to the question “What would be your level of concern about hygiene on public transport today?”.

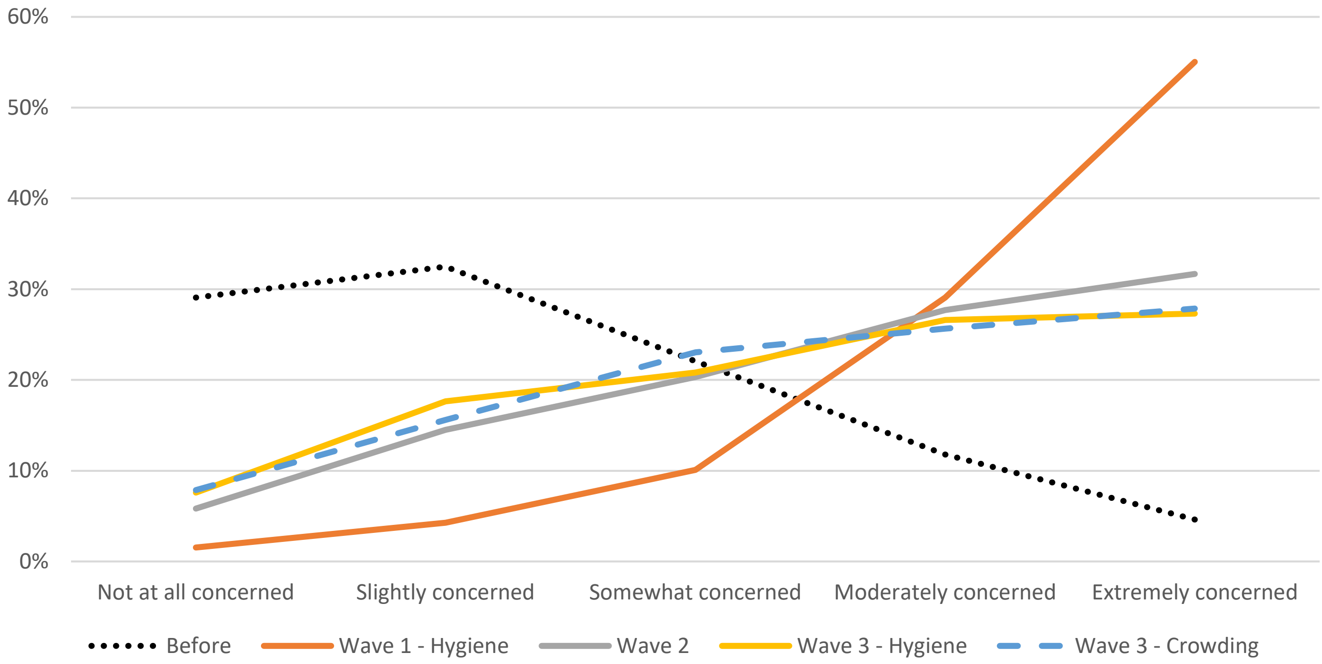


Figure 4: Level of hygiene (all waves) and crowding (Wave 3 only) concern about public transport

As would be expected there is a dramatic difference in the concern about hygiene on public transport before COVID-19 and immediately after the first outbreak at Wave 1 in early to mid-April 2020 (the blue and orange lines are almost diametrically opposed). Concern in Wave 2 (late May to mid-June) had diminished, but still more than half the number of respondents reported moderate to extreme concern. While concern has decreased between the two Waves (consistent with an easing of conditions) average concern still remains at a level that is appreciably higher than that prior to COVID-19; 60% of respondents were extremely or moderately concerned at Wave 2 compared to 17% before COVID-19. Levels of concern remained largely unchanged from Wave 2 to Wave 3 (when the survey was in the field from early August to early October; thus, encompassing the second wave in Victoria). It might be expected over time that results could be influenced by the availability of better information. At the beginning of the pandemic, contagion through surfaces was deemed to be much more prevalent than today, when it has been established that air is the most critical path of virus spreading. In September 2020 the NSW Transport Minister announced that one million extra cleaning hours on public transport had been reached since the start of the pandemic. Thus it is expected that the relevance of cleaning surfaces has changed in the perceptions of people.

It is interesting to look at changes in the level of concern over time based on broad socio-demographics.

- *Before COVID-19:* There were no differences based on gender or income, however older respondents reported significantly less concern about the hygiene of public transport.

- *Wave 1:* There were no differences based on gender; however older respondents now reported significantly more concern about the hygiene of public transport (the reverse of before COVID-19), as did those on higher incomes.

- *Wave 2:* Males reported significantly less concern about public transport hygiene, older respondents continued to report significantly higher levels of concern, and income no longer discriminated between differing levels of concern.

- *Wave 3:* Neither gender, nor age, nor income was significant in differentiating between levels of concern.

In anticipation that confidence with using public transport might diminish again rather than continue to improve as more transport users return to the system, in Wave 3 a further question about concern regarding the number of people using public transport was added in addition to the question about concern with hygiene of public transport. The respondents' expressed concern about the numbers of people (i.e. crowding) almost exactly mirrors that of concern about hygiene with 54% of respondents indicating that they were extremely or moderately concerned (Figure 4).

5.3 Correlation between Public Transport Concern and trip behaviour

In order to examine the possible influence of level of concern about public transport on trip-making behaviour in each wave of data, the correlation between the reported concern about public transport and the use of public transport was examined (Tables 2 - 4). The Wave 2 and Wave 3 survey also included a question about COVID-19 and the workplace ("How concerned are you today about COVID-19 and work, given the environment that you normally work in?"), and the correlation with this variable was also examined.

Table 2: Correlation between Concern about Public Transport and Total Trips – Wave 1

	Total PT Use - Before	Hygiene Concern - Wave 1	Total PT Use - Wave 1	Change in PT Use
Hygiene Concern - Before	-0.05	0.23*	-0.003	-0.07
Total PT Use - Before	---	-0.11*	0.54*	0.82*
Hygiene Concern - Wave 1	---	---	-0.12*	-0.09*
Total PT Use - Wave 1	---	---	---	0.10*

There was no correlation between concern about public transport and public transport use before COVID-19 or during the Wave 1 survey; however, there is a significant albeit weak positive correlation with concern during Wave 1, which indicates that a respondent who held a higher degree of concern before COVID-19 also held a higher degree of concern after the initial outbreak. The level of concern before is not related to any observed change in the amount that someone uses public transport. The significant but weak negative correlation between concern during Wave 1 and the use of public transport use before indicates that individuals who expressed a higher degree of concern about the hygiene of public transport in Wave 1 used it to a lesser extent prior to COVID-19. Likewise, the similarly negative and weak correlation between concern about hygiene in Wave 1 and number of public transport trips during Wave 1 indicates that those who held a higher concern about public transport, used it for a lesser number of trips. Similar findings are reported by Eisenmann et al. (2021) who questioned travellers in Germany about their "comfort" with using public transport, and found that those who continued to use public transport after lockdown maintained a higher degree of comfort (24% were much more uncomfortable than before) than those who ceased using public transport at lockdown (48%) or had never used public transport (40%).

Overall, these results confirm with what might be expected since, generally speaking, until the onset of COVID-19 concern about public transport hygiene was not an issue that traditionally featured highly as a factor affecting perception of quality of service (see for example Kinsella and Caulfield, 2011).

Table 3: Correlation between Concern about Public Transport and Total Trips – Wave 2

	Total PT Use - Wave 2	Work Concern - Wave 2
Hygiene Concern - Wave 2	-0.171*	0.515*
Total PT Use - Wave 2	---	0.081*

Concern about hygiene is significantly negatively related to public transport use in Wave 2, indicating those with higher concern used public transport less during the Wave 2 period, as might be expected. In Wave 2, a question was included about respondents concern with the rise of COVID-19 in the workplace. We find a significant and strong positive correlation between both variables indicating those with higher concern about the hygiene of public transport also held higher concern about COVID-19 at work; again this is not unexpected.

Table 4: Correlation between Concern about Public Transport and Total Trips – Wave 3

	Crowding Concern - Wave 3	Total PT Use - Wave 3	Work Concern - Wave 3	PT Concern Latent Factor
Hygiene Concern - Wave 3	0.869*	-0.148*	0.404*	0.977*
Crowding Concern - Wave 3	---	-0.134*	0.353*	0.952*
Total PT Use - Wave 3	---	---	0.117*	-0.151*
Work Concern - Wave 3	---	---	---	0.394*

As noted above in Wave 3, a further question about public transport was asked, examining the concern held about the numbers of people using public transport during the pandemic ("Imagine you had to catch public transport tomorrow, what would be your level of concern about the number of people using public transport?"). Unsurprisingly, there is a significant and strongly positive correlation between concern about crowds and concern about hygiene. As a result, factor analysis was used to reduce these two variables into one underlying latent factor termed "PT Concern". Both concern about crowds and hygiene have a significant and negative correlation with public transport use during Wave 3 and are both positively correlated with concern about COVID-19 and the workplace. The PT Concern latent factor has a significant and negative correlation with public transport use in Wave 3 also indicating that those with high concern about public transport during Wave 3, used public transport less during this time period (consistent with messaging that public transport is a spreader of the virus). Those concerned about public transport also hold concern about COVID-19 and the workplace, as indicated by the positive and significant correlation between these two variables.

5.4 A Note on Attitudes

Across the waves of data collection, respondents were given a differing series of attitudinal statements around perceptions of COVID-19 and associated business and government response were asked, as well as questions around the level of comfort respondents felt in engaging in different social and recreational activities, and also their experiences with working from home during the pandemic (where relevant). Prior to estimating models of public transport use, exploratory factor analysis was conducted to identify latent variables that, while not directly observed, could be inferred by the attitudinal indicators used. It was found that attitudes to COVID-19 were a function of three latent constructs (termed “Institutional Response”, “Societal Response” and the “Impact of COVID-19”) in Wave 1, but only two in subsequent waves (“Institutional Response” and “Societal Response”), comfort in activities were informed by two latent constructs (“Large Group Comfort” and “Small Group Comfort”), and working from home attitudes driven by two latent factors (“Current Experience” and “Future Intentions”). More information on these attitudinal statements and analysis can be provided upon request.

5.5 Influence on Public Transport Use

Further analysis is conducted to examine the role that bio-security concerns may have determining patronage. A Poisson regression is used to predict a dependent variable that consists of "count data". In an extension of this model type, the zero-inflated Poisson regression is used to model count data that has an excess of zero counts. Further, theory suggests that the excess zeros are generated by a separate process from the count values and that the excess zeros can be modelled independently. In the data on use of public transport, through Wave 1, Wave 2 and Wave 3, there are many respondents who make zero trips using public transport; hence the zero-inflated Poisson is chosen. Each model estimated is compared to an unaltered Poisson regression, and in every instance the zero-inflated (ZIP) model is found to perform significantly better. The results of the models on each of the waves are shown in Table 5 (count model coefficients) and Table 6 (zero-inflated model coefficients). Within the tables (---) indicates a variable that was trialled but found to be statistically insignificant, and (na) indicates a variable that was not present in that survey wave and thus could not be used.

The ZIP model has two components: the count model which predicts increases or decreases in the use of public transport (not directly via the number of trips, rather changes to the odds of having higher number of trips), and the zero-inflation model which predicts membership of the zero group (i.e., the odds of not using public transport at all).

Findings relevant to explaining the role that bio-security concerns may have determining patronage may be summarised as follows:

- Before COVID-19 results from the zero-inflation model show that those who expressed concern about public transport hygiene as a result of COVID-19 have a higher probability of not using public transport before COVID-19. Those who use public transport as their main mode, obviously, have a lower probability of not using public transport, which represents the captive nature of public transport users.
- The count model coefficients show that individuals who express higher levels of concern about public transport hygiene both before COVID-19 and during the Wave 1 time period are more likely to be making a higher number of trips. It is perhaps more likely that higher public transport use and thus greater exposure, is driving the attitudes around hygiene and risk, rather than the other way around (i.e., those that use public transport a lot would be expected to be more concerned about its hygiene, particularly if they must use it, which is likely the case).
- The zero-inflation model indicates that those who express concern about the hygiene of public transport during the time of data collection, all have higher odds of making zero public transport trips in the last week during Wave 1.
- The count model coefficients show that individuals who express greater concern about public transport hygiene during Wave 1 have a greater chance of making more trips

- In Wave 2, the positive coefficients in the zero-inflated model indicate that those who express concern about public transport hygiene have greater odds of making no public transport trips.
- The count model coefficients indicate that those who expressed higher concern about public transport hygiene were amongst the types of respondents more likely to make a higher number of public transport trips in Wave 2; thus reflecting the captive nature of some public transport users.
- In Wave 3 the zero-inflation component of the model indicates that respondents with a higher Concern about Public Transport (hygiene and crowds) latent factor have higher odds of not making public transport trips.
- The count model coefficients indicate that those who express greater concern about public transport crowd numbers in Wave 3 are more likely to make fewer public transport trips.

There is an interesting finding in Wave 3 that is somewhat similar over all the waves, in that those that express concern about public transport are more likely to not use it, but among those that do use it those who have higher concern about hygiene are more likely to make more trips. This suggests that they are captive travellers who are potentially having to use the mode to get around (typically commute), perhaps because of this feel they are more at risk, so are perhaps more concerned than others. It would also seem that it is perhaps more the numbers of other people that act as a barrier (crowding), than hygiene alone. Perhaps this also translates to the perspective that COVID-19 is of greater risk to them. The presence of captive travellers is also evidence of the value of public transport as an essential service.

Table 5: Explaining Public Transport Use (Count Model Coefficients)

	Before COVID-19		Wave 1		Wave 2		Wave 3	
AIC	784.33		2436.47		2059.71		2518.55	
BIC	857.22		2494.00		2193.74		2645.62	
LL	-374.16		-1204.24		-99.86		-1230.27	
Pseudo R2	0.40		0.17		0.36		0.43	
	Par.	*t.value*	*Par.*	*t.value*	*Par.*	*t.value*	*Par.*	*t.value*
(Intercept)	-0.37	-1.18	2.41	13.40	1.89	10.95	0.50	2.45
Days worked in last week	0.23	7.46	-0.03	-1.72	---	---	---	---
Days worked from home	-0.18	-5.97	0.04	2.50	0.22	10.92	-0.05	-3.71
White collar occupation	-0.36	-3.46	-0.38	-7.45	0.28	4.28	---	---
Medium size business (20-199 employees)	na	na	na	na	na	na	---	---
Large size business (200 plus employees)	na	na	na	na	na	na	---	---
All my work can be done from home (Y)	na	na	na	na	na	na	---	---
Have my own space at home to work (Y)	na	na	na	na	na	na	---	---
Main commute mode is public transport	-0.80	-5.57	0.39	7.98	---	---	0.65	11.76
Relative productivity of work from home	na	na	na	na	-0.19	-6.90	---	---
Concern about COVID-19 in the workplace	na	na	na	na	-0.11	-4.48	0.18	6.01
Current WFH Experience (latent factor)	na	na	na	na	-0.10	-2.51	-0.25	-5.49
Future WFH Intentions (latent factor)	na	na	na	na	-0.18	-4.74	-0.29	-6.93
Overall Comfort with Activities (latent factor)	na	na	na	na	0.31	9.26	na	na
Comfort with Large Group Activities (latent factor)	na	na	na	na	na	na	0.06	1.91
Comfort with Small Group Activities (latent factor)	na	na	na	na	na	na	0.26	7.82
Institutional Response (latent factor)	-0.61	-7.34	---	---	---	---	-0.06	-1.82
Societal Response (latent factor)	-0.32	-6.87	---	---	-0.27	-8.21	-0.16	-5.70
Impact Evaluation (latent factor)	-0.34	-5.96	-0.07	-2.60	na	na	---	---
Risk of COVID-19 to own health	-0.06	-2.57	---	---	---	---	0.12	8.45

Risk of COVID-19 to health of someone known	---	---	---	---	-0.07	-3.35	-0.07	-4.45
Risk of COVID-19 to health of general public	0.15	4.39	---	---	0.13	4.86	---	---
Risk of COVID-19 to health of the economy	---	---	-0.03	-2.62	-0.09	-4.93	-0.12	-7.70
How long until life returns to something like "normal"	na	na	na	na	na	na	---	---
How ready is Australia to combat a future pandemic	na	na	na	na	na	na	0.10	5.46
Satisfaction level with life nowadays	na	na	na	na	---	---	---	---
How worthwhile are the things you do in life	na	na	na	na	---	---	---	---
How happy did you feel yesterday	na	na	na	na	0.04	2.98	0.03	2.58
How anxious did you feel yesterday	na	na	na	na	0.06	4.89	0.03	3.24
Gender (male = 1)	---	---	0.41	9.02	0.34	5.78	0.28	5.31
Income ($'000)	0.01	7.32	---	---	0.00	9.05	-0.45	-7.83
Age	---	---	-0.01	-8.34	-0.03	-9.67	0.01	4.73
Concern about public transport hygiene - Before	*0.28*	*4.66*	---	---	*na*	*na*	*na*	*na*
Concern about public transport hygiene - Survey Wave	*0.21*	*3.48*	*0.14*	*5.13*	*0.19*	*6.21*	*0.31*	*7.30*
Concern about public transport crowds - Wave 3	*na*	*na*	*na*	*na*	*na*	*na*	*-0.26*	*-7.17*

Table 6: Explaining Public Transport Use (Zero-Inflation Poisson Model Coefficients)

	Before COVID-19		Wave 1		Wave 2		Wave 3	
	Par.	*t.value*	*Par.*	*t.value*	*Par.*	*t.value*	*Par.*	*t.value*
(Intercept)	-0.04	-0.04	-0.48	-0.73	1.75	2.19	1.54	2.73
White collar occupation	0.89	2.40	---	---	---	---	---	---
Main commute mode is public transport	-2.16	-5.87	-2.90	-9.41	-2.68	-8.94	-2.20	-8.48
Days worked from home	---	---	---	---	0.43	3.59	0.60	6.64
Relative productivity of work from home	na	na	na	na	-0.44	-3.25	-0.58	-6.23
All my work can be done from home (Y)	na	na	na	na	na	na	0.76	2.55
Institutional Response (latent factor)	---	---	---	---	0.46	3.54	---	---
Overall Comfort with Activities (latent factor)	na	na	na	na	-0.37	-2.65	na	na
Future WFH Intentions (latent factor)	na	na	na	na	0.38	2.00	---	---
Risk of COVID-19 to own health	---	---	---	---	-0.22	-2.99	---	---
Risk of COVID-19 to health of general public	---	---	---	---	-0.21	-2.19	---	---
How worthwhile are the things you do in life	na	na	na	na	0.12	2.03	---	---
Age	0.03	2.55	0.01	1.82	0.02	1.83	0.04	3.86
Gender (male = 1)	---	---	---	---	---	---	-0.94	-4.06
Concern about public transport hygiene - Survey Wave	*0.31*	*1.73*	*0.23*	*1.71*	*0.55*	*4.26*	---	---
Public Transport Concern (hygiene and crowds latent factor)	*na*	*na*	*na*	*na*	*na*	*na*	*0.64*	*4.29*
Concern about COVID-19 in the workplace	*na*	*na*	*na*	*na*	---	---	*-0.31*	*-2.62*

6 Discussion and Conclusions

This concluding section discusses the main trends and changes across the three waves with respect to changing levels of use and concern about public transport and considers some of the responses that may be required for a sustained return of public transport patronage.

6.1 Concern about public transport and influences on use

The correlation results confirm that, generally speaking, until the onset of COVID-19 concern about public transport hygiene was not an issue that traditionally featured highly as a factor affecting perception of quality of service. Concern about hygiene is significantly negatively related to public transport use in Wave 2, indicating those with higher concern used public transport less during the Wave 2 period, as might be expected. In Wave 2, we find a significant and strong positive correlation between both variables indicating those with higher concern about the hygiene of public transport also held higher concern about COVID-19 at work; again this is not unexpected. Unsurprisingly, there is a significant and strongly positive correlation between concern about crowds and concern about hygiene. Both concern about crowds and hygiene have a significant and negative correlation with public transport use during Wave 3 and are both positively correlated with concern about COVID-19 and the workplace. The public transport concern latent factor has a significant and negative correlation with public transport use in Wave 3 also indicating that those with high concern about public transport during Wave 3, used public transport less during this time period.

The regression model results provide further insights. The zero-inflation model coefficients are used to explain use versus no use of public transport. Concern about public transport is consistently positive over all waves with more concern translating into more likely to make zero trips.

The count model coefficients are used to explain the number of trips if public transport is used. Results show that concern about public transport exhibits consistent positive impact across all waves with higher concern equating with more trips; this could be an indication of captive use and an awareness by travellers that they may be more at risk because of their use of public transport.

6.2 Implications for public transport operations and policy

Given the experiences of 2020, it may not be a surprise if we see some serious rethinking of public transport planning and delivery. The pandemic has been a reminder of how important public transport is as a crucial part of society's basic infrastructure, especially for those for whom public transport is their essential means of transport. In particular, the concern over bio-security issues around public transport use are enduring (Figure 4). Our findings also show that travellers are as concerned about crowding levels on public transport as they are about hygiene. As a result, it may be that public perception will force operators to revise what is considered an acceptable capacity in public transport vehicles; for example, the ability to reserve a seat on certain services (perhaps over a certain trip length) could provide a more personalised and safer experience. Similarly, Gkiotsalitis and Cats (2020) suggest that the physical distancing measures introduced to combat the virus spread call for focusing on the need to avoid crowding by distributing passenger demand as evenly as possible in both time and space. This, they suggest, can be attained by means of re-designing services, re-allocating resources and re-distributing passenger flows. In subsequent work Gkiotsalitis and Cats (2021) have developed a frequency planning model, using the Washington D.C. metro as a case study that can be applied when the passenger demand has almost returned to its pre-pandemic levels yet public transport operators need to comply with the social distancing regulations to avoid the spreading of the virus.

Crowding on public transport must be mitigated as people increasingly return to using public transport. Crowding management via both physical and digital means is identified as a priority by Tirachini and Cats (2020) in their proposed future research agenda to promote the recovery of public transport. The flattening of the peaks (as a result of WFH) can save resources that might be used to strengthen the basic, off-peak transport services. But whereas we might have thought that we now have plenty of public transport capacity, it may be the opposite if we want to control crowding and hence future operations will need more capacity which could be a challenge for trains more than buses given track capacity limits. We need to rethink traditional approaches to peak vehicle availability. Those working from home have the flexibility to use public transport selectively and should be encouraged to do so. However, since there is no guarantee that subsequent local outbreaks of COVID-19 (as witnessed in both Melbourne and Sydney during both 2020 and 2021) will not occur and given the enduring nature of bio-security issues shown by our study, adaptation strategies must be sufficiently robust to cope with future outbreaks (Gkiotsalitis and Cats, 2020).

The issue of ventilation has been shown to be important as knowledge of COVID-19 has improved and must also be addressed by public transport operators. Since the virus is now known to spread through aerosols as well as droplets, maintaining airflow inside enclosed areas, while avoiding overcrowding, is important (Morawska and Milton, 2020). Shen et al (2020) describing a series of precautionary measures to prevent the spread of COVID-19 within public transport vehicles highlight the importance of enhanced ventilation noting that mechanical ventilation can be adapted to clean air and that windows should be opened at low speeds or when a vehicle is stopped. This is echoed by Vuorinen et al (2020) who, as a result of detailed simulations of aerosol transmission indoors, emphasise the risk posed by crowded public transport and that operators should pay careful attention to passenger densities and ventilation.

What does this mean for future policy? No government policy can attract unlimited funding and so it is clear that there must be a limit to the support given to public transport when patronage is so low. However, a future that maintains the pandemic's response of lower service levels and lower quality will not only reduce equity but also lead to a downward spiral in public transport demand. Differential pricing of both public transport (and private car traffic), such as the 30% off-peak discount introduced in Melbourne from January 2021 as part of a policy to encourage people to return to the workplace by public transport, can be implemented to stimulate patronage growth. But public transport planners need to be innovative in the way they look forward. Innovative technology could bring the offers of different mobility providers together. Public transport contracts could become 'mobility contracts' forcing public transport operators to think about how to provide the mobility required, using a mixture of vehicle sizes and modes (Hensher, 2017). Vickerman (2021) makes a fundamental point arguing that urban transport and particularly commuting will need to be planned as a whole if public transport systems are to recover.

We will not fix public transport by concentrating only on the supply side. In Australia, where there are less COVID-related restrictions, the travel patterns being exhibited suggest that public transport customers have become both more adaptable and less predictable, probably as a result of the greater flexibility as to where and when they work, which has been supported by the breaking of managerial resistance to WFH (Beck and Hensher, 2020c). As a result, a more personalised transport offer with elements of flexibility, supported by journey planning tools to facilitate COVID-safe travel, for example with information about crowding on public transport vehicles, should be expected to be seen as more attractive. In some locations it may be more efficient to run flexible and demand responsive services instead of conventional fixed route bus services on a larger scale to reflect this new demand.

This study has confirmed the enduring concern over public transport hygiene and crowding and like other studies (e.g. Shibayama et al., 2021) has confirmed this as a major reason for avoiding public transport during COVID-19. Thus, it is imperative that all forms of public transport are supported by clear messaging from Government and operators to build confidence in using and remaining loyal to public transport[99]. Such an approach can reasonably be expected to reduce the level of concern associated with public transport use. As Tirachini (2020) notes, associating public transport indefinitely with the spread of

[99] Such as provided in New South Wales: https://transportnsw.info/covid-19/covid-19-what-you-can-do#accordion-maintain-physical-distancing-content

coronavirus (as many official statements have done) will condemn it to be used only by those who have no choice.

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Appendix N. Paper #10: What does the Quantum of Working from Home do to the Value of Commuting Time used in Transport Appraisal?

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Matthew J. Beck
Camila Balbontin

Abstract

The need to recognise and account for the influence of working from home on commuting activity has never been so real as a result of the COVID-19 pandemic. Given a recognition that WFH activity during the pandemic has reduced the amount of commuting activity compared to pre-COVID-19, the inevitable question is raised as to what this might mean for some of the crucial inputs in the appraisal of transport initiatives. One critical value used in benefit-cost analysis is the value of time which converts time into monetary units in the calculation of user benefits. We are interested in whether reduced commuting activity is associated with higher or lower willing to pay to save time. We investigate this possibility with data from the Greater Sydney Metropolitan Area in late 2020 when working from home was at a high level. The findings of a higher average commuter VoT have major implications for the VoT used in transport appraisal given that time savings are the largest user benefit. We suggest a percentage adjustment required to align with the 'new normal' as currently known.

***Keywords**:* COVID-19, working from home, Australian experience, commuter mode choice, value of time (VoT) distribution, mixed logit, change in VoT during COVID-19

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1 Introduction

As commuters spend more time working from home (WFH), whether by choice or by directive as a consequence of COVID-19, the amount of time and money spent commuting over a week has changed, often quite substantially[100]. Although WFH is not available to all occupations and industries, it has changed to a significant degree since the beginning of the COVID-19 pandemic (in March 2020), and questions are being asked as to whether we will return to pre-COVID-19 levels of commuting activity as we move out of the pandemic (or indeed live with COVID-19 in a vaccinated world), whenever that is. With an increasing number of new strains (notably the UK, South African and Indian mutations), lockdown has occurred in many countries at the beginning of 2021 as a second or third spike or a continuation of the 2020 levels of transmission. Even though the promise of a vaccine has begun to be realised, the rollout will not be instant in many countries and the overall efficacy is still unknown.

Over the last 10 months to the end of 2020, we observed massive reductions in commuting activity which have, in some countries, slowly increased but to a level that is well below the pre-COVID-19 level. For example, in the Greater Sydney Metropolitan Area (GSMA) and South East Queensland (SEQ) in September 2020, we found that close to 50% of the pre-COVID-19 commuting time outlays were 'saved'[101]. On average, each commuter saved $2,949 per annum in the SEQ and $3,546 in the GSMA[102], of which $779 and $906 respectively is out of pocket costs. These are sizeable reductions, and while we might expect this quantum in savings to be less in time as we find more workers returning to their traditional office[103], WFH is likely to continue at significant levels, supported by employers and the preferences of employees (Beck and Hensher 2020, 2020a).

With a reduced outlay of time and money for commuting, an obvious question to ask is what this might mean for the values of travel time used in generalised cost calculations and transport appraisal? With the real possibility of revised time and cost budget constraints defining potentially greater unspent commuting time and money compared with pre-COVID-19 associated with commuting, individuals on average are expected to have additional income and time available for other activities (including non-commuting travel), but also are likely to have a revised view on the sensitivity they have to outlays of travel time and cost for commuting, including which mode to use (see Figure 1 for the GSMA). One possibility is that the budgeted levels associated with tolerance to outlays of commuting time and cost may be revised as the amount of weekly commuting changes. At one extreme we have workers who now WFH all the time and they may now have a preference function (because of the available choice) that is associated with a very high willingness to pay to save travel time, *ceteris paribus*, on the reduced occasion of commuting simply because the trip is no longer so essential but often discretionary[104]. This is an example of a very low level budget threshold of acceptance. In contrast, someone who works from home very little (including not at all), is more likely to get used to a certain higher (in relative terms) threshold level and hence are less sensitive to levels of travel time and/or cost, and thus place a lower value on saving a unit of time. The implication for an average value of time (VoT), weighted or otherwise, by the incidence of the number of weekly days WFH, is that it is likely to change as the incidence of

[100] The focus of this paper is on the commuting trip between an individual's home and a regular work location. We do not include people who travel as part of their work.
[101] Hensher et al. (2021) present the equivalent evidence for late May 2020. All dollars are in $AUD.
[102] Based on the recommended (pre-COVID-19) VoT of each State government
[103] In Australia there is a strong push for only 25% of public servants and 50% of private sector business employees to be in the office at any one time for at least the next year. Almost daily there are media reports of surveys suggesting significant resistance to returning to the traditional office.
[104] There is growing anecdotal evidence that the desire to get out of home and go to work to obtain some much needed social interaction is resulting generally in disappointment as few are in the office at any one time.

WFH is greater, although whether it will be higher or lower on average is unknown; but that regardless of the directional impact, the distribution of the value of time is likely to be non-linear given the skewed distribution of days WFH (Figure 2 for the GSMA), and to vary for example, by income and distance to the regular workplace.

In addition to possible changes in commuting travel budgets, there are a number of additional features of the COVID-19 period that we must consider that have the potential to influence the commuting trip travel time and cost trade-off. Modal switching for the commute (Figure 1) can occur for at least two reasons - a bio security concern in using public transport and ride share, and the desire to use a car because of greater affordability (parking and tolls in particular) due to reduced weekly commuting.

We suggest that a change in VoT could be, in part, due to an added "biosecurity" premium, with the resulting VoT related to minimising travel time on a currently perceived "risky" alternative (Nelson 2021). To account for this biosecurity concern, we have used a 5-point rating variable represented as a dummy variable for high level of concern (defined by the moderate and extreme levels of concern) which has been shown also in Beck et al. (2021) to be highly correlated with crowding where the latter is also related to a health concern. There may also be different mixes of commuters since some occupations have a greater or lesser propensity to be able to WFH and we add these in. Beck and Hensher (2020) show that the main groups that are more likely to WFH are professionals and managers.

The concern over using PT as a proxy for health and crowding is included in the PT modes, and the occupation effects in all modes as interactions with travel time so that they might influence the VoT. The mode switching dummy variables are included in the alternative associated with mode a respondent switches to. We also considered changing residential location or main regular office, but there were so few such changes.

We recognise that we are estimating models at one point in the COVID-19 progression (i.e., late 2020) and that is why we are undertaking regular surveys to continue to see how VoT is moving and hopefully settling to a new level associated with the new or better normal. The VoT estimates presented in this paper are a very relevant positioning set after six months of COVID-19, in September 2020.

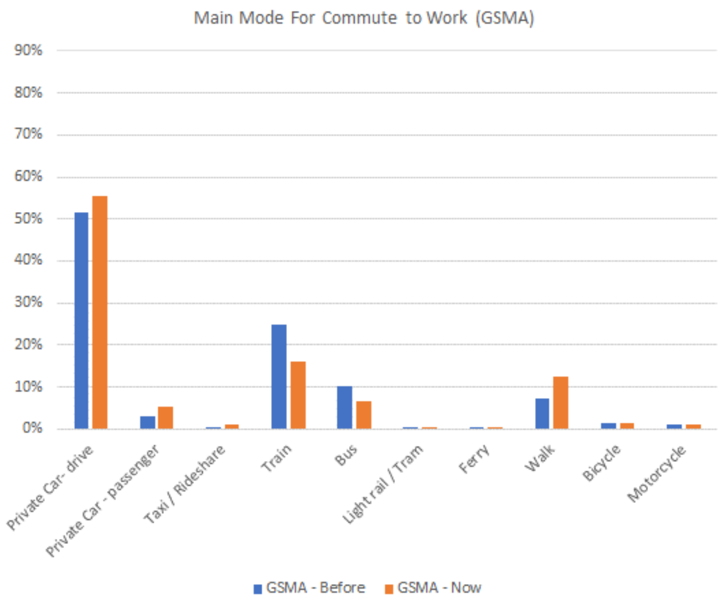

Figure 1: Commuter Mode Changes, pre-COVID-19 and September 2020

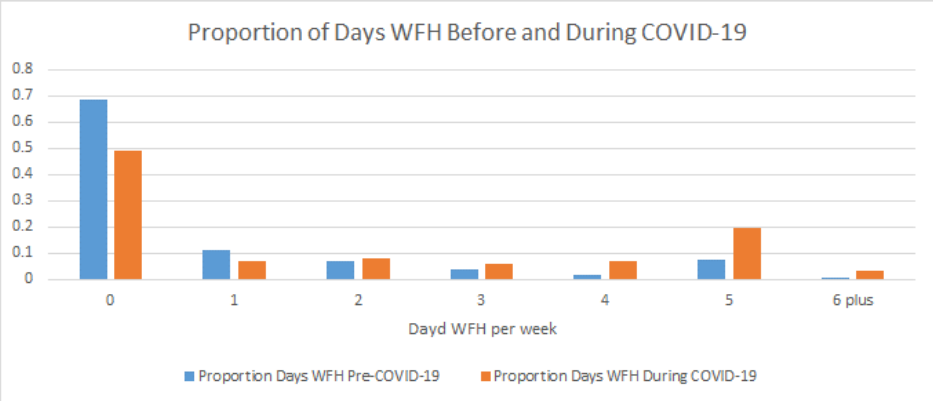

Figure 2: Distribution of Days WFH in 2019 and September 2020

The direction of causality of the joint increase in the number of days WFH and average commuter VoT is not clear. A lower estimate might be because individuals who tend to commute more due to the nature of their work (i.e., essential services), tend to have lower personal incomes and hence represent the population of commuters who generally have a lower mean estimate of VoT. Hensher at al. (2021) ran a simple model of the relationship between the number of days WFH and personal income and obtained a direct elasticity of 0.298 (standard error of 0.0059) for the SEQ and 0.282 (standard error of 0.0055) for the GSMA[105]. What this indicates is that there is a possible relationship between those who commute more and personal income, indicating that a 1 percent increase in income results, ceteris paribus, in a 0.298 (SEQ) or 0.282 (GSMA) percent increase in the number of days WFH. This relationship has to be weighed against a position that reduced commuting activity may mean that an individual is willing to pay more to save time simply because they commute less and the burden of commuting time and cost outlays is reduced. We interact income with travel time in deriving empirical estimates of VoT that are influenced by income.

The objective of this paper is to empirically investigate this matter further and to see to what extent (if at all) the commuter VoT does increase or decrease with increasing days WFH in the GSMA area; and to comment on how the mean estimate compares to recommended (in government guidelines) pre-COVID-19 VoT values in the GSMA. We add an important caveat. By engaging in WFH, individuals have more time *and* income at their disposal to spend on non-commuting activities, so that the marginal utility of both associated with the commute decreases. The ratio between both (i.e. the VoT) may decrease, increase, or remain unchanged, a testable proposition. In our model we allow for the marginal utility of income and tested the amount of time committed to commuting pre-COVID-19 (defined as one-way trip travel time of the proportion of travel time outlaid per week during COVID-19 compared to before) as a good proxy for a time budget threshold which is now relaxed in order to reveal the role of time and budget constraints in this context[106].

[105] We also have evidence that it tends to be those in white collar occupations (managers/professionals/clerical and admin), the first two occupational groups of whom are typically on higher incomes.

[106] A referee suggested that an activity-based model with two alternative schedules (WFH vs. travel to/work in the office) is an appealing way to capture the changes in the good-leisure framework caused by WFH. While we agree we would argue that the approach in this paper provides a way of at least recognising the role that WFH plays is releasing time and money from commuting to be used on other activities (undefined). On these other activities we provide some evidence on the allocation to additional paid and unpaid work as well as increased leisure as well as how the money released might be used.

The paper is organised as follows. In the next section we provide a brief literature review with a focus on the role of various attributes in travel choice and their influence on VoT. We do not review the literature on working from home (or teleworking) given that much of the material has been summarised and commented on in detail in Beck and Hensher (2020, 2020a) and Beck et al. (2020), which list many of the main contributions by different authors. We then provide a descriptive profile of the context within which we are modelling the role that WFH and other considerations, such as income, occupation and concern about using public transport, play in a commuter mode choice model for the GSMA. We then present the way in which we have represented the role of the incidence of working from home in a mixed logit commute mode choice model, followed by the model results for the GSMA and the important behavioural findings. The paper concludes with a summary and suggested ongoing research activity.

2 Brief Literature Review on context setting for key influences on the Value of Commuting Time

The value of travel time is one of the most important behavioural outputs from travel behaviour studies and continues to have a significant role to play in decisions made for transport infrastructure investments and service improvements. As a dominant user benefit, there has accumulated a significant body of literature on both theoretical and empirical approaches to valuing travel time (e.g., Hensher 2011, Jara Diaz 2000, 2007, Batley et al. 2019, Daly and Hess 2020). A key consideration in establishing a theoretically rigorous and behaviourally meaningful VoT is to recognise the role of time and money budget constraints that define the utility space within which individuals assess the role of specific attributes such as travel time and travel cost in making travel choices. Historically, the commuter mode choice model has been the main model used to obtain estimates of VoT, with distributions that account for preference heterogeneity either through random parameters and/or interactions of time and/or cost with contextual characteristics such as personal income, or simpler choice models that retain preference homogeneity and obtain a single mean estimate of VoT.

Although the typical daily commuter trip continues to be the basis of identifying the role of various modal attributes, empirically identified from revealed and stated preference data, it has always, implicitly at least, been assumed that the cycle of repeated commuting activity remains constant and typically at 5 days a week with some small amount of telecommuting (evidentially so small that it is ignored). Furthermore, it has been assumed that there is a well-defined time and money budget allocated to commuting that accommodates a fixed period of time such as a five-day week. Writing out a utility expression subject to these constraints results in the well-known VoT result which has its roots in classic papers such as DeSerpa (1971) with elaborations and refinements by Jara Diaz (2007) and others. The important result is that there exist technical constraints relating to time and goods that establish that the consumption of a given good requires a minimum assignment of time. The formal model resulted in identifying the value of time in a specific activity. Therefore, the value of saving time in a constrained activity is equal to the value of leisure (or work) minus its marginal utility value (presumably negative). For more information see Jara-Diaz (2000, 2007) and Appendix B.

Several studies have addressed the issue of how the VOT changes due to different factors. An important result from Rich and Vandet (2019) of relevance to a setting of major disruption, using the data collected from a Danish national travel survey from 2006 to 2016, is that the VOT changed over time, increasing approximately 10% over the 10-year period, with the global financial crisis (GFC) having a significant impact on the average VOT as well as the differing values for each income group.

There are many studies we can cite that have investigated how VoT varies according to the nature of activities undertaken during the travel experience. For example, Varghese & Jana (2018) in Mumbai show that there was a 26% reduction in VOT for those individuals who perform multi-tasking such as using social media, conversed on the smart phone and played digital games (also shown in Wardman, Chintakayala, & Heywood (2020). Kouwenhoven & de Jong (2018) using stated preference data in the Netherlands context, suggest that people who can spend their time usefully have a lower VOT and having a computer available during the trip increases the probability of travel time being useful. In 2021 it is reasonable to assume that such multi-media capability has already impacted on the VoT regardless of the number of days commuting compared to WFH. Additionally, we might relate this to working from home (Figure 3) where the time not commuting is converted, on average, to greater perceived productivity associated with a new experience, namely WFH (although we have no data in productivity while commuting). Their results also suggest that travellers who said a shorter trip duration is useful or longer trip duration is very inconvenient, have a higher VOT. This might be equivalent to the reduced amount of commuting travel over a week in the growing presence of WFH. What these studies, as examples, indicate is that within the commuting activity, the disutility effects of travel in addition to the opportunity cost of time vary substantially and contribute to a distribution of VoT that results in higher or lower VoT depending on the positive or negative nature of additional activities for a given travel time and travel cost outlay. The overlay of WFH is also suggestive of a definite change in the VoT with fewer weekly commuting trips.

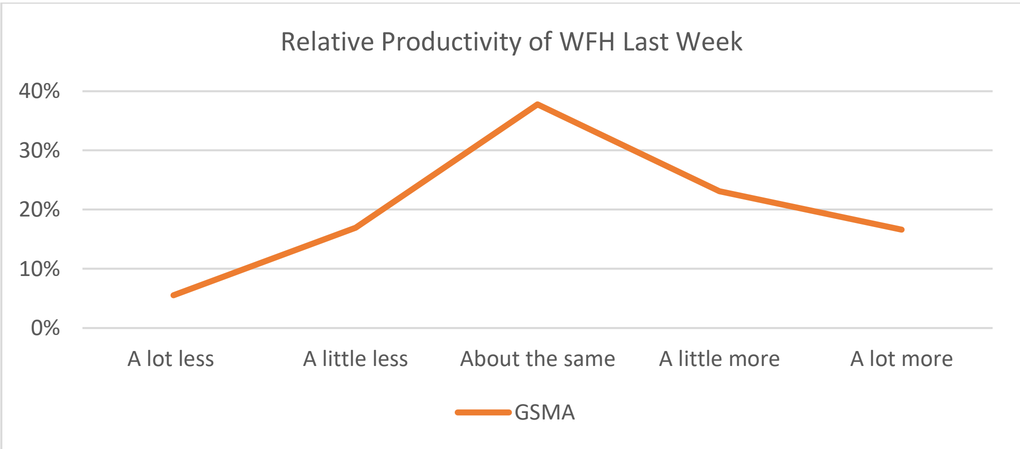

Figure 3: Perceived productivity associated with WFH, September 2020 (Beck et al. 2020)

With the exception of the reference to the GFC as a major external shock, the other effects represented as examples above, are all related to the travel experience and are not reflective necessarily of the role that other significant exogenous shocks have on the commuting experience and, hence, the inferred VoT. Our focus is not on the multi-tasking activities on a commuter trip but on the effect of reduced commuting and greater take up of WFH on the VoT. Working from Home (WFH) is a response, voluntary or forced initially on a significant part of a population with seismic implications for the commuting trip, which has been either totally curtailed or undertaken at a far lesser rate per week than before the COVID-19 pandemic. With many views on what the future may or may not look like as we move out of the COVID-19 period and start to see a 'new normal', one thing is becoming more certain, which is that the quantum of weekly commuting is likely to change substantially with fewer people travelling to a regular workplace on any one day (see Beck and Hensher 2021).

The other literature that had gained a lot of traction and support pre-COVID-19 relates to the stability of travel time budgets for specific activities. Stopher, Ahmed, & Liu (2017), for example, investigated the idea of stability of travel time budgets using GPS data collected for 29 Australian households over a period of eight years. Their results show that there seems to be an average travel time expenditure of around one hour per person per day. There were, however, significant differences in the levels of travel time expenditure, with 55% of the sample having an average within ±15 minutes from the mean. Milakis, Cervero, van Wee, & Maat (2015) investigated the acceptable threshold for commuting travel times using open and closed-ended interview questions on a sample of 30 persons in Berkeley, USA. Their results show that there was a negative satisfaction for zero minutes commute time, which represents telecommuting, and trips of 30 minutes or longer. Respondents said they disliked telecommuting when asked about the hypothetical zero commute time, suggesting that the ideal commute time is around 18 minutes.

As interesting as these results may appear, it is increasingly unlikely that the evidence can be used to inform circumstances that have arisen as a result of the COVID-19 pandemic which is much more severe and global in its impact, changing the whole fabric of society in terms of its view and preferences on travel and WFH. Additionally, it is important to again state that the impact of COVID-19 is not to completely replace the office with WFH, but rather has the aforementioned potential to change the number of commuting trips that would be required in a "new" average week, and thus how a commuter may evaluate those fewer trips that they might make. While it might be too early to claim any sense of a stable predictable 'new normal', we believe that the current circumstance is sufficiently different to the pre-COVID-19 era for regular modal commuting that it is timely, and appropriate, to ask if the mean VoT may be different to what was anticipated and recommended in guidelines back in 2019.

From ancillary questions we have the following evidence of the way in which any change in available time and money due to reduced commuting and increased WFH has been used. 57% of the sample in the GSMA responded yes to the question "Since you started working from home, do you think you are saving money in an average each week, by commuting less (or not at all)?". Also, in response to the question 'In the short-term, what are you doing with the money that you are no longer spending on commuting?', 79% said they save it, with no current plans to spend it on anything; 10% indicated saving for a specific activity such as a holiday, and 11% indicated that they are now spending the money on something else already. On time allocation, in response to a question 'Thinking about working from home and the time you save from not commuting, how much of that time do you spend working versus using it for other activities that do not involve work?', 32 percent on average (33 percent standard deviation) was spent doing additional work that was paid for, 22 percent on average (25 percent standard deviation) was spent doing additional work that was not paid for, and 46 percent on average (standard deviation of 34 percent) was spent on leisure or family activities in the GSMA area[107]. What this suggests is that the reallocation of time and money between work, commuting and leisure as a consequence of increased WFH appears to result in a mix of increased working time and increased leisure time, in lieu of reduced time spent commuting. While we have not been able to find any statistically significant influence of these responses on the VoT associated with commuting (see later model results), they provide informative evidence on how realised changes in time and money spent on commuting is used.

3 Descriptive Overview of the Data used to obtain Revised Estimates of VoT

The data used in this paper is part of a larger study on the impact of working from home on commuting and non-commuting travel activity (see Beck and Hensher 2020, 2020a, and Beck et al. 2020). Full Details of the sample and the overall longitudinal approach is given in Beck

[107] The percentages can be related to average travel times and cost outlays given in Table 2, typically 60 minutes for car and 80 minutes for public transport per day.

and Hensher (2021) in which some respondents are in multiple waves and other respondents are in a single wave, with approximately 50% being workers, where a worker is defined as anyone who was working at least 1 day prior to COVID-19 restrictions. Data was collected in a series of Waves from March 2020 with the current data in Wave 3 collected in September 2020[108]. The online survey company PureProfile was hired to randomly sample respondents and surveys were available across Australia. Quotas were not introduced on those completing the survey, other than ensuring representation from all states and territories. Given the focus on New South Wales and Queensland (as the funding sources), we have a larger sample of over 1,000 interviews per State with the data used in this paper on workers drawn from the Greater Sydney Metropolitan Area (GSMA).[109]

We have used the subset of observations of individuals who had paid work before and during the COVID-19 pandemics and who have a regular place of employment when they commute, since our focus is on gaining an appreciation of the extent to which the preferences of commuters have changed as they have increasingly, to varying degrees, experienced WFH and hence changed the pattern and frequency of commuting to a given work location outside of the home.

The profile of respondents' characteristics as well as the descriptive profile of the alternative's attribute levels are presented in Table 1. For the GSMA (metropolitan area of New South Wales, NSW) we have 409 respondents (after data cleaning), which for the commuter mode choice model is a total of 11,328 observations given that for each respondent we have 7 days of the week and four times of day[110]. The modal choice sets also vary according to the perceived availability of each mode (Table 3). The modal attributes are summarised in Table 2[111]. The main differences in travel times are by bus, ferry and bicycle which are much higher than the other modes.

Table 1: Descriptive profile of respondents - mean (standard deviation)

Variables	**GSMA**
Age	39.18 (12.2)
Average personal annual income (AUD$000)	90.21(60.4)
Number of people in the same house	2.83 (1.3)
Number of cars in your household	1.53 (0.9)
Number of children in household	1.77 (1.0)
Number of modes available	2.92 (1.4)
Proportion who used car as driver to commute prior to COVID-19	0.510
Distance from home to regular workplace location (kms)	22.28 (29.5)
Proportion of sample who are blue collar workers	0.078
Proportion who have a high level of concern number of people in PT	0.575
Occupation professional (1,0)	0.375

[108] Data collection is a continuing activity with another four surveys throughout 2021 and beyond until there is evidence of a stable relationship between travel and WFH.
[109] The GSMA includes Newcastle, Sydney, Central Coast, Illawarra, Nowra-Bomaderry, St Georges Basin- Sanctuary Point, Milton-Ulladulla, and Kangaroo Valley-Southern Highlands.
[110] There are 42 ToD/DoW periods representing 10 modes for each of the four times of day plus now work and WFH. Each DoW is a separate observation which is why we controlled for the potential correlation between observations over 7 days common to each respondent.
[111] The attributes were obtained from modal choice sets obtained from each respondent but were subject to extensive checking using postcode information of home and work location to ensure that reported (i.e. perceived) levels of times and costs (tolls, in-vehicle fuel and fares) etc. were validated with the levels in aggregated networks and other sources such as google travel times. This was a significant task to ensure that what we are using is indeed reliable perceived levels but not levels that we would deem are outliers.

Variables	GSMA
Occupation manager (1,0)	0.176
Occupation sales (1,0)	0.072
Occupation clerical and administration (1,0)	0.236
Occupation community and personal services (1,0)	0.072
Occupation technology (1,0)	0.053
Occupation machine operators (1,0)	0.007
Occupation labourers (1,0)	0,0180
NSW - Wollongong residential location (1,0)	0.097
NSW - Newcastle residential location (1,0)	0.101
NSW – Central Coast residential location (1,0)	0.109
Work located in CBD (1,0) (postcodes = 2000, 2007, 2009 and 2011)	0.245
Number of respondents	**409**

Table 2: Mode attributes - mean (standard deviation) for one-way trips

Variables	GSMA
Travel time car driver (min)	29.73 (28.3)
Travel time car pax (min)	28.48 (23.3)
Travel time taxi/ride share (min)	26.44 (26.5)
Travel time train (min)	37.20 (37.8)
Travel time bus (min)	47.21 (41.7)
Travel time light rail (min)	28.64 (21.1)
Travel time ferry (min)	33.00 (23.7)
Travel time walk (min)	52.71 (38.9)
Travel time bicycle (min)	50.68 (62.6)
Travel time motorcycle (min)	26.50 (20.1)
Fuel car driver (AUD$)	2.61 (3.4)
Fuel car pax (AUD$)	2.48 (2.6)
Fuel motorcycle (AUD$)	2.91 (3.0)
Parking car driver (AUD$)	4.60 (13.7)
Parking car pax (AUD$)	2.49 (11.6)
Parking motorcycle (AUD$)	3.00 (7.1)
Toll car driver (AUD$)	1.46 (4.6)
Toll car pax (AUD$)	0.98 (3.8)
Toll motorcycle (AUD$)	1.38 (3.6)
Waiting time taxi/ride share (min)	10.35 (8.2)
Waiting time train (min)	8.68 (6.5)
Waiting time bus (min)	10.69 (8.0)
Waiting time light rail (min)	6.43 (4.6)
Waiting time ferry (min)	16.10 (12.1)
Egress time taxi/ride share (min)	3.34 (8.2)
Egress time train (min)	13.47 (14.9)
Egress time bus (min)	10.19 (12.9)
Egress time light rail (min)	9.57 (10.7)
Egress time ferry (min)	14.30 (17.2)
Access time taxi/ride share (min)	9.94 (16.5)
Access time train (min)	22.04 (24.7)
Access time bus (min)	21.40 (30.1)
Access time light rail (min)	19.71 (19.0)
Access time ferry (min)	23.10 (12.8)
Ride Share fare ($)	40.54 (69.8)
Train Fare ($)	5.56 (5.2)
Bus Fare ($)	4.40 (3.4)
Light Rail Fare ($)	4.13 (2.7)
Ferry Fare ($)	4.14 (2.4)

Although our focus is on estimating a traditional commuter mode choice model enhanced by measures to assess the influence of the number of weekly days working from home in particular on VoT, we provide in Table 3 the shares of commuting trips by 10 modes, No Work and WFH across seven days of the week for four times of day[112]. As expected, many times of day and days of the 7-day week involve no formal paid work (35.1%); in contrast we see that of the ToD/DoW periods, 26% involved working from home (out of 68.9% who reported were able to WFH), with 38.9% involving a commuting trip to a location outside of the home. This has significant implications on the quantum of commuting activity on any one day of the week and time of day, and if maintained post-COVID-19 is expected to have a massive impact on the performance of the transport network. There has been a greater decline in public transport trips compared to car travel linked to the biosecurity risk, real or otherwise in using public transport, and hence the increased dominance of the car in the commuter modal share.

Table 3: Modal availability and shares in the presence of WFH and No Work for each day of week and time of day

		GSMA area count	GSMA area %
Availability	No Work	409	100.0%
	WFH	282	68.9%
	Car driver	293	71.6%
	Car passenger	141	34.5%
	Taxi/ride share	122	29.8%
	Train	192	46.9%
	Bus	214	52.3%
	Light rail	28	6.8%
	Ferry	10	2.4%
	Walking	105	25.7%
	Bicycle	65	15.9%
	Motorcycle	26	6.4%
Number of respondents			***409***
Choices	No Work	993	35.1%
	WFH	735	26.0%
	Car driver	750	26.5%
	Car passenger	61	2.2%
	Taxi/ride share	7	0.2%
	Train	120	4.2%
	Bus	67	2.4%
	Light rail	11	0.4%
	Ferry	2	0.1%
	Walking	54	1.9%
	Bicycle	16	0.6%
	Motorcycle	16	0.6%
Number of respondents			***409***

Table 4 differs from previous tables in that it summarises the key attributes that we investigated in arriving at the final preferred model used to obtain the overall average VoT and the VoT segments by the number of days over a 7-day period working from home. Specifically, we investigated a number of interactions between travel time, WFH (linear and quadratic), personal income (linear and quadratic), occupation and concern over using public transport, as well as conditioning the one-way trip travel time of the proportion of travel time outlaid per

[112] The times of day are 7am to 8.59am, 9am to 2.59pm, 3pm to 5.59pm and 6pm to 6.69am, which are consistent with the GSMA transport authority strategic models.

week during COVID-19 compared to before. We also investigated interacting income with cost as multiplicative and by division. The final models, presented below, finally settled on interactions between travel time, the quadratic of WFH, the inverse of personal income and a linear interactions of travel time with a dummy variable for managers and professionals, and a dummy variable for high bio-security concern in using public transport.

Table 4: Attribute profiles - mean (standard deviation)

Attribute	Mean (std deviation)
One-way trip travel time (minutes)	36.172 (33.83)
One-way trip travel time * Number days WFH	77.312 (137.50)
One-way trip travel time (min) * Personal income '00,000 ($AUD)	29.898 (8.55)
Number days WFH	1.878 (2.19)
(Number days WFH)^2	8.306 (11.05)
One-way trip travel time * (Number days WFH)^2	342.699 (671.40)
One-way trip travel time (min) *Manager/Professional dummy variable	19.838 (31.06)
One-way trip travel time (min) *High level of concern about public transport dummy variable	0.448 (0.497)
Car/motorcycle cost: fuel + toll + park per one-way trip (AUD$)	7.995 (17.16)
Public transport one-way trip fare (AUD$)	10.944 (17.22)
Commuting weekly travel time pre-COVID (min)	151.805 (194.50)
Commuting weekly travel time post-COVID (min)	129.619 (163.29)
Commuting weekly cost pre-COVID (AUD$)	28.326 (73.28)
Commuting weekly cost post-COVID (AUD$)	22.179 (56.82)
Before - during COVID weekly commuting travel time	22.186 (127.07)
Before - during COVID weekly commuting cost	6.147 (36.29)
One-way trip travel time * TT post-COVID/TT pre-COVID	17.705 (28.65)
Weekly number of days worked post-COVID	4.707 (0.96)
Weekly number of days worked pre-COVID	4.405 (1.24)
Weekly number of days WFH post-COVID	1.878 (2.19)
Weekly number of days WFH pre-COVID	0.738 (1.51)
Number of days WFH/Total worked days post-COVID	0.158 (0.32)
Number of days WFH/Total worked days pre-COVID	0.404 (0.46)

4 Methodology

The mode choice model has 40 alternatives, which represent the mode that the respondent used to go to work and the time of day they left their house (ToD). Each day is separated into four time-of-days (ToDs) used, which are consistent with the GSMA transport authorities' strategic model: AM peak: 7-9 am, Inter-peak: 9 am - 3 pm, PM peak: 3 pm - 6 pm, and Evening: 6 pm - 7 am[113]. The different alternatives and their description are presented in Table 5.

[113] These times of day are the ones used by Transport for NSW and hence we used them in the GSMA model.

Table 5: Alternative description

Alternative	ToD	Mode	Alternative	ToD	Mode
1	**-**	No work	**22**	**2**	Motorcycle
2	**-**	Work from home	**23**	**3**	Car passenger
3	**1**	Car driver	**24**	**3**	Car passenger
4	**1**	Car passenger	**25**	**3**	Taxi/rideshare
5	**1**	Taxi/rideshare	**26**	**3**	Train
6	**1**	Train	**27**	**3**	Bus
7	**1**	Bus	**28**	**3**	Light rail
8	**1**	Light rail	**29**	**3**	Ferry
9	**1**	Ferry	**30**	**3**	Walk
10	**1**	Walk	**31**	**3**	Bicycle
11	**1**	Bicycle	**32**	**3**	Motorcycle
12	**1**	Motorcycle	**33**	**4**	Car driver
13	**2**	Car driver	**34**	**4**	Car passenger
14	**2**	Car passenger	**35**	**4**	Taxi/rideshare
15	**2**	Taxi/rideshare	**36**	**4**	Train
16	**2**	Train	**37**	**4**	Bus
17	**2**	Bus	**38**	**4**	Light rail
18	**2**	Light rail	**39**	**4**	Ferry
19	**2**	Ferry	**40**	**4**	Walk
20	**2**	Walk	**41**	**4**	Bicycle
21	**2**	Bicycle	**42**	**4**	Motorcycle

We added the interaction over all modes between travel time and the combined occupations of management and professional, as well as an interaction between travel time and concern about biosecurity (as a proxy for crowding an health risk) in the four public transport modal alternatives.

The utility functions for the mode choice model are described by two types of alternative specific constants: one that refers to mode *m*, and one that refers to the time-of-day *t*. The utility function for the public transport modes (including rides share) is defined by travel time TT_{Mode_m} as a main effect which is mode-specific[114] and estimated as random to account for preference heterogeneity, and as a mode-generic interaction with the inverse of annual personal income $PInc$[115], the number of days working from home, the latter expressed as a quadratic effect $WFHd$, a dummy variable for managers and professionals *MgrProf*, and a dummy variable representing a high level of concern over using public transport *ConPT*; access time AcT_{Mode_m}; egress time EgT_{Mode_m}; waiting time WT_{Mode_m} and fare $Fare_{Mode_m}$, as shown in equation (1). The parameter estimate β for access, egress and waiting times is generic[116]. The βs represents the estimated parameters associated with the different attributes or characteristics.

[114] This standalone parameter is later considered common between public transport and car, but different to the active modes.
[115] We began by relating income to cost but could not get a statistically significant relationship as either a ratio or a product. By relating income to travel time we are recognising that individuals with varying incomes have different marginal dis-utilities associated with levels of travel time.
[116] They were estimated as specific first and the results suggested that they were not statistically different.

$$\begin{aligned} U^{PT}_{Mode_m,ToD_t} = & ASC_{Mode_m} + ASC_{ToD_t} + (\beta_{TT,Mode_m} + \beta_{TT,PInc} / Pinc + \beta_{TT,WFH} \cdot WFHd^2 \\ & + \beta_{TT,\mathrm{MgrProf}} \cdot Mgr\,\mathrm{Pr}\,of + \beta_{TT.ConPT} \cdot ConPT) \cdot TT_{Mode_m} \\ & + \beta_{Cost,Mode_m} \cdot Fare_{Mode_m} + \beta_{TTAEW} \cdot \left(AcT_{Mode_m} + EgT_{Mode_m} + WT_{Mode_m} \right) \end{aligned} \quad (1)$$

The utility function for the car driver and motorcycle alternatives is described by travel time, by itself as a main effect estimated as random to account for preference heterogeneity and also as an interaction with the inverse of personal income and number of days WFH squared, as in the public transport modes, as well as a dummy variable for managers and professionals; fuel cost $Fuel_{Mode_m}$; parking cost $Park_{Mode_m}$; and toll costs $Toll_{Mode_m}$. Different respondents' socioeconomics were tested in different modes of transport, but in addition the inclusion on occupation and income interacted with WFH), only the number of cars per person in household was statistically significant in the car driver mode (as Z_n). Note that the parameter estimate β for fuel, toll and parking was estimated in the preferred model as generic[117]. For the car passenger alternative, cost was excluded since the evidence supported only the driver incurring that cost.

$$\begin{aligned} U^{Car/moto}_{Mode_m,ToD_t} = & ASC_{Mode_m} + ASC_{ToD_t} + (\beta_{TT,Mode_m} + \beta_{TT,PInc} / Pinc + \beta_{TT,WFH} \cdot WFHd^2 \\ & + \beta_{TT,\mathrm{MgrProf}} \cdot Mgr\,\mathrm{Pr}\,of) \cdot TT_{Mode_m} \\ & + \beta_{Mode_m,Cost} \cdot \left(Fuel_{Mode_m} + Park_{Mode_m} + Toll_{Mode_m} \right) + \sum_n \beta_{Mode_m,n} \cdot Z_n \end{aligned} \quad (2)$$

The quadratic form provides a well-known way of establishing whether there is a non-linear relationship, in our case, between the VoT and the #days WFH. This is of greater interest than simply identifying a relationship between VoT and WFH per se. We also investigated the role that modal switching between pre-COVID-19 and during COVID-19 might play but could not find any statistically significant effects for each and every modal pair. Mackie et al. (2003) suggest that when income is associated with a function for travel time (or trip length) that 'Making further allowance for income variation introduces some complications because of the potential interdependence between income and journey length.' We investigated this before finalising the model form, and found that the partial correlation between personal income and travel time was very low, namely -0.03736.

It is important to note the difference between the mode-specific random parameter associated with travel time, $\beta_{TT,Mode_m}$ and the mode-generic fixed parameter associated with the interaction of travel time and the inverse of income, $\beta_{TT,PInc}$. The first one, $\beta_{TT,Mode_m}$ represents the differences in the value of public transport and car travel time relative to active modes, and it also represents the unobserved preference heterogeneity in the value of public transport and car modes (as this parameter was estimated as random). The second parameter, $\beta_{TT,PInc}$, represents observed heterogeneity in the value of travel time (across all modes) explained by the income level of the respondent.

5 Results

The final mixed logit model is summarised in Table 6. It was selected after extensive consideration of alternative preference expressions for a one-way single trip travel time and travel cost, personal income, the number of days per week WFH, occupation and bio-security concern in using public transport, with random and fixed parameters. We also conditioned travel time on the change in the proportion of weekly travel time outlay before and during

[117] They were estimated as specific first and the results suggested that they were not statistically different.

COVID-19, as well as the absolute difference, but they did not improve on the overall model performance and we suspect this is because the presence of the number of days WFH provided a better representation of the change in weekly travel time associated with the period during COVID-19. Also, we suspect that any time budgets pre-COVID-19 have been greater than during COVID-19 or at least not reached, and hence the use of the number of days WFH is a very good proxy for the impact of allocations of time and cost to commuting.

Overall, the model is statistically very good, with an impressive Pseudo-R^2 of 0.5 with constants and 0.36 excluding constants, with all parameter estimates, excluding the alternative-specific constants, being statistically significant at 90% or better. The random parameters were estimated as a constrained normal distribution, setting the standard deviation of travel time to 1.28 of the mean and the standard deviation of cost to 0.9 of the mean[118]. This is an appropriate way to identify the extent of preference heterogeneity which is often poorly captured by unconstrained distributions. 1,000 intelligent (Halton) draws were used and observations that are common within each respondent were accounted for using a panel form of the likelihood expression.

The majority of the parameter estimates are generic across the alternatives where that attribute is included. Initially we investigated mode-specific parameter estimates and found that the improved statistical fit and significance of particular parameter estimates gravitated to a generic specification, notably in-vehicle travel time and cost. While this is not uncommon in many models, this may be reflective of the way in which the commuter trips are viewed during COVID-19, where the focus is more on whether to commute or not instead of WFH, and hence a downgrade of the differences in modal choice (with the exception of bio-security risk) within this setting. Some attributes such as access, egress and wait time are associated with subsets of modes such as public transport and are treated as generic and aggregated across all available public transport modes. The marginal disutility is lower than the in-vehicle parameter; however, the travel variable has a generic parameter across car and public transport. A possible explanation is linked to the significant drop in use of public transport (reduced to less than 50% of the pre-COVID-19 levels) and hence there is less sensitivity to these travel time components. The inclusion of walking and bicycling is important during COVID-19 since these modes have grown in popularity as the main commuting mode, and hence have a renewed role in the overall estimate of the commuter VoT.

In addition to socioeconomics influence of personal income, we identified the number of cars per adult in a household to be positive and statistically significant in the car driver utility expression; suggesting, as expected, that as the number of cars per adult in a household increases, the probability of commuting by car as a driver increases. The usual mode-specific constants are included, but we have also added in time-of-day of trip commencement constants for three of the four times of day. All other influences being held constant, we see that the contribution to the overall marginal (dis)utility of an alternative is greatest during the peak period compared to the inter-peak and the evening; hence there is a time of day deflation effect partially offsetting the marginal disutility contribution of travel time and cost for trips undertaken during the peaks compared to other times of day.

It is important to also point out that we have modelled a seven-day week in contrast to the five-day week, since we know from our surveys that an increasing number of workers chose

[118] Extensive estimation was undertaken to ensure that the number of draws and constraints on the normal distribution provided very stable estimates under repeated draws. We also undertook analysis with constrained and unconstrained triangular distributions and in willing to pay space and found similar results.

to WFH on the weekend which prior to COVID-19 would have occurred at the office during the 5-day week, consistent with an increasing flexibility in work. Thus, any analysis of the relationship between commuting and WFH must include all seven days, recognising this greater flexibility that is available when working from home. Separately, although our focus is not on demand predictions, the use of a typical daily trip prediction expanded up to a week, month, or any period must be qualified since we no longer can talk about a simple number of average weekly trips under the now observed distribution of the number of days WFH.

Table 6: Mixed logit model parameter estimates

Parameters	Acronym	Alternatives	Mean (t value)
ASC car driver/motorcycle (1,0)	ASC_CarMoto	1, 10, 11, 20, 21, 30, 31, 40	2.963 (4.40)
ASC car passenger (1,0)	ASC_CarP	2, 11, 22, 32	0.865 (1.68)
ASC taxi/ridesharing (1,0)	ASC_Taxi	3, 13, 23, 33	-0.913 (1.11)
ASC public transport (1,0)	ASC_PT	4-7, 14-17, 24-27, 34-37	1.418 (2.07)
ASC active modes (1,0)	ASC_Act	8, 9, 18, 19, 28, 29, 38, 39	0.792 (1.22)
ASC ToD 1 and 3 (AM and PM peak) (1,0)	ASC_T13	1-10, 21-30	0.578 (6.01)
ASC ToD 4 (Evening after 6pm) (1.0)	ASC_T4	31-40	0.375 (3.39)
Car driver - Number of cars per adult in household	NCar_CarD	1, 11, 21, 31	0.492(3.75)
Travel time (minutes) all modes except active - *mean*	TT_CarPT	1-7, 10-17, 20-27, 30-37, 40	-0.016 (2.04)
- *standard deviation*			0.020 (2.04
Interaction with inverse of personal income '00,000 ($AUD)	TT/PInc	1-7, 10-17, 20-27, 30-37, 40	0.007 (3.09)
Interaction with number days WFH squared	TT_WFH^2	1-7, 10-17, 20-27, 30-37, 40	-0.007 (1.97)
Interaction with Managerial & Professional occupation (1,0)	TT_MgrProf	1-7, 10-17, 20-27, 30-37, 40	0.016 (2.06)
Interaction with High level of concern about Public Transport	TT_ConsPT	4-7, 14-17, 24-27, 34-37	-0.013 (-2.12)
Travel time walking (minutes)	TT_Walk	8, 18, 28, 38	-0.035 (3.24)
Travel time bicycle (minutes)	TT_Bike	9, 19, 29, 39	-0.073 (1.97)
Cost ($) all modes except car pax and active - *mean*	Cost_CarPT	1, 3-7, 10, 11, 13-17, 20, 21, 13-27, 30, 31, 33-37, 40	-0.063 (3.18)
- *standard deviation*			0.063(3.18)
Access + egress + waiting time taxi/PT modes (minutes)	TTAEW	3-7, 13-17, 23-27, 33-37	-0.008 (1.98)
Number of parameters estimated			15
Sample size			831
Log Likelihood at convergence			- 1,517.68
Log likelihood at zero			- 3,065.46
Log likelihood at constants only			-2,355.31
McFadden Pseudo R squared (without constants)			0.51 (0.36)
AIC/n			3.70

The particular focus of this paper is on the VoT. The formula extracted from the estimated model is given in equation (3) expressed in $/person hour, with *rna* the constrained normal distribution and $sd\beta$ the standard deviation beta profile for a random parameter, with the other notation as before. The form of VoT is obtained as the ratio of the marginal disutility of travel time to travel cost. The Marginal (dis) utility of WFH is 2* $\beta_{TT,WFH} \cdot WFHd$ (the derivative of travel time with respect to WFDd). The same logic applies to personal income.

$$VoT = 60 * \frac{\left(\begin{array}{l} ((\beta_{TT} + rna \cdot sd\beta_{TT}) + 2 \cdot \beta_{TT,WFH} \cdot WFHd + \beta_{TT,PInc} \cdot \left[1/(PInc)^2 \right] \\ + \beta_{TT,\text{MgrProf}} \cdot Mgr\,\text{Pr}\,of + \beta_{TT.ConsPT} \cdot ConsPT)) \end{array} \right)}{\left(\beta_{Cost} + rna \cdot sd\beta_{Cost} \right)} \quad (3)$$

The VoT expression is the mean over the joint distribution of the random parameters in the utility specification as shown in Table 6, with the random coefficients being independently distributed. Since there are random coefficients appearing in both the numerator and denominator of equation 3, the expression is an approximation for the true mean. The key findings are presented in Table 7 for each segment of days WFH as well as a weighted average across the number of days WFH. The sign of the relationship between WFH and VoT is clear: the higher the higher (positive) VoT is proven empirically by the parameter TT_WFH2, which has just passed the threshold of significance. The statistically significant sign for the interaction between one-way trip travel time and the square of #days WFH suggests that, ceteris paribus, the more days someone works from home, the greater the marginal disutility of a commuting trip's travel time and this changes as the number of days increases and the positive sign for the interaction between travel time and personal income, the latter divided into travel time, suggests that as personal income increases, ceteris paribus, the lower the marginal utility effect which results in a smaller reduction in the overall marginal disutility of travel time.

Holding travel time constant, the positive parameter on professional and managerial occupation suggests a reduced marginal utility of travel time, which may seem surprising given that these occupations typically have higher incomes; however, it is the impact of both the income and WFH interactions with travel time and the occupation dummy variable that contribute to the resulting VoT. We also see a negative parameter for concern over using public transport suggesting, ceteris paribus, contributing to a lower VoT. The sign of the latter is interesting since it is far from obvious as to what direction that influence could have taken. However the inclusion vs exclusion of the occupation dummy variable and concern about public transport did not noticeably influence the mean VoT across all days of week WFH. When excluding these two interactions, the overall mean estimate is $25.15 per person hour compared to $25.53 per person hour. Hence, as the return to public transport slowly increases (being at 85% in Sydney in March 2021), as well as some switch back to public transport away from the car, we do not expect this to result in a noticeable change in the mean VoT as long as the distribution of days WFH remain.

The overall mean estimate for the VoT is $25.53 per person hour[119] with a distribution from a low mean estimate of $20.39 for individuals who do not work from home at all (i.e., commute 5-7 days a week), to a high mean estimate of $36.95 per person hour for individuals who WFH five to seven days a week but still might commute a small amount (Table 7 and Figure 4[120]). Hence, the more days someone works from home in a week, *ceteris paribus*, the more they value a unit of commuting travel time. This suggests that our initial hypothesis appears to be borne out by the empirical evidence; namely, that reduced weekly commuting activity means that an individual is willing to pay more to save time on a single trip simply because they commute less and hence have more travel budget to spend to maximise the utility of commuting, as well as being less sensitive to travel outlays including delays (i.e., a higher threshold). All else being equal, if the same total travel budget is now being allocated over a reduced number of trips, the willingness to pay per trip would increase.

[119] This overall the VoT of $25.53 per person hour at the 95% confidence interval varies from $9.04 to $41.77 per person hour given a standard error of $8.45.

[120] The standard errors of the estimates and the confidence intervals were obtained using the Delta method (see Hensher et al. 2015, Chapter 7.4, pp340-351). This is an appropriate method when interest is in variances of function and willingness to pay.

With an estimate of VoT obtained during COVID-19, the logical next issue is to ask whether this is different to the mean estimates used and/or recommended by government planning agencies before COVID-19. In the Australian context for the GSMA, Transport for NSW appraisal guidelines recommend $17.72 for the value of travel time savings per person hour (TfNSW 2020, page 10), which is based on very little working from home (less than 4%) and hence the appropriate comparator VoT is for zero days WFH, or $20.39. Our mean estimate differs from the TfNSW recommended value, that appears to be an update based on an assumption that private travel time is valued at 40 per cent of the seasonally adjusted full time Average Weekly Earnings (AWE) for Australia, assuming a 38-hour working week, and assumed to be applicable for the private car, motorcycle, bicycle, walking and public transport for commuting and recreational trip purposes. No distinction was made between congested and non-congested travel time conditions in terms of parameter estimates, which is also the situation during COVID-19, although it is clear that traffic congestion on the roads overall was lower at the time of the survey. Importantly, this government recommended estimate includes non-commuting trips and hence a commuting specific VoT is expected to be greater than this recommended value, with the $20.39/person hour being quite reasonable.

To obtain a pre-COVID-19 estimate, we have to make a number of assumptions. In particular we need to use the distribution of days WFH in 2019 from the same sample (shown in Table 7) and also hold personal income and other socio-economic contextual variables fixed at the current level. Importantly we are using a 7-day week and not a 5-day week and hence the somewhat higher incidence of WFH. We also assume that the preference for a unit of travel time and cost only varies between the two periods due to the changing mix of incidence of commuting and WFH.[121] Given these assumptions, $22.69 per person hour seems eminently reasonable for the pre-COVID-19 reference value. With a mean VoT of $25.53 per person hour during COVID-19, when we weight the mean estimates for each of the number of days WFH by the incidence of such days pre- and during COVID-19, it is 12.55% higher than the pre-COVID-19 estimate.[122]

This evidence suggests that the use of pre-COVID-19 mean estimates of VoT must be questioned as being an under-estimate of what commuters are, on average, willing to pay to save time when they are increasingly relating the utility of the commuting trip to the opportunity to work from home. What is especially pleasing is that the evidence from a model in which we did not interact travel time with the number of days working from home for commuting modal alternatives, but included alternatives for WFH and No Work, produces a mean estimate of VoT of $26.02 per person hour with a range at the 95% confidence interval of $9.17 to $42.85 (Hensher et al. 2021a). We can be very confident that during COVID-19 and beyond, if WFH is maintained to some extent at a level greater than pre-COVID-19, the mean estimate of the commuting VoT is likely to be higher than before COVID-19.

[121] The distribution of travel times and costs pre- and during COVID-19 are very similar for the majority of the sample, and while the mean travel time and cost was higher pre-COVID-19 (see Table 4), the majority of the sample had levels of time and cost during COVID-19 that were contained in the greater part of the pre-COVID-19 distribution (See Appendix A).
[122] Wages grew 1.4% over the year to September quarter 2020 (https://www.abs.gov.au/statistics/economy/price-indexes-and-inflation/wage-price-index-australia/latest-release), but inflation was 0.7% (https://www.abs.gov.au/statistics/economy/price-indexes-and-inflation/consumer-price-index-australia/sep-2020); hence a minimal difference could reasonably be expected at the individual level.

Table 7: Mean Estimates of VoT Overall and #Days WFH

	Proportion Days WFH		VoT ($/person hour) Mean (lower and upper bounds)
# Days WFH	Pre-COVID-19	During COVID-19	During COVID-19
0	0.6844	0.4899	20.39 (7.3-39.2)
1	0.113	0.0693	23.15 (8.4-40.1)
2	0.0684	0.0829	25.91 (9.1-40.9)
3	0.039	0.06	28.67 (9.5-41.5)
4	0.0163	0.0714	31.4 (10.2-42.2)
5	0.0729	0.1954	34.19 (10.5-43.6)
6 plus	0.006	0.0311	36.95 (12.2-46.9)

Weighted average	**VoT ($/person hour)**
Pre-COVID-19	22.69
During COVID-19	25.53
Percent increase	*12.55*

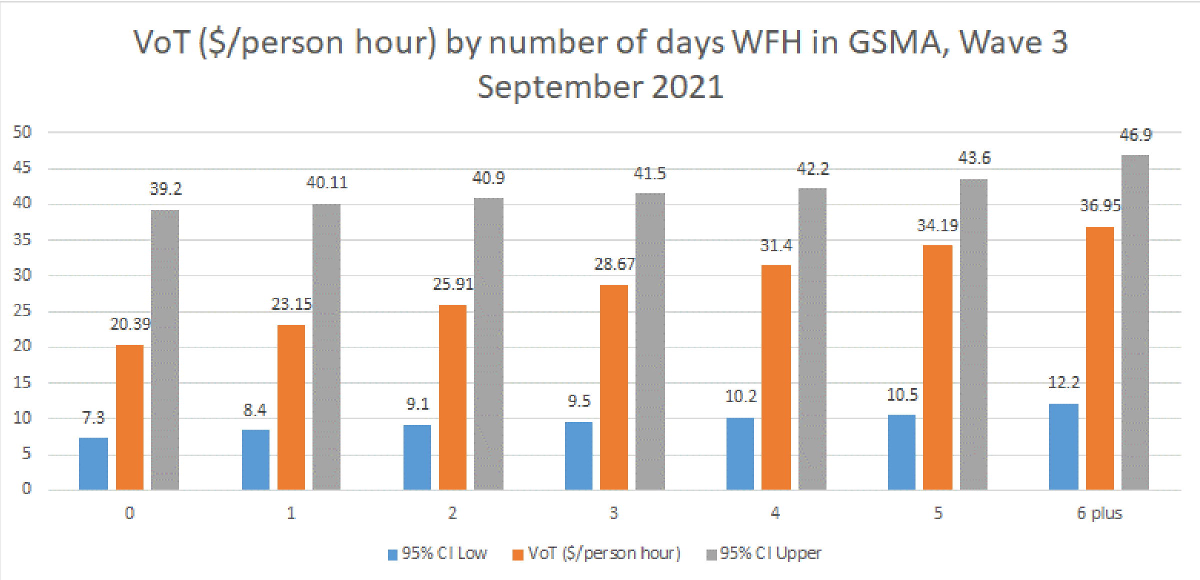

Figure 4: Distribution of the VoT for Days WFH, with upper and lower limits of 95% confidence interval

6 Conclusions

This paper has investigated how the value of time might change during the COVID-19 pandemic when there is a sudden and significant shock resulting in a noticeable reduction in the amount of commuting activity accompanied by a sizeable increase in working from home. Regardless of whether the incidence of working from home will subside to some extent or completely post COVID-19, whenever that is likely to be, we need to assess and reassure ourselves that key economic parameters still have numerical credibility.

With travel time being the most influential attribute in the identification of user benefits in transport appraisal, it is beholden on us to establish the case for maintaining or changing the mean estimates of the value of time (in $/person hour) in order to ensure that we are better informed on its role in the future under what many have described as a 'new normal' without a return to the patterns of past preferences and behaviour.

This paper was motivated by the desire to investigate the possibility of a revision in the VoT. We began by promoting a view that the mean VoT may be different (higher or lower) than prior to COVID-19, for a number of reasons including the change in the incidence of commuting as WFH increased over a week, as well as an accompanying revision of the way in which travel time and travel cost, in particular, are assessed under a revised set of preferences now that much of commuting activity can be avoided (including the bio-security risk of using public transport), changing the view of time and money budget thresholds and the marginal value of a unit of travel time when there is less time and cost outlaid over a week. Theory suggests that constraints on the goods-leisure trade off will change dramatically, and indeed this appears to be the case.

The most important finding from this study is that not only does the mean estimate of the VoT appear to be higher by 12.55% compared to pre-COVID-19, but that the mean estimate is higher for individuals who opt for a higher number of days WFH, and hence reducing the impost of the commute. Individuals appear to be willing to pay more to save a unit of commuting travel time when they undertake less frequent trips. The logic is very plausible and aligns with evidence in other contexts that less frequent trips for a given a trip purpose, tend to have a greater willingness to pay for a specific level of service. We also found in Hensher et al. (2021a) that individuals who live further from their normal workplace and, hence, have a longer commuter trip, also tend to work from home more days a week, and by evidence have a higher VoT. A 12.55% increase has huge implications on the economic benefits of transport initiatives, and for many large roads and public transport infrastructure projects where commuting activity is hundreds of millions of hours per annum, the dollar value of increased user benefits will be significant, and likely change the prioritisation of investments where the evidence of benefit-cost analysis is used in decision making.

Like any research effort there are always caveats. After extensive modelling in this paper and in Hensher et al. (2021), additional segments to account for occupation and industry (beyond the important distinction for managers and professionals) will be of interest although we doubt this will influence the overall message, given what we have found to date. It will, however, enable practitioners to further adjust the evidence to allow for this additional composition of the working population since we know that many occupations and industries have varying degrees of capability to be able to WFH given the essential nature of many jobs that require a face-to-face presence. We have focussed on commuting (between home a regular office location), and in other research we have recognised that reduced commuting activity associated with increased WFH results in some amount of increased non-commuting activity. In ongoing research, we are investigating the implications of this change on the VoT of non-commuting activity, accounting for the changing spatial context in which many of these trips are now taking place, especially in a more local setting closer to home. In addition, it will be interesting to investigate further the extent to which direction causality might lead to antagonistic interpretations of what will happen if WFH becomes more prevalent in society. Specifically (1) WFH influences VoT will cause the VoT to *increase* at the margin, because more WFH makes people value travel time higher (more negatively). (2) WFH influenced by VoT will cause the VoT to *decrease* at the margin, because the share of travellers with low WFH suggest a low Value of leisure time will increase.

Finally, we acknowledge that behaviour in the post-COVID-19 (or more likely referred to as 'living with COVID-19') world is currently unknown. However, we do know that many people have adopted WFH and there are clear signals that WFH will continue to a greater extent in the future than before. The impacts of this for ongoing research are two-fold. Firstly, transport agencies should continue to monitor how values of time have changed and/or continue to change during COVID-19 to provide better insight for future disruption, and equally this research should be ongoing into the long-term as we do not yet know if the budgetary allocation of time or money as it pertains to commuting will remain the same into the long-term or be reallocated to other expenditure, changing the constraints and thus the calculus once more.

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Appendix. Kernel density estimate for travel time and cost pre and post-COVID-19.

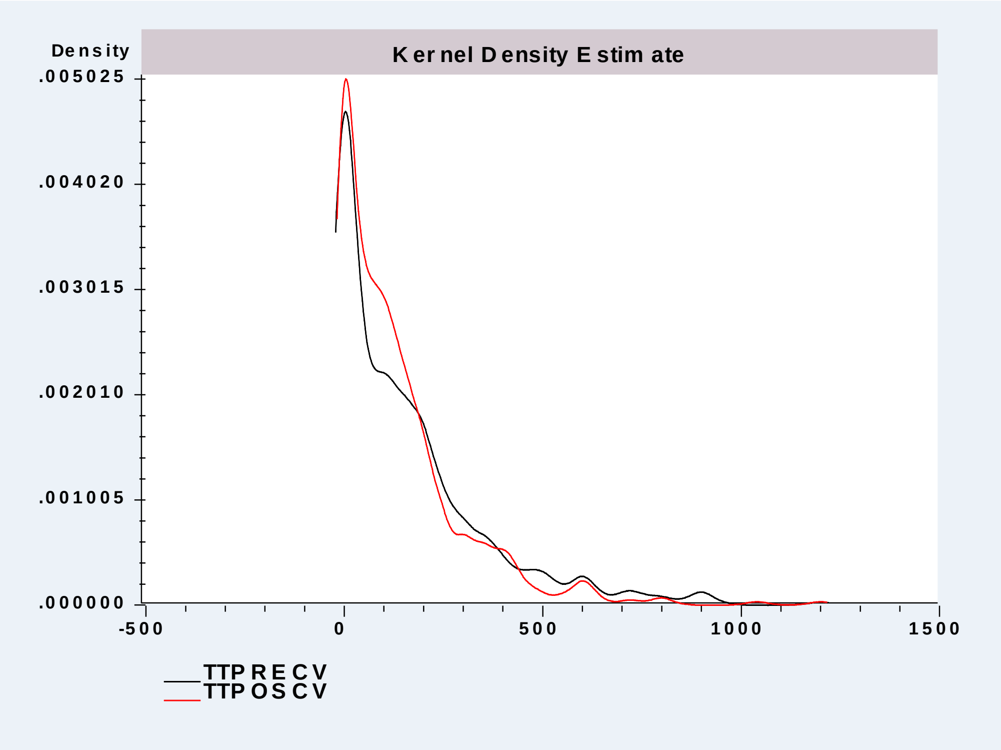

Figure A1: Travel time pre-COVID-19 (TTPRECV) and during COVID-19 (TTPOSCV)

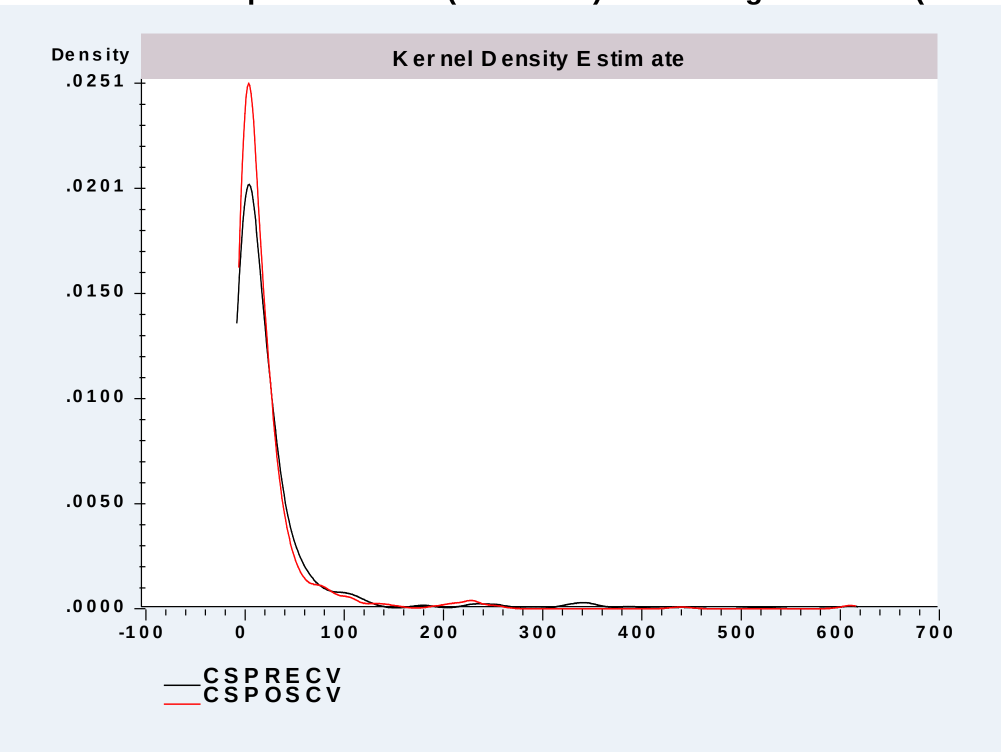

Figure A2: Travel cost pre-COVID-19 (CSPRECV) and during COVID-19 (CSPOSCV)

Appendix. Recognising the impact of constraints under a growing incidence of WFH and reduced commuting activity per time period.

Consider a regular commuting activity involving 10 one-way trips each week, which requires an allocation of time and money. An individual will choose the modal alternative that provides the greatest amount of utility or satisfaction, given the individual's preference for mixtures of travel time and cost in line with the time and money budget that have made available for consumption in the commuting activity. With reduced commuting activity due to increased time spent working from home, we can expect a revision of the binding nature of the time and money constraints that will, in turn, influence the value of time for such activity. This context can be embedded within the theory of the allocation and valuation of travel time, under which an individual consumes time and goods.

The realisation that time is a scarce resource which affects the demand for market goods and services, just like the allocation of scarce money resources, suggests that time is an important input in consumption activities. It is also a factor in production activity (i.e., work). The use of time in 'non-productive' activities thus involves an opportunity cost that must be valued. Theories of time allocation form a natural framework within which to derive a theoretical measure of VoT. Key ideas are presented below with more detail in many sources, especially contributions in more recent times by Jara Diaz (1998, 2000, 2007) and Jara Diaz and Candia (2020).

Time can be viewed as a commodity because it can generate utility directly to the individual when 'consumed' in specific activities. But at the same time, it also acts as a *means for the consumption* of market goods and services, just as money is a means for the purchasing (and hence, consumption) of these goods and services. In its role as a commodity, time in a specific activity *i* is not the same commodity as time in another activity *j*. Consider the following model in (A1) after DeSerpa (1971). The individual's utility function can be expressed as:

$$U = U\left(x_1,\ T_1;\ x_2,\ T_2;\ ...;\ x_n,\ T_n\right) \qquad \text{(A1)}$$

where $\{T_1, ..., T_n\}$ is the time spent in activities 1 to *n*, and $\{x_1, ..., x_n\}$ is market goods and services consumed jointly with time in the *n* activities. 'Commodities' denote market goods and/or services and/or time inputs into activities, the latter defined in terms of inputs rather than 'output'. In its role as a means for the consumption of goods and services x_i's, time is subject to a resource constraint of T (or time budget):

$$\sum_{i=1}^{n} T_i \le T \qquad \text{(A2)}$$

Similarly, the means for purchasing the x_i's, at price p_i's, are also subjected to a resource constraint of M (or monetary budget):

$$\sum_{i=1}^{n} p_i \cdot x_i \le M \qquad \text{(A3)}$$

Time consumption in many activities a_i is not entirely a matter of an individual's own free will. In addition to the time-resource constraint (A2), there are time consumption constraints:

$$T_i \ge a_i \cdot x_i;\ i = 1, ..., n \qquad \text{(A4)}$$

These constraints include technological and institutional constraints. Examples of technological constraints are the available set of transport modes that have limits on the combinations of travel times and costs that can be offered. An example of an institutional constraint is the legal speed limit. The application of microeconomic theory recognises these limits imposed on a solution to the value of transferring time (Truong and Hensher 1985).

This model has the following characteristics. The level of utility is dependent on the consumption of all goods and on the time assigned to all activities including work, unlike Becker (1965; see also Evans 1972). There are time and income constraints, and the latter includes a variable work time that generates income through a wage rate; there are exogenous minimum time restrictions for travel and fixed work, and endogenous ones for all the other activities, that depend on goods consumption.

To establish the trade-off between time and price, we have to define the consumer's optimisation problem as that of maximising utility subject to the time and money resource constraints and the time consumption limit, as follows:

$$L = U\left(\underset{\sim}{X}, T\right) + \mu\left(\mathrm{T}^0 - \sum_i \mathrm{T_i}\right) + \lambda\left(M - \sum_i \mathrm{p_i}\cdot\mathrm{x_i}\right) + \sum_i \kappa_i \cdot\left(\mathrm{T_i} \geq \mathrm{a_i}\cdot\mathrm{x_i}\right) \qquad \text{(A5)}$$

We use the Lagrange Multiplier (L) to specify the objective function and the set of three budget and time consumption constraints. The theoretical interpretation of the Lagrange multipliers within the framework of non-linear programming, establishes that they correspond to the variation of the objective function evaluated at the optimum due to a marginal relaxation of the corresponding restriction. This way, the multiplier μ associated with the time restriction is the marginal utility of time representing by how much utility would increase if individual time available was increased by one unit. Equivalently, λ is the marginal utility of income and κ_i is the marginal utility of saving time in the i^{th} activity.

The first order conditions for maximum utility are required to establish the marginal rate of substitution between time and money, noting that $\partial U/\partial z$ is the marginal utility of attribute z:

$$\begin{aligned} &\frac{\partial U}{\partial X_t} = \lambda \cdot \mathrm{p_i} + \kappa_\mathrm{i} \cdot \mathrm{a_i} \\ &\frac{\partial \mathrm{U}}{\partial \mathrm{T_i}} = \mu - \kappa_i \\ &\frac{\partial \mathrm{U}}{\partial \mathrm{M}} = \lambda \\ &\kappa_\mathrm{i} \cdot \left(\mathrm{T_i} - \mathrm{a_i} \cdot \mathrm{x_i}\right) = 0 \end{aligned} \qquad \text{(A6)}$$

To derive the value of travel time we divide the second condition by the third condition:

$$\frac{\partial U/\partial \mathrm{T_i}}{\partial U/\partial \mathrm{M}} = \frac{\mu - \kappa_\mathrm{i}}{\lambda} \qquad \text{(A7)}$$

From the interpretation of the multipliers, three concepts of time value were defined by DeSerpa (1971): the value of time as a resource for the individual ($\boldsymbol{\mu/\lambda}$); the value of saving time in the i^{th} activity (κ_i /$\boldsymbol{\lambda}$); and the value of assigning time to the i^{th} activity

($(\partial U/\partial T_i)/\lambda$). The last two definitions are activity specific while the first is not. Also, the value of assigning time to an activity is the money value of the direct marginal utility. Beyond these definitions, one can add the marginal price of assigning time to an activity which, in the case of work, would correspond to minus the marginal wage (Gronau 1986). The value of saving time in the ith activity will be zero if the individual voluntarily assigns to it more time than the required minimum (which is how DeSerpa defined a leisure activity)[123]. It will be positive otherwise. This means that the individual will be willing to pay to reduce the time assigned to a certain activity only if he is constrained to assign more time to it than desired.

To establish a relation between the different concepts of time value, the first order conditions in (A6) can be manipulated to obtain a result originally established by Oort (1969).

$$\frac{\partial U/\partial T_W}{\lambda} = \frac{\partial U/\partial T_i}{\lambda} \qquad \text{(A8)}$$

This expression shows that the value of saving time in the i^{th} activity is equal to the value of doing something else minus the value of assigning time to that particular activity because it is being reduced. Equation (A8) improves over Becker (1965), for whom time was valued at the wage rate (W), and over Johnson (1966), for whom the value of time was μ/λ. For those activities that are assigned more time than the minimum required (κ_i = 0, a leisure activity), the value of assigning time ($\partial U/\partial T_i$)/λ is equal to μ/λ for all of them. This is the reason why DeSerpa called it the value of leisure. On the other hand, μ/λ is also equal to the total value of work, which has two components: the money reward (the wage rate) and the value of its marginal utility. Therefore, the value of saving time in a constrained activity is equal to the value of leisure (or work) minus its marginal utility value (presumably negative). Jara-Diaz (2000, 2008) presents the details.

If we consider the particular case of travel, it can be shown that the value of saving travel time, κ_i/λ, corresponds exactly to the ratio between the marginal utilities of time and cost that are estimated as part of the modal utility in a discrete travel choice model. This has been shown in different forms by various authors (Bates 1987, after Truong and Hensher 1985, Jara-Díaz 1998, 2008). Although empirical values for K_i/λ can be estimated using the discrete travel choice framework (as in the current paper), no methodology has been developed to estimate all of the different elements in equation (A8) from a model system. The best antecedent is Truong and Hensher's (1985) effort at obtaining μ/λ as part of the coefficient of travel time in mode choice models (which they claim was μ/λ- K_i/λ), which prompted Bates' (1987) identification of that coefficient as κ_i/λ only.

There is nothing in this theoretical framework that should differ with reduced commuting activity other than the empirical nature of the degree to which particular constraints are

[123] The value of *saving* time in an activity is the willingness to pay to reduce that activity. If the individual assigns voluntarily more time than the minimum required, she is not willing to pay to reduce it precisely because the value of the marginal utility is positive (what De Serpa called the value of time assigned to the activity). See (2.42) in Jara Diaz (2007) where the value of saving time is the expression on the left hand side, and the value of time assigned is the value of the marginal utility (far right term). Thus, if the individual assigns more time than needed, the multiplier κ_j is zero and the value of the marginal utility is μ/λ (positive and equal for all activities whose κ_j is nil). Discussions with Sergio Jara Diaz are appreciated.

binding and the value of κ_i/λ might change. Working from home is simply a reallocation of time between commuting and other activities of which the main ones are increased working time and leisure time. Hence, we might expect a different empirical value of travel time savings, due in large measure, we hypothesise, to the availability of additional time to reallocate to non-commuting activities with T_i and x_i, i= commuting, reduced per period of time. In general, if there is a change in U from reallocation of commuting time to another activity$_i$: $(\mu_{commute}/\lambda) > \lambda_i/\lambda$ and the value of time saving on commuting is expected to increase. If the change in U is from a reallocation of the commuting budget to another spend$_i$: $(\kappa_{commute}/\lambda) > \kappa_i$, then value of time savings for the commute trip is expected to decrease. If the value of time is constant, we can expect a proportional change in μ and κ_i such that value of time stays in equilibrium. The final result is empirical.

Appendix O. Paper #11: Working from Home in Australia in 2020: Positives, Negatives and the Potential for Future Benefits to Transport and Society

Matthew J. Beck
David A. Hensher

Abstract

The year 2020 has been marked by the most extraordinary event we have witnessed since World War II. While other health threats and geographical disasters have occurred, none have been on the global scale of COVID-19. Although many countries have experienced more than one wave of the pandemic throughout 2020, Australia has been largely able to contain the impact of the virus. While there are many reasons for this, a key component of reducing transmission has been restrictions on movement, and the widespread adoption of working from home (WFH) by those who can. In describing the experience Australian's have had with working from home across 2020, via three waves of data collection, we find that WFH become a positive unintended consequence in contributing to the future management of the transport network, especially in larger metropolitan areas. Evidence suggests that support for WFH will be continuing in the form of a hybrid work model with more flexible working times and locations, linked to largely positive experiences of WFH during 2020, an improved wellbeing of employees, and no loss of productivity to the economy. We highlight potential future benefits of WFH to society, including significant implications for congestion and crowding, concluding that WFH is a formidable transport policy lever that must become embedded in the psyche of transport planners and decision makers so that we can gain some benefit from the pandemic.

Keywords*:* COVID-19, working from home, Australian experience in 2020, employer and employee support, implications on the performance of the transport network, longitudinal data

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1 Introduction

The COVID-19 global pandemic has brought sweeping disruption to travel and activity on a global scale. At the time of writing (early January 2021), there have been more than 80 million confirmed cases, and over 1.8 million deaths attributable to the disease (OWD 2021). In terms of global movements, in May 2020 air passenger travel fell by 91% relative to the same time last year and is not expected to return to pre-COVID-19 levels until 2024 (IATA 2020). Even now in Australia, international borders remain closed. Cities also witnessed similar seismic shifts in transit as activities were curtailed and in many instances the home became the main place of work.

It is important to note that Australia has had a markedly different experience with COVID-19 on a global scale. For example, total deaths per million are estimated at 57 in Australia compared to: 2,028 in the United Kingdom; 2,152 in the United States; 1,125 in Germany; 745 in Canada; and 143 in Japan (OWD 2021). There are structural advantages facilitating the relative success of supressing COVID-19, such as not having to share borders with other countries, and a manageable number of state governments working largely in unison via a specially formed National Cabinet[124]; but decisive and effective policy making has been equally important. For such policy to work, there has been the need for strong public-private collaboration: collaboration that is not only transferable and repeatable in other economies, but collaboration that will also likely mean that the trajectory of impacts due to COVID-19 will continue to differ in Australia as compared to other economies.

A key component of the policy response has been the requirement to work from home (WFH), which lasted for most of the year. In Victoria it was November 30, 2020 when office workers were able to return to the workplace, albeit with a limit of 25% of staff being allowed onsite, and in New South Wales it was only on December 14, 2020, when the public health order requiring employers to allow employees to work from home (where it is reasonably practicable to do so) was fully repealed. The upshot of these measures is a reduction in time spent at the workplace (Figure 1).

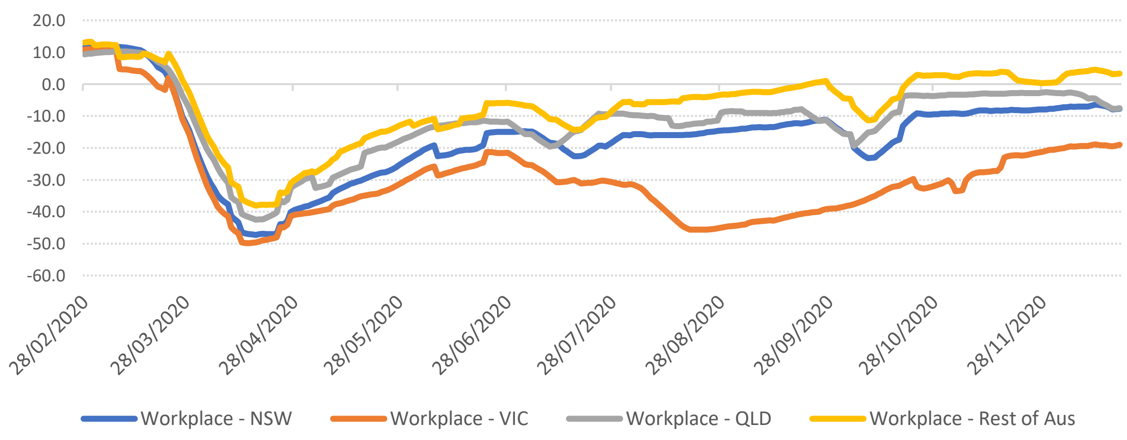

Figure 1: Time Spent at Workplace (Google Mobility Data)

124 National Cabinet is a forum comprising of the Prime Minister, Premiers and Chief Ministers, established on 13 March 2020 to facilitate a collaborative and nationwide pandemic response.

In understanding the experiences with, and future impacts of, working from home, this paper is structured as follows. We begin with a brief overview of some of the literature on telecommuting and its links to travel. In Section 3 we introduce the ongoing waves of data collection and summarise the composition of each of the three initial waves of data; in Section 4 we examine nine different aspects of the WFH experience in Australia; and in Section 5 we draw insight from the analysis and summarise what the experiences might mean moving forward, especially for the transport network and commuter activity. In Section 6 we in turn discuss what future research is required and what might be next for policy and planning with regards to WFH and commuting. Finally, in Section 7 we provide concluding remarks. This paper builds on the contributions of Beck and Hensher (2020a,b) where the focus was on the early days under restriction (Wave 1) and under easing of restrictions (Wave 2), by now also including a time point where many freedoms had returned to individuals but WFH home remained a defining feature (Wave 3).

2 Telecommuting and Transportation

From a transportation perspective, working from home represents a long-discussed policy lever for reducing congestion (e.g., Nilles et al. 1976). Several earlier studies focussed on the role of telecommuting in the white-collar sector (Salomon and Salomon 1984) and the challenges that this type of work might engender such as lack of social interaction, inability to separate home from work, and lack of visibility for advancement (Salomon 1986, Hall 1989, Mokhtarian 1991), along with potential benefits such as greater flexibility in time management (Nilles 1988, Olszewski and Mokhtarian 1994). Research has also explored the societal benefits that might accrue with increased working from home, including improved traffic flows (Kitamura et al. 1990; Maynard 1994) and reductions to energy consumption (Mokhtarian 1991) and air pollution and CO_2 emissions (Nilles 1988)[125]. Many forms of telecommuting have been explored; working at different times of the day, from different locations, changes to the frequency or proportion of work time and duration, and type of employment (Mokhtarian and Salomon 2005, Pratt 2000), noting that home-based businesses and overtime work should not be considered telecommuting due to the small impact such behaviour would have on commuting (Mokhtarian 1991).

Some studies have shown the potential for significant benefits related to telecommuting. For example, the potential for time savings of up to 44 hours per year for the telecommuter (Lari 2012), and reductions of between 7-to-11% in congestion and cost savings in a city like Tokyo, equivalent to up to 26% of annual spending on public transportation (Mitomo and Jitsuzumi 1999). Reduced work-life conflict is another benefit that an individual might accrue due to working from home (Hayman 2009), with benefits also being enjoyed by business in the form of capacity for longer work hours (Hill et al. 2010). Overall, the availability of flexible work arrangement leads to greater enrichment from work which, in turn, is associated with higher job satisfaction and lower turnover intentions (McNall et al. 2009).

Irrespective of the benefits or the different rates of uptake, the growth of telecommuting pre-COVID-19 has been marginal. Mokhtarian (2009) provides 12 possible reasons why, with the ongoing spread of ever-improving technologies, travel and congestion continue to increase. These include noting that not all activities have a telecommuting (work from home)

[125] Although it has been suggested that energy consumption at home has increased due to greater presence and notably higher computer use time. See for example Cheshmehzangi (2020) who suggests that “the impact on household entertainment is likely to increase in the longer term, with a potential increase in computing entertainment that became more popular in recent months. Hence, we anticipate steady and higher energy consumption for household entertainment activities”, and a report by WSP (2020) that suggests that due to home heating inefficiencies the carbon production of a WFH employee could be more than an office worker.

counterpart, and even when feasible telecommuting may not always be a desirable substitute. When looking to identify what might facilitate more flexible work, it is common place to find that management trust of employees, the ability to secure the technology involved, and a rational workplace culture which emphasises human resources and member participation, facilitate telecommuting (Harrington and Ruppel 1999).

In Australia prior to COVID-19, the number of people who have worked from home regularly since 2001 was 4.6%, and only for an average of 11 hours per week (DSS 2019). A report by the Productivity Commission found that rising demand for telecommuting was effectively stymied by incompatible management practices and cultural norms in workplaces, rather than technology barriers (PC 2014). An Australian study conducted prior to COVID-19 showed the existence of a positive attitude toward anywhere working (work conducted anywhere outside of the traditional office that formal work might be done), regardless of the amount of time spent the participant commuting each day (Hopkins and McKay 2019). Importantly, the authors also found that the desire for ‘anywhere’ working grew stronger once workers had participated in remote work themselves.

3 Overview of Data

The data is comprised of three waves of data collection *throughout 2020*. *Wave 1* was completed in *March* immediately after National Cabinet announced restrictions on travel and activities. *Wave 2* was in field from the *May 23 to June 15*, after a relatively sustained period of low new case numbers and just prior to the second wave of infection in Victoria. It built upon the Wave 1 survey and started to examine work from home behaviour in more detail as it became increasingly apparent that the disruption to where work was done was large and ongoing. *Wave 3*, the most recent data, was collected across the *August 4 to October 10*: a period that saw the second wave in Victoria (VIC) result in significant lockdowns (including border closures between States) while the rest of Australia had either practically eliminated COVID-19 or had experienced low rates of community transmission (almost exclusively in Sydney).

While some questions were asked in all three waves, differing combinations of questions were deployed, which places limits on what can be compared across all waves. Wave 1 was conducted extremely early in the pandemic, going to field before it was really known what the impact would be. From this, and in each subsequent wave, we developed a greater understanding of key issues, in particular the need to explore the change in work in more detail. In this paper, we focus only on the working from home questions asked over the three waves. To accommodate the multifaceted nature of the survey, some questions were also asked on a rotational basis, a common approach in large panel-like surveys.

The online survey company PureProfile was engaged to randomly sample respondents across Australia. Table 1 provides an overview of the sample composition in each of the three waves. Quotas were not introduced on those completing the survey, other than ensuring representation from all states and territories. The impact of COVID-19 is sufficiently widespread that no demographic can escape the disruption caused.

Table 1: Overview of National Sample in Each Wave

	Wave 1	Wave 2	Wave 3
Female	52%	58%	58%
Age	46.3 (σ = 17.5)	48.2 (σ = 16.2)	48.2 (σ = 16.2)
*Income**	$92,826 (σ = $58,896)	$92,891 (σ = $59,320)	$62,551 (σ = $46,964)
Have children	32%	35%	35%
Number of children	1.8 (σ = 0.8)	1.7 (σ = 0.9)	1.8 (σ = 0.8)
*# Workers***	714	916	741
Total Sample	1074	1457	956
New South Wales	22%	32%	31%
Aust. Capital Territory	2%	2%	1%
Victoria	28%	24%	24%
Queensland	22%	18%	22%
South Australia	11%	11%	9%
Western Australia	11%	10%	10%
Northern Territory	1%	1%	1%
Tasmania	2%	3%	1%

** In Wave 1 and 2 household income was asked, in Wave 3 personal income was asked.*
*** A worker is defined as anyone who was working at least 1 day prior to COVID-19 restrictions.*

4 Results

4.1 Changes to Work and Working from Home

Figure 2 shows the dual impact of COVID-19 and associated restrictions on the availability of work and the nature of working from home. During Wave 1, the 25% of respondents who employed prior to COVID-19 (i.e., reported working one or more per week prior to COVID-19), were no longer working (i.e., reported 0 days of work in the last week). During Waves 2 and 3 this number started to return towards the pre-COVID-19 levels of employment. Interestingly, in the early stage of the pandemic, younger respondents and those on lower incomes were impacted more heavily, working significantly fewer days per week on average than other age and income groups. However, in the Wave 3 data, the only broad socio-demographic difference identifiable is that older respondents, on average, work fewer days per week in Wave 3; but this group also worked fewer days per week prior to COVID-19. In Victoria, where the entire state was placed in lockdown (including curfews in place in Melbourne restricting the hours a person was allowed outside their home), unemployment had moved back towards the highs of Wave 1.

In Wave 1 almost half of the respondents (47%) indicated they could WFH, a result more prevalent among those on higher incomes and/or those middle-aged. This trend, including the differences by age and income, held through to Wave 3 where 29% of respondents indicated that all their work could be done from home, and a further 33% that some of their work could be done from home. There are also broad geospatial differences in terms of the type of employment where work can be done from home, with regional respondents more unable to WFH (46%) versus those in metropolitan areas (32%). Over the waves, we see that as the rate of infection is brought under control, people work from home less, albeit at a rate that remains significantly higher than before COVID-19 (average of 1.5 days across the sample in

Wave 3, versus 0.8 before COVID-19). The outlier is Victoria, where the reintroduction of restrictions resulted in WFH home levels returning to those observed in Wave 1.

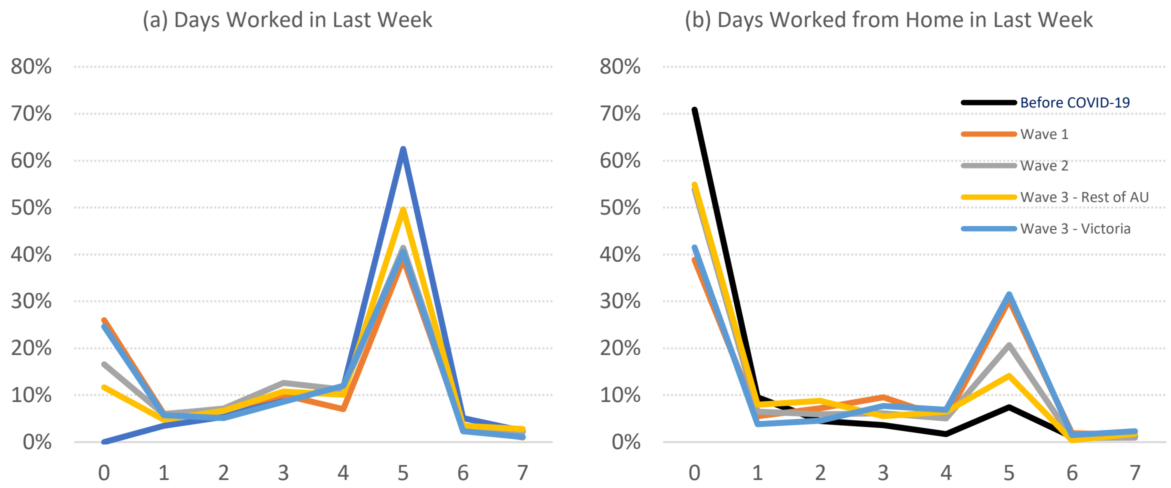

Figure 2: Changes to Work and Work from Home in the Last Week

Unsurprisingly, the ability to WFH differs based on the occupation of the individual[126]. White-collar workers are more likely to either be directed to WFH or given the choice during the pandemic (Table 2). For a large majority of blue-collar workers, the workplace policy towards WFH remains restrictive (Table 3). As a result, those in white-collar occupations work significantly more days from home than others (4.2 days on average compared to 1.5 for blue-collar). These differences exist through each wave of data collection.

Table 2: Workplace Work from Home Policy by Occupation (Wave 3)

	No Plans to WFH	Cannot WFH	Choice to WFH	Directed to WFH	Workplace Closed
White Collar	31%	16%	24%	27%	2%
Blue Collar	40%	45%	10%	4%	1%

Table 3: Change in Workplace Work from Home Policy by Occupation (Wave 3)

	None before, none now	Could before, same now	More now allowed	Less now allowed
White Collar	40%	16%	39%	4%
Blue Collar	84%	9%	5%	2%

4.2 Benefits and Challenges of Working from Home

As part of the Wave 2 data collection (primarily in June 2020; 3 months after the initial COVID-19 outbreak in March 2020), a series of questions were asked to identify the challenges and potential benefits experienced while WFH. As shown in Figure 3, the most beneficial aspect of WFH is not having to commute (particularly the case among younger and middle-aged respondents), followed by having a more flexible work schedule (also more prevalent among

[126] As per the Australian Bureau of Statistics ANZSCO major occupation groupings, white collar workers include Managers, Professionals, Community and Personal Service Workers, Clerical and Administrative Workers, and Sales Workers. Blue collar workers are those categorised in ANZSCO as Technicians and Trades Workers, Machinery Operators and Drivers, and Labourers.

younger and middle-aged respondents, along with females). Spending more time with family, while relatively lower in terms of the perceived benefit, is significantly more important among those respondents with children. Interestingly, there are no differences in the perceived benefits of WFH between metropolitan and regional areas.

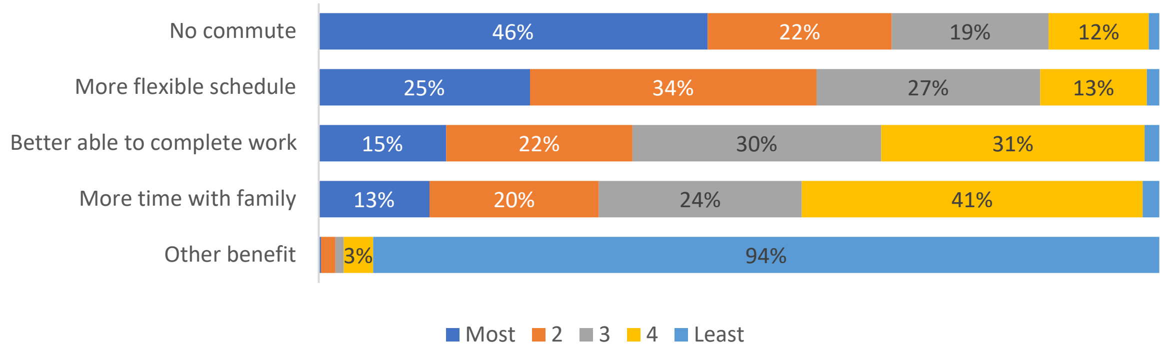

Figure 3: Most Important Benefits of Working from Home (Wave 2)

Figure 4 shows that the greatest challenges in WFH are interruptions from family and children during working hours (data confirms that it is a significantly greater challenge for those with children as expected), followed by being able to concentrate on work. The challenges are largely the same across gender, age, income and regional versus metropolitan areas: although younger respondents were less likely to rate "dealing with email and communication" as one of their most or second most challenging aspects of WFH. On a similar theme, Figure 5 shows that respondents found online meetings to be, on average, just as effective on average as normal face-to-face meetings. Data also revealed that, during Wave 2, respondents had an average of 3 online meetings per week ($\sigma = 6$).

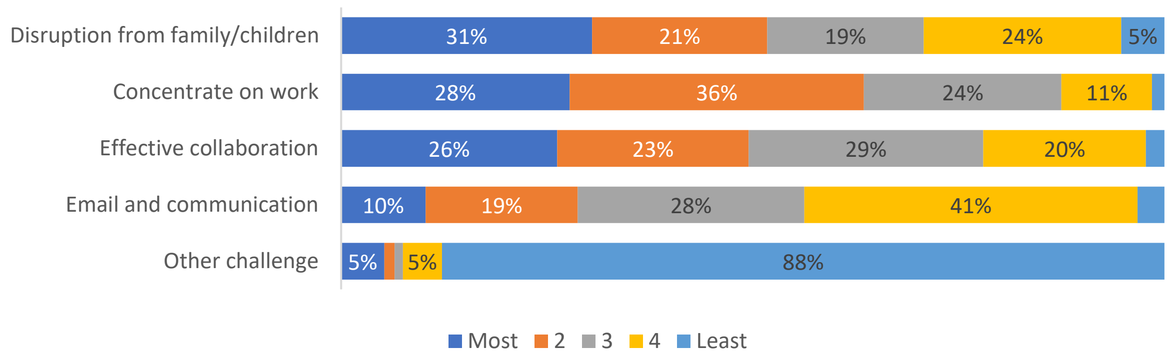

Figure 4: Most Challenging Aspects of Working from Home (Wave 2)

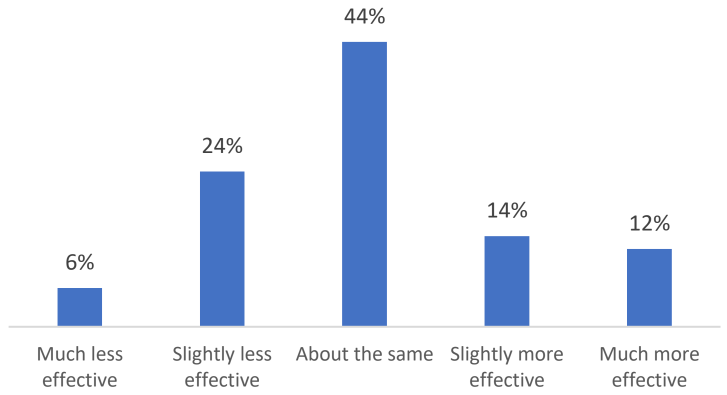

Figure 5: Relative Effectiveness of Online Meetings (Wave 2)

4.3 The Experience of Working from Home

In Waves 2 and 3 we examined how the current WFH experience might be perceived and how that might translate into desires for changes to working arrangements in the future. Figure 6 shows that from 3 months after (June 2020) the initial outbreak in March 2020, to 9 months after (September 2020), attitudes towards the WFH experience unchanged and overall positive when taking all factors into account. For each attitudinal statement, there is no difference in the average scores from each wave between those who WFH at least before COVID-19 and those who did not in normal pre-COVID-19 week, indicating that relative inexperience with WFH has not made the experience less positive.

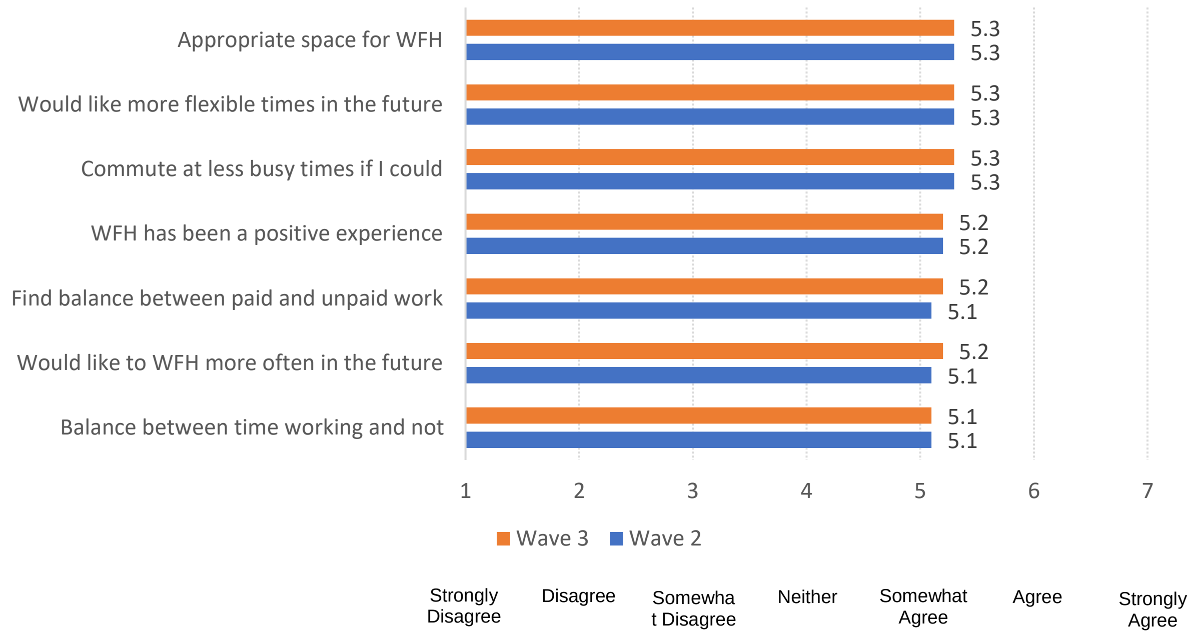

Figure 6: Evaluation of the Work from Home Experience (Wave 2 and Wave 3)

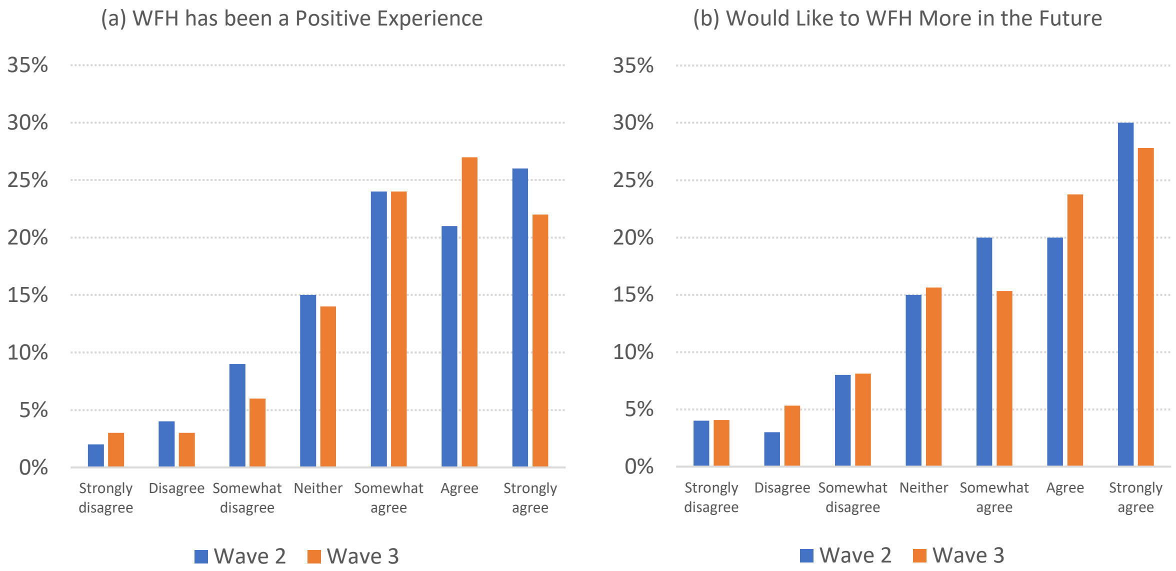

Figure 7: Current Work from Home Experience and Preference for Future (Wave 2 and Wave 3)

We also sought to understand the overall evaluation of the WFH experience (Figure 7a), and if the experience meant they would like to WFH moving forward (Figure 7b). The overall numbers of respondents agreeing to the statements substantially exceeds those who disagree. Additionally, there is a significant and strong positive correlation (r = 0.78) between the two statements suggesting that the more positive the experience, the more likely someone would want to WFH more in the future. Looking at the most recent data (Wave 3), there are significant, albeit weak, positive correlations between the number of days WFH in the last week and how positive the experience has been (r = 0.17), and the desire to WFH in the future (r = 0.24), indicating the WFH has seemingly been more positive for those who WFH to a greater extent. Unsurprisingly, white-collar workers report significantly higher agreement with both statements.

4.4 Working from Home and Commuting

Figure 8 shows that the number of commuting trips more than halved in Wave 1 compared to the average number of one-way trips conducted before COVID-19 (a 53% fall). There was a reduction in all modes, but it was particularly pronounced for train (92% below pre-COVID-19 levels) and bus (78% lower). In Wave 2 we saw an uptick in commuting as restrictions eased and more people returned to work at the office (41% below pre-COVID-19), which appeared to have stabilised for all states by Wave 3, excluding Victoria. In Wave 2 (r = -0.51) and Wave 3 (r = -0.60) there are significant and strongly negative correlations between the number of commuting trips made per week and the number of days WFH, as expected. Bio-security risks associated with public transport remain despite the effort by government to move away from the initial messaging (in the Wave 1 and 2 periods) to not use public transport, to Wave 3 where the message was that with social distancing and recommended mask wearing, it was now safe to use these modes. Hensher et al. (2021a) found that biosecurity concern associated with using public transport was a statistically significant positive influence on the increased probability of WFH.

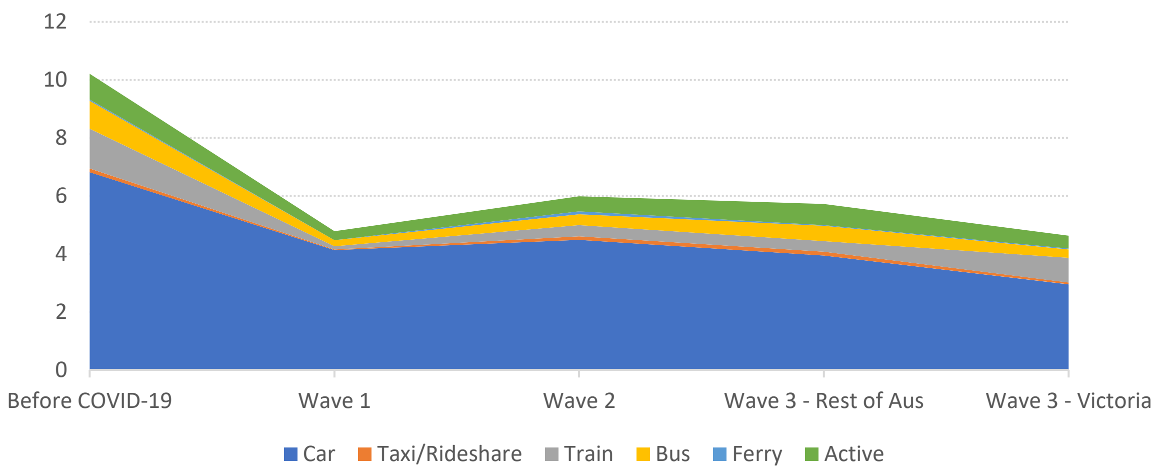

Figure 8: Commuting Activity by Mode (Wave1, Wave 2, and Wave 3)

Figure 9 shows that WFH behaviour is relatively consistent across the working week, with approximately 30% of respondents working only from home on any one day, with just over half travelling for work. Figure 9 does not consider when travelling might be occurring for those that do travel. It might be the case that with increased ability to WFH, people might also be taking this opportunity to stagger their working hours, so that when they do travel for work, they can do so outside of peak periods and thus avoid traffic congestion or crowding on public transport.

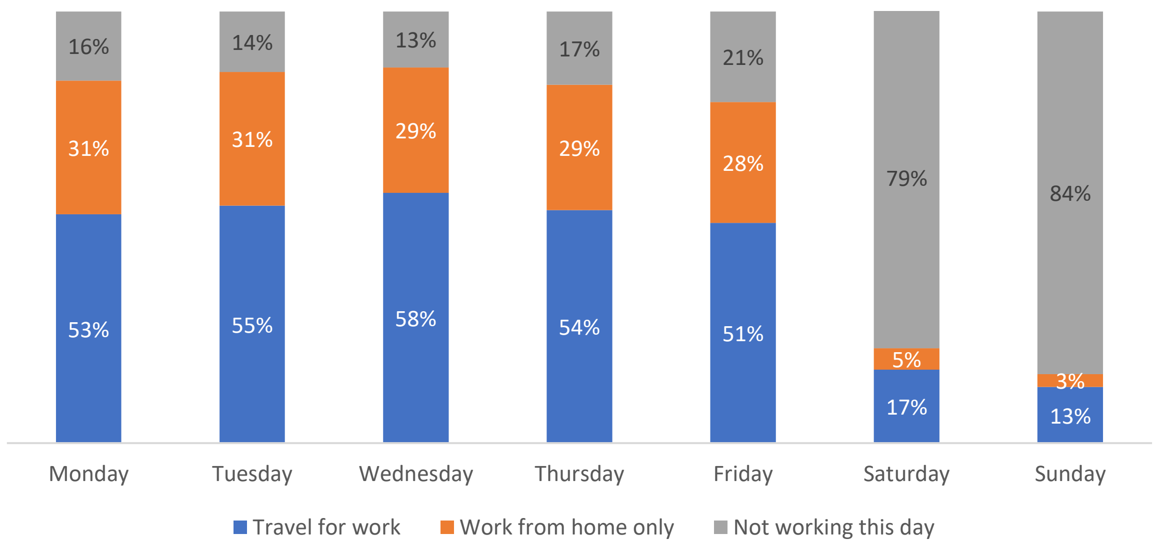

Figure 9: Commuting / Work Travel and Working from Home by Day of Week (Wave 3)

4.5 Relative Productivity of Work from Home

An important component of WFH is the extent to which employees can be productive while doing so. Starting in Wave 2, we asked respondents to assess how productive they felt they had been in the last week while WFH, relative to their normal place of work. Figure 10 shows that employees perceive their WFH productivity to equal to that of their normal work environment prior to COVID-19. In fact, the sample average of this measure is significantly greater than the neutral point (3 = about the same) for both Wave 2 (3.11) and in Wave 3 (3.23), noting that the while statistically significant the difference is only slight. That aside, the data indicates that productivity remains relatively unchanged, and there is the potential that people may well become more productive as WFH becomes entrenched and new norms are developed. Indeed, there is a weakly positive (but significant) correlation between relative productivity and: the number of days WFH prior to COVID-19 (r = 0.12); and the number of days WFH in Wave 3 (r = 0.11), providing some suggestion that the more you WFH, the more productive you find the experience to be. There are no differences in productivity across occupation, gender, age, gender, or income.

To complement the qualitative assessment, we developed an ordered logit model[127] to investigate the drivers of increased vs same or decreased perceived productivity. The key findings focussed on the elasticities, suggest that the direct elasticities are typically, for all significant influences, in the range of (-) 0.2 to 0.5 with a noticeable probability of perceived productivity being increased compared to pre-COVID-19 (i) as age and income increases, (ii) occupation is a manager, (iii) distance to work from home increases, (iv) persons living at home enrolled in a tertiary institution such as a University, (v) the ability to balance work and non-work time more, and (vi) a preference to WFH even more in the future. The Pseudo R^2 for this model is 0.173.

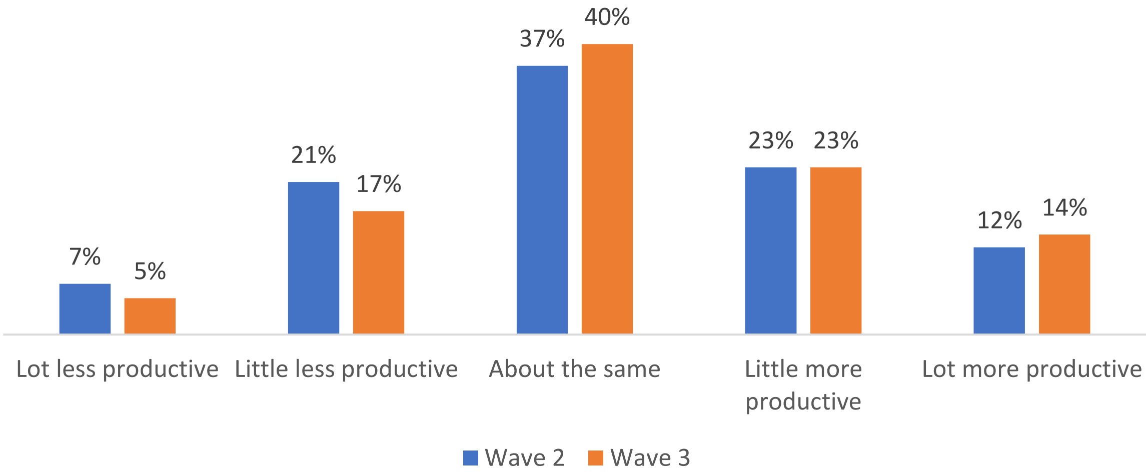

Figure 10: Relative Productivity while Working from Home (Wave 2 and Wave 3)

4.6 Adding an Employer Perspective

The random sample of respondents across Australia means that the sample also contains respondents who are employers and managers[128] (Wave 2 = 106, Wave 3 = 125). With regards to the risk that COVID-19 presents in the workplace, employers and managers are no less concerned than employees; however, employers and managers in larger companies of 20 or more employees appear to be significantly more concerned about the risk than those who are in smaller businesses.

With regards to future policy towards WFH, Figure 11 shows that between Wave 2 (June 2020) and Wave 3 (September 2020) there was an increase in the number of employers who would adopt a flexible work policy whenever COVID-19 restrictions were to end. The response from employees in Wave 3 highlights a potential mismatch between what they might think is the policy their workplace would adopt versus what an employer or manager might support; specifically, there is the potential that employers might be more supportive of increased WFH

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[127] Available on request

[128] Importantly, many employees in an organisation act in an employer-like role in terms of any advice and decisions being made about the support or otherwise for employees to be able to WFH more flexibly.

than an employee might think. This is a finding that Brewer and Hensher (2000) found many years ago when interviewing employers and employees on telecommuting options.

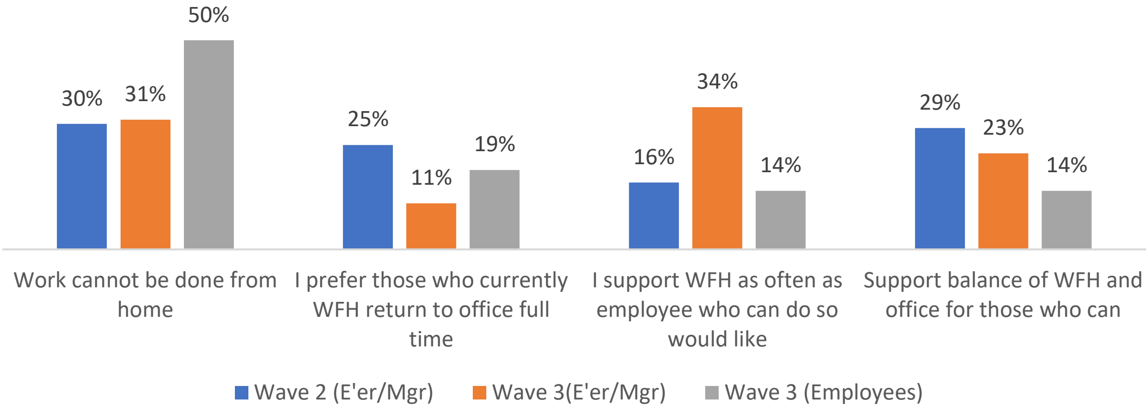

Figure 11: Views on Work from Home Policy when Restrictions End (Wave 2 and Wave 3)

Figure 12 shows the number of days that an employer and manager think are appropriate for staff to WFH. The results are very similar in Wave 2 and Wave 3, with no significant difference in the average number of days thought to be appropriate; however, managers and employers provide an average number of days of WFH that is higher than what an employee states that they would like. There is no difference in the average number of days based on size of business however, managers in white collar roles support a higher average number of days WFH in the future.

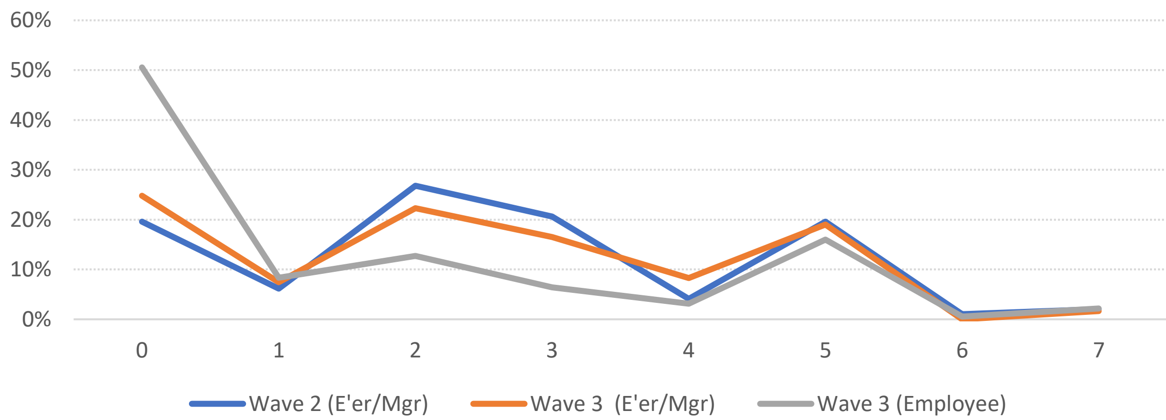

Figure 12: Number of Days Appropriate for Staff to Work from Home when Restrictions End (Wave 2 and Wave 3)

In Wave 2 we asked employers and managers to justify the number of days they felt were appropriate for staff to WFH. Those arguing for high levels of work from home did so because it works, it minimises office space or they believe staff like it. Those advocating for a balance tended to cite reasons around maintaining collegiality, keeping connections, generating value through interaction, the need for face-to-face meetings, and mentoring. In Wave 3 we repeated the question, and the nature of the responses is similar. Those who state that employees cannot WFH cite the nature of the job restricting ability to do so; and those advocating a mix do so because of the ability of an employee to concentrate while working from home, but still needing the interaction of colleagues for team building, collaboration and working on complex problems. Interestingly several employer's state that while most of their work cannot be done from home, some can be done from home and thus one day a week might be appropriate moving forward. On the other hand, a small number also state that an employee could WFH as often as they would like, so long as productivity is not diminished.

With regards to productivity of staff, Figure 13 similarly shows that the perspective of employers and managers has been stable from Wave 2 to Wave 3, with the general view being that productivity of staff is unchanged. Female employers/managers report significantly higher average productivity scores for staff. There is a significant positive correlation between productivity and the number of days that an employer/manager thinks appropriate for a staff member to work from home once restrictions end. There are no differences based on metropolitan versus regional responses.

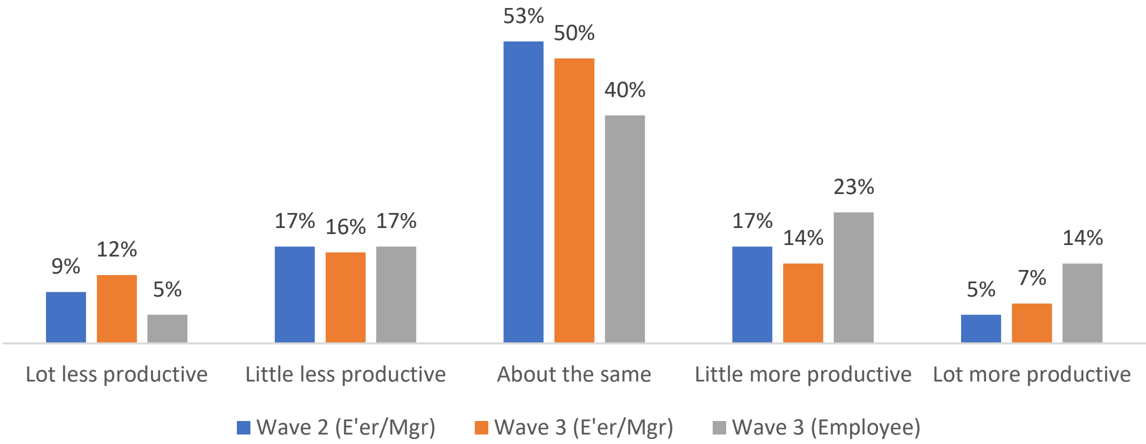

Figure 13: Relative Productivity of Staff while Working from Home (Wave 2 and Wave 3)

5 Discussion of Policy Implications

In this section we draw on the descriptive overview of how employees and employers have responded to the COVID-19 pandemic with a particular focus on working from home. The focus is on benefits to an individual, benefits to employers and wider societal implications.

5.1 Benefits to the Individual

Rather than having to imagine the future of WFH we may already be seeing that future state now, given that future WFH intentions have been shown to closely match the current levels of working from home that are observed during Wave 3 (September 2020). If this is the case, then future with a more flexible use of WFH would mean that on any given weekday there would be 30% of people WFH resulting in significantly lower number of commuting trips and thus commuters on the road or public transport networks. Using evidence presented in Hensher et al. (2021b), assuming the average person works 48 weeks of the year (with 4 weeks of annual leave), this equates to 90 hours of saved time or just over two and a half standard working weeks (there are 38 hours per standard working week in Australia). This is not an insignificant amount of time that a person could spend in ways that offer themselves, or their family, higher levels of utility. Given that a large percentage of Australians have been WFH at a consistent high level for what has now been an extended period, it is reasonable to assume that new habits towards WFH have developed, and people have begun to embed routines that will see them be able to productively WFH at the level they prefer.

5.2 Benefits to the Employer

Although there are time savings benefits that accrue to the employee who is WFH, there are also benefits for employers. Most directly, there is the potential for significant cost savings on rent. For example, in the Sydney CBD the average commercial rent is $1,075 per square metre per annum (Lenaghan 2020), with an estimated 8-12 square metre needed for each employee (Calautti 2019). By having more staff WFH, with less office space required overall, the potential savings to the business quickly add up, typically between $8,500 to $13,000 per employee per year. There is also the indirect benefit of staff who are WFH having more time to spend on work; many of our respondents indicated that the time saved on the commute was of benefit because it allowed them to reinvest that time into more hours of work[129]. The research in the literature review also strongly indicates that WFH and flexible working arrangements lead to better staff retention and create a more attractive employment offer which is particularly important for attracting highly skilled workers.

The recent experiences of both staff and employers/managers indicate that flexibility can be given without any loss to productivity. Both groups indicated that, in the face of a non-marginal change to the nature of work, relative productivity has remained *unchanged*. The results suggest that management should be more amenable to allowing staff to WFH more often in the future, potentially to the extent currently observed in Wave 3 (September 2020). There are a growing number of reports of large organisations already embracing increased WFH in a significant way (e.g., Bleby 2020, Smith 2020), essentially as a hybrid model.

Many employees express reservations about their workplace and the risk of COVID-19. At the time of writing, a cluster in Sydney is emerging, with one of the more the concerning hotspots being an inner-suburb bottle-shop where a close contact of a hotel quarantine worker infected a staff member in the store, who in turn infected another staff member, and as a result over 2,000 customers are now being asked to get tested and self-isolate. Workplaces, particularly large white-collar workplaces that are often indoors and in shared spaces and represent a risk for forming such a COVID-19 cluster. As such, any organisation seeking to manage risk should be looking at policies such as rotating staff through the office on different days, to minimise the impact on the business should one staff member develop the disease. Additionally, a public relations reality is that should a cluster emerge within in organisation, having a robust COVIDSafe plan to point to will be beneficial.

5.3 Wider Economic Benefits

While WFH benefits confer more fully to segments of the working population, such as those in white-collar jobs, typically on higher incomes, in middle or younger age groups, and living in metropolitan areas, there are non-trivial wider economic benefits that can be shared, if people who are able to WFH successfully are able to do so more often.

Infrastructure Australia highlighted that in the six largest capital cities and neighbouring satellite cities, the total annual cost of road congestion (pre-COVID-19) was $19 billion in 2016, and the cost of public transport crowding was estimated at $175 million (IA 2019). By 2031 this was projected to grow to forecast total annual cost of road congestion of $39 billion, and $837 million for public transport crowding. During the height of the pandemic, private vehicle use plummeted with aggregate indicators such as the Apple Mobility Trends showing car use falling by up to 60% (Apple 2020). Global GPS firm TomTom also publishes data via their Global Traffic Index (TomTom 2020), wherein they construct a metric termed the Congestion Level index. An index level of 100 percent means that a 30-minute trip takes an hour to complete (i.e., due to traffic on the network, travel time doubles). During a typical pre-COVID-

[129] Later surveys (already conducted) seek to explore where that saved time is invested in more detail.

19 weekday, peak Sydney records a congestion level of approximately 80, but throughout April 2020 it went above 30 on only two days. These results indicate a very large reduction in congestion.

While car use was never expected to stay at the low levels observed during March/April 2020, it has rebounded strongly: SCATS (Sydney Coordinated Adaptive Traffic System) data shows that car use is now tracking 5-6% below that of a similar time last year (MySydney 2020). The fact that it remains some percentage lower is still important in gaining significant improvements in traffic flow. For example, Infrastructure Victoria (2016) indicated that if just five per cent of drivers change their behaviour, driving conditions on Melbourne's road network would be the same as in the school holidays, every day of the week.

There has been an even bigger and sustained reduction in public transport patronage. During April 2020, Opal Card data reveals that monthly trips on public transport fell by 80% compared to the same period in 2019. As of November 2020, total trips on all public transport modes remain 45% below the same period last year, and over 2020 public transport patronage has more than halved on the year, down 54% (TfNSW 2020). While much of this reduction (and subsequent rebound in car use) can be explained by the concerns people have towards the risk of COVID-19 on public transport (Beck and Hensher 2020a, 2020b), encouraging WFH as restrictions ease is a viable and cost-effective measure for transport authorities to ease crowding during the peak. Reduced crowding will have significant positive dividends for those individuals who have no choice but to commute to work, given that negative crowding events are memorable (Abenoza et al. 2017) and may be the main driver of public transport dissatisfaction (Börjesson and Rubensson 2019).

There are also potential benefits to regional areas in terms of growth in economic activity. Recent media reports highlight the strong growth in regional house prices, which have risen at a higher annual rate than in capital cities for the first time in more than 15 years (Terzon 2020). It is speculated that part of the reason for the 7% average increase across all regional marketplaces (compared to 2% in cities) is the desire for urban dwellers to leave the city because of COVID-19 and the associated ability to WFH[130]. While it is hard to disentangle if the interest in regional areas is due to prior growth in the regions, or the desire to move out of an urban environment because of COVID-19 itself; the disruption and consequent uptake of digital work solutions cannot be ignored as a factor in making working outside of capital cities a more tenable proposition. If the increase in property prices is a leading indicator of potential growth and thus improved economic activity in regional areas, there are positive long-term implications for jobs, accessibility, and amenity[131]. Growth in regional areas is a noted strategic objective (DIRDC 2017), especially given that 51% of the national population is in the three capital cities of Sydney, Melbourne, and Brisbane (ABS 2020).

[130] This is linked in part to the continuing low interest rates with a lower threshold for a minimum home deposit together with a significant increase in the shortage of housing in regional areas as more people locate there in part attributed to the ability to WFH and hence less need to commute to a major Centre. It is also possible that COVID-19 has prompted many to consider a lifestyle change due to greater flexibility. Indeed, in early June 2021 in Australia, a national advertising campaign has launched encouraging movement to regional areas (in part funded by the Federal Government - http://www.regionalaustralia.org.au/home/move-to-more/).

[131] We would also suggest that the relevance of physical connectivity that is the cornerstone of agglomeration economies (also known as effective employment density) is no longer as relevant with a growing use the digital connectivity. Hence the ability to undertake business from a geographically more disperse location is expected to change the meaning and metric of agglomeration economy.

6 Directions for Future Policy and Research

COVID-19 has been a crippling event, but WFH has the potential to be an unintended positive consequence of the widespread disruption. There are benefits to the individual employee, to employers and businesses, and to the wider economy, including the transport network. Our data indicates that those who WFH have found the experience to be positive and would like to continue doing so to a greater extent than they did before. Additionally, the data also shows that productivity remains relatively unchanged, and that employees are potentially becoming more productive as WFH becomes entrenched and new norms are developed. The benefits are great and should not be ignored in any ambition to the return to pre-COVID 19 ‘normality’.

Even where there may be pressure from certain circles for employees to return to the office en masse, to do so would not only ignore the inherent risks that remain with larger indoor gatherings, but also the redistributive impact of WFH on more localised or suburban economic activity. While the impact on central business districts (CBDs) is currently large, a greater balance between WFH and the office is likely still enough activity to revitalise much of the business in the supply chain that is currently suffering. While traffic has been quick to rebound, there is currently lower CBD focused congestion, but this may return quickly if the uplift in second-hand car purchases (IA 2020), combined with the concern about public transport, indicates that a higher car mode share may persist for some time. To avoid congestion at levels which would be *worse* than before COVID-19, authorities and policy makers should do everything in their power to facilitate the choice to WFH rather than the choice to drive to work. Government policy to support more WFH will likely be a more popular strategy than what has been the politically unpalatable option of road pricing.

While there are limited sociodemographic differences that have emerged in our analysis thus far, highlighting just how widespread disruption has been, it does not mean that such differences or inequalities will not arise or become embedded in the future. This is something the transport community, and indeed social scientists more broadly, need to be keenly aware of such that we do not further embed income or social exclusion inequalities, or give rise to new forms of inequality (such as technology accessibility for example).

A barrier that might exist to ongoing WFH is the position of management within organisations. Research cited in the literature review shows that managerial resistance is perhaps the biggest barrier to flexible work practices. However, the widespread and extended nature of the COVID-19 disruption is such that this barrier may have been broken. Our empirical evidence suggests that employers and managers show favourable attitudes to increased WFH, which have remained stable over the multiple periods of data collection. That said, research has shown that many managers express low self-confidence in their ability to manage workers remotely which in turns undermines their support for WFH (Parker et al. 2020). Rather than reduce WFH due to a lack of managerial confidence, organisations should seek to equip managers with new skills to boost their ability to manage in a technologically advanced environment. This is especially true as a meta-analysis of 46 telecommuting studies proves the benefits on job satisfaction, performance, employee turnover and stress that WFH can have (Gajendran and Harrison 2007). There is more work required to understand the response of employers to COVID-19.

While we use the term “working from home” within this paper, there is also the concept of the third office, or “anywhere working” (Blount and Gloet 2017) which covers any space where work might be completed that is outside of the traditional office environs. There is contemporary anecdotal evidence which suggests that individuals conduct paid work from public locations such as coffee shops, parks, and libraries, yet no documented evidence of the rate of use of these alternative locations was found outside of one study that found a small percentage of telecommuters worked from summer cottages or from 'elsewhere' (Helminen and Ristimaki 2007). More research should be undertaken to determine exactly where people have been doing work from, and how productive that work has been, and thus facilitate a conversation about how remote working can be more than just WFH[132].

There is also the need to continue to investigate increased levels of WFH as either a complement or substitute for non-commuting trips. In many jurisdictions, the current data being collected on travel activity may not yet be appropriate for such analysis, as it is likely that travel activity is still suppressed, to varying degrees. However, in the research prior to COVID-19 the evidence on this relationship is mixed. Mokhtarian et al. 1995 find a reduction in both commute and non-commute-based trips, and Mokhtarian et al. 2004 find that while telecommuter have long average commute distances when they do travel, they telecommute often enough to compensate for longer one-way commutes. Choo et al. (2004) find that while telecommuting reduces vehicle-miles travelled by a small amount on the surface, it appears to be far more effective policy than public infrastructure expenditure. Others have found that telecommuting can increase personal travel and non-commute activity (Zhu 2012, Kim et al. 2015). In unpublished research on Wave 3, we have found that WFH has resulted in less commuting, work related, and home-based education trips, but that home-based shopping and personal business trips have not been impacted. We continue to investigate this moving forward.

7 Conclusion

Working from home is not and should not be seen as an all or nothing affair: there is no expectation that people will either work only from home or only from the office. Analysis herein indicates that respondents (for whom it is possible) would like a mix of work where WFH is a greater percentage of the mix than it was before (referred to in mainstream media in Australia as a hybrid model whose adoption is gaining popularity). Even without all work being WFH, simply *more* WFH than was the case before COVID-19 (i.e., more people who can do so, working more flexibly) would have significant positive dividends. We fully acknowledge that not every worker is able to WFH, nor that the widespread increase in WFH that has meant that the barriers to WFH have disappeared. To that end, policies that support formal childcare resources could relieve the family-to-work conflict and encourage people to work at home (Zhang et al. 2020); direct financial support for telecommuting facilities or a subsidy for firms adopting telecommuting could be considered (Mitomo and Jitsuzumi 1999); and even rethinking the opening hours of shops and leisure facilities (Saleh and Farrell 2005). As a formidable transport policy lever, WFH must become embedded in the psyche of transport planners and decision makers as well as the tools they use to arrive at a future that can benefit from the unfortunate imposition of a virus pandemic. This is the challenge that we all should work on as we seek to understand what the new priorities might be for the future delivery and maintenance of and efficient and effective transport network that aligns with the aspirations of society.

[132] Remote or satellite offices remain an interesting part of the remote working toolkit, as an effective way of holding meetings with other members of staff or clients. Travel to such sites should not be an issue if carefully planned. Indeed, it not only avoids the need to meet at someone's home if the traditional office location has been downsized, and the flexibility of space enables the location to be booked to suit the group attending. Indeed, there may even be a new Office-Space-as-a-Service model that emerges.

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Appendix P. Paper #12: Impact of COVID-19 on the number of days working from home and commuting travel: A cross-cultural comparison between Australia, South America and South Africa

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Abstract

The COVID-19 pandemic has changed the way we go about our daily lives in ways that are unlikely to return to the pre-COVID-19 levels. A key feature of the COVID-19 era is likely to be a rethink of the way we work and the implications on commuting activity. Working from home (WFH) has been the 'new normal' during the period of lockdown, except for essential services that require commuting. In recognition of the new normal as represented by an increasing amount of WFH, this paper develops a model to identify the incidence of WFH and what impact this could have on the number of weekly commuting trips. Using data collected in eight countries (Argentina, Australia, Brazil, Chile, Colombia, Ecuador, Peru and South Africa), we developed a Poisson regression model for the number of days individuals worked from home during the pandemic. Simulated scenarios quantify the impact of the different variables on the probability of WFH by country. The findings provide a reference point as we continue to undertake similar analysis at different points through time during the pandemic and after when restrictions are effectively removed.

Keywords: Working from home, COVID-19, Poisson Regression, Cross-Cultural comparisons, Australia, South America, South Africa

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1 Introduction

Every country has faced major challenges since COVID-19 started in early 2020. The seriousness of this pandemic has meant that millions of people have changed the way their entire life operates. This study aims to understand the impacts of COVID-19 on work behaviour, i.e., work from home and commuting, and its effect on the transport network. Data was collected in eight different countries around the world: Argentina, Australia, Brazil, Chile, Colombia, Ecuador, Peru and South Africa to understand the impact of COVID-19 in the daily life of respondents and their work behaviour. The surveys were not identical but did share some questions used in this study to enable a cross-cultural comparison of the effects of COVID-19 in work and travel behaviour.

The governments of the countries included in this study have had very different strategies in facing this health crisis, which has led to different impacts regarding the number of cases and deaths by country and different work from home (WFH) policies and attitudes towards COVID-19. Australia has had one of the best COVID-19 management strategies and results across the globe with 36 deaths per million habitants up until 1 December 2020, while other countries, such as Peru, have had the worst results out of the countries included in this study with 1,106 deaths per million habitants.

The most useful response data in understanding the impact of COVID-19 on work behaviour is the comparison prior to COVID-19 and during COVID-19 of the number of days commuting, the mode used to go to work and the number of days working from home. In this study, modal shares and commuting days prior to COVID-19 and at the time of data collection (August-December 2020) are compared to quantify the implications of COVID-19 on the transport network.

A Poisson regression model is estimated with the dependent variable defined as the weekly number of days worked from home (WFH) and several explanatory variables that refer to the transport modes available and the ones used prior to COVID-19, the place of employment and the employer's attitudes towards WFH, the travel time to the office, socioeconomic characteristics such as income and age, and country-specific dummy variables. This model is estimated to understand better the probability of the number of days WFH and the differences across countries. Elasticities and simulations of the impact of specific variables on the probability of WFH are presented to identify different response patterns across the countries studied.

This paper is organised as follows. The following section presents a brief literature review of the COVID-19 impacts on the transport network around the world. Section 3 explains the data collection process and sample sizes. Section 4 presents a cross-cultural comparison of the different samples regarding how respondents have been affected by COVID-19, WFH behaviour, attitudes towards WFH, COVID-19 and their government. Section 5 presents the working from home Poisson regression model results as well as elasticities. Section 6 presents simulated scenarios to quantify the impact of the different variables in the probability of WFH by country. The final section discusses the main findings and implications of this study.

2 Literature Review

Even though COVID-19 has had a significant impact on work and travel behaviour, there is still a limited literature on its effects, although it is growing fast. The existing literature includes general policy-oriented studies and statistical analysis of mobility data based on cross-city and city-specific surveys. This section focuses on some illustrative survey-based studies, with papers that review the broader literature on tele-commuting prior to COVID-19.

Beck & Hensher (2020) conducted an online survey in Australia during March and April 2020 to identify the impact of health-related measures on people's travel and activities. Their results show that reported trips had decreased by more than 50%, with a higher decrease in public transport modes and commuting trips. An increase in unemployment, partial employment and WFH was observed. People with higher incomes were more likely to WFH. Social activities, such as meeting with friends or visiting restaurants, were suspended by most respondents.

Beck et al. (2020) modelled the impact on commuting and WFH due to the slow relaxing of restrictions implemented by the Australian government in May 2020 by applying a second wave of the surveys reported in Beck & Hensher (2020). Compared with the March-April 2020 survey, average commuting trips per week rose from 3.0 to 3.8, and more commuting was planned for the following week. A Poisson regression model found that more commuting is made in capital cities. For people who cannot WFH, a higher income is associated with more commuting trips by car. Meanwhile, people working at least one day per week increased from 74% to 83%, while working from home five days a week fell from 30% to 20%. An ordered logit choice model identified that positive attitudes towards WFH, such as having a positive experience, having appropriate space to work, or reporting more productivity, significantly influence working from home more days a week.

Vallejo-Borda et al. (n.d.-b) applied the original survey by Beck & Hensher (2020) in five South American capitals (i.e., Bogotá, Buenos Aires, Lima, Quito and Santiago) to explain mode shifting from public transport to private and active modes through SEM-MIMIC models. Even though the factors that explain mode changes differ across cities, common variables related to changes to active modes include worse subjective well-being and the poor perception of authorities' response, with a negative correlation in Santiago and Bogotá, and a positive correlation in Buenos Aires. How people perceive authorities' response to confront COVID-19 is also relevant to explain migration from public transport to private modes in most cities. A good perception of authorities' response is associated with more migration to private modes in Bogotá and less migration in Buenos Aires and Quito.

Hensher et al. (2021) focused on WFH implications during the early days of the pandemic. Using data from the first wave of surveys performed in Australia, first published in Beck & Hensher (2020), they performed an ordered logit model to explain the number of WFH days per week and a Poisson regression explaining the weekly one-way commuting trips by car and public transport. As expected, respondents who could WFH or were directed to do so reported more WFH, and also, people that work in administration and services reported more days WFH. Naturally, a higher proportion of WFH days was associated with less commuting. Older respondents performed more commuting by car and public transport, and men commuted more than women in cars. Compared with the base scenario, public transport trips would be reduced by 50% and car trips by 30% if all employees could choose WFH. If people were directed to WFH, car trips would decrease by 56%, and public transport trips by 84% relative to the base scenario.

Remote work during the pandemic was also studied in surveys undertaken in the United States (Brynjolfsson et al., 2020), Chile (Astroza et al., 2020), Spain (Farré et al., 2020), among others. WFH has been identified as a determinant of commuting behaviour and, once restrictions are relaxed and we move forward, it will be vital to monitor and understand WFH as part of strategic and urban planning (Beck et al., 2020). Besides, WFH was also preferred by people as an alternative instead of commuting during the early Covid-19 periods (Bhaduri et al., 2020). Other relevant studies on WFH during the pandemic analysed mental health issues (Bouziri et al., 2020), enterprise management (Foss, 2020), employees' income

(Bonacini et al., 2021), finding that with the proper digital tools, people can adequately complete their duties (Winslott Hiselius & Arnfalk, 2021).

Barrero, Bloom, & Davis (2021) is the most recent extensive survey in the USA that surveyed over 30,000 Americans over multiple waves to investigate whether WFH will stick, and why. The most important finding is that 20 percent of full workdays will be supplied from home after the pandemic ends, compared with just 5 percent before, of which 2 days a week is not uncommon. This aligns with the Australian evidence (including a 4.6% WFH pre-COVID-19). They five reasons for this large shift: better-than-expected WFH experiences, new investments in physical and human capital that enable WFH, greatly diminished stigma associated with WFH, lingering concerns about crowds and contagion risks, and a pandemic-driven surge in technological innovations that support WFH.

Different studies suggest a significant increase in WFH and the possibility to WFH, mainly in developed countries and younger people with high educational levels (Shibayama et al., 2021). Studies indicate that people with lower incomes have less flexibility to WFH than people with medium and high-income levels (Astroza et al., 2020; Bonacini et al., 2021). Likewise, it is also found that unemployment affects more women, who are the ones who have the greatest number of unpaid work duties at home (Farré et al., 2020).

Research on teleworking (or telecommuting), which is now referred to as work from home, suggests a relatively low degree of impact in the transport network and on commuting behaviour. Hensher, Beck, et al. (2021b) and Beck & Hensher (2020a, 2020b) provide a detailed review of earlier literature (Mokhtarian, 1991; Mokhtarian et al., 1995, 2004). This section has reviewed several studies that have emerged as a result of COVID-19, which has caused a significant increase in WFH worldwide. The contribution of this research is to identify and quantify the main drivers in the number of days WFH in different countries. This study includes sociodemographic characteristics, which other studies have suggested play an important role in the decision to WFH, but it also takes into account the employer's view towards WFH and how it might influence the number of days an employee chooses to WFH. All these indicators provide a better understanding of the different social, economic and cultural context characteristics that affect the number of days people WFH.

3 Data Collection

The data used in this study was obtained from online panel surveys undertaken in Australia, Argentina, Brazil, Chile, Chile, Colombia, Ecuador, Peru, and South Africa. In Australia, this comparison paper is part of a larger study on the impact of working from home on travel behaviour (Beck & Hensher, 2020; Beck et al., 2020; Hensher, Wei, et al., 2021). An online survey company was hired to randomly sample respondents across Australia, using quotas only to ensure a correct representation of New South Wales (NSW) and Queensland (QLD) which are the focus of the study. In South America, key research groups were contacted in each country who recruited participants based on their connections and, in addition, participants were recruited randomly asked through social media platforms including LinkedIn, Facebook and Instagram. To increase participation and improve the representation of the sample, the requested responses in Facebook and Instagram for South America were both paid and unpaid (Vallejo-Borda et al., n.d.-a, n.d.-b). In South Africa, a market research company recruited respondents from their online consumer panel, focusing exclusively on residents of Gauteng Province. To reduce the risk of under-sampling amongst lower income people who are underrepresented on the panel, the sample was supplemented by face-to-face recruiting at public transport hubs in the area, after which respondents completed the survey on their own mobile phones. No financial incentive was offered.

Table 1 pre sents the survey collection dates and the number of observations per country. The purpose of this study is to understand how COVID-19 has changed the way people work and commute, so the data used in this study only includes workers, with a total of 4,628 observations. The first survey used in this study was collected in Australia from August to September 2020 as a nationwide survey. The survey was designed to understand the impacts of COVID-19 on how people work and travel to work. It included questions on attitudes towards COVID-19, response of their authorities, number of days they used to work and where before COVID-19 and now, modes of transport used, among others. The full dataset collected in Australia includes both metropolitan and regional areas[133]. However, given that the South American and South African surveys were collected in metropolitan areas, this study only considers respondents from metropolitan areas for comparison purposes.

Table 1: Collection date and number of observations per country

Country	Collection date	Number of observations[134]	Sample %
Argentina	Sept 2020	552	12%
Australia	Aug - Oct 2020	656	14%
Brazil	Sept - Nov 2020	680	15%
Chile	Aug - Sept 2020	522	11%
Colombia	Aug 2020	155	3%
Ecuador	Sept - Nov 2020	668	14%
Peru	Sept 2020	706	15%
South Africa	Nov - Dec 2020	689	15%
Total number of observations		***4,628***	***100%***

A similar survey was designed to collect data in different counties (metropolitan areas) in South America: Argentina (Buenos Aires); Brazil (Sao Paulo, Porto Alegre, Rio Janeiro, and Belo Horizonte); Chile (Santiago); Colombia (Bogota); Ecuador (Quito); and Peru (Lima). Data was collected from August to November 2020. These surveys were translated and adapted to the local language, in Brazil it was designed in Portuguese while in the other countries in Spanish, even though some words vary by country. These cities have varied modes of transport, so each survey had to be revised to include the modes available in each city. Similarly, the Australian survey was used as the base but adapted to the South African context. This survey was collected in English in the Gauteng area (Tshwane/Johannesburg) from November to December 2020. Although core questions remained unchanged, the survey was adapted to reflect local modes (particularly informal taxis) and terminology. Some non-core questions were omitted in the South African survey due to restrictions of the online survey platform. All the surveys required respondents to report their travel behaviour prior to COVID-19 and their travel behaviour in the most recent week – which is referred to in this study as *last week*.

[133] More information on working from home behaviour and its impact in commuting and non-commuting activity in regional and metropolitan areas in Australia can be found in Beck & Hensher (2021a); Beck & Hensher (2021b); Balbontin et al. (n.d.)

[134] The working from home model that will be discussed in Section 5 pools all the data within the one model including country-specific parameters, interactions and heterogeneity which allows for a country-specific analysis. The sample size in Colombia is smaller than in other countries; however, the results show that Colombia did not have a statistically different behaviour than the other countries in South America.

4 Cross-Cultural Comparison

COVID-19 has had serious implications worldwide. This section will focus on understanding the general implications of COVID-19 on respondents' work (mainly working from home and commuting) and their attitudes. The questions included in the survey vary by country; therefore, not every country is included in the comparisons. Moreover, there are several questions with missing information – the most interesting ones will be compared in this analysis but will be excluded from the models presented in Section 5.

It is essential to get a broader picture of the effect of COVID-19 in each country to compare the effect of COVID-19 in the different countries included in this study. The first column in Table 2 presents the percentage of internet users per country according to the latest information available. The surveys used in this study were collected online and hence the percentage of internet accessibility is relevant as to their representativeness. However, it is important to note that this study includes only workers in metropolitan areas, who are more likely to have internet accessibility than the country average, and thus this percentage only provides an overview of what can be expected and inferred from this study. The percentage of internet users in Argentina, Australia, Brazil and Chile are all above 70% which suggests that the online survey data collection is likely to reach most workers in metropolitan areas. In Colombia, it is around 65%, and in Ecuador, South Africa and Peru it is below 60%. This should be considered when analysing and interpreting the results, since there might be over-representation of high-income respondents who in general have good digital connectivity.

The last two columns in Table 2 present the total number of cases and deaths from COVID-19 reported by country up until 1 December 2020. Out of all the countries included, Australia had by far the best management of the pandemic, with only 1,101 positive cases and 36 deaths per million habitants. South Africa was the second best with 13,530 positive cases and 370 deaths per million habitants. Ecuador had reported 11,150 positive cases per million habitants but had 777 deaths by million habitants. The worse results are in Peru where they had 29,640 cases per million habitants and 1,106 deaths per million habitants. This is followed by Argentina which had 31,877 cases per million habitants and 866 deaths per million habitants. Brazil and Chile followed Argentina closely with around 30,000 cases per million habitants and more than 800 deaths per million habitants.

Table 2: Internet users and COVID-19 total number of cases and deaths by country

Country	Internet users (% population)[135]	Cases per million habitants	Deaths per million habitants
Argentina	74.29	31,877	866
Australia	86.55	1,101	36
Brazil	70.43	30,269	824
Chile	82.33	29,175	814
Colombia	65.01	26,317	734
Ecuador	54.06	11,150	777
Peru	59.95	29,640	1,106
South Africa	56.17	13,530	370

Source population density and internet users: World Bank data (https://data.worldbank.org/)
Source COVID-19 statistics: Google News (https://news.google.com/covid19/map) date 1 December 2020

The mean and standard deviation by country of different variables of interest related to the samples in the survey are presented in Table 3, as well as the number of observations.

[135] This column contains the latest data available in the World Bank website. The numbers shown for Ecuador belong to 2016; for Argentina, Australia, Chile and South Africa to 2017; for Brazil to 2018; and for Colombia and Peru to 2019.

Table 3: General descriptives – mean (standard deviation)

Variable/Country	Argentina	Australia	Brazil	Chile	Colombia	Ecuador	Peru	South Africa	Observations
Age (years old)	36.74 (10.04)	40.05 (13.39)	40.01 (11.73)	33.04 (7.35)	33.11 (8.73)	34.57 (7.81)	35.40 (10.18)	44.47 (13.46)	4,625
Gender female (0,1)	64%	64%	49%	66%	48%	56%	48%	50%	4,625
Income ('00AUD$) personal/household[1]	$1.38 ($0.93)	$6.50 ($4.48)	$2.84 ($2.35)	$3.00 ($2.45)	$0.86 ($0.91)	$1.32 ($1.23)	$1.42 ($1.51)	$3.43 ($3.29)	4,241
Employer view towards WFH after COVID: my choice (0,1)	14%	16%	9%	11%	12%	12%	16%	18%	3,464[2]
Employer view towards WFH now: my choice (0,1)	10%	29%	16%	19%	8%	17%	13%	31%	4,625
Employer view towards WFH now: mandatory (0,1)	42%	19%	31%	39%	28%	20%	30%	21%	4,625
Employer view towards WFH now: not possible (0,1)	19%	21%	12%	20%	34%	24%	21%	23%	4,625
Total travel time to office (minutes)	41.90 (27.89)	29.88 (29.23)	35.55 (30.62)	35.92 (25.10)	57.98 (33.51)	39.50 (25.49)	47.05 (31.54)	34.11 (25.38)	3,060
Total travel cost to office (AUD$)	$2.69 ($9.08)	$5.99 ($14.02)	$5.87 ($13.90)	$6.16 ($13.80)	$3.27 ($4.53)	$5.70 ($11.87)	$4.40 ($5.35)	-	2,337
Car driver or passenger available (0,1)	25%	83%	57%	42%	27%	45%	24%	79%	4,625
Public transport available (0,1)	94%	65%	84%	93%	95%	78%	82%	28%	4,625
Number of days worked at the time of the survey (***"last week"***)	4.90 (1.10)	4.51 (1.28)	5.13 (0.90)	5.00 (1.07)	5.60 (0.86)	5.34 (1.05)	5.45 (1.11)	4.90 (1.12)	4,625
Number of days WFH at the time of the survey (***"last week"***)	3.43 (2.13)	1.64 (2.11)	3.01 (2.15)	3.19 (2.17)	3.09 (2.47)	2.84 (2.32)	3.15 (2.44)	2.31 (2.39)	4,625
Number of days WFH after COVID-19 restrictions are eased	3.02 (1.41)	1.77 (1.98)	3.07 (1.47)	2.91 (1.27)	3.30 (1.59)	3.15 (1.48)	3.52 (1.44)	3.18 (1.97)	2,894

Note: The monetary values were calculated using the currency exchange rate for the date of data collection.

[1]The survey collected in Australia asked for personal income, while the other countries asked for household income.

[2]This question was answered only by employees, there was no information missing.

The average age of respondents is relatively low in the South American countries, except for Brazil, which is around 40. The highest is in South Africa and around 45 years old. Even though the respondents in the South American countries are younger than in other countries, we will compare the responses directly in this section, but we will later include this variable in the WFH model to separate the effect of age on the number of days WFH. Over 60% of respondents are women in Argentina, Australia and Chile, which is allowed for in the models.

The income difference between countries is significant. The survey in Australia asked for this variable as personal income, while in the other countries the question referred to household income. Despite this difference, the highest monthly income is in Australia (AUD$6,500) which represents personal income, as opposed to household income as in the other countries. Colombia has the lowest monthly household income (around AUD$860), followed by Ecuador (AUD$1,230). The highest household monthly income is in South Africa (AUD$3,430), followed by Chile (AUD$3,000). As mentioned above, due to the relatively low internet usage in South Africa, it is likely that high-income workers were over-sampled, which results in higher average household income than expected and will likely have an effect on the car availability. These variables, including country-specific variables, will be tested in the WFH models in case they have an effect on its probability, but this possible bias should be considered throughout the paper and in the interpretation of results.

The travel time information was complete in the Australian and South African data, but several responses were missing in the South American data. The longest reported trip to the office is in Colombia with an average trip of approximately 58 minutes, followed by Peru with 47 minutes. The shortest trip to the office is in Australia with an average of 30 minutes, followed by South Africa with 34 minutes, and Brazil and Chile with 36 minutes. The travel cost information had a lot of information missing in all the datasets, so it will not be possible to include it in the models, but it can still be used to compare the travel costs across countries. The lowest reported travel cost to the office is found in Argentina, followed by Colombia; and the highest is in Chile, followed by Australia.

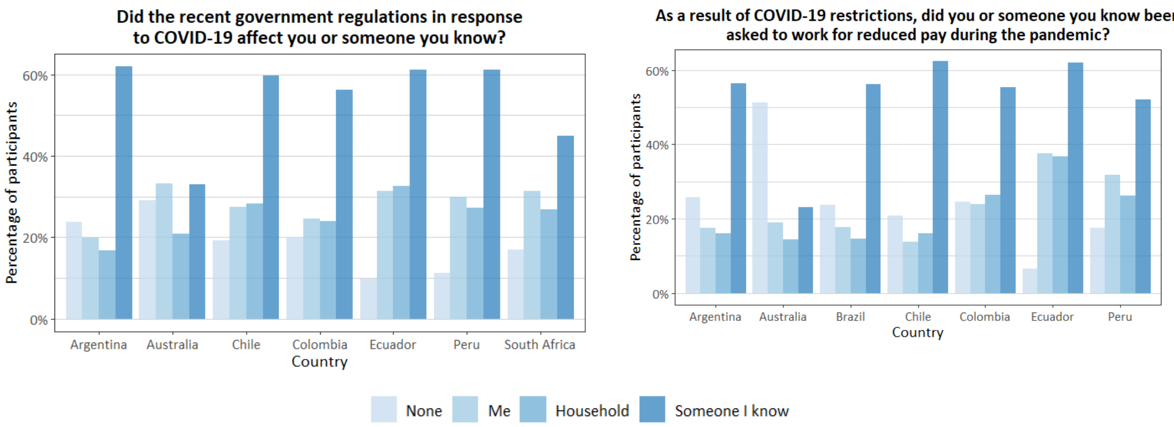


Figure 1: Impact of government regulations in response to COVID-19

Questions were included to understand the effect that government regulations and restrictions has had on individuals and their work. Figure 1 presents two figures, the left one represents if the respondent or someone he/she knows has been affected by the government regulations, and the one in the right if they have been asked to work for reduced pay during the pandemic. Around 60% of respondents in the South American cities know someone who has been affected by the regulations and has been asked to work for reduced pay. However, between 20-30% of respondents have been affected themselves, and less than 20% have been asked to work for reduced pay in Argentina, Brazil and Chile, with a higher percentage (between 25-30%) in Colombia and Peru. In Australia, over 30% have been affected by the regulations or know someone that has; but less than 20% has been asked to work for reduced pay. In South Africa, around 30% have been affected, and around 45% know someone that has been affected[136].

4.1 Working: WFH and commuting days

One of the most important variables in this study refers to the number of days worked from home or commuting. Figure 2 presents this information for respondents' current situation (the week before they answered the survey), and it also includes the number of days commuting prior to COVID-19, which is the only pre-COVID information available in Australia and South America.

In terms of the total number of days worked at the time of the survey, which was referred to as *last week* (top left figure), in all countries the most frequent weekly number of days worked is 5. In South Africa and all South American cities, the second most frequent number of worked days is 6. In Australia, the second most frequent is 4. In all countries the less frequent number of weekly worked days is 0 and 1.

The distribution of the total number of commuting days prior to COVID-19 (bottom left figure) is relatively similar to the total number of worked days *last week*, where the most frequent number of commuting days prior to COVID-19 is 5; followed by 6 days in all South American cities and by 4 days in Australia. If we compare this latter to the number of days commuting *last week* during COVID-19 (bottom right figure), we can see the major change caused by COVID-19, where the most frequent number of commuting days is 0 days in all countries, followed by 5 days. This finding suggests that people are either working every day from home (never commuting) or commuting everyday (commuting 5 days, presumably because their work is such that it cannot be done from home). This information certainly aligns with most of the government regulations, which have encouraged people to work from home when possible.

The average number of days worked and WFH in a week for each country are presented in Table 3. The average total number of days worked in a week for every country can be rounded to 5 days, except for Colombia, which has an average of 5.57 days. Australia has the lowest average (4.50), followed by South Africa (4.83), and the second highest after Colombia is Peru (5.39). The number of days working from home has more variation across countries, where the lowest is in Australia with 1.63 average days WFH, followed by South Africa with 2.31 days; and the highest is Argentina with 3.43 days WFH followed by Chile with 3.19 days.

Figure 3 presents the number of days respondents said they would like to WFH once COVID-19 restrictions are eased, and the average days are presented in Table 3. In all South American countries, the most frequent response was 3 days, followed by 2 days. The highest average is 3.52 days in Peru, followed by 3.30 days in Chile. In Australia, the most common response was 0 days followed by 2 and 5 days – with an average of 1.77 days. In South Africa, the most common response was 5 days, followed by 3 and 0 days with an average of 3.18 days.

[136] The question regarding reduced pay (Figure 1) was not included in the South African survey.

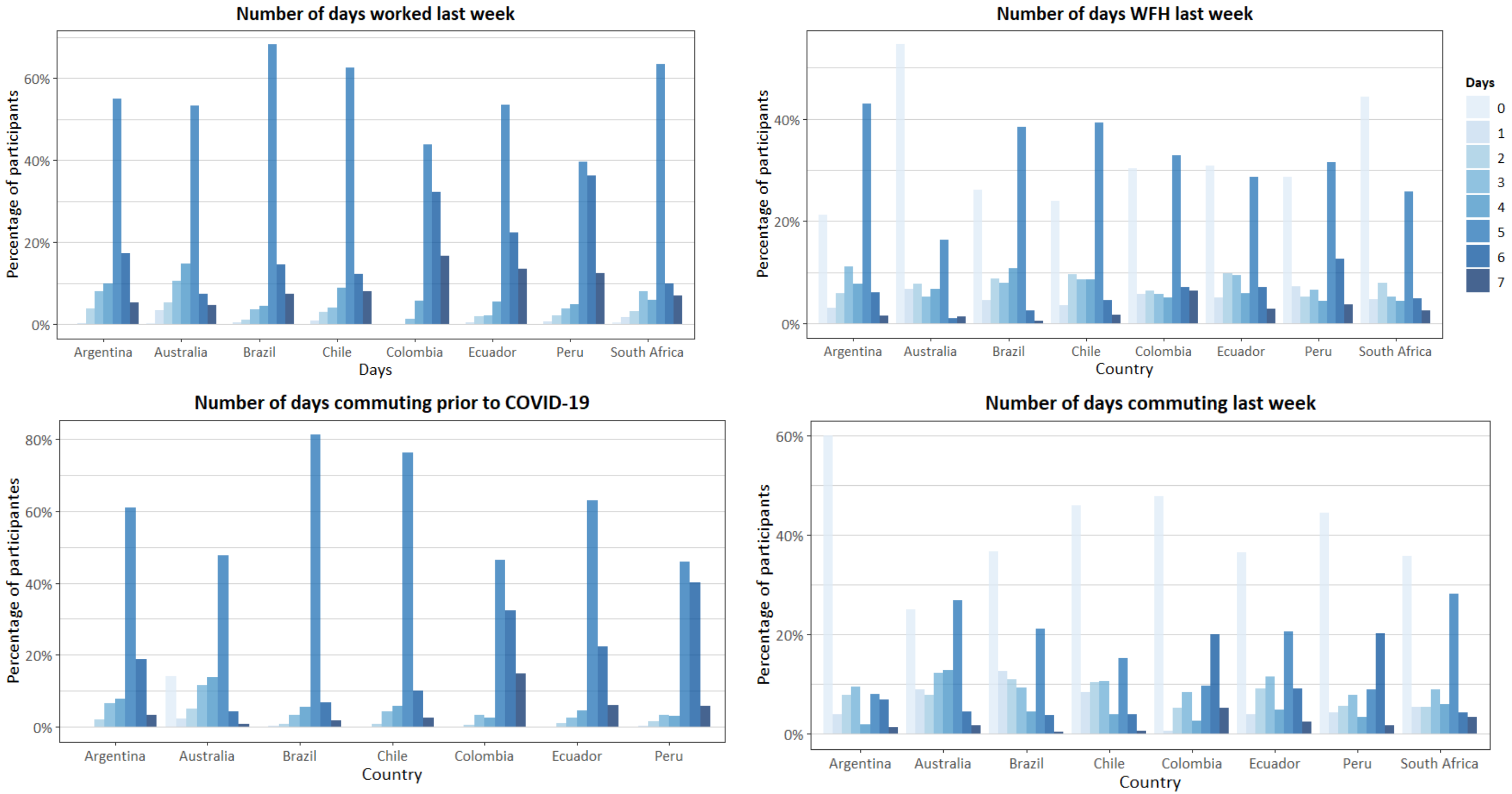


Figure 2: Number of days worked and WFH *last week*, and commuted *last week* and prior to COVID-19

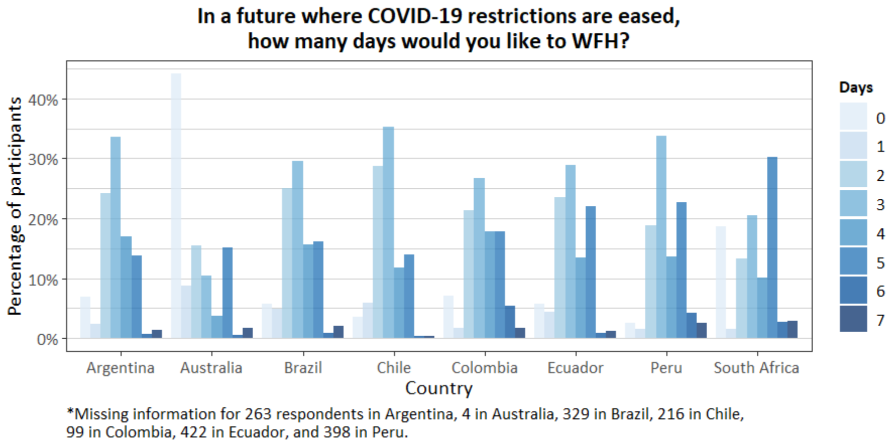


Figure 3: WFH number of days in the future

4.2 Commuting modal shares prior to COVID-19 and now

The available modes of transport and which ones were used prior to COVID-19 and at the time of the survey (*last week*) are presented in Figures 4 to 6. Given that several respondents were not commuting at the time of the survey (i.e., only working from home), the question about which mode of transport are they using now was not displayed in every country, so there is a lot of information missing about their current mode (details in the figures' captions).

The data shows that around 80% of respondents in Australia and South Africa have private vehicles available (i.e., car driver, passenger or motorcycle). It should be noted that it is likely that the South African only survey over-sampled high-income workers due to the general population low internet access, which probably has a positive influence in private mode availability. In Brazil private vehicles are available for around 58% pf respondents, to 48% in Ecuador, to 42% in Chile, to 36% in Colombia, to 28% in Peru, and to 27% in Argentina. Public transport is available to over 90% of respondents in Argentina, Chile and Colombia, to 83% in Brazil, to 82% in Peru, to 78% in Ecuador, to 65% in Australia; and the lowest public transport availability is of around 28% in South Africa.

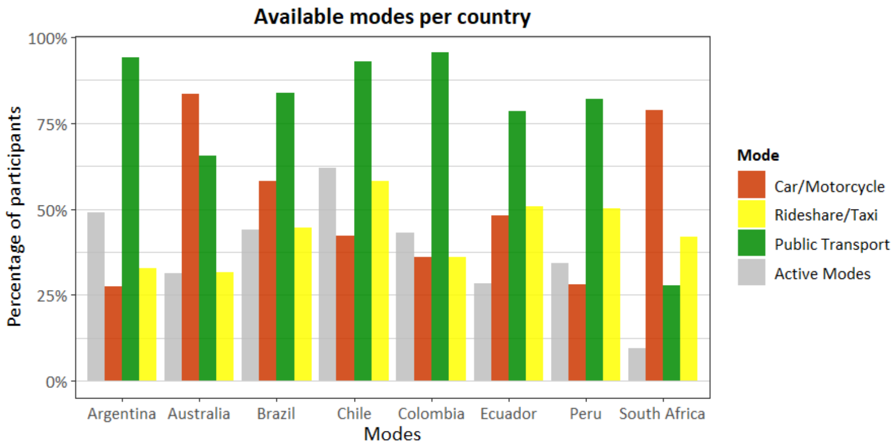


Figure 4: Available modes per country

Regarding modal shares, prior to COVID-19 private vehicle usage in Australia was of around 63%, which has increased to 68% at the time of the survey (i.e., *last week*). The public transport usage decreased from 29% to 19%; and the active modes usage increased from around 8% to 12%. The situation prior to COVID-19 in South America is a bit different, where public transport was the most frequently used mode of transport.

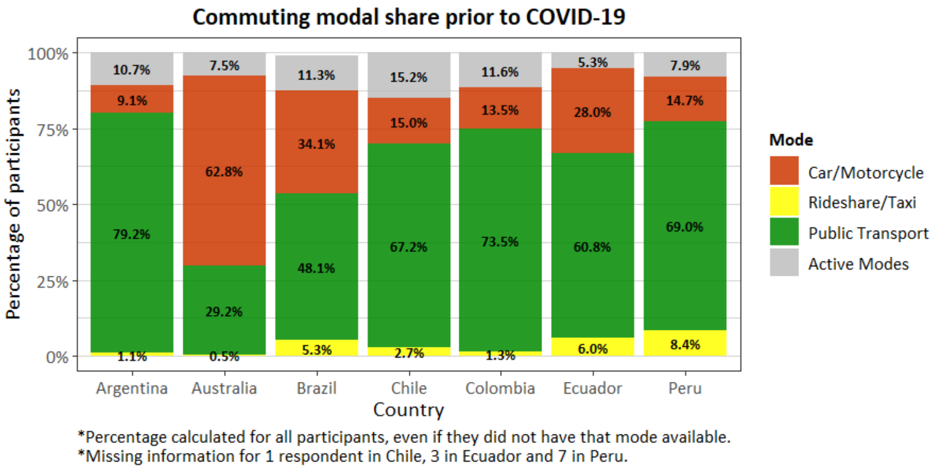


Figure 5: Commuting modal share prior to COVID-19

The difference in the modal shares prior to COVID-19 to *last week* in South America is significant. In Argentina, car/motorcycle use increased from 9% to 17% while public transport use decreased from 79% to 45%. In Chile, car use increased from 34% to 50%; while public transport use decreased from 67% to 40%. In Colombia, car use increased from 14% to 16%; while public transport use decreased from 74% to 60%. In Ecuador, the car/motorcycle use increased from 28% to 38%; while public transport use decreased from 61% to 40%. In Peru, car use increased from 15% to 19%; and public transport use decreased from 61% to 53%. However, it does not seem that all of the respondents that stopped using public transport moved to car/motorcycle, as the active mode usage also increased in every country. The highest change was in Argentina, where prior to COVID-19 the active mode share was 11% and now it is 32%.

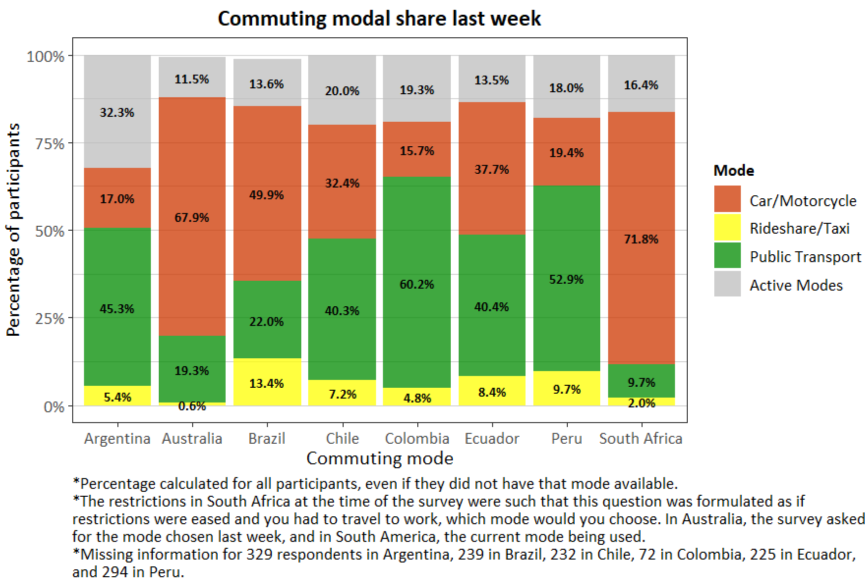


Figure 6: Commuting modal share *last week*

The private vehicle use prior to COVID-19 can be compared to car availability, and results show that 76% of respondents that have car available use it to go to work in Australia; around 57% in Brazil, Ecuador and Peru; 34% in Chile; 31% in Argentina; and 26% in Colombia. These results prior to COVID might be an indicator of other costs and difficulties associated with driving a private vehicle, for instance, parking, fuel, tolls that might have a higher influence in South American countries. Comparing the results at the time of the survey, more than 78%

of respondents that have car available use it to go to work in most countries, except Argentina (which is 68%) and Colombia (58%).

4.3 Attitudes towards working from home

The survey included questions about the position of businesses towards WFH as it stands today, and the employers' position expected once restrictions end, which are presented in Figure 7. The data suggests that in Chile and Argentina, around 40% of respondents are required to WFH; while in Brazil, Peru and Colombia 30% are required to; and in Australia and South Africa around 20%. 35% of respondents in Colombia said their work cannot be done from home, followed by Ecuador, South Africa, Peru, Australia and Chile with more than 20% of respondents. In Australia, the most frequent response was 'not allowed' with over 30%, followed closely by 'allowed to WFH whenever I want' (almost 30%). In South Africa, over 30% of respondents reported being allowed to WFH whenever they want; in Chile almost 20% of respondents said the same; and in Brazil and Ecuador this percentage was just over 15%. In South American countries, between a 5-10% of respondents said their office was closed at the time of the survey, so they are not able to go to work (regardless of where they work from); and in Australia and South Africa this percentage is almost insignificant.

The right hand-side of Figure 7 presents the positions of respondents' employers towards WFH once COVID-19 restrictions end, which was only answered by those that said they were employees (i.e., have employers). Over 40% of employees in the Australian sample said it is not possible to do their work from home, followed by 35% in Colombia and 30% in Peru. In Brazil, the most frequent response was a balance between WFH and office (over 40%), with similar percentages in Chile (35%), Argentina (35%) and Ecuador (over 30%). In Colombia, this was the second most frequent (35%) response after 'not possible to do their work from home'. In South Africa, the most frequent answer was they expect their employer to ask them to return to the office (45%) followed by a balance between WFH and office (over 35%); but the response 'not possible' was not available in South Africa. The least frequent response in every country was that the employer would allow them to WFH whenever they want.

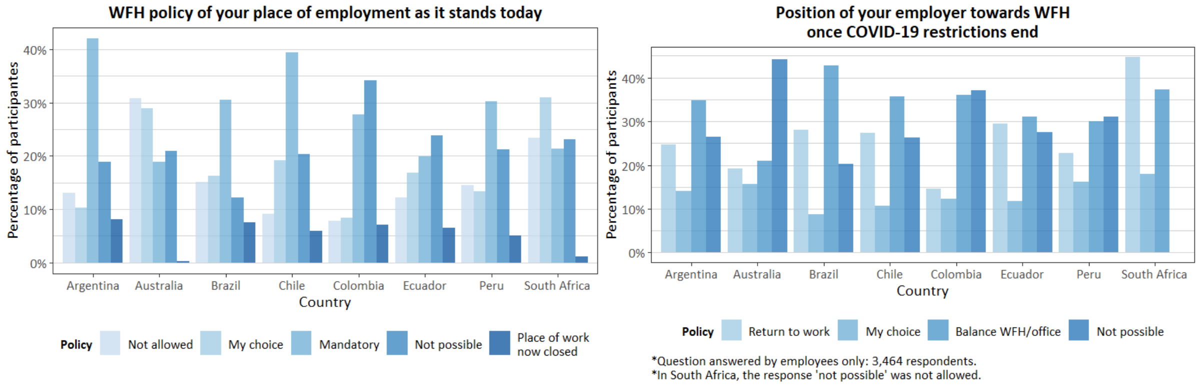


Figure 7: Working from home (WFH) policy of your place of employment

Figure 8 presents the responses on how productive respondents feel WFH is relative to working in the office. Unfortunately, due to different survey designs, every respondent did not answer this question (as detailed in the caption), and so it cannot be included in the models later. In Brazil, Colombia Australia, Argentina and Ecuador, the most frequent response was feeling more productive – although in Argentina and Australia this answer was closely followed by same productivity level. In Chile, almost 40% of respondents said they felt less productive, while 30% said they felt the same and 30% said they felt more productive. In Peru, a bit over 35% said they felt the same, almost 35% said they felt less productive, and around 30% said they felt more productive.

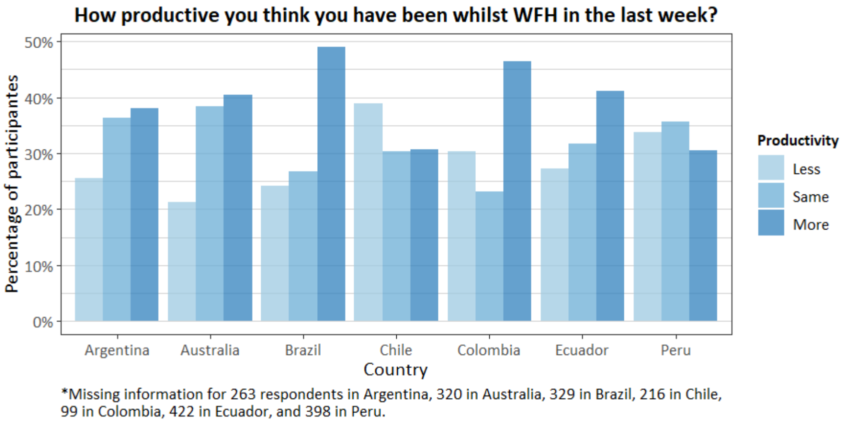


Figure 8: How productive you think you have been whilst working from home (WFH) in the *last week*?

4.4 Attitudes towards COVID-19 and government response

The surveys included several opinion statements, were respondents indicated how much they disagreed or agreed with each. Two interesting statements refer to how concerned people are about COVID-19 and work, given the environment they usually work in (i.e., prior to COVID); and if they believe their Federal/National government response to COVID-19 has been appropriate. In Brazil, almost 80% of respondents said they agree or strongly agree with being concerned about COVID-19; and more than 80% thinks that the government response has not been appropriate. Around 50% of respondents who work in Chile, Ecuador and Colombia are concerned (agree or strongly agree) about COVID-19, while 20-30% are not concerned. In Ecuador, almost 70% of people think the government response has not been appropriate, while slightly more than 10% think it has; in Chile around 65% think the response has not been appropriate, while around 15% think it has; and in Colombia, around 50% think the government's response has not been appropriate, while 30% think it has.

In Peru and Argentina, around 45% are concerned about COVID-19 and their work. In Argentina, 50% of respondents think the government's response has not been appropriate, while 30% think it has. In Peru, 30% of respondents think the government's response has not been appropriate, while 40% think it has. In Australia, around 45% of respondents said they are concerned about COVID-19 and work, while more than 75% thinks the federal government response has been appropriate. These results suggest a relationship between respondent's level of concern with the government response to COVID-19.

5 Working from Home (WFH) Model

A Poisson regression model was estimated to understand the key variables that influence the number of days working from home. The model was estimated using the pooled data from the three different geographical jurisdictions: Australia, South America and South Africa, but estimating area-specific variables. This approach was preferred over estimating a separate model for each area, as it allows for a direct comparison of behavioural outputs, enabling us to understand the different influence of the explanatory variables in the probability to WFH in each area.

As a non-negative discrete count value, with truncation at zero, discrete random variable, y_i, observed over one period of time, and observed number of days WFH in a week, *k* (k = 0,1,…7), the Poisson regression probability is given by equation (1).

$$P(y_i = k \mid \mu_i) = \frac{\exp(-\mu_i) \cdot \mu_i^k}{k!} \qquad k = 0,1,...,7 \qquad (1)$$

The prediction rate, μ_i, is both the mean and variance of y_i and is defined as follows:

$$\mu_i = E\left(y_i = k \mid x_i\right) = \exp(\beta' x_i) \tag{2}$$

In this study, we allow for unobserved heterogeneity through the incorporation of random parameters. The prediction rate or expected frequency of the number of days WFH was calculated as a function of different explanatory variables, shown in equation (3).

$$\mu_i = \exp\left(\beta_0 + \sum_n \beta_n \cdot z_n \cdot d_a + \sum_m \beta_m \cdot x_m \cdot d_a + \sum_c \beta_c \cdot d_c + \varepsilon\right)$$

(3)

where β_0 represents the constant; z_n represents respondents socio-demographics (e.g., age, gender, income); x_m other respondents' characteristics such as mode availability, employer's attitude towards WFH, etc.; d_a dummy variables associated to each area; d_c dummy variables associated to each country – which were estimated as random and normally distributed; and the β represent the parameter estimate associated to each of the variables.

The elasticities in this nonlinear model specification are presented in equation (4).

$$\text{Elasticity} \Rightarrow \frac{\partial E\left(y_i \mid x_i\right)}{E\left(y_i \mid x_i\right)} \cdot \frac{x_i}{\partial x_i} = \beta \cdot x_i \tag{4}$$

The model results from the preferred final model are presented in Table 4. The constant parameters for Australia and South Africa were estimated as random and normally distributed, which represent the error variance relative to South America. We also estimated separate models for each area (i.e., Australia, South Africa and South America), but the pooled model with interactions between explanatory variables and location are more informative in a cross-country comparison (since we have controlled for scale through a single model). The results show that older respondents in South America are more likely to work from home, the same as female respondents in South America. However, these variables (age and gender) were not statistically significant in Australia or South Africa. Income was statistically significant in Australia and Ecuador and had a positive influence on WFH, which could be considered a proxy for occupation[137]. The current employer view towards WFH was statistically significant with the expected relationship: if it is mandatory to WFH or if the employer allows employees to decide where they work from, then people are more likely to WFH – and the influence on the probability to WFH is higher in Australia, followed by South Africa. The dummy variable representing that it is not possible to WFH was only statistically significant in South America, showing that when respondents are not allowed to WFH, they are less likely to WFH.

Results show that the employer view towards WFH after COVID-19 also has a statistically significant influence: if the respondent believes the employer will allow him/her to decide when to WFH in the future, then he/she is more likely to WFH now. This variable was significant in all three areas, with a higher value in South Africa, followed by Australia.

The travel time to the office was included only in Australia and South Africa, since there was a lot of information missing in South America. The results show that the longer it takes a respondent in South Africa to get to the office, the more likely they are to WFH. If respondents have access to a car as a driver or passenger available in Australia, they are less likely to WFH, which could be a proxy for the biosecurity risk of using public transport compared to the

[137] Occupation was excluded from this study since it was not asked in any of the South American cities.

car. The dummy variables that represent different countries show that respondents in Australia are the least likely to WFH, followed by South Africa, Chile, Brazil, and Argentina, relative to all the other countries (i.e., Colombia, Ecuador, and Peru). This finding could certainly be related to the progress of the health crisis in each country, particularly in Australia where the pandemic was fairly controlled at the time of the survey, so people are able to go to work with little or no risk.

Given the quantum of non-available data on some variables in one or more countries, there is a real possibility that this will impact on the error variance in the Poisson regression model, and hence such heterogeneity should be accounted for. We have included this and found statistically significant differences between each of the three regions. The last row in the table represents the standard deviation of the dummy variables for Australia and South Africa. Both are statistically significant, which says there are some unobserved effects that vary between locations, and the higher parameter estimate for South Africa indicates greater heterogeneity relative to Australia and South America.

Table 4: Poisson regression model results – mean (t values)

	Australia	South America	South Africa
Constant	0.807 (20.04)	-	-
Age (years)	-	0.004 (3.83)	-
Gender female (0,1)	-	0.111 (5.66)	-
Personal income ('000AUD$)	0.025 (5.22)	-	-
Household income Ecuador ('000AUD$)	-	0.016 (3.07)	-
Employer view towards WFH after COVID: my choice (0,1)	0.327 (4.94)	0.114 (2.53)	0.421 (7.02)
Employer view towards WFH now: my choice (0,1)	2.044 (21.87)	0.268 (9.33)	1.303 (19.32)
Employer view towards WFH now: mandatory (0,1)	2.560 (26.00)	0.499 (17.17)	1.708 (23.63)
Employer view towards WFH now: not possible (0,1)	-0.714 (3.79)	-1.150 (39.58)	-
Total travel time to the office (minutes)	0.003 (2.78)	-	0.002 (2.42)
Car driver or passenger available (0,1)	-0.220 (3.07)	-	-
Dummy variable Australia (0,1)	-2.187 (17.80)	-	-
Dummy variable South Africa (0,1)	-	-	-1.462 (18.67)
Dummy variable Brazil (0,1)	-	-0.132 (4.89)	-
Standard deviation dummy variables	0.333 (10.31)	-	0.766 (25.22)
Restricted Log-likelihood		-11,177.43	
Log-likelihood at convergence		-8,748.19	
Number of estimated parameters		24	
Sample size		4625	
AIC/n		3.79	

The log-likelihood ratio test can be used to test if our model is superior to the restricted version with only constants, where:

$$LR_{95\%,df} = -2 \cdot \left[l(\theta_r) - l(\theta_c) \right] = -2 \cdot \left[-11,177.43 + 8,748.19 \right] = 4,858.48 > \chi^2_{95\%,23df} = 35.172$$

The statistical evidence suggests that the estimated parameters in the pooled with country interactions model, improves the models overall statistical performance, justifying the selection of the pooled model.

The elasticities of the expected frequency of the number of days WFH for each of the variables are presented in Table 5 by country. These represent the behavioural sensitivity of the expected days working from home for each of the explanatory variables. As an example, the elasticity of car availability in Australia relative to the expected frequency of the number of days WFH is -0.182, which says that if there is a change of not having a car available to having one, *ceteris paribus*, there is likely to be a reduction in the expected frequency of the number of days WFH of 18.2%. The elasticity of travel time shows that for a 10% increase in the travel time to the office, there would be a 0.83% increase in the number of days WFH in Australia, and a 0.76% increase in the number of days WFH in South Africa.

Table 5: Elasticity of expected frequency of the number of days WFH

Variables	Arg.	Aus.	Bra.	Chi.	Col.	Ecu.	Peru	S. Af.
Age (years)	0.147	-	0.160	0.133	0.133	0.139	0.142	-
Gender female (0,1)	0.072	-	0.055	0.073	0.054	0.063	0.054	-
Personal income Australia ('000AUD$)	-	0.160	-	-	-	-	-	-
Household income Chile ('000AUD$)	-	-	-	0.049	-	-	-	-
Employer view towards WFH after COVID: my choice (0,1)	0.012	0.043	0.008	0.010	0.008	0.007	0.011	0.076
Employer view towards WFH now: my choice (0,1)	0.028	0.591	0.044	0.051	0.022	0.045	0.036	0.403
Employer view towards WFH now: mandatory (0,1)	0.210	0.485	0.153	0.197	0.138	0.099	0.151	0.365
Employer view towards WFH now: not possible (0,1)	-0.217	-0.149	-0.140	-0.233	-0.393	-0.274	-0.244	-
Total travel time to office (minutes)	-	0.083	-	-	-	-	-	0.076
Car driver or passenger available (0,1)	-	-0.182	-	-	-	-	-	-
Dummy variable Australia (0,1)	-	-2.187	-	-	-	-	-	-
Dummy variable South Africa (0,1)	-	-	-	-	-	-	-	-1.462
Dummy variable Brazil (0,1)	-	-	-0.132	-	-	-	-	-

The contribution of this paper is to understand work from home and commuting behaviour. Except for travel time, which was the only geographically spatial variable statistically significant (only in Australia), the results show predominantly socio-economic effects (i.e., age, gender, income) and employer’s support to WFH as well as country-specific dummy variables as having a statistically significant influence in the number of days WFH. From a strategic modelling and urban planning perspective, there are three main variables that play a significant role in WFH: employer support towards WFH, travel time to the office and car availability[138]. The following section analyses the behavioural sensitivity of the number of days WFH based on these three main variables using simulated scenarios for each country, which is more interesting than looking at the evidence for the pooled data.

6 Simulated Scenarios

An informative way of appreciating the different behavioural responses in terms of the number of days WFH between the various locations is to undertake a number of scenario simulations. The base scenario for each country is obtained using the variables’ averages presented in Table 3, with the results summarised in Figure 10. In the base scenario, Australia has the highest probability of 0 days to WFH (0.46), followed by South Africa (0.31) – this is also shown in the simulated average number of days WFH which is lowest in Australia (1.58), followed by South Africa (1.74). Comparing the probabilities of the South American countries, the

[138] The use and availability of active modes was not statistically significant in the models.

probabilities to WFH 0 days a week is lower in Argentina and Chile, and higher in Brazil and Colombia – which is also represented with a higher and lower average number of days WFH, respectively. The countries with the lower average number of days WFH, namely Australia and South Africa, are the ones with the lowest death rates per million habitants, followed by Colombia and Ecuador (Table 2). This shows the significant impact of the different government strategies and results in the number of days WFH – those countries that have faced more difficulties facing this pandemic are the ones who have faced a higher reduction in commuting. Moreover, car availability and use are significantly higher in Australia and South Africa (Figure 4-5), which could also play an important role in the decision to commute to work in what is perceived as a more bio-secure mode of transport. The estimated average number of days WFH are lower than those observed in the sample for most countries except for Chile (Table 3), where the estimated number of days WFH is higher than the observed average.

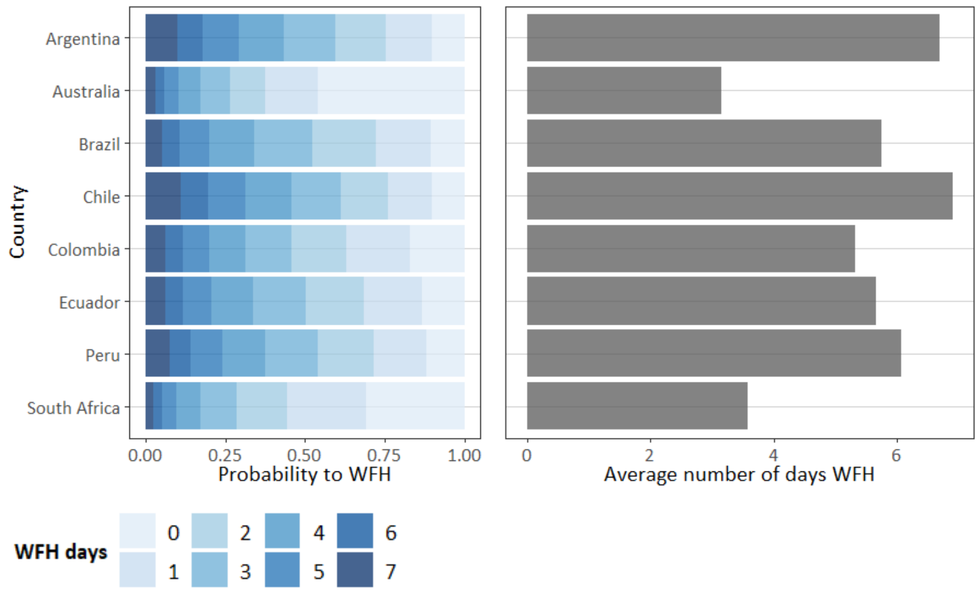


Figure 10: Base scenario WFH probabilities

Seven scenarios were simulated to show the change in the probabilities of working from home for each country. A description of each scenario is presented in Table 6, and the results of the average number of days WFH for each simulated scenario are summarised in Figure 11. In all the scenarios, the percentage change in the number of days WFH is highest in Australia followed by South Africa. This finding shows that the probability to WFH in Australia and South Africa - even if lower than in South America - is more sensitive to changes in the explanatory variables.

The first three scenarios represent variations of the variable that related to the employer's view towards WFH now. The first one is the closest to the base scenario, where respondents are allowed to work from home whenever they want (their choice), except for those that said it was mandatory for them to WFH or it was not possible. This scenario represents an increase in the number of days WFH for all countries – although the percentage change relative to the base scenario is higher in Australia (34.9%) followed by South Africa (21.1%) and lower in Chile (5.5%). The second simulated scenario represents the situation where everyone can decide whether to work from home or the office (it is not mandatory to WFH for anyone), except for those that said their work cannot be done from home. The results suggest a decrease in the number of days WFH in Chile and Argentina, probably because these two countries had the highest percentage of people required to WFH (Figure 7) and in this scenario some people would be choosing to go to the office instead of staying home every day. There was a slight decrease in the number of days WFH in Colombia, and a slight increase in Peru. In the rest of the countries, the second scenario represents an increase in the average number of days WFH relative to the base scenario – which is higher in Australia (15.0%) followed by South Africa (6.5%) and Ecuador (4.9%). The third simulated scenario allows every respondent to decide to work from home or the office (even those that said their work could not be done from home). This scenario represents an extreme situation of WFH that assumes everyone can work from home excluding those jobs that cannot be done from home and, as such, its results should be interpreted carefully as they do not replicate the full sample of workers. It is included to show a boundary condition with regards to the adoption of WFH, rather than to provide a feasible solution that could be pursued by transport policy makers. The third scenario represents an increase in the average number of days WFH for all countries relative to the base scenario, higher in Australia (39.5%) followed by Colombia (34%), and by Ecuador (27.7%); and lower in Argentina (10.7%) and Chile (10.8%).

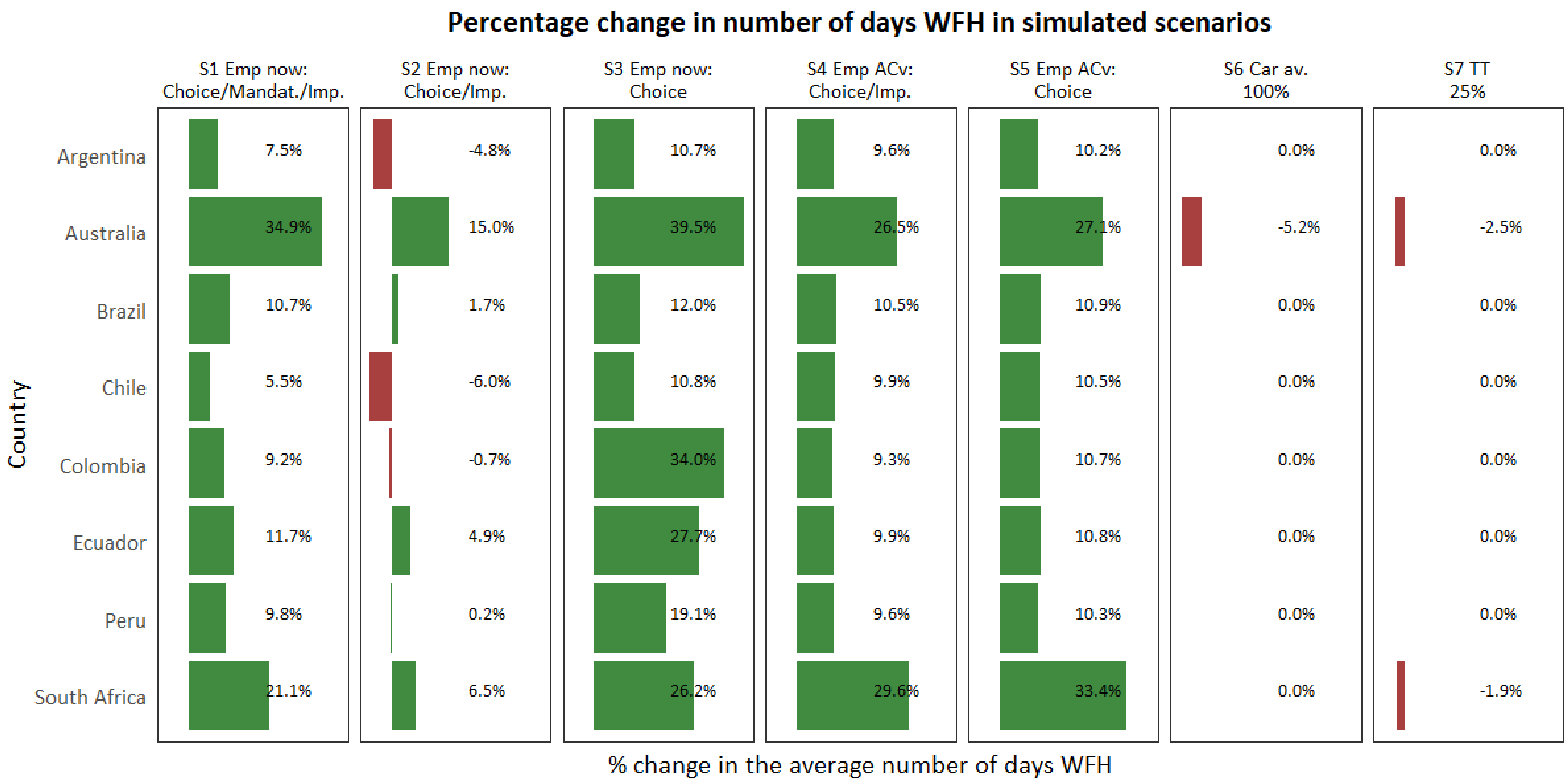
Table 6: Simulated scenario descriptions

	Scenario	Description
0	**Base**	Base Scenario
1	**Emp now: Choice/Mandat./Imp.**	Employer view towards WFH now: my choice for everyone that did not say it was mandatory or not possible
2	**Emp now: Choice/Imp.**	Employer view towards WFH now: my choice for everyone that did not say it was not possible
3	**Emp now: Choice**	Employer view towards WFH now: my choice 100% of the sample
4	**Emp ACv: Choice/Imp.**	Employer view towards WFH after COVID: my choice, except for those that said it is not possible
5	**Emp ACv: Choice**	Employer view towards WFH after COVID: my choice 100% of the sample
6	**Car av. 100%**	Car driver or pax available to everyone in the sample
7	**TT 25%**	Travel time to the office 25% faster

The following two scenarios (4 and 5) represent variations in the employer's view towards WFH after COVID-19 restrictions end. Scenario 4 represents the situation where everyone can decide to WFH when they want to, except those that said their work cannot be done from home. Scenario 5 represents the situation where 100% of the sample is allowed to decide where to work from regardless of their work (similar to scenario 3 which excludes those participants whose jobs cannot be done from home). These scenarios show a significant increase in the number of days WFH, which is always highest in South Africa, followed by Australia, and lowest in Argentina, Peru and/or Colombia.

Scenario 6 represents a situation where all respondents have the car as a driver or passenger available, which only affects Australia as this variable was not significant in South Africa nor South America. This scenario represents a 5.2% decrease in the average number of days WFH. Scenario 7 represents 25% decrease in the travel time to the office, variable which was statistically significant in Australia and South Africa only. The results show that a 25% decrease in the travel time to the office would mean a reduction of 2.5% in the number of days WFH in Australia, and 1.9% in South Africa.

These simulated scenarios show the impact of the employer's view now and after COVID-19 restrictions end, car availability and travel time on the average number of days WFH. The results show that, even though the average number of days WFH is lowest in Australia, the simulated scenarios represent a higher percentage variation in Australia than in the other countries. In countries where the average number of days is higher, namely Argentina and Chile, the scenarios represent lower percentage changes – but this could also be explained by these two countries having more restrictions that require a higher percentage of respondents WFH.



*The red bars represent a decrease in the average number of days WFH relative to the base scenario; the green bars represent an increase.
*Table 6 describes each of the simulated scenarios.

Figure 11: Average number of days WFH simulated scenarios – percentage change relative to base scenario

7 Conclusions

This study aims to understand the implications that COVID-19 has had, in eight countries, due to the increase in working from home (WFH). The relevant authorities of the countries included in this study have had very different approaches to managing COVID-19 with significantly different results, where Australia stands out with a significantly lower reported number of cases and deaths per million habitants. However, in all countries studied, the incidence of WFH has increased dramatically since the beginning of the COVID-19 pandemic in early 2020. The results suggest that a large number of respondents were working every day from home or commuting every day, where the latter supports no change in WFH behaviour. This result can be partly explained by the different government restrictions in each country; for example, in Chile and Argentina around 40% of respondents said it was mandatory for them to WFH. However, the majority of respondents said they would like to WFH one or more days in the future once COVID-19 restrictions are eased, which aligns with the US evidence in Barrero, Bloom, & Davis (2021): with the highest average being 3.52 days in Peru and 3.30 in Chile; and the lowest in Australia at 1.77 days. A significant number of respondents said they believe that their employer will support a balance between WFH and the office once COVID-19 restrictions are eased – around 20% in Australia and more than 30% in the rest of the countries. Many employers have found that WFH does not impact productivity anywhere near the extent it was thought prior to COVID-19, reinforcing the value of forced change as a revealed preference experiment.

A Poisson regression model, given the count data nature of the number of days working from home, was estimated to identify the systematic influences on the number of days working from home in each country and across all eight countries. The results show that the role of socioeconomic characteristics varies between countries; for example, age and gender are statistically significant in South America only, where older respondents tend to work from home more often, as well as women; while income was statistically significant in Australia and Chile, both having a positive impact on the number of days WFH in a week. The current employer's view towards WFH was statistically significant in all countries, suggesting that when the employer is more supportive towards WFH, respondents are likely to WFH more days in a week. Interestingly, if respondents think their employer will be supportive towards WFH once COVID-19 restrictions are eased, it had a positive influence on the number of days WFH in all countries. The travel time to the office was statistically significant in Australia and South Africa and had a positive influence on WFH, i.e., if a respondent's trip to the office is longer, then he/she is more likely to have more days of WFH. Car availability had a negative impact on number of days WFH in Australia, suggesting that respondents that have a car available are likely to WFH fewer days per week. Seven scenarios were simulated to analyse the sensitivity of the expected frequency of the number of days WFH due to changes in the explanatory variables. The results show that Australia and South Africa are more sensitive to changes in these variables, which can be attributed to the fact that the average number of days WFH are lower in these countries than in South America. Contrary, Argentina and Chile are less sensitive to changes in the explanatory variables, which can be attributed to higher COVID-19 restrictions and a higher number of days WFH. It should be noted that the data was collected using online panel surveys, and internet accessibility in Ecuador, Peru and South Africa is below 60%. This is a limitation when collecting data in countries with a lower digital connectivity, as there is likely to be over-sampling of high-income workers. Although such internet accessibility is generally low for the entire country, including remote areas – our study only includes workers in metropolitan areas, who are more likely to have internet access. Regardless, the results presented in this study for Ecuador, Peru and South Africa in particular should not be transferred to the entire population without careful consideration.

The most important message from the assessment of the impact of working from home across all metropolitan areas in this study is that there is growing support from both employers and employees for more flexible working practices which has become known as the hybrid model. The reported productivity levels by employees have either increased or remained the same, and there has been growing support from employers to allow employees to decide where to work from. In Australia, for example, we have growing evidence to support a hybrid model with WFH occurring for 1 to 2 days per week for many occupations, notably professional and managers (Beck & Hensher, 2021b). This hybrid work model involves working from home to some extent and fewer days commuting to a regular workplace location. This will mean that with reduced commuting travel on any one day, assuming this continues beyond the pandemic period (which we are referring to as the period of living with COVID in a vaccinated world), we can expect metropolitan planning agencies to take this transport setting into account when revising their strategic transport plans and associated modelling used to forecast traffic activity on the roads and on public transport in particular. Importantly, however, any change in the quantum of commuting associated with increased WFH will also require an assessment of what this means for changes in the amount of non-commuting travel (see Balbontin et al., n.d.) and other uses of time ‘saved’ through reduced daily commuting. It is also likely to mean a greater focus of activities at the suburban level and pressures on governments to invest in improved local transport services including footpaths, bicycle ways and localised on-demand bus services. We describe the impact of WFH due to the pandemic as an unintended positive consequence and one that should not be lost as a return to pre-COVID-19 levels of crowding on public transport and the stress on long commutes 5 days a week. In the medium to long-term, it remains to be seen how this trend on reducing how often people commute to work might impact their household location. Whether the WFH behaviour findings will eventuate over time remains to be seen, but we have some new evidence that an increased incidence of working from home can make a positive contribution and be one of the strongest transport policy levers we have seen for many years, as long as people do not move further away from where they work.

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Appendix Q. Paper #13: Advanced modelling of commuter choice model and work from home during COVID-19 restrictions in Australia

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Abstract

The decision to work from home (WFH) or to commute during COVID-19 is having a major structural impact on individuals' travel, work and lifestyle. There are many possible factors influencing this non-marginal change, some of which are captured by objective variables while others are best represented by a number of underlying latent traits captured by attitudes towards WFH and the use of specific modes of transport for the commute that have a bio-security risk such as public transport (PT). We develop and implement a hybrid choice model to investigate the sources of influence, accounting for the endogenous nature of latent soft variables for workers in metropolitan areas in New South Wales and Queensland. The data was collected between September-October 2020, during a period of no lockdown and relatively minor restrictions on workplaces and public gatherings. The results show that one of the most important attributes defining the WFH loving attitude is the workplace policy towards WFH, with workers that can decide where to work having a higher probability of WFH, followed by those that are being directed to, relative to other workplace policies. The bio-security concern with using shared modes such as public transport is a key driver of WFH and choosing to commute via the safer environment of the private car.

Keywords: Working from home; hybrid choice model, commuting activity, COVID-19

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1 Introduction

The COVID-19 pandemic has had serious global implications, particularly for health matters, which have resulted in significant changes in the way businesses and people operate on a daily basis. Businesses around the world have adapted quickly to the changing circumstances, allowing their workers to work from home (WFH) when possible – which has had a major influence on not only the nature of where and how work is done, but on the performance of the transport network. During these uncertain times, attitudes, perceptions, and beliefs are likely to be playing, and continue to play, a very important role in individual choice making and behaviour related to working from home and/or commuting, and most notably on the use of shared modes such as public transport (PT).

In this paper, a hybrid choice model will be used to identify the nature and role of underlying attitudes, perceptions and beliefs that influence the decision to work from home for a specified number of days per week, and how this relates to the incidence of commuting by day of the week and time of day. The hybrid choice model is estimated to account for the latent structure associated with a number of important soft variables related to perceived productivity and overall advantages of working from home, and concern towards the use of public transport due to COVID-19. These soft variables cannot be directly measured (i.e., asked to respondents), so they are estimated using individual responses to multiple attitudinal questions included in the survey (e.g., I have felt productive this last week while working from home, or I am able to find a balance between paid and unpaid work). The choice model considers 12 different alternatives for each day of the week: not to work, WFH, and to commute by up to 10 different modes of transport (depending on which modes are available to each individual). The latent variables feed into this model in an endogenous way to understand how the attitude towards WFH and the concern towards PT influence the probability to not work, WFH or commute by a specific mode each day of the week. The data was collected during late 2020 as part of a larger ongoing study to understand the implications of COVID-19 on the transport network around Australia (see Hensher et al., 2021; Beck & Hensher, 2020). Data from workers in two metropolitan areas will be used, the Greater Sydney Metropolitan Area (GSMA) and Southeast Queensland area (SEQ).

This paper is organised as follows. The next section presents a brief background of literature on the impacts of COVID-19 on travel behaviour and how the pandemic has been considered to date within the setting of a hybrid choice model. Section 3 presents the data used in this study. The next section describes the methodology used in this study, followed by the model results and elasticities. Section 7 presents simulated scenarios, and the final section discusses policy implications and conclusions.

2 Literature Review

2.1 COVID-19 and Working from Home

The earliest studies on working from home, termed telecommuting, focused on how information technology was changing the nature of white-collar work and how a progression towards higher levels of remote working might create negative externalities with respect to social interaction and the work-life balance, but also how it could generate benefits associated with greater flexibility in time management and positive social externalities such as reduced congestion (see pioneering studies such as Salomon & Salomon, 1984; Nilles, 1988; Hall, 1989; Kitamura et al., 1990; Mokhtarian, 1991; and Maynard 1994). While telecommuting did not quite grow at the rate first envisaged, indeed in Australia only 8% of people had a formal WFH arrangement (PC, 2021) and only 5% of people were working from home on the day of the most recent census (ABS, 2016), studies in transportation continued to examine factors affecting the uptake of telecommuting (Mokhtarian et al., 1998; Choo et al., 2005; Fu et al., 2012; Caulfield, 2015).

However, as a result of the COVID-19 pandemic there have been many studies that examine the impact of the virus and associated measures in different jurisdictions to reduce the spread. For example, Transport Policy launched a special issue on the impact of COVID-19 on passenger transit (Transport Policy, 2021). There has been great interest in the way in which travel restrictions have helped stop the spread of the virus (Chinazzi et al., 2020) or how travel can spread the virus (Böhmer et al., 2020), and how transport policy makers might need to react to these changes (Zhang, 2020; Gkiotsalitis & Cats, 2021). Similarly, there has been interest in the role of working from home, mostly in literature outside of transportation examining the impacts of working from home on work-life balance (Chu et al., 2022), the strengths and weaknesses of WFH and associate transition policies (Vyas & Butakhieo, 2020), however research has examined the intersection of lockdowns, working from home, transportation and mental health (Dam et al., 2020). In interesting work conducted prior to COVID-19, an Australian study found that people's desire for greater work location flexibility increased once experiencing such freedoms (Hopkins & McKay, 2019). In the US, several studies have shown that as with the earlier research in transportation, that occupation is often the best predictor of working from home both before COVID-19 and currently (Bick et al., 2021) and in echoing themes from Beck & Hensher (2021) that working from home is likely to stick due to better-than-expected experiences (Barrero et al., 2021).

Given that it is likely that working from home will be a greater feature of work moving forward from the pandemic, it is important to begin to understand how choices are made regarding working from home beyond the aggregate level, to look more closely at what might motivate choice at a disaggregate, individual level.

2.2 Hybrid Models of Choice Behaviour

Hybrid choice models which integrate discrete choice models with latent variables have been developed over a number of years, with early examples by Walker (2001) and Walker & Ben-Akiva (2002), and are reviewed in a number of sources such as Hensher et al. (2015). These models emphasise the importance of amorphous influences on behaviour such as knowledge and attitudes. Several articles have found interesting results when incorporating latent variables, that allow for a better understanding of individuals preferences and how these underlying attitudes affect their choice making (Daly et al., 2012; Prato et al., 2012; Morikawa et al., 2015; Beck & Hess, 2017). COVID-19 as an extreme event has influenced in a significant way how we work, travel and live, resulting in changes that have impacted on the transport systems, notably attributed to working from home and bio-security concerns over using public transport and other shared modes. Our interest in this paper is how we might integrate revealed preference data on actual changes in travel behaviour and the growth in WFH with a number of soft latent variables that represent underlying attitudes and opinions that condition observed travel and non-travel activities. Before presenting new evidence, we review a number of existing studies that are relevant to the focus of this paper and that also used hybrid choice models in this context.

Beck et al. (2021) use data collected across three waves in Australia throughout 2020 to study the impacts of COVID-19 on the number of trips by public transport. They used a zero inflated Poisson regression model to explain the number of trips by public transport by different socioeconomic characteristics and attitudes towards the use of public transport. They incorporate latent variables as explanatory variables in the utility function (estimated through factor analysis). The findings suggest that individuals concerned about public transport before COVID-19 and during the first (March 2020) and second (June 2020) data collection periods, usually make more weekly trips, suggesting that greater exposure is driving the attitudes towards hygiene and risk. Those that are more concerned about the hygiene in public transport tend to have higher odds of making zero public transport trips in the data collected after COVID-19, switching to greater use of the private car.

Balbontin et al. (2021) undertook a similar study using data collected in Australia in late 2020. They incorporate latent variables as additional explanatory variables in a model explaining weekly commuting and non-commuting trips. The results in metropolitan areas suggest that people that love WFH tend to commute more than those that do not love WFH, suggesting that people prefer a balance between WFH and going to the office. In terms of concern towards public transport, these results suggest that public transport commuters also tend to do less work-related travel and fewer social/recreation trips. The focus of this study was understanding the influences on the number of weekly commuting and non-commuting trips, as opposed to the current paper, which focuses on identifying the influences on the daily probability to not work, work from home or commute.

Hurtubia et al. (2021) estimate a hybrid choice model that integrates a discrete choice model with latent variables to identify the probability of working from home versus going to the office. They use data collected in Chile at the beginning of the pandemic, during March 2020 and consider two latent variables: one associated with concern towards health and the other one concern towards the economy. Their results show that female respondents, respondents with a lower income, and older residents, are more concerned about health, which has a positive influence on the probability to WFH, possibly due to greater transmission risk outside the home and the severity of COVID-19 if they catch it. Their results also suggest that respondents with a lower income, without secondary education, or independent workers, are more concerned about the economy, resulting in a negative influence on the probability to WFH.

Aaditya and Rahul (2021) also develop a hybrid choice model to identify the influence of awareness of COVID-19 on the modal shift in India. Their results suggest a significant modal shift from public transport to personal vehicle use, attributed to the increased awareness of COVID-19 and a perception of the deterioration in public transport safety. Their findings suggest that respondents were willing to reconsider using public transport in a post-lockdown scenario if several preventive measures towards COVID-19 were implemented (e.g., social distancing, crowd management, and sanitisation).

Hensher et al. (2022), developed a model system to identify the choice between working from home as opposed to commuting and not working by day of the week and time of day in Australia. They estimated a mixed multinomial logit model to determine and map the probability to WFH using individuals' socioeconomic characteristics, modal attributes such as time and cost, day of week and time of day and some attitudinal variables such as concern about using public transport. The model outputs provide evidence of the key drivers of the probability of WFH compared to commuting over a week and form the basis of a mapping equation in the construction of a full origin-destination (OD) matrix for the study area to identify the varying spatial incidence of WFH across the OD pairs.

Since the start of COVID-19 in March 2020, there has been an accumulating body of research undertaken to gain an understanding of the impact that the pandemic has had on some major consequences, notably WFH and reduced use of public transport. These studies have identified a range of key influences, both of a quantitative nature such as socioeconomic descriptors, but also of a qualitative nature such as attitudes and opinions. These latter latent variables require an endogenous treatment when mixed with the other explanatory variables, resulting in a preference for a hybrid choice model. To the best of our knowledge, there are no current studies that have investigated attitudes towards public transport and work from home in the context of daily mode choice into a hybrid choice model, including not to work and work from home as possible alternatives. In this paper we focus on gaining a greater understanding on how attitudes towards work from home and concerns about COVID-19 are influencing individuals' decision not to work, to work from home or to commute by different modes of transport.

3 Data Description

The data was collected during late 2020 as part of a larger ongoing study to understand the implications of COVID-19 on the transport network around Australia (Beck & Hensher, 2020; Hensher, Beck, & Wei, 2021). Data from two metropolitan areas will be used in this paper, the Greater Sydney Metropolitan Area (GSMA) comprising the Sydney Metropolitan Area, Newcastle and the Illawarra/Wollongong, and Southeast Queensland area (SEQ), the latter comprising the Sunshine Coast, Brisbane metropolitan area and the Gold Coast. During the time period being analysed, Australia had pursued an elimination strategy with relative success, having emerged from lockdown in June 2021 and (outside of Victoria) having had a sustained period of zero community transmission, with COVID-19 cases in the GSMA and SEQ being almost exclusively within the hotel quarantine system. As such, in October 2020 both metropolitan areas had returned to minimal government-imposed restrictions on travel, activities, and work.

Respondents answered questions about work behaviour prior to COVID-19, for example: which days they worked (Monday, Tuesday, etc., including weekends), where did they do work each day, and the modes of transport available to them for commuting and non-commuting. A number of attitudinal statements were included, with a specific focus on attitudes towards WFH and public transport use (PT), which will be used as indicators in the hybrid choice model. 650 respondents completed the survey, indicating where they worked from each day of the week. In this paper, the decision to not work/WFH/commute will be modelled for each day of the week separately, which will be detailed in Section 4. For each respondent we have up to[139] 7 observations representing each day of the week and, in total, we have 4,518 observations for modelling. An overview of the sample is presented in Table 1. 63% of respondents are located in the GSMA and the rest in SEQ. 39% of respondents have their own place or room to WFH. In terms of WFH, prior to COVID-19, on average, respondents worked 0.86 days from home, while they worked on average 1.64 days last week (i.e., at the time of the survey). The total number of days worked is relatively similar, with an average of 4.59 days worked prior to COVID-19 and 4.51 last week. We note that in comparison to the population level statistics there is an overrepresentation of females in the sample data, and white-collar workers are also disproportionately represented (which is to be expected as they are the occupation groups more likely to be able to WFH; particularly WFH more often).

Table 1: General sample characteristics

Variable	Sample Mean (std deviation)	GSMA & SEQ Averages (ABS 2016)
Age (years old)	40.10 (13.40)	42.29 (13.81)
Gender female (1,0)	0.64	0.51
Income ('00AUD$) personal	78.13 (51.81)	94.28
Number of adults in household	2.79 (1.32)	2.8
Number of cars per adult in household	0.65 (0.36)	
Occupation labour and machine operators (1,0)	0.06	0.14
Occupation white collar (1,0)	0.84	0.66
Workplace located in CBD (1,0)	0.21	

[139] Some respondents did not provide the correct information for all the days of the week which had to be excluded.

Variable	Sample Mean (std deviation)	GSMA & SEQ Averages (ABS 2016)
Has their own space to WFH (1,0)	0.39	
Located in the GSMA in New South Wales (1,0)	0.63	
Located in Brisbane (1,0)	0.21	
Located in the Sunshine Coast (1,0)	0.05 (0.22)	
Number of days WFH last week	1.64 (2.11)	
Number of days worked last week	4.51 (1.28)	
Number of days WFH prior to COVID-19	0.86 (1.60)	
Number of days worked last week prior to COVID-19	4.59 (1.06)	
Sample size	**650**	

For those respondents who made a commuting trip(s) over the last week, the trip characteristics reported are presented in Table 2. It is important to note that, for each day of the week, respondents said if they worked and where they worked from. However, respondents identified once which modes they had available to go to work and which one they used last week and prior to COVID-19, regardless of how many days of the week they commuted. For each mode available, respondents identified their service levels such as travel time and costs. The majority of respondents (68%) used a private car to go to work last week (prior to COVID-19 it was 62%), while 12% used active modes (walk, bicycle including e-scooters) (prior to COVID-19 it was 8%). In terms of mode changes, 27% of the respondents that used public transport to go to work prior to COVID-19 used car last week, 11% used active modes, while the rest are still using public transport. As to respondents that used car to go to work prior to COVID-19, 95% are still using car, 3% used active modes last week, and 2% used public transport. The average travel time by active modes is of 33.3 minutes, the average in-vehicle time in public transport is 32.9 minutes, taxi/rideshare averages 25.2 minutes, and in private motorised vehicles, the average time is 28.6 minutes.

Table 2: Commuting trip characteristics

Variable	Mean (std deviation)
Used car to go to work last week (1,0)	0.68
Used public transport to go to work last week (0,1)	0.19
Used bicycle or walked to work last week (1,0)	0.12
Used car to go to work prior to COVID-19 (1,0)	0.62
Used public transport to go to work prior to COVID-19 (0,1)	0.29
Used bicycle or walked to work prior to COVID-19 (1,0)	0.08
Walking or bicycle available to go to work (1,0)	0.31
Public transport available to go to work (1,0)	0.66
Rideshare/taxi available to go to work (1,0)	0.32
Car driver, passenger or motorcycle available to go to work (1,0)	0.83
Walking or bicycle travel time (minutes)	33.31 (27.63)
Public transport in-vehicle travel time (minutes)	32.86 (23.97)
Rideshare/taxi travel time (minutes)	25.15 (22.26)
Car driver, passenger or motorcycle travel time (minutes)	28.64 (30.96)
Public transport fare (AUD$)	6.83 (8.91)
Rideshare/taxi fare (AUD$)	39.05 (56.33)
Car driver, passenger or motorcycle cost (AUD$)	6.22 (15.35)
Public transport access, egress and waiting time (minutes)	42.89 (33.02)

Figure 1 summarises the work from home policy of participants' place of employment at the time of the survey, i.e., end of 2020[140]. Over 30% of respondents said their place of employment did not have plans to allow them to WFH, 29% of respondents said they were given the choice to WFH when they chose to, 21% of respondents said it is not possible for them to WFH as they need to be onsite to do their job, and over 19% of respondents said their place of employment is directing them to WFH.

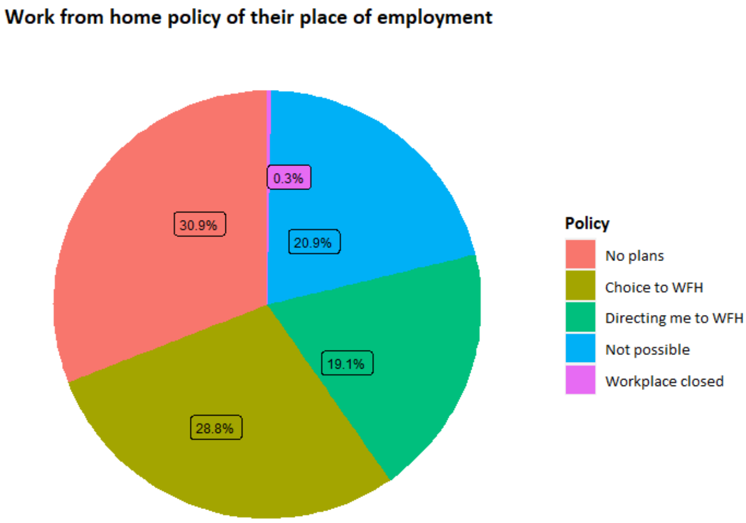

Figure 1: Work from home policy of their place of employment as it stands today

Figure 2 presents the commuting, work from home and not work partition in the sample, by day of week. Work from home is relatively stable across weekdays, varying between 35% and 39%. The variation in behaviour is observed mainly in commuting and not working on any given day, perhaps indicating that those who are required to travel to work are working less days per week compared to those who are able to work from home. On Fridays, the percentage of participants not working is the highest across weekdays, where 26% of participants reported not working; the lowest is on Wednesdays where less than 15% of participants reported not working. On weekends, the majority of participants do not work (almost 84% Saturday and over 90% on Sunday), but the existence of a reasonable amount of weekend work means that all seven days should be included in the analysis in WFH opens up greater flexibility for many workers as to when work is undertaken. There seem to be some (see Hensher et al., 2022 and Beck & Hensher, 2020) differences across days of the week, although the main change is between weekdays and weekends, as expected.

[140] Note that, while no longer in place, during the early part of the year when more stringent health orders were in force, workplaces were required to allow staff to work from home if it was reasonably practicable to do so.

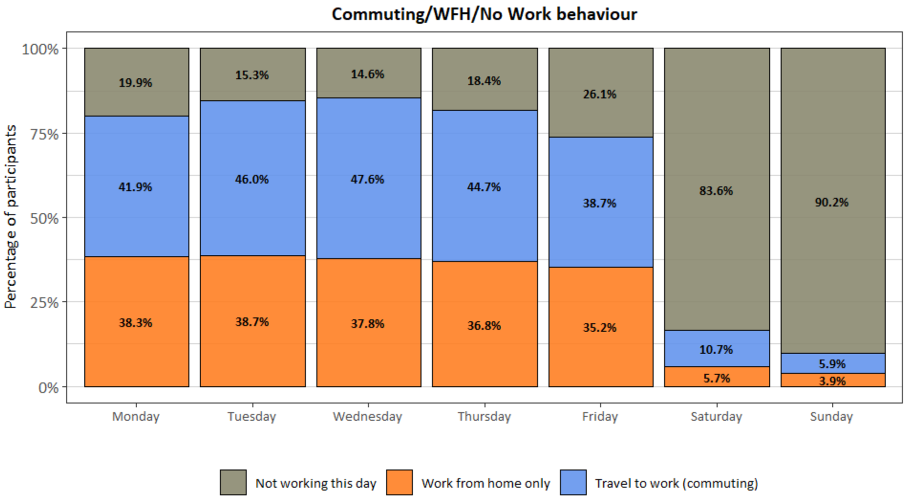

Figure 2: Commuting, WFH and no work behaviour

Figure 3 summarises the overall modal share prior to COVID-19 compared to the situation at the time of the survey. Results show a significant increase in the use of motorised private vehicles (car driver, passenger and motorcycle), with a particular increase in car driver, as is expected given the health concerns associated with shared modes. The results indicate a significant decrease in the use of train from almost 19% to slightly more than 12%; and in the use of bus from almost 10% to almost 7% of participants. The modal share of light rail and ferry is not significant compared to the other two modes of public transport: bus and train. In terms of active transport, results show an increase from 5.9 to 9.7% in walking, whereas the use of bicycle has remained almost the same.

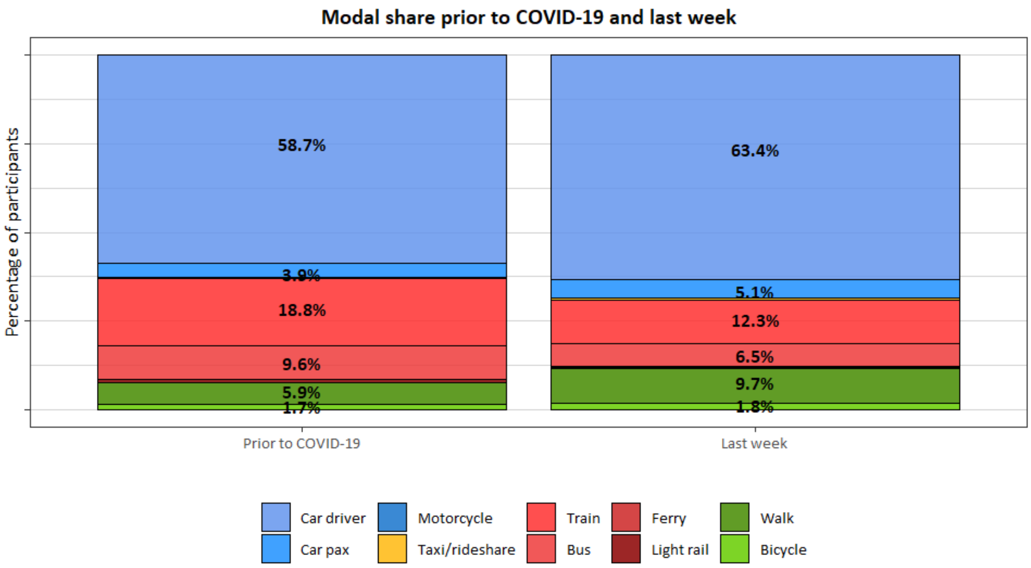

Figure 3: Modal share prior to COVID-19 and currently

A particularly interesting finding related to the modal services is shown in Figure 4, summarising the sample's experience when waiting for public transport. Around 33% of participants do not have public transport available to go to work (which is accounted for when modelling mode choice), so they did not answer this question; approximately 59% of participants said they entered a PT mode when they wanted to without delay, while 7% said they had to wait longer than normal, and less than 1% said they had to wait so long that they gave up using PT. In this study, we are interested in understanding if the experience in waiting for PT, which is related to crowding and frequency, has any impact on participants' concern towards using public transport.

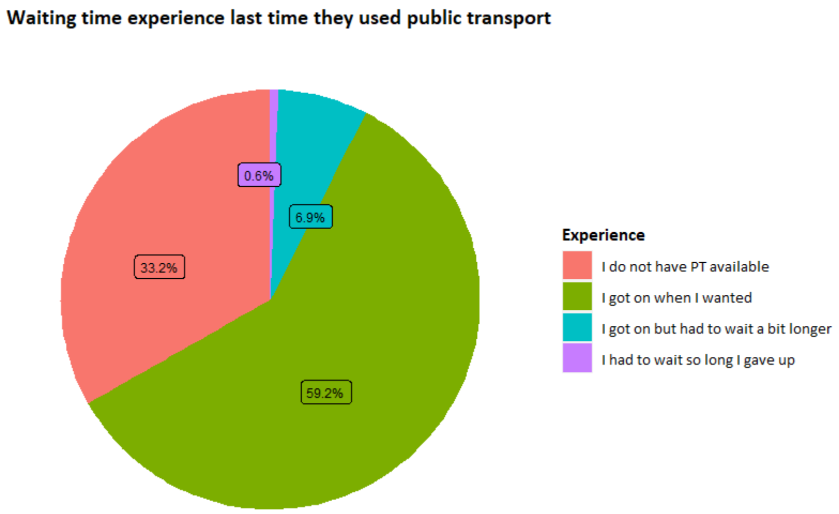

Figure 4: Waiting time experience last time they used public transport

4 The Model Framework

The hybrid choice model is formed by two models that are estimated simultaneously: (1) an ordered probit model that represent the latent variables, measured using attitudinal questions in the survey; and, (2) a mixed multinomial logit model that represents the WFH/commute decision for each day of the week. The WFH/commute model considers three alternatives for each day of the week: not work, work from home, or work outside home. If someone decided to work outside home, the mode used is relevant in understanding individual commuting behaviour. The daily alternatives' structure is presented in Figure 5.

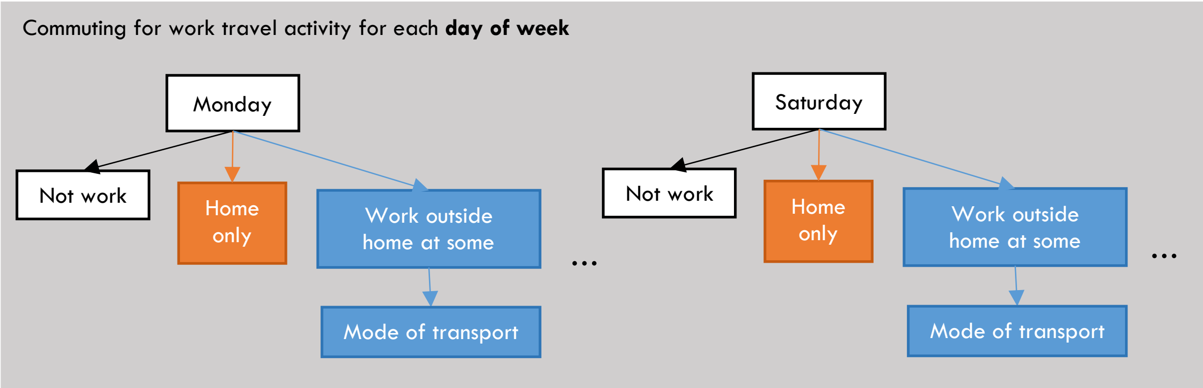

Figure 5: Individuals' daily alternatives structure

For each day of the week, respondents can have up to 12 alternatives available, which are presented in Table 3. The alternatives available will depend on which modes of transport are available to the respondent for commuting, and if they can work from home.

Table 3: Alternative numbers per DoW

	Monday - Sunday
Altij	**Description**
1	Not work
2	Work from home only
3	Work outside home - car driver
4	Work outside home - car passenger
5	Work outside home - taxi/rideshare
6	Work outside home - train
7	Work outside home - bus
8	Work outside home - light rail
9	Work outside home - ferry
10	Work outside home - walk
11	Work outside home - bicycle
12	Work outside home - motorcycle

The overall modelling framework is presented in Figure 6, showing the latent variable and the WFH/commute model. The structural and measurement equations of the latent variable model, as well as the WFH/commute choice model each have their own associated error term: ω, υ and ε, respectively. The proposed WFH/commute choice model accounts for preference heterogeneity through random parameters (error components) and allows for the panel effect across the observations related to the same individual for different days of the week. This error component is alternative-specific, that is, there is a ε_{NoWork} for the no work alternative, and one $\varepsilon_{Commute}$ common for all the commuting alternatives. The second one creates a hierarchical structure allowing for a correlation between all commuting alternatives.

There is an additional error component considered, η_n, which takes into account the relationship between the structural equations and the WFH/commute choice model derived from using simultaneous estimation of the hybrid choice model, referred to as serial correlation (Bierlaire, 2016; Sottile et al., 2019). If this error term was not included, the simultaneous estimation would be assuming that the error terms involved in these models are independent. Serial correlation is taken into consideration by including an agent effect in the model specification, which is an error component in all the models involved (i.e., structural equations and mode choice).

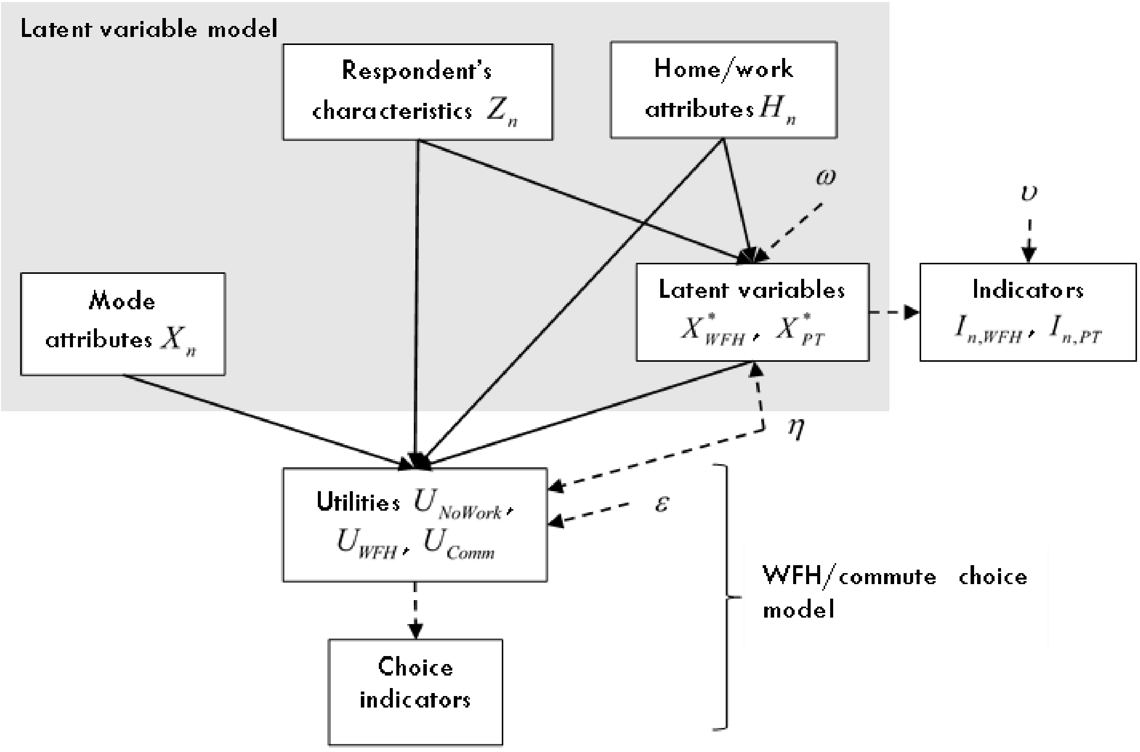

Figure 6: Hybrid model framework

The latent variables refer to variables that cannot be directly observed but are explained by certain indicators. A factor analysis was carried out using all the attitudinal variables included in the survey (Balbontin et al., 2022). The results suggested five different factors: WFH loving attitude, authorities and community's response supporters, social meeting lovers, massive meeting lovers, concerned about health, and concerned about public transport. Balbontin et al. (2022) use these factors to explain the number of commuting and non-commuting weekly trips. In the exploratory phase of this study, these factors were included as explanatory variables in the mode choice model, and only the WFH lover and concerned about public transport factors were statistically significant. Therefore, two latent variables will be considered: (1) WFH lovers, X^*_{WFH} and (2) Individuals concerned about using public transport (PT) to go to workplace due to COVID-19, X^*_{PT}. The linear structural equations of the latent variables are expressed as follows:

$$X^*_{WFH} = \sum_j \theta_j \cdot Z_{qj} + \sum_i \theta_i \cdot H_{qi} + \omega_{WFH} + \eta_{WFH}$$

$$X^*_{PT} = \sum_j \theta_j \cdot Z_{qj} + \sum_i \theta_i \cdot H_{qi} + \omega_{PT} + \eta_{PT} \quad (1)$$

Where Z_{qj} represents attribute *j* of respondent *q* (e.g., age, gender, income, occupation); H_{ni} represents attribute *i* of the home or work of respondent *q* (e.g., distance to work, travel time, has their own WFH space, mode used to go to work, location); and θ are the estimated parameters associated with each attribute. These represent the deterministic part of the linear structural equations, which allow for deterministic heterogeneity through the inclusion of socio-demographics and work/home characteristics. The random part (unobserved) of the linear structural equations is defined by ω_n, which are the error terms associated to the latent variable *n;* and η_n is a part of the error term that takes into account serial correlation. The error terms ω and η are normally distributed with a mean of 0 and a standard deviation equal to 1, but they defer in that the second one will also be included in the choice model explained below (representing serial correlation) and that is why both can be estimated simultaneously.

The measurement equations of the latent variables are linear additive, as follows:

$$I_n = \alpha_n \cdot X_n^* + \upsilon_n \tag{2}$$

where I_n represents an indicator associated with the latent variable X_n^*; α are the parameters to be estimated; and υ_n the error term. The indicators are attitudinal questions asked in the survey, as shown in Table 4 and Table 5[141]. Given the high complexity in the estimation of hybrid choice models, a thorough process was carried out to analyse which attitudinal questions should be used as indicators for each latent variable. The attitudinal questions were chosen based on the results from the factor analysis explained earlier and a correlation analysis between the responses to the different attitudinal questions. If the responses to two attitudinal questions were highly correlated (correlation over 0.9) then only one of them was included. This was an iterative process where different simple hybrid choice models to ensure that the results were not statistically different when removing one attitudinal question as an indicator.

These indicators were measured on a Likert scale with 5 levels and for model estimation we define four parameters, τ_i. We assumed symmetry in the indicators, using two positive parameters as follows:

$$\begin{aligned} \tau_1 &= -\delta_1 - \delta_2 \\ \tau_2 &= -\delta_1 \\ \tau_3 &= \delta_1 \\ \tau_4 &= \delta_1 + \delta_2 \end{aligned} \tag{3}$$

The probability of a given response is given by an ordered probit model (Greene & Hensher, 2010), where the observed responses to the attitudinal questions and the measurement equations are related as follows:

$$Y_n = \begin{cases} 1 \text{ if } & I_n \le \tau_1 \\ 2 \text{ if } & \tau_1 < I_n \le \tau_2 \\ 3 \text{ if } & \tau_2 < I_n \le \tau_3 \\ 4 \text{ if } & \tau_3 < I_n \le \tau_4 \\ 5 \text{ if } & \tau_5 < I_n \end{cases} \tag{4}$$

[141] The attitudinal questions included in the survey have been developed overtime as we continue to collect waves of survey data. In the instance of these public transport questions, we initially asked about hygiene concern and also included an open text field for any other concerns. Analysis of this qualitative information revealed a consistent theme that was not just the threat of COVID-19 alone, but also how many other people were on the PT service as well. This behavioural dimension was added to the set of questions about public transport and in subsequent analysis proved to give results that have been consistently deemed logical and plausible. Indeed, it is intuitive that a person's sense of "risk" of COVID-19 is a dual function of how risky they feel the virus is and how many other people are around/close by that could give it to them.

Table 4: Indicators associated with the latent variable WFH lovers

Acronym	Question
WFHPrdM	How productive do you think you have been in the last week whilst working from home?*
BalPdUnP	I am able to find a balance between paid work and unpaid work (e.g., housework, yard work, childcare)**
ReqEqu	I still require equipment / technology to be able to complete work from home as well as I would like**
WFHIFlex	I would like to have more flexible starting and finishing times in the future**

*Scale: A lot less productive (1), A little less productive (2), About the same (3), A little more productive (4), A lot more productive (5)

**Scale: Strongly disagree or disagree (1), Somewhat disagree (2), Neither agree nor disagree (3), Somewhat agree (4), Agree or strongly agree (5)

Table 5: Indicators associated with the latent variable concerned about PT and workplace*

Acronym	Question
ACvConc	Imagine you had to catch public transport tomorrow, what would be your level of concern about hygiene be?
ACvCoNUs	Imagine you had to catch public transport tomorrow, what would be your level of concern about the number of people using public transport?
WkEnvCnc	How concerned are you today about Covid-19 and work, given the environment that you normally work in (i.e., before Covid-19)?

*Scale: Not at all concerned (1), Slightly concerned (2), Somewhat concerned (3), Moderately concerned (4), Extremely concerned (5)

The latent variable that represents attitudes towards WFH will be included in the utility function of the WFH alternative, which can be expressed as follows:

$$U_{WFH} = \beta_0 + \sum_j \beta_j \cdot Z_{qj} + \sum_i \beta_i \cdot H_{qi} + \beta_{WFH} \cdot X^*_{WFH} + \varepsilon_{WFH} + \eta_{WFH} \quad (5)$$

The latent variable that represents concern towards the use of public transport is included in the commuting alternatives using a mode *m*-specific parameter estimate, β_{PTm} [142]. The utility function to commute in mode *m* is given by:

$$U_{Commute_m} = \beta_0 + \sum_j \beta_j \cdot Z_{qj} + \sum_i \beta_i \cdot H_{qi} + \sum_k \beta_k \cdot X_{mk} + \beta_{PTm} \cdot X^*_{PT} + \varepsilon_{Commute_m} + \eta_{PT} \quad (6)$$

The utility function of the *no work* alternative is expressed in equation (7):

$$U_{NoWork} = \beta_0 + \sum_j \beta_j \cdot Z_{qj} + \varepsilon_{NoWork} \quad (7)$$

It is important to note that the error term associated with the WFH alternative, ε_{WFH}, is different to the error term associated with the WFH latent variable structural equation, η_{WFH}. Similarly, with the error term associated with the alternative to commute by mode *m*, $\varepsilon_{Commute_m}$, and the error term associated with the PT concern latent variable structural equation, η_{PT}. Respondents provided responses on the choice made each day of the week, and hence there are 7 choice sets per respondent. To recognise this, the error terms account for the panel structure of the data, i.e., varying across individuals but the same within individuals. The hybrid

[142] Allowing the parameter associated with the latent variables to be alternative-specific provides a link between the choice of modal alternatives or WFH and the underlying influences in the latent variable. By changing a particular demographic associated with the latent variables (e.g., age), it is carried forward with a revised latent variable in the choice model where these variables have alternative-specific parameters.

model was estimated simultaneously using the Apollo Software (Hess & Palma, 2019) and using a high-speed computer with 24 nodes.

5 Results

The final model includes the structural equations for the WFH and PT variables, as well as the choice model between the alternatives of no work, WFH, and commute by each mode. All the parameter estimates in the final model are statistically significant at a 90% confidence level[143], with the majority being so at the 95% confidence level.

5.1 Structural Equations

The model results for the structural equations for the WFH lover and PT concern latent variables are presented in Table 6 and Table 7, respectively. The results show that respondents between 25 and 40 years old are the ones that feel more positive towards WFH, followed by those older than 40 years. Our broader research on WFH (Beck and Hensher 2021) suggest that younger employees are keener to return to the office for a number of reasons including social interaction and building networks for career progression. Respondents with a personal annual income above AUD$200,000 tend to be less positive towards WFH, as well as people that work as labourers. There are only a few respondents in the sample with an income level over AUD$200,000, and most of them are either managers or employers, who might be more inclined to attend the office perhaps preferring to manage people in a non-remote environment[144]. If the respondent has their own space or room to WFH, they are more positive towards doing so. There are some location-specific dummy variables that were statistically significant in the WFH lover latent variable, which shows that respondents whose work is located in the Sunshine Coast are more positive towards WFH, followed by those who work in Brisbane, relative to the rest of the study locations (including the GSMA). The workplace attitudes towards WFH have a statistically significant influence on the attitude towards WFH, showing that people that are being directed to work from home or are given the choice to do so, are more positive towards WFH than those who are not.

The structural equation results representing the level of concern towards the use of public transport (PT) show that those respondents in white collar occupations tend to be more concerned about PT. One possible explanation for these results could be because white collar workers tended to use PT more pre-COVID-19 than blue collar workers[145]. People that used the car to commute to work in the last week are the most concerned about the use of PT, somehow explaining the amount of PT users prior to COVID-19 who are now driving, followed by those that used active modes to go to work last week. Respondents that work in central business districts (CBD) areas tend to feel more concerned about the use of PT (because they are mainly office workers travelling in relatively high-density PT settings pre-COVID-19), followed by those who work in the GSMA in NSW, relative to the rest of the study locations (including SEQ in QLD). Results suggest that people that could board the bus/train/light rail without delay in waiting are less concerned about the use of PT than those that had to queue longer than prior to COVID-19, presumably linked to crowding and its associated transmission risk. An alternative way of interpreting these findings could be that time spent waiting could be a proxy for reliability, which impacts their concern towards using PT.

[143] We allowed for a lower confidence level for some variables of interest, such as location dummy variables, or variables that have to be interpreted together with other statistically significant ones (e.g., age over 40 years old has to be interpreted together with between 20-40).
[144] https://hbr.org/2020/07/remote-managers-are-having-trust-issues
[145] In our sample, 30% of white-collar workers used public transport prior to COVID-19, as opposed to 22% of blue-collar workers.

Table 6: Structural equation model estimates for WFH lover latent variable

Description	Mean	T-Value
Intercept	0.790	0.459
Personal income above AUD$200,000 (1,0)	-4.835	-2.002
Age between 25 and 40 years old (1,0)	2.324	2.114
Age older than 40 years old (1,0)	2.046	1.874
Has own space or room to work from home (1,0)	2.018	2.789
Occupation labourer (1,0)	-4.080	-1.981
Workplace located in Brisbane (1,0)	2.188	2.261
Workplace located in Sunshine Coast (1,0)	2.875	1.874
My workplace is directing me to work from home (1,0)	6.785	4.090
My workplace gives me the choice to work from home (1,0)	4.384	3.753

Table 7: Structural equation model estimates for PT concern latent variable

Description	Mean	T-Value
Intercept	-0.704	-3.231
Occupation white collar (1,0)	0.542	3.670
Workplace located in CBD (1,0)	0.343	2.262
Workplace located in New South Wales (1,0)	0.435	3.771
Last week used car to go to work (1,0)	1.020	6.314
Last week used bicycle or walked to go to work (1,0)	0.667	2.924
Last time I used public transport I got on when I wanted (1,0)	-0.305	-2.457

5.2 Choice Model

The choice model parameter estimates are presented in Table 8, together with the results of a stand-alone mixed logit model (MML). This MML model includes an error component in the no work and the commuting alternatives that takes into account the panel nature of the data, which is normally distributed with mean 0 and an estimated standard deviation, equivalent to the hybrid choice model. The overall goodness of fit of the choice model component of the hybrid model[146] is statistically superior to the MML model, reinforcing the position that taking into account respondents' underlying attitudes towards WFH and the concern towards the use of PT as latent variables significantly improves the statistical fit of the model and provides an improved understanding of individual preferences. The running time of the hybrid choice model is considerably higher than the MML, which is expected considering it is estimating two latent variables' models and the MML model simultaneously.

Table 8: Choice model parameter estimates

Description	Alternative	MML	Hybrid model
Alternative specific constant no work (base)	No Work	-	-
Alternative specific constant WFH	WFH	-2.24 (9.52)	-7.39 (8.97)
Alternative specific constant commute by car driver	Car driver	0.20 (1.57)	0.17 (1.21)
Alternative specific constant commute by car pax	Car pax	-1.37 (10.73)	-1.39 (10.29)
Alternative specific constant commute by taxi/rideshare	Taxi/Rideshare	-3.05 (8.96)	-3.14 (9.10)
Alternative specific constant commute by train	Train	-2.58 (8.19)	-1.73 (6.24)
Alternative specific constant commute by bus	Bus	-3.04 (9.67)	-2.29 (8.29)
Alternative specific constant commute by light rail	Light rail	-2.76 (6.11)	-1.89 (4.54)
Alternative specific constant commute by ferry	Ferry	-3.78 (5.33)	-2.90 (3.99)
Alternative specific constant commute walking	Walking	-0.17 (0.84)	-0.26 (1.27)

[146] The log-likelihood of the full hybrid model takes into account the estimation of the ordered probit model of the latent variables, and of the mixed logit model of the choice model. The log-likelihood of the second model of the hybrid choice model is calculated to be able to compare it with a simple MML model.

Description	Alternative	MML	Hybrid model
Alternative specific constant commute by bicycle	Bicycle	-1.17 (4.98)	-1.16 (4.82)
Alternative specific constant commute by motorcycle	Motorcycle	-1.21 (4.38)	-1.22 (4.31)
In-vehicle travel time (mins)	All modes	-0.003 (1.83)	-0.003 (1.93)
Travel time active modes (mins)	Walking and bicycle	-0.02 (5.46)	-0.02 (5.22)
Access, egress and waiting time (mins)	Train, Bus, Light Rail and Ferry	-0.01 (2.38)	-0.01 (2.30)
Cost (AUD$)	All modes except walking and bicycle	-0.02 (5.20)	-0.02 (4.58)
Female (1,0)	No Work	0.26 (2.96)	0.29 (2.90)
Personal income ('000$AUD)	WFH	0.00 (4.11)	0.01 (2.83)
Number of individuals per household	WFH	0.09 (2.15)	0.13 (1.73)
Monday (1,0)	WFH	3.20 (17.07)	4.39 (17.87)
Tuesday (1,0)	WFH	3.09 (16.58)	4.21 (17.42)
Wednesday (1,0)	WFH	2.95 (15.92)	4.01 (16.83)
Thursday (1,0)	WFH	2.95 (15.91)	3.99 (16.78)
Friday (1,0)	WFH	2.89 (15.67)	3.91 (16.57)
Workplace located in New South Wales (1,0)	WFH	0.07 (0.67)	0.79 (2.54)
Number of cars per person in household	Car driver	0.45 (3.49)	0.47 (3.32)
Latent variable PT concern	Train	-	-0.69 (5.47)
Latent variable PT concern	Bus	-	-0.54 (4.40)
Latent variable PT concern	Light rail	-	-0.69 (2.24)
Latent variable WFH lovers	WFH	-	0.37 (4.28)
Standard deviation error component ε_{NoWork}	No Work	2.53 (10.82)	-1.74 (8.69)
Standard deviation error component $\varepsilon_{Commute_m}$	Train, Bus, Light Rail and Ferry	-0.52 (8.86)	0.63 (9.58)
Sample size		***650 respondents and 4,518 observations***	
Choice model			
Number of parameters		***27***	***31***
Log-likelihood		***-4521.05***	***-4,327.04***
AIC/n		***2.013***	***1.929***
McFadden's Pseudo-R^2		***0.323***	***0.352***
Hybrid model (full)			
Number of parameters		***-***	***69***[147]
Log-likelihood		***-***	***-8,537.28***
AIC/n		***-***	***3.810***
Running time (minutes)		***8***	***217***

The results suggest that female respondents are more likely to not work any given day. If the respondent has a higher personal income, then they are more likely to WFH, same if they live in a household with more people, if they have more cars per person in their household or if their occupation is clerical and administration. Similarly, if they work in the GSMA of NSW they are more likely to WFH. This is reinforced by evidence in Hensher et al. (2022) where SEQ displays a lower incidence of WFH than the GSMA. In terms of the days, respondents seem more likely to WFH on Mondays, followed by Tuesday, then Wednesday, Thursday and Friday, relative to weekends. Even though the parameter estimates for each day of the week are relatively similar, we decided to estimate them as specific since even minor changes in the probability to WFH on weekdays particularly are of interest for policymakers. As expected, the travel time, access, egress and waiting time and cost have a negative marginal utility influence in the choosing of a specific mode of transport, with separate parameter estimates for motorised and non-motorised (i.e., walk and bicycle) modes. In this study we are specifically interested in the effect of WFH versus commute or not work, and that is why most of the

[147] The total number of parameters in the hybrid model include the parameter estimates of the choice model (31 parameters), of the structural equations which are presented in Table 6 (10 parameters) and Table 7 (7 parameters), and the measurement equations parameters which are presented in Table 11 (21 parameters) in the Appendix.

explanatory variables are included in the WFH alternative. We did test for different socio-demographics in the modal alternatives (all those presented in Table 1 except for the ones that refer to the number of days worked or WFH), but the number of cars in a household was the only one statistically significant in the car driver alternative. We also tested for some non-linear effects in travel time and costs (i.e., liner plus quadratic) but they were not statistically significant.

The WFH lover latent variable has a positive influence on the probability to WFH, while the level of concern towards public transport has a negative influence on the probability to commute by train, followed by light rail and bus, relative to the other modes of transport.

Given that we are interested in understanding the choice to WFH versus not, we are not as interested in the valuation of travel time vis a vis the commute. Additionally, previous studies have suggested that the value of travel time savings is in a state of flux and will continue to be until there is some equilibrium with regards to WFH and the factors that influence the probability of doing so (Hensher, Beck, & Balbontin, 2021). Therefore, the next section will analyse the sensitivity in the probability to WFH given variations in the explanatory variables.

6 Elasticities

The sensitivity of the probability to WFH or to commute to changes in the attributes can be analysed through the elasticities, which are the preferred indicators of the nature and extent of behavioural response of most interest. The elasticities are calculated as follows:

$$E\left(x_i\right)=\frac{\partial \Pr_i}{\partial x_i}\cdot\frac{x_i}{\Pr_i} \quad \text{, where } \Pr_i=\frac{\exp(U_i)}{\sum_{j\in Alts}\exp(U_j)}$$

For each individual we use the measurement equations to estimate the value of the latent variables, and then use them to calculate the utility functions and probability of choosing each alternative (i.e., WFH, no work, and commute by different modes). The results are summarised in Figure 7 ordered from highest to lowest elasticity (mean and standard errors are presented in Table 10 in the Appendix). In terms of WFH, results show that a person that has their own space to WFH, *ceteris paribus*, is 13.5% more likely to do so than a person that has to share a space or does not have such space at all. The workplace policy towards WFH is logically a very relevant influence, incorporated through the WFH loving latent variable. It suggests, *ceteris paribus*, that people directed to WFH are 18.0% more likely to do so, while respondents that are given the choice to WFH are 26.5% more likely to do so, relative to other respondents. Since this influence is through the WFH loving attitude, these results are showing that people that are given the choice to WFH have a more positive attitude towards WFH, followed by those that are being directed to WFH. This is an interesting finding. Given that respondents who are able to choose when to work from home and when not to, thus presumably having flexibility to work between home and the regular work environment, are more positive than those who are being directed to WFH and thus presumably must only work from home, we hypothesis that a balance between WFH and going to the office leads to better WFH experiences.

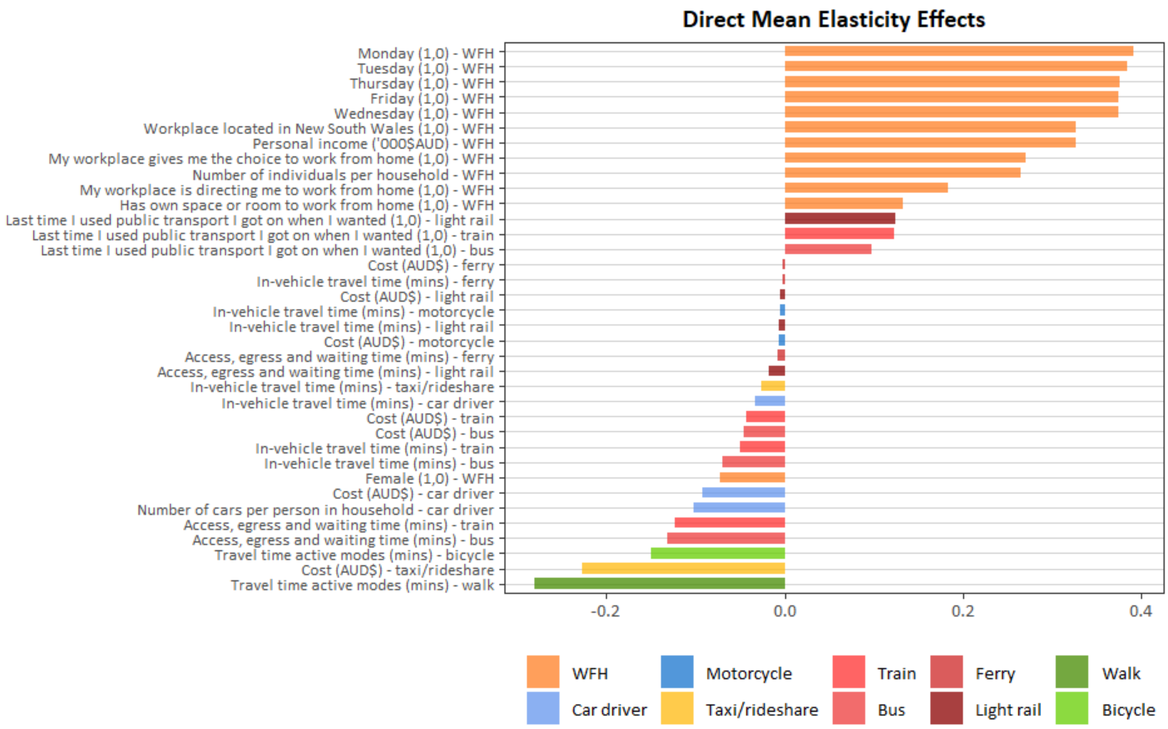

Figure 7: Direct Mean Elasticity Effects Hybrid Choice Model

Specifically for public transport, a person that does not have to queue when waiting for their bus, linked we suggest to exposure to others, *ceteris paribus*, is 9.6% more likely to use the bus than a person who has to wait longer than they did prior to COVID-19; and 12.2% more likely in the case of train and light rail. Mask wearing is mandated on-board PT but not at the stops and station, so the health concerns in the stops and stations might be higher than inside the vehicles. The higher influence associated with train and light rail probably could be related to the fact that if there are more people waiting, the vehicles will be more crowded – and considering the train and light rail have a higher capacity of compartments relative to buses, the biosecurity risk associated with them might be higher.

7 Probability of Working from Home Simulated Scenarios

Five scenarios were simulated to show the sensitivity of the probability to WFH variable due to variations in the explanatory variables. The observed versus estimated results for the hybrid model probability to WFH are presented in Figure 8. The observed probabilities to WFH are lower than the estimated ones using the hybrid model, and they decrease from Monday to Friday. That is, the probability to WFH on Monday is higher than on Tuesday, and so on. The probability to WFH on weekends is much lower which, as was presented in Figure 2, is due to a high proportion of people not working on weekends. These probabilities are the base scenarios, and the simulations represent variations in these base scenarios due to changes in the explanatory variables, which are described in Table 9 with the results presented in Figure 9.

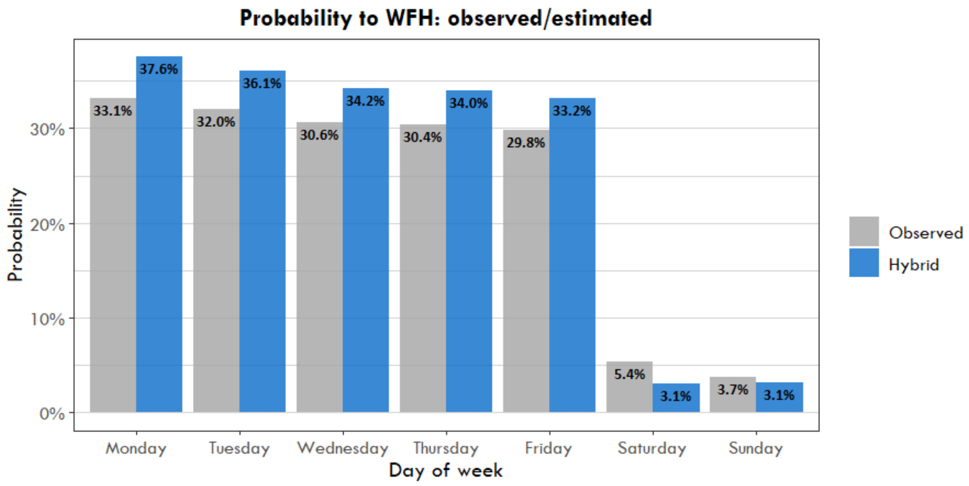

Figure 8: Observed versus estimated (base scenario for simulation) probability to WFH

Table 9: Simulated scenarios description

Scenarios	Description
1	Everyone has their own space or room to work from home
2	Everyone is a blue-collar worker
3	Everyone has an income level above AUD$200,000 with a population average of AUD$201,000
4	The number of cars per person in the household increase by 1 on average
5	Travel time in all modes of transport increases by 50%

The first scenario represents a situation where everyone has their own space or room to work from home which currently is 39% (Table 1), which would generate an increase between 1.4% and 1.6% in the probability to WFH on weekdays and 0.4% on weekends.

Scenarios 2 to 4 represent subgroups of the population and their behaviour towards WFH. Scenario 2 represents a situation where everyone was a blue-collar worker (i.e., technicians and trades, machine operators/drivers and labourer) where the probability to WFH would decrease between 14.0% and 14.7% on weekdays and 2.3% on weekends.

If everyone in the sample would have a high income of above $200,000 with a population average of $201,000 (scenario 3) then this would represent a decrease in the probability to WFH between 9.5% and 10.7% on weekdays, and 2.1% on weekends. A high income of above $200,000 has a negative influence in the latent variable WFH lover (which has a positive impact in the probability to WFH), but a higher income has a positive influence in the probability to WFH. This shows that a higher income implies a higher probability to WFH, unless the income is very high (above $200,000), in which case individuals seem to be less positive towards WFH. As previously discussed, this might be due to the fact that only a few individuals in the sample have a very high income (above $200,000) and most of them are managers or employers, who in turn may still prefer to manage or supervise staff in a more traditional framework for reasons of trust and authority, but also that managing during the pandemic has its own set of challenges that may create greater burden (Teodorovicz et al., 2021).

Scenario 4 represents a situation where vehicle ownership per adult increased by 1 on average, which has a negative influence in the probability to WFH. The results suggest that if vehicle ownership per adult increased by 1, then there would be between a 1.7 to 1.8% decrease in the probability to WFH on weekdays and 0.3% on weekends.

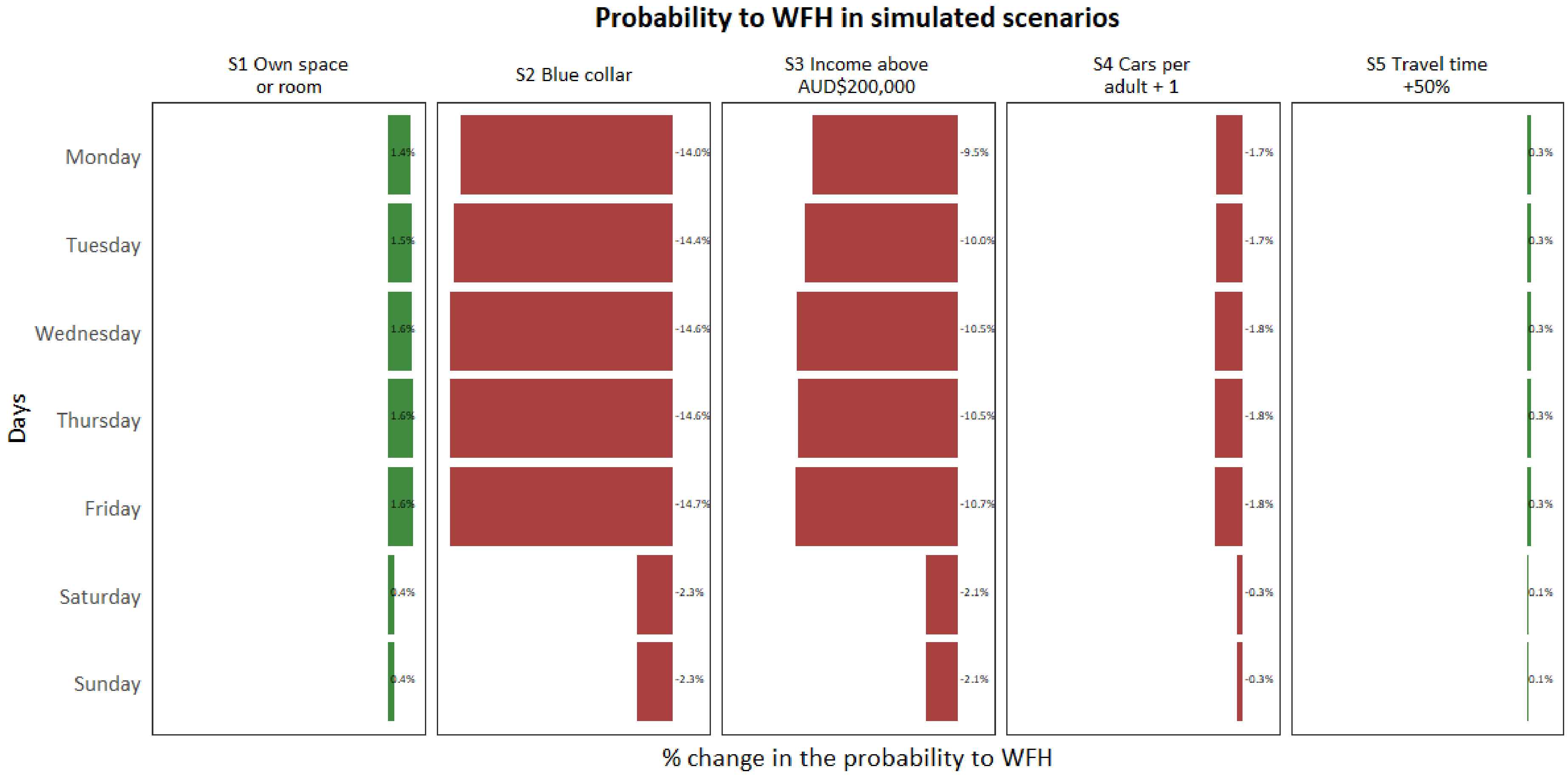

Figure 9: Simulated scenarios results

The last scenario shows the situation where all travel times increase by 50%, which would imply an increase of 0.3% in the probability to WFH on weekdays and 0.1% on weekends. This last scenario is interesting as it shows that travel times are not the most important factors when deciding to WFH (as shown also in Hensher et al., 2022), compared to having their own space to work from home, workplace attitudes towards WFH or even having to wait longer than prior to COVID-19 when waiting for the bus or train/light rail.

8 Policy Implications and Conclusion

The main focus of this study is to understand the influence of underlying attitudes towards COVID-19, namely in relation to WFH and the use of PT, in the probability to WFH, to commute or not to work for each day of the week. A hybrid choice model was developed and estimated, integrating a choice model with two latent variables; - WFH loving attitude and PT concerned attitude.

It is not surprising that a key indicator of working from home, is a positive attitude towards the experience. This positive attitude is highest among those 20-40 years of age who likely appreciate the flexibility that WFH brings, and those whose workspace at home is more conducive to doing so. In the longer term we may see further pressure on suburban real estate markets where homes are typically larger, or a rethink in the design of higher density homes to facilitate work from home. It is interesting that those on very high incomes are less positive towards WFH: these people may be managers who are not as positive towards managing people who are WFH, but equally they may also have sufficient income to overcome household constraints more easily, thus are not as appreciative of greater work flexibility. The simulations also show that socioeconomic characteristics such as occupation or income have a high influence on the probability to WFH, as compared to the travel times exhibited by the different modes or the number of cars per adult in the household. These are structural issues that are difficult for transport policy makers to directly influence.

However, from a transport policy perspective, it is key to note that respondents that used the car to go to work the week prior to the survey tend to be more concerned about PT, followed by respondents that used active modes, relative to other modes of transport. We see the implications of this result playing out in many jurisdictions outside of just the GSMA and SEQ, where car use has rebounded strongly and is above pre-pandemic levels in many instances. This should be an alarm for transport policy makers. If the attitudes towards public transport are not improved rapidly, the models suggest that the car will become even more dominant than ever. The elasticities' results showed that people that did not have to queue were 12.2% more likely to use train and light rail, and 9.6% more likely to use the bus, compared to those that had to queue before getting on the bus or train. These results highlight the bio-security risk associated with COVID-19 where mask-wearing and social distance was enforced on public transport but not so waiting for public transport; and that an overall regular and reliable service (as proxied by shorter queuing times) creates a positive public transport experience even in the context of COVID-19. This result is also important as it suggests that maintaining rather than reducing services may be key to the recovery of public transport.

Another key result from the models, in particular the elasticities, is the ability for the respondent to have flexibility in deciding if they work from home increases their positive attitude towards WFH and therefore, the probability of doing so. Through the elasticities and simulations, we believe that respondents seem to prefer a balance in WFH, rather than being directed to do so, and that the WFH policies and workspace facilities linked to productivity are one of the most influential factors in the probability to WFH. These are structural issues that are difficult for transport policy makers to directly influence. It seems like a hybrid work model, as opposed to working entirely from the office or from home, will make people more productive and satisfied, obtaining the best of both worlds. To that end, the mechanism for transport policy makers is not only to think of the provision of transport, but how can investment in good technology be seen as a transport investment (i.e., in a new WFH future ICT like the NBN is now also a transport investment).

Overall, these findings have a great deal of plausibility, but what is especially relevant is that we have a series of behaviourally informative model outputs that can be used to provide useful advice into the policy debate on what WFH and resistance to using PT means in respect of changing levels of commuting activity by specific modes.

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Appendix Paper

Table 10: Elasticities Hybrid Choice Model

Alternative probability	Variable	Mean	Std error
WFH	Has own space or room to work from home (1,0)	0.133	0.003
WFH	My workplace is directing me to work from home (1,0)	0.184	0.008
WFH	My workplace gives me the choice to work from home (1,0)	0.270	0.008
WFH	Female (1,0)	-0.073	0.001
WFH	Personal income ('000$AUD)	0.327	0.004
WFH	Number of individuals per household	0.265	0.003
WFH	Monday (1,0)	0.392	0.017
WFH	Tuesday (1,0)	0.385	0.017
WFH	Wednesday (1,0)	0.374	0.016
WFH	Thursday (1,0)	0.376	0.016
WFH	Friday (1,0)	0.374	0.016
WFH	Workplace located in New South Wales (1,0)	0.327	0.004
Car driver	Number of cars per person in household	-0.102	0.002
Car driver	In-vehicle travel time (mins)	-0.033	0.001
Car driver	Cost (AUD$)	-0.092	0.004
Taxi/rideshare	In-vehicle travel time (mins)	-0.026	0.001
Taxi/rideshare	Cost (AUD$)	-0.228	0.010
Train	Last time I used public transport I got on when I wanted (1,0)	0.123	0.002
Train	In-vehicle travel time (mins)	-0.050	0.001
Train	Cost (AUD$)	-0.042	0.001
Train	Access, egress and waiting time (mins)	-0.123	0.003
Bus	Last time I used public transport I got on when I wanted (1,0)	0.097	0.001
Bus	In-vehicle travel time (mins)	-0.070	0.002
Bus	Cost (AUD$)	-0.046	0.004
Bus	Access, egress and waiting time (mins)	-0.132	0.004
Light rail	Last time I used public transport I got on when I wanted (1,0)	0.124	0.002
Light rail	In-vehicle travel time (mins)	-0.006	0.000
Light rail	Cost (AUD$)	-0.005	0.000
Light rail	Access, egress and waiting time (mins)	-0.017	0.001
Ferry	In-vehicle travel time (mins)	-0.002	0.000
Ferry	Cost (AUD$)	-0.002	0.000
Ferry	Access, egress and waiting time (mins)	-0.008	0.001
Walk	Travel time active modes (mins)	-0.280	0.010
Bicycle	Travel time active modes (mins)	-0.150	0.009
Motorcycle	In-vehicle travel time (mins)	-0.005	0.000
Motorcycle	Cost (AUD$)	-0.006	0.001

Table 11: Parameter Estimates Hybrid Model Measurement Equations

Note: The role of the delta δ parameters in the measurement equations is explained in more detail in Equation (3), and of the alpha α parameters in Equation (2). The names used to describe the indicators are defined in Table 4 and Table 5.

Description	Mean	T value
Alpha parameter ACvConc	2.645	4.34
Delta parameter 1 ACvConc	1.254	4.53
Delta parameter 2 ACvConc	3.121	4.56
Alpha parameter ACvCoNUs	2.340	5.56
Delta parameter 1 ACvCoNUs	1.041	5.52
Delta parameter 2 ACvCoNUs	2.967	5.82
Alpha parameter WkEnvCnc	0.445	12.92
Delta parameter 1 WkEnvCnc	0.354	13.41
Delta parameter 2 WkEnvCnc	0.994	20.56
Alpha parameter WFHPrdM	0.038	3.11
Delta parameter 1 WFHPrdM	0.539	13.21
Delta parameter 2 WFHPrdM	0.739	12.54
Alpha parameter BalPdUnP	0.091	3.59
Delta parameter 1 BalPdUnP	0.227	6.77
Delta parameter 2 BalPdUnP	0.671	12.06
Alpha parameter ReqEqu	0.016	2.24
Delta parameter 1 ReqEqu	0.187	7.41
Delta parameter 2 ReqEqu	0.468	11.88
Alpha parameter WFHlFlex	0.108	3.76
Delta parameter 1 WFHlFlex	0.323	7.37
Delta parameter 2 WFHlFlex	0.558	10.21

Appendix R. Paper #14: Reducing congestion and crowding with working from home

David A. Hensher
Matthew J. Beck
John D. Nelson
Camila Balbontin

Abstract

COVID-19 has changed the landscape within which we travel. Working from Home (WFH) in many countries has increased significantly, and while it was often forced on a society it has delivered some unintended positive consequences associated in particular with the levels of congestion on the roads and crowding on public transport. With a likelihood of some amount of WFH continuing as we move out of the active COVID-19 period, the question being asked is whether the post-COVID-19 period will return the pre-COVID-19 levels of traffic congestion and crowding. In many jurisdictions there is a desire to avoid this circumstance and to use WFH as a policy lever that has appeal to employees, employers and government planning agencies in order to find ways of better managing future levels of congestion and crowding. This chapter uses the ongoing research and surveys we have been undertaking in Australia since March 2020 to track behavioural responses that impact on commuting and non-commuting travel, and to examine what the evidence tells us about opportunities into the future in many geographical settings to better manage congestion and crowding. This is linked to a desire by employers to maintain WFH where it makes sense as a way of not only supporting sustainability charters but also the growing interest in a commitment to a broader social licence. We discuss ways in which WFH can contribute to flattening peaks in travel; but also the plans that some public transport authorities are putting in place to ensure that crowding on public transport is mitigated as people increasingly return to using public transport. Whereas we might have thought that we now have plenty of public transport capacity, this may not be the case if we want to control crowding, and more capacity may be needed which could be a challenge for trains more than buses given track capacity limits. We conclude the chapter by summarising some of the positive benefits associated with WFH, and the implications not just for transport but for society more widely.

Keywords: COVID-19; Road congestion; Crowding on public transport; Working from home; Positive benefits of WFH; Societal impacts

1 Introduction

The COVID-19 pandemic has had a cataclysmic impact on the movement of people in particular and more generally the way in which life is likely to change as we slowly recover out of the worst period of the virus. While it is expected that we will need to learn to live with such a transmissible disease in all its variants, even with widespread vaccination, life as we knew in pre-COVID-19 (i.e., before March 2020) is unlikely to return with a 'new normal' evolving. While the look and feel of this new future is uncertain, evidence garnered over the 15-month period since March 2020 throws up many clues as to what life may look like post-COVID-19, whenever that is. A highly visible consequence of the pandemic has been the structural (in contrast to cyclical) change in the movement patterns of individuals as they increasingly worked from home either by choice or enforcement and who have since found some amount of working from home a new preference, which has also garnered support from many employers. Beck and Hensher (2020, 2020a, 2020b, 2020c, 2020d) have documented the impact that working from home (WFH) has had on the performance of the road and public transport networks in Australia, with evidence aligning with the experiences in many countries, especially the change in levels of congestion on the roads and crowding on public transport. The notable signs of a return to road congestion[1] (e.g., Figure 1) as many individuals choose to avoid public transport out of bio-security[2] concerns, suggests that the public transport network will not bounce back to pre-COVID numbers for years (be it real or misperceived). The growing support for WFH from employees and employers and the wider community signals important repositioning of what future travel activity might look like, especially the commuting trip and its flow through impacts on non-commuting travel.

FIG 1 HERE

WFH has substantial implications on what the spatial nature of work might look like and especially whether the central areas of cities in, at least, Western societies will return to the pre-COVID-19 levels of office activity. At the time of writing (June 2021), the central business districts of the capital cities on the east coast of Australia exhibit a 60-70 percent return to the office with a 75 percent use of public transport compared to pre-COVID; and working from home (with variants by occupation) averaging two days per week. In Sydney, for example by end March 2021 public transport patronage overall had surpassed 70 per cent of the pre-pandemic level, with bus patronage down by 35% compared to 2020 (Figure 2). The expectation is that only 80 per cent of the people who travelled by public transport before COVID-19 will return to the same mode. Road traffic, however, is sitting at 98 per cent of pre-coronavirus levels after commuters moved towards private travel amid the pandemic (see footnote 1). A report by Transurban[3], which surveyed more than 3,000 people, found that 20 per cent of daily public transport users in Sydney predicted they would use public transport less than they did pre-pandemic. This switch is accompanied by a 14 per cent increase in private car sales in December 2020, and a 400,000 increase in average daily car traffic between July and December 2020.

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[1] Congestion on Brisbane's roads in early 2021 is worse than pre-COVID levels, largely due to the impact of coronavirus restrictions and the reluctance of commuters to return to the state's public transport network. Using TomTom traffic tracking data, congestion levels for the month of February have so far been well above average compared to previous years, with Tuesday February 2nd seeing 90 per cent more congestion on Brisbane's roads than the same date in 2019 and 2020. See https://www.abc.net.au/news/2021-02-09/coronavirus-queensland-brisbane-traffic-congestion-transport/13121108

[2] Bio-security refers to situations associated with the introduction and/or spread of harmful organisms such as COVID-19 that create risk of transmission of infectious disease.

[3] https://www.smh.com.au/national/nsw/sydney-toll-road-profits-grow-despite-pandemic-as-public-transport-usage-dropped-20210211-p571pr.html

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FIG 2 HERE

In response to the drifting away of patronage from public transport together with a desire to avoid the level of pre-COVID-19 crowding, governments are talking and acting on this challenge. In Sydney, thousands of additional public transport services have been extended to keep current commuters and hoped for increasing numbers of commuters COVID-safe. More than 1,200 additional bus and train services introduced in early December 2020 have been extended into autumn, running until at least the end of March to keep commuters socially distanced[4], warranted by the steady return of schools and office workers in early 2021.

What does all of this suggest about the performance of the transport network going forward? In general, the quantum of uncertainty suggests that it is a ‘wait and see’ environment; however, there are many triggers that government, and individuals in general as employees or employers, can ignite to support a future which avoids the negative features of the pre-COVID transport system. What we have as a result of the forced imposition of restrictions and resulting WFH is possibly the greatest policy lever we have ever had in order to change the performance of the transport network. We have described this as an unintended positive consequence of COVID-19 (Beck & Hensher, 2020b) suggesting that governments and employers working with employees can, and should, take advantage of the unintended positive consequences of COVID-19.

While we are starting to see, as of June 2021, an increase in the number of days commuting compared to WFH in September 2020, the average number of days WFH is still much higher than pre-COVID-19 (Figure 3). Typically, on average we see 1 to 2 days WFH per week. Major capital cities exhibit a higher incidence of WFH compared to regional and rural locations. Perth has a higher incidence of WFH in mid-2021 compared to late 2020 and this is due to the success in 2020 in containing the pandemic compared to other States. Perth closed down their borders but opened them in 2021 with some amount of transmission of COVID-19 transmitted from people arriving from overseas; the reversed trend seen in WA might reflect these lockdowns. This was also the first time (Feb 2021) people in Perth were required to wear masks at work and on public transport.

FIG 3 HERE

There is plenty of evidence that this is a global trend. Slack, a channel-based messaging platform for fostering teamwork and collaboration within organisations, commissioned a survey of workers who identify as ‘skilled office workers’ in the US, the UK, France, Germany, Japan and Australia, fielded between June 30 and August 11, 2020. A key finding of this survey was the extent to which employees would prefer to work in the future in a hybrid way, mixing time working both from home and from the office, with only 11.6% wanting to return to the office full-time (Elliot, 2020, 2020a). Figure 4 shows the proportion of respondents in each country who would prefer a hybrid work model. What is important about this evidence is that employers are increasingly supportive of WFH to some extent where it is appropriate to do so. Figure 5 illustrates this for Australia, drawn from ongoing longitudinal surveys throughout the nation (see Beck & Hensher, 2020b) where there appears to be an increase in the number of employers who would adopt a flexible work policy whenever COVID-19 restrictions were to

[4]https://www.dailytelegraph.com.au/coronavirus/extra-nsw-public-transport-services-to-continue-for-covid-safe-travel/news-story/eded9eacc0eb49682218ea7193f44427?btr=e760a07b86bd3c7be44b7ab5cd9cce72

end between Wave 2 (May 2020) and Wave 3 (September 2020). Also shown is the response from employees in September 2020 which also highlights a potential mismatch between what they might think is the policy their workplace would adopt versus what an employer or manager might support; specifically, there is the potential that employers might be more supportive of increased working from home than an employee might think, although this does vary by occupation and age of employee.

FIG 4 HERE

FIG 5 HERE

Barrero et al. (2021) surveyed more than 30,000 USA residents over multiple waves in 2020 to investigate whether WFH will stick, and why. They found that 20 percent of full workdays will be supplied from home after the pandemic ends, compared with just 5 percent before, of which 2 days a week is not uncommon. They provide five reasons for this large shift: better-than-expected WFH experiences, new investments in physical and human capital that enable WFH, greatly diminished stigma associated with WFH, lingering concerns about crowds and contagion risks, and a pandemic-driven surge in technological innovations that support WFH. The consequences are that employees will enjoy large benefits from greater remote work, especially those with higher earnings; the shift to WFH will directly reduce commuting spending in major city centres by at least 5-10 percent relative to the pre-pandemic situation; data on employer plans and the relative productivity of WFH imply a 5 percent productivity boost in the post-pandemic economy due to re-optimized working arrangements; and only one-fifth of this productivity gain will show up in conventional productivity measures, because they do not capture the time savings from less commuting.

2 Recent evidence on how WFH is changing commuting and non-commuting travel

With respect to how commuting behaviour has changed in response to COVID-19 restrictions and the resultant increase in working from home, we see in Figure 6 that, using data we are collecting in Australia through surveys throughout 2020-2022, the number of commuting trips more than halved in April 2020 (Wave 1) compared to the average number of one-way trips conducted before COVID-19. There was a reduction in all modes, but it was particularly pronounced for the public transport modes of train (92% below pre-COVID-19 levels) and bus (78% lower). In late May 2020 (Wave 2) we saw an uptake in commuting as restrictions eased and more people returned to work (41% below pre-COVID-19), which appeared to have stabilised for all States excluding Victoria in September 2020 (Wave 3). Within Victoria, however, the rising second wave and resulting restrictions saw commuting levels fall once more (54% below pre-COVID-19 behaviour). In both Wave 2 ($r = -0.51$) and Wave 3 ($r = -0.60$) there are significant and strongly negative correlations between the number of commuting trips made per week and the number of days worked from home, which is to be expected. Bio-security risks associated with public transport remain despite the effort by government to move away from the initial messaging (in the Wave 1 and 2 periods) to not use public transport, and that with social distancing (every 3rd seat can only be used on trains and buses) it is now (Wave 3) safe and mask wearing is recommended. Hensher, Beck and Wei (2021) found that bio-security concern associated with using regular public transport was a statistically significant positive influence on the increased probability of working from home. This is discussed in more detail in a later section. These findings in late 2020 have not changed a great deal in the first half of 2021, with new outbreaks in Sydney and Melbourne in particular that resulted in partial or complete lockdowns for periods between 2 weeks and 3 months. The Delta strain has been a major concern in mid-2021 given it is easy to catch by simply passing someone, with Sydney imposing mandatory mask on public transport, offices and all public places in late June 2021. This uncertainty and volatility are resulting in the preservation of WFH where possible.

FIG 6 HERE

We also undertook a comparison of commuting activity by mode in Australia and six South American countries, at various times in 2020 (Balbontin et al., 2021a), summarised in Figures 7 and 8. Regarding modal shares, prior to COVID-19 private vehicle usage in Australia was of around 63%, which has increased to 68% by the last week of 2020. The public transport usage decreased from 29% to 19%; and the active modes usage increased from around 8% to 12%. The situation prior to COVID-19 in South America is a bit different, where public transport was the most frequently used mode of transport. The difference in the modal shares prior to COVID-19 to the last week of 2020 in South America is significant. In Argentina, car/motorcycle use increased from 9% to 17% while public transport use decreased from 79% to 45%. In Brazil, car use increased from 34% to 50%; while public transport use decreased from 48% to 22%. In Chile, car use increased from 15% to 32%; while public transport use decreased from 67% to 40%. In Colombia, car use increased from 14% to 16%; while public transport use decreased from 74% to 60%. In Ecuador, the car/motorcycle use increased from 28% to 38%; while public transport use decreased from 61% to 40%. In Peru, car use increased from 15% to 19%; and public transport use decreased from 69% to 53%. However, it does not seem that all of the respondents that stopped using public transport moved to car/motorcycle, as the active mode usage also increased in every country. The highest change was in Argentina, where prior to COVID-19 the active mode share was 11% and now it is 32%.

FIG 7 HERE

FIG 8 HERE

In terms of when people are working from home in Australia (and thus when they might be commuting), Figure 9 shows that working from home behaviour is relatively consistent across the working week, with approximately 27% of respondents working only from home on any one day in September 2020 (Wave 3) decreasing to 16% in June 2021. Although there is an expected return to the office to some extent, we have a very important piece of evidence about the equal spread across the week of commuting, making it easier for governments to plan infrastructure requirements. It should be noted that Figure 9 does not consider when travelling may be occurring for those that do – it might be the case that with increased ability to work from home people might also be taking this opportunity to stagger their working hours so that when they do travel for work, they can do so outside of peak periods and thus avoid traffic congestion or crowding on public transport. Indeed with reduced office space as a growing number of businesses downsize their space there will be an increased need for staggered working hours.

FIG 9 HERE

Changes in patterns of commuting are likely to influence non-commuting activity as individuals rearrange when they undertake a range on non-commuting trips. Figure 10 summarises the relationship between the probability of working from home and how it influences the average amount one-way weekly trips in South East Queensland (which is typical of all locations in

Australia). This evidence in important as a way of illustrating how changes in the incidence of working from home not only impact on the amount of commuting activity but also on all trip purposes. While we see a greater behavioural response for commuting as the probability of working from home increases, all of the curves are downward sloping as the probability of WFH increases.

FIG 10 HERE

The elasticities of the expected frequency of the number of weekly one-way commuting trips for workers located in SEQ area are presented in Balbontin et al. (2021), which represents the behavioural sensitivity of the number of trips for each of the explanatory variables. For example, -0.166 for commuting trips indicates that, ceteris paribus, a 20% increase in the number of days working from home (i.e., 1 extra day per a 5-day week), results in a 3.32% reduction in the average number of one-way weekly commuting trips. The elasticity of age is -0.391, which says that a person 10% older (e.g., 24 years old relative to 20 years old) makes on average 3.91% less one-way weekly commuting trips.

TABLE 1 HERE

Another issue, almost in parallel with WFH, is the growing commitment to electric cars and the emission benefits where the risk of increased driving coming out of the pandemic long term means that electric cars should be a greater focus What is often neglected is what this might mean for congestion given the anticipated lower price of purchase and usage of cars when the sales levels provide scalable outcomes[5]. It is predicted that by 2040, 24% of all cars sold in Australia will be electric and, in many countries, it will be even higher[6]. Hensher, Wei and Liu (2021) have recently shown that for the Sydney area we can expect a 9% increase in car VKM by 2040 without any revision of the road user charge model, given assumptions on the purchase price of such cars. We anticipate that a distance-based charge of between 1 c/km and 15 c/km would be required to manage congestion through VKM back to levels associated with a cost of ownership and usage that is the same as forecast for petrol-fuelled cars. This also has impacts on the use of public transport with anticipated containment of growth in crowding.

3 What does this mean for a return or otherwise to pre-COVID-19 levels of crowding on public transport?

Public health concerns relating to fear of infection and/or inability to be physically distant from fellow travellers has emerged as a clear and enduring concern for public transport travellers during the pandemic. When associated with a "do not use" message from politicians[7] this has highly negative consequences for public transport from which the sector will struggle to recover (Tirachini, 2020). It is arguable that public transport should always be supported by clear messaging to build confidence in use, and this has become an imperative during the

[5] This is exacerbated with plans to see electric cars online without the need for a showroom and stock. An individual can purchase directly or via an agent and the vehicle will be delivered straight from the factory with a potential saving of 20% on what is paid through a showroom.

[6] Bloomberg New Energy Finance. Suggest that global EV sales will jump from 1.7M in 2020 to 54M in 2040.
https://about.bnef.com/electric-vehicle-outlook/

[7] A particularly stark response to this came from Lawrence Frank of University of British Columbia who commented that "Promoting private vehicle use as public health strategy is like prescribing sugar to reduce tooth decay" (see: https://www.cnbc.com/2020/06/04/cdc-guidance-against-mass-transit-sparks-fears-of-congestion-emissions.html).

pandemic as operators and authorities seek to reduce the level of concern passengers associate with public transport use.

In many countries including Australia, the public transport sector response to COVID-19 was several fold. As well as increased cleaning measures (with extra hours measured in hundreds of thousands), some operators instituted a shift to rear door boarding. Marshalling of queues of intending passengers was used to maintain physical distancing and on-board buses and trains, e.g., Sydney introduced “No dot, no spot” to guide travellers as to where to sit and stand. As elsewhere, journey planners have been modified to help travellers plan their journeys more safely by showing whether physical distancing can be observed, and COVID-19 travel advice web pages have become readily available.

Figure 11 charts the influence of bio-security issues perception that people have about the cleanliness and hygiene of public transport. There is a dramatic difference between concern before COVID-19 and immediately after the first outbreak at Wave 1 in April 2020 (the blue and orange lines are almost diametrically opposed). Concern in Wave 2 (May) had diminished, but still more than half of respondents reported moderate to extreme concern. While concern has decreased between the two Waves (consistent with an easing of conditions), average concern still remains at a level that is appreciably higher than that prior to COVID-19; 60% of respondents were extremely or moderately concerned at Wave 2 in May 2020 compared to 17% before COVID-19. Levels of concern remained largely unchanged from Wave 2 to Wave 3 (September 2020; a period encompassing the second wave in Victoria).

FIG 11 HERE

In anticipation that confidence with public transport might diminish again rather than continue to improve as more transport users return to the system, in Wave 3 a further question about concern regarding the number of people using public transport was added. The concern about the numbers of people (i.e., crowding) almost exactly mirrors that of concern about hygiene. Unsurprisingly, there is a significant and strongly positive correlation between concern about crowds and concern about hygiene ($r = 0.86$). Both concern about crowds and hygiene have a significant and negative correlation with public transport use during Wave 3 and are both positively correlated with concern about COVID-19 and the workplace.

In March 2021 we asked a series of questions about public transport use as part of an Australia wide ITLS Transport Opinion Survey series (TOPS)[8]. Among all the states, Australians living in Victoria and South Australia feel the least safe in using public transport (5.8 and 6 out of 10). Australians living in West Australia feel the safest (6.9 out of 10) (Figure 12). On average, Australians feel 6.2 out of 10 in terms of being safe in using public transport under the current COVID-19 situation. Overall, 24% of respondents have returned to using public transport with 11% having never abandoned it while 9% do not plan to use public transport again in the next couple of years. An additional 13% will return to using public transport once they are vaccinated. 36% of the sample have never used public transport (Figure 13). Overall, survey findings strengthen the general perception that a return to public transport will be contingent on a successful vaccination program and improved messaging programme around safety, and that current delays will only add to the challenges in attracting Australia back to public transport.

FIG 12 HERE

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[8] https://www.sydney.edu.au/business/our-research/institute-of-transport-and-logistics-studies/transport-opinion-survey.html

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FIG 13 HERE

Given the experiences of 2020, it may not be a surprise if we see some rethinking of public transport planning and delivery. The pandemic has been a reminder of how important public transport is as a crucial part of society's basic infrastructure, especially for those for whom public transport is their essential means of transport. This is a good reason for using public money to finance the system and ensure the recovery. The flattening of the peaks (as a result of WFH) can save resources that might be used to strengthen the basic, off-peak transport services. For now, the concern over bio-security issues around public transport use is enduring (Figure 11)[9]. Public perceptions arising from the way travellers are as concerned about crowding levels on public transport as they are about hygiene (discussed above) may force operators to revise what is considered an acceptable capacity in public transport vehicles; furthermore, the ability to reserve a seat on certain services (perhaps over a certain trip length) could provide a more personalised and safer experience.

Crowding on public transport will need to be mitigated as people increasingly return to using public transport. Whereas we might have thought that we now have plenty of public transport capacity, it may not be the case if we want to control crowding with more capacity being needed which could be a challenge for trains more than buses given track capacity limits. We need to rethink traditional approaches to peak vehicle availability. Those working from home have the flexibility to use public transport selectively and should be encouraged to do so. Differential pricing of both public transport (and private car traffic) would support this development. For example, a 30% off-peak discount has been introduced in Melbourne from January 2021 as part of a policy to encourage people to return to the workplace in a way which may include staggered work start and finish times[10].

Of course, we will not fix public transport by concentrating only on the supply side. But in Australia, where there are less restrictions than in many other parts of the world, the travel patterns being exhibited suggest that public transport customers have become both more adaptable and less predictable, probably as a result of the greater flexibility as to where and when they work. As a result, a more personalised transport offer with elements of flexibility, supported by journey planning tools to facilitate COVID-safe travel, for example, with information about crowding on public transport vehicles, should be expected to be seen as more attractive. In some locations, it may be more efficient to run demand responsive instead of conventional fixed route bus services on a larger scale to reflect this new demand.

Since Australia has a relatively high-income per capita, commuters might stay away from public transport longer than other places where public transport may be a more essential mode. Equally, a counteracting force may be a resultant level of road congestion already being witnessed that goes well beyond the capacity of the road network. Thus, there may be some natural protection that will stop public transport use from dropping below current levels of recovery. However, it is imperative that all forms of public transport are supported by clear messaging to build confidence in using and remaining loyal to public transport. Such an approach can reasonably be expected to reduce the level of concern associated with public transport use.

[9] The December 2020 COVID-19 outbreak in Sydney's Northern Beaches perfectly exhibits the vulnerability of public transport to public health concerns. In Sydney patronage in early December 2020 was at the highest levels since March's lockdowns having returned to around 150,000 trips / day. However, only about 80,000 to 100,000 trips were taken during the peak morning and afternoon periods in Sydney on Monday 11th Jan 2021, when people would be expected to return to work after a summer break which is less than half of the 200,000 to 250,000 trips on the corresponding day one year earlier.
[10] https://www.ptv.vic.gov.au/more/return-to-network/

4 Challenges and opportunities to manage congestion and crowding given the 'new normal'

There are a growing number of structural responses that should be given serious consideration which will have a direct or indirect impact on congestion and crowding, and we now set out a number of likely futures post-COVID-19. Although illustrated in a NSW context, we assert that they have relevance in many geographical jurisdictions. It will be useful to list a number of potential changes to the fabric of society that could occur due to increased WFH brought on by the pandemic and is likely to continue well after the pandemic has subsided. We are also getting a sense that people do not primarily want to go back to the traditional office per se for work[11] but for social interaction (that is not work related, especially for younger people), and this can be adequately provided through fewer days than five per weekdays. These should, at a minimum, be part of any discussions by government in particular, but more generally, on future transport and land use agendas.

1. Most pundits have suggested that we are likely to see a recovery to around 80% of office workers back to the Central Business District (CBD)[12] of cities on any given day, which will not only support reduced road traffic congestion but also manage crowding on public transport compared to pre-COVID-19. Central areas of major metropolitan cities will continue to have a role, but as we discuss below, the idea of reinvigoration in suburbia should not be dismissed lightly in any attempt to protect and preserve the CBD as a matter of faith. Although this CBD impact is still a dent in the revenue sources for many businesses in the central city precincts that depend to a large extent on office trade, it is still enough activity to revitalise much of the business in the supply chain that is currently suffering. We must recognise that much of the loss in the supply chain is due to restrictions that are separate to restrictions on office workers, and which are slowly being lifted. Furthermore, an increasing number of businesses have been moving to online trading and consequentially, one can expect a decline in traditional bricks and mortar trade. Restaurants and other food outlets will be the biggest winners as activity returns to some degree of normality in the CBD; however, some structural change is likely, with new opportunities opening up in suburbia, and especially the locations that have already started to take on the appearance of a CBD or a small but growing business precinct.

2. 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 minute city, which remains a challenge given a strong radial and CBD focussed strategy in many cities. We need to promote 'be local and buy local'[13] to help capture the redistributive effect of increased WFH where small business in suburban areas can benefit from increased economic activity that they would otherwise not participate in. This will result in potentially greater congestion at the local level in contrast to the longer trip setting, although both might suffer with reduced public transport use.

3. 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 (especially the reduced number of workers in the office at any one time), and while lower rents may attract a

[11] Although the main feature of work that is attractive in the office is the informal interaction that often results in the spawning of new ideas. It is also important to have face to face contact for new employees who still have to build networks within the office.

[12] There are numerous sources referring to this drop; for example: https://www.afr.com/property/commercial/the-big-office-return-is-under-way-and-it-s-filled-with-uncertainty-20211013-p58zlk'

[13] And encourage local travel by sustainable means.

new class of small to medium sized businesses into (or back into) the CBD, we would suggest that this will be balanced against the benefits of a more local office plan, where rents will also be competitive and office space more convenient to where people live, again reducing the pressures of the commute and supporting more flexible working hours.

4. Although there is much talk about getting back to the pre-COVID-19 office versus continuing to WFH, 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. This has the advantage of supporting ‘working close to home’ (WCTH) (reduced time spent in travel), but not at home with all of its accompanying limitations such as lack of social interaction, and poor space to work effectively without interruptions from, or interrupting, other family members. It also significantly reduces the lease cost of office space and its associated overheads as well as creating work or social connections locally, effectively reducing excess office capacity in this new world of connectivity through digital capability. What we have here is similar to efforts to reduce the fixed costs of private car ownership through mobility services such as Mobility as a Service (MaaS), with the prospect of growing demand for the lower cost ‘Mobile Office Location’. In a 2021 conference on the future office, it was concluded that ‘flexibility is here to stay’ and ‘employers who offer a balance of WFH and in office will attract and retain more high-quality employees’ (The Future of Office Space Summit, 2021).

5. 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. This also has impact for travel demand management measures typically in use to reduce congestion. If Mobility as a Service (MaaS) reboots after the pandemic (Hensher, 2020), there is a need to rethink monthly subscription plans to allow for subscriptions that have value when used for lesser number of days compared to the typical monthly pay plan. These might be repackaged for specific combinations of numbers of days per month. A greater focus on local shared mobility offerings, especially bicycles and e-scooters, should increasingly be built into the offered subscription bundles. This could also facilitate use of more sustainable modes for local travel in days spent WFH.

6. We should also reflect on long distance domestic travel as border restrictions are lifted. Specifically, we are likely to see a significant reduction in domestic business air travel, replacing for example, the Sydney to Melbourne return flights (typically 4 hours out of the day) to attend a one-hour meeting with an online meeting. This may translate into a growth in local non-commuting activity with time freed up. This growth is already being witnessed in regional aviation travel, with State border closures contributing to increased tourism to regional locations that are, for some people, too far away to drive for a short getaway.

7. With a greater focus on local activity, there will be a need to reprioritise improvements in local public transport, safer pedestrian walkways and precincts, and bicycle lanes, serving short distant trips throughout the day, with the added benefit of improving first and last mile connectivity to public transport and (hopefully) contributing to improved health outcomes through greater physical activity (see also Chapter 17). Local road amenity and safety may also need to be revisited, with a greater focus on localised

maintenance and traffic control measures to cope with a potential change to localised traffic flow. This will take on new meaning and require organisations such as Infrastructure Australia (IA) to remove the minimum dollar threshold for project assessment and funding, which for IA is $100m. Generally, we need a rethink where infrastructure funding should go, including deferring major infrastructure spend[14]. We might even find that active travel strategies can become embedded within investment in key public infrastructure and COVID-19 may come to be seen as the inflection point which enabled cities to pursue more long-term sustainability initiatives and active transportation infrastructure investments.

8. Governments can lead the way in supporting WFH as a way of reducing pressure on the transport network, especially in metropolitan settings, but where this pressure is not of great consequence (e.g., many regional and rural contexts), they should encourage and support reduced travel and improvements in wellbeing associated with greater flexibility in work hours and days of the week working at home. Evidence through doing (leading by example) can flow through to the private sector to use WFH and WCTH to deliver on their sustainability charter.

5 Conclusions

While the pandemic forced change without choice for almost all individuals and households, it has resulted in both positive and negative unintended consequences. We are in the midst of a real-world experiment and although the pandemic has been a terrible experience, through its unfolding, people have come to appreciate the benefits of working from home and maybe leaders should embrace this in their forward thinking about ways to support the positive outcomes such as more flexible working hours, reduced commuting and improved wellbeing.. There are many good legacies from COVID-19 but there is a general view that the four most positive ones are busting the myth that you cannot WFH, authenticity of our leaders and managers in a business or entity, conscious culture such that we can trust our employees as an output and not solely an input, humanity and ability to adapt, and dependence on each other.

There are, however, negative outcomes associated with the challenging, if not traumatic including bereavement, experience for some individuals and households associated with job loss, social isolation, and inter-personal pressures within the household.

However, a notable and potentially lasting consequence with positive impact, is working from home (WFH) and how this translates into many impacts through the supply chain of businesses, particularly those that depend heavily on workers at the office, or who work outside of the home. In focussing on WFH[15], we emphasise that while the pandemic forced a

[14] The Grattan Institute has recently criticised the Australian government's budget focus on big infrastructure (Australian Financial Review, 13 October 2020). An historical underspend on maintenance of existing assets has contributed to a backlog across all infrastructure sectors, which will erode the quality and reliability of many assets and lead to higher costs for future asset maintenance and renewal. "Unless addressed, maintenance of our transport networks will become increasingly unsustainable," Infrastructure Australia says. Furthermore, with a focus on jobs, it is not a foregone conclusion that a public infrastructure project is an effective stimulus. While the condition of many assets is unknown, and the maintenance backlog is serious, the Grattan Institute suggest that this is a productivity opportunity that is both urgently needed and is shovel-ready.

[15] Studying from home (SFH) has also occurred, and while this has subsided in Australia for primary and secondary education, it largely remains in place for tertiary education, and in many instances international students are now studying from their home country (though in considerably less numbers than before across the sector). The physical absence of tertiary students has had a significantly large

cataclysmic change on our lives without much time to prepare, it has happened, and as we continue to respond to the pandemic by keeping our distance, evidence is building on the pros and cons of WFH and the extent to which WFH will continue at a level that is greater than pre-COVID-19. At a high level, indications as in June 2021, are that we can expect to see (in Australia and the USA) a growing number of workers in some occupation classes (notably white collar but not exclusively) working from home from one to two days a week, and that this comes with the blessing of employers in particular, who believe there is generally no difference, on average, in productivity for employees who are currently working from home compared to before COVID-19 (Beck & Hensher 2020, 2020a-d).

While we have had disruption in the past, a key difference with COVID-19 compared to those such as SARS, MERS, the Global Financial Crisis and natural disasters, has been the duration, coverage and the extent to which disruption has occurred and continues to occur. Our evidence suggests that COVID-19 has also broken the back of significant business resistance to WFH, and at a time where many businesses are looking to reduce costs, many see WFH as an appealing and viable option to reduce the cost of office space provision where lease costs in the CBD in particular, are often sizeable. Ongoing levels of WFH would also be a prudent risk management strategy should the COVID-19 pandemic re-emerge, or another replace it in the future. Significantly lowering the environmental impact of staff travelling every day can also allow big corporates to deliver on their sustainability charter which has generally alluded them to date.

There are other benefits that accrue to the employee who is able to WFH successfully (acknowledging again that not all can WFH as well as others – see Beck and Hensher (2020a, 2020d)) such as being able to allocate their work hours in a more flexible way, or most importantly recovering time that is often lost to commuting. Employees (and/or their employers) have also likely made investments in the last six months to enable WFH (e.g., improved home office capability)[16] and given the duration of the pandemic, new strategies and habits are likely being developed to make WFH work for them. There does remain, however, some hurdles to the ongoing levels of WFH such as social connectedness, teamwork, collaboration and creativity, but many of these barriers can be addressed with innovation and a work environment where there is a mix of WFH and working in "the office".

The growth in WFH translates into some important positive changes in the performance of the transport network, particularly in the larger cities. In summary, we might anticipate at least a 10 to 15 percent improvement in the metropolitan transport networks due to reduced traffic congestion on the roads and crowding on public transport (Hensher, Beck and Wei2021, Hensher, Wei et al. 2021). We suggest that WFH promises to be the greatest 'transport' lever for policy makers to reduce congestion and crowding that the sector has ever had. What we are seeing in our tracking surveys to date since March 2020 (Beck & Hensher 2020, 2020a-d) is that the increase in WFH is spread evenly throughout the five weekdays. This is important, since infrastructure and service capacity are typically determined by peak demand, and if this can be flattened as it suggests it might through also peak spreading, then the implications for prioritising and deferring funds and planning in transport are potentially significant, even going forward over many years.

In summary, the liminal threshold imposed on society by the COVID-19 pandemic provides an opportunity to allow decision-makers to take a hard look at the assumptions being used pre-COVID-19 that underlie many of the decisions made on transport and land use futures. Doing this offers a real opportunity for sustained change that many have been seeking. COVID-19

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and negative impact on local suppliers of student accommodation, and other support industries and services.

[16] The popular TV program 'The Block' has recently suggested (18 October 2020, Channel 9) that the home office will become an important addition to all dwelling renovations.

has brought us all together and the future must be seen as an all of society commitment. The pandemic has hastened existing trends rather than created new trends. We have to ‘design’ the future for wellness, choice, ease, connection and meaning with the ‘new normal’ focussed on improved connectedness (in contrast to social distancing) and agile development space ensuring greater happiness and wellbeing. Taming congestion and crowding should be aligned with these aspirations. The strongest message is to reach for a new normal that is a better normal that becomes the new real.

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TABLES / FIGS / PICTURES / ILLUSTRATIONS / TABLES HERE

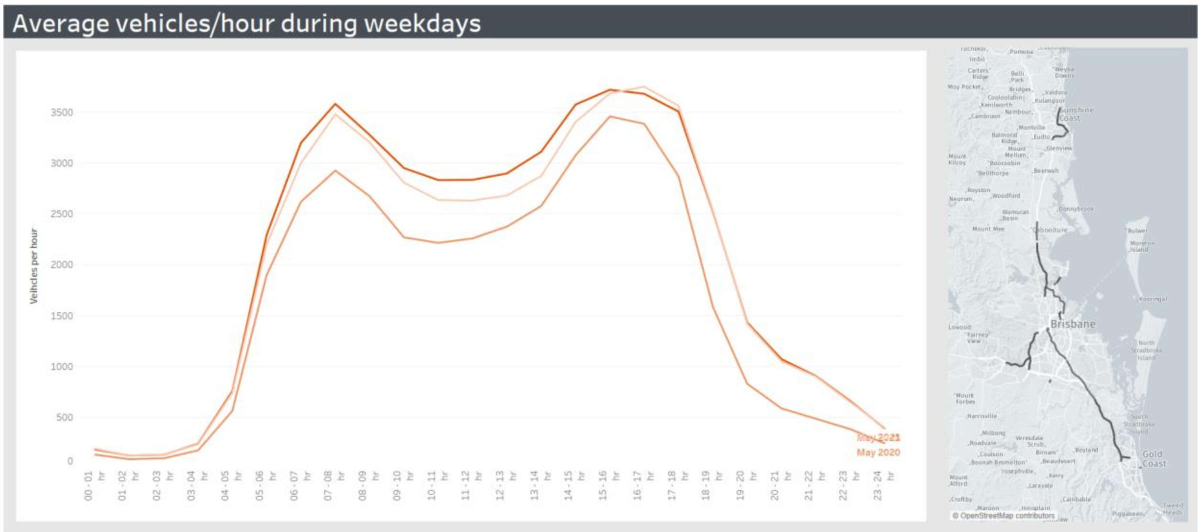

Figure 1: An example of a return to high levels of road congestion (Source: Transport and Main Roads, Queensland)

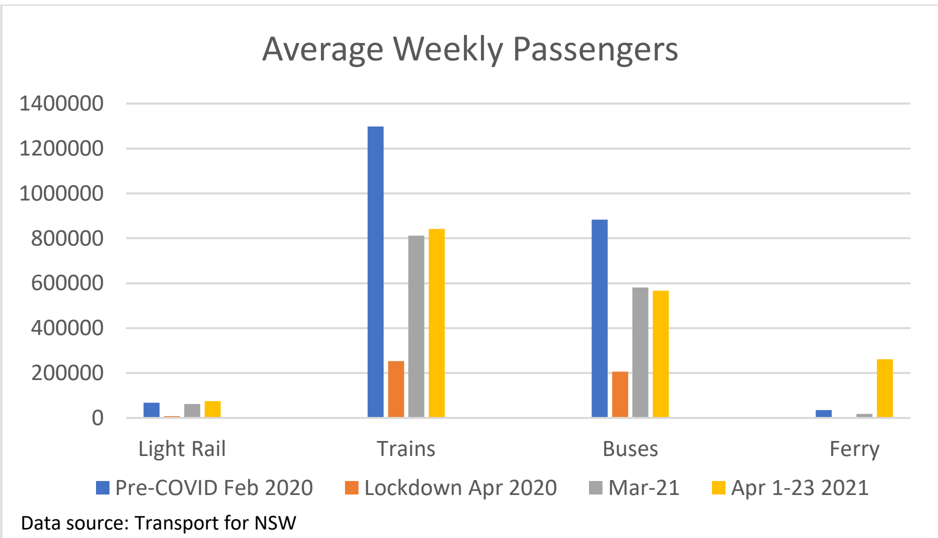

Figure 2: Changes in public transport use in Sydney

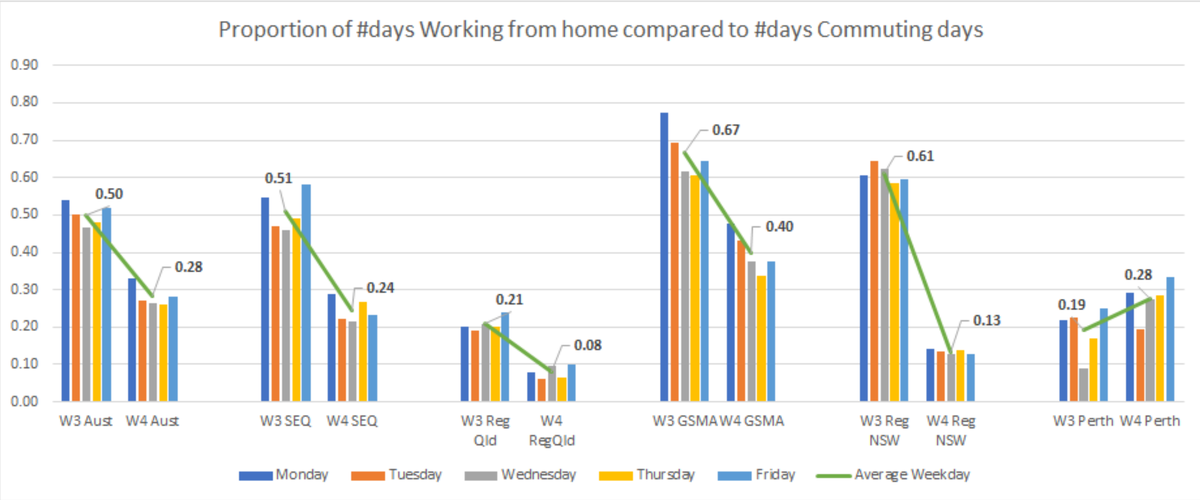

Figure 3: Change in the incidence of WFH compared to commuting by various locations in Australia in September 2020 (W3) and May/June 2021 (W4) (Source: ITLS Waves 3 and 4 surveys). GSMA = Greater Sydney Metropolitan Area; SEQ = South East Queensland (Brisbane, Sunshine Coast and Gold Coast), Reg = regional locations in NSW and Queensland.

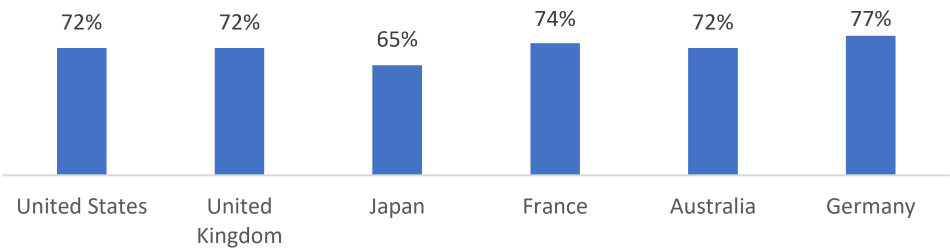

Figure 4: Workers who would prefer mix of work from home and office (July / August 2020)

Source: https://slack.com/intl/en-gb/blog/collaboration/workplace-transformation-in-the-wake-of-covid-19

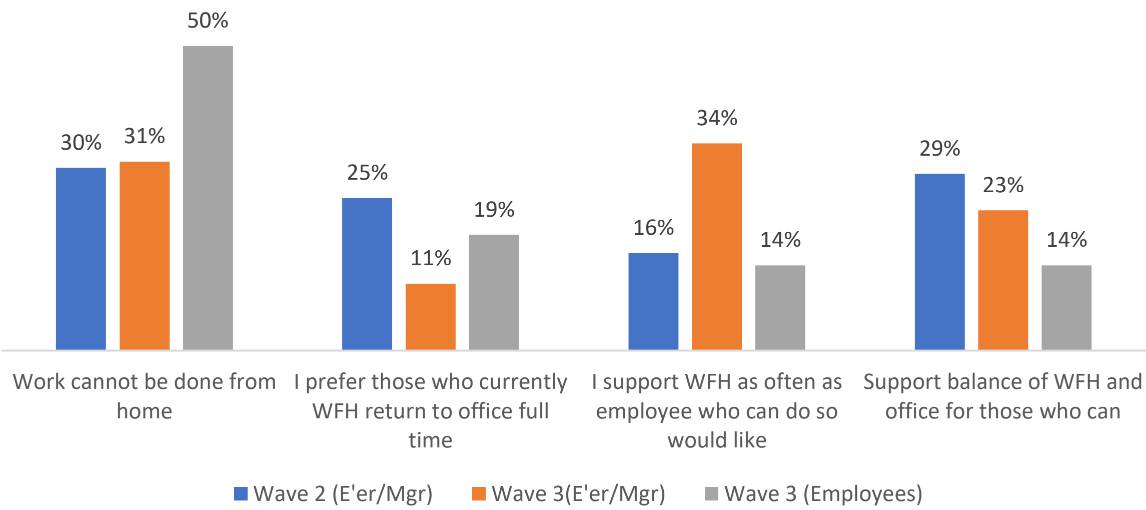

Figure 5: Employer and Employee View on Work from Home Policy when Restrictions End (Wave 2 = May and Wave 3 = September 2020)

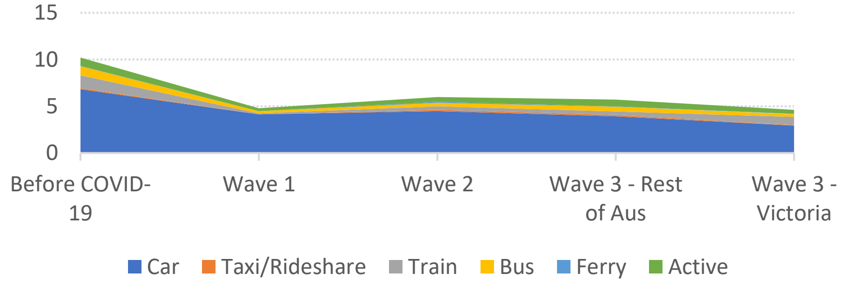

Figure 6: Commuting Activity by Mode (Wave 2 and Wave 3)

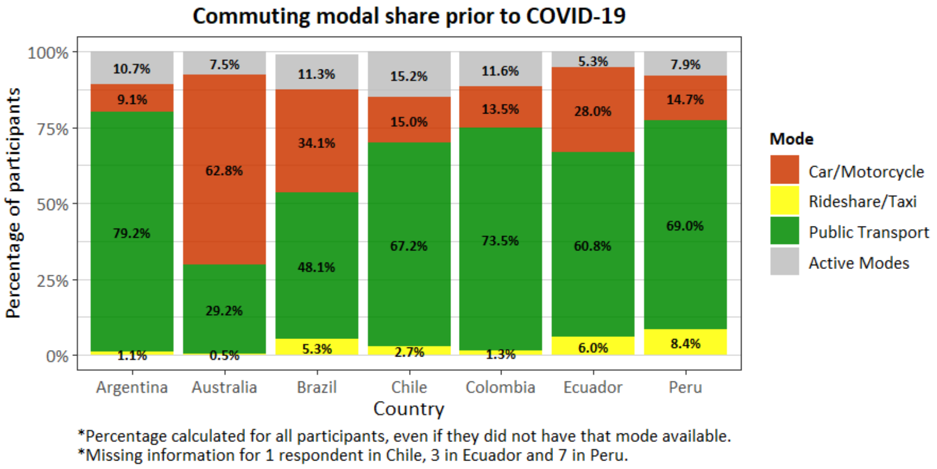

Figure 7: Commuting modal share prior to COVID-19 (Australia and South America)

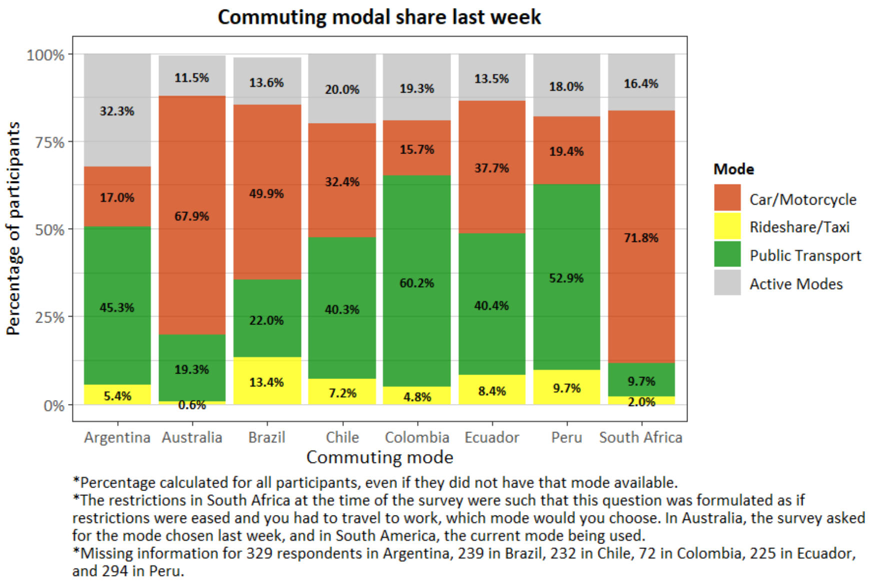

Figure 8: Commuting modal share last week in 2020 (Australia and South America)

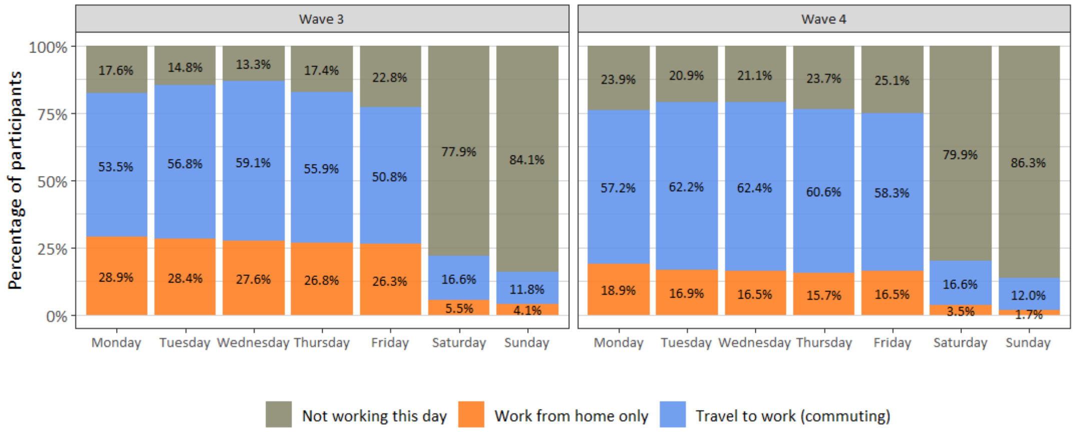

Figure 9: Commuting / Work Travel and Working from Home by Day of Week (Wave 3 and Wave 4)

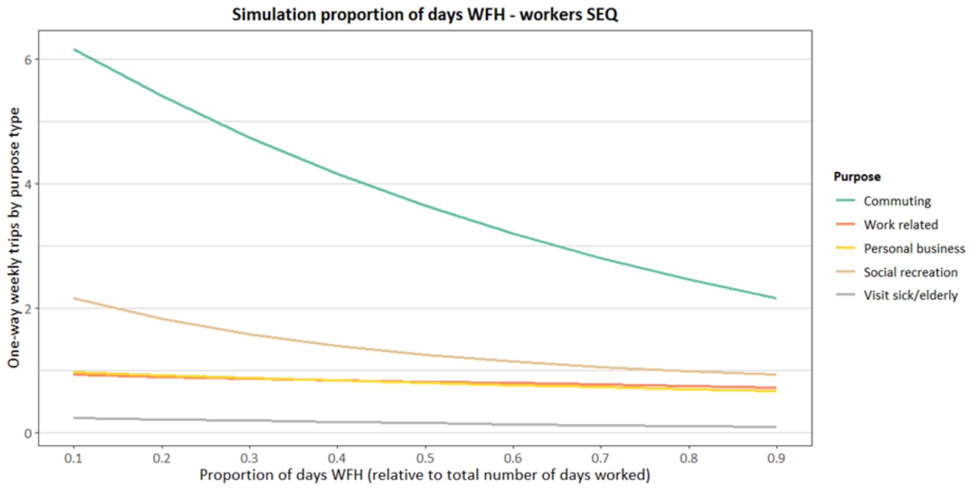

Figure 10: The relationship between the proportion of days working from home and one-way weekly trips for each trip purpose (Balbontin et al., 2021)

Table 1: Implied direct mean elasticities of the one-way weekly trips by trip purpose with respect to the probability of WFH (Balbontin et al. 2021)

SEQ workers	Commute	Work-related	Education	Food shopping	General shopping	Personal business	Social recreation	Visit sick/elderly
Age (years)	-0.391					-0.617		
Gender female (0,1)		-0.265	0.580			0.226		
Personal income ('000AUD$)	0.132				0.297		0.256	
Number of children in household	0.099		0.875		0.120	0.125		
At least one child in primary school (0,1)	-0.044		0.079	-0.059	-0.069			
Number of cars per adult in household		0.289	0.337					
Distance from home to office (kms)								-0.493
Proportion of days WFH	-0.166	-0.091				-0.140	-0.117	-0.328
Occupation clerical and administration (0,1)		-0.208						
Occupation manager (0,1)						0.055		
Industry category retail (0,1)					0.058			
Prior to COVID-19 used car to go to work (0,1)	-0.239		-0.260		-0.316	-0.280	-0.180	
Work located in CBD area		0.086	-0.079		-0.080			
Brisbane (0,1)	-0.087	-0.381				-0.261	-0.157	-0.637
Age (years)	-0.391					-0.617		
Gender female (0,1)		-0.265	0.580			0.226		
Personal income ('000AUD$)	0.132				0.297		0.256	

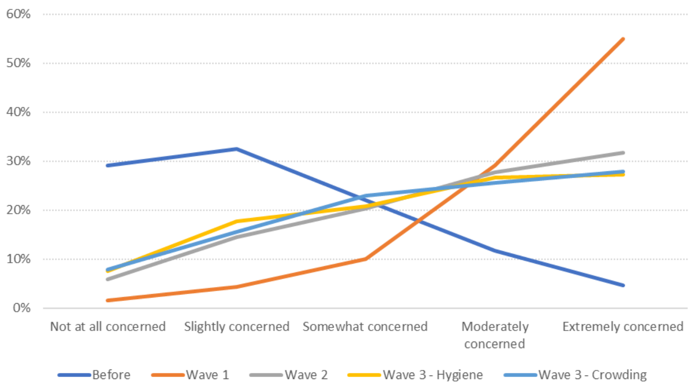

Figure 11: Level of concern about public transport (hygiene and crowding)

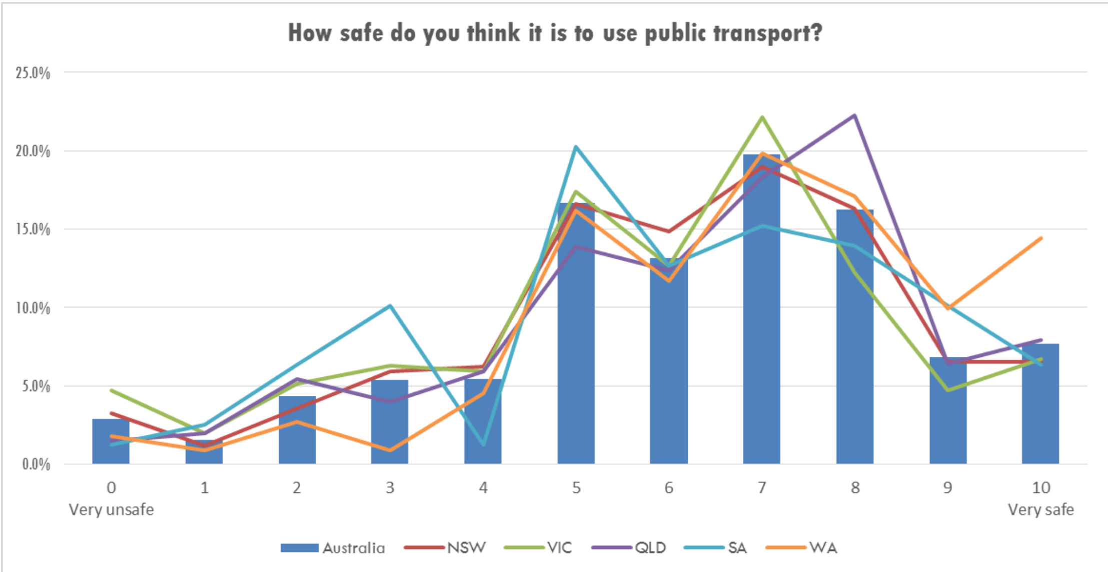

Figure 12: Perception of safety of using public transport (Source: ITLS Transport Opinion Survey, March 2021)

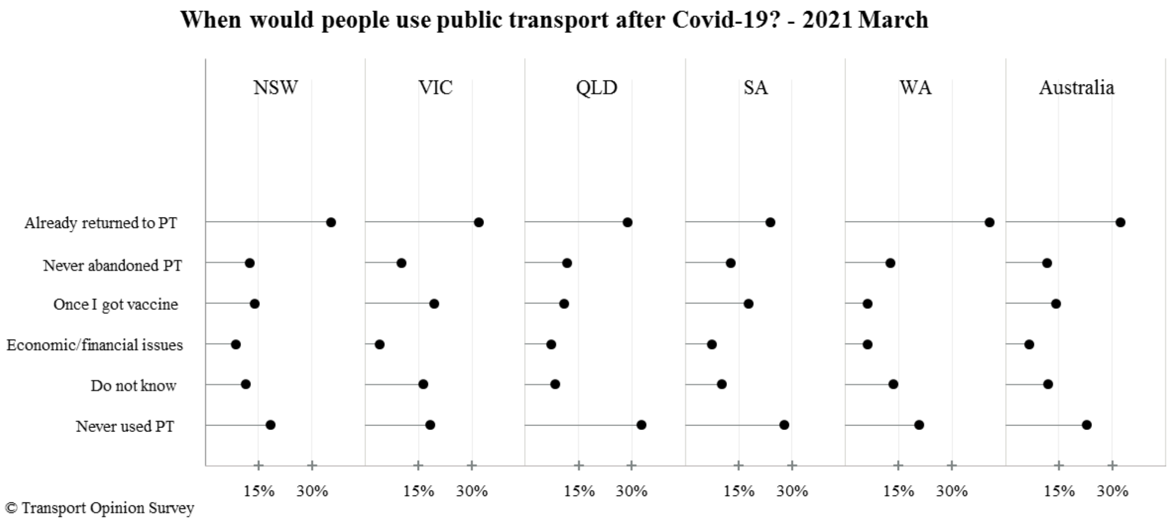

Figure 13: Returning to using public transport (Source: ITLS Transport Opinion Survey, March 2021)

Appendix S. Paper #15: Relationship between commuting and non-commuting travel activity under the growing incidence of working from home and people's attitudes towards COVID-19

Camila Balbontin
David A. Hensher
Matthew J. Beck

Abstract

The COVID-19 pandemic has reshaped the way we live and travel, possibly for many years to come. The 'New Normal' seems to be one that is best associated with living with COVID-19 rather that 'after COVID-19'. After a year or more since the pandemic spread throughout the world, we have amassed a significant amount of evidence on what this is likely to mean for patterns of commuting activity in a setting where working for home (WFH) is becoming a more popular and legitimate alternative to choosing a commuting mode. With WFH continuing to some extent, non-commuting travel is also likely to change as workers and their families have greater flexibility in when and to what extent they conduct their shopping, social-recreation and other non-commuting trip activity. This paper recognises that all trip purpose activity is being impacted by the pandemic and that the drivers of changing number of trips by each and every trip purpose need to be identified as a way of establishing likely future levels of frequency of all trip making. In this paper we develop a series of trip making models for workers and non-workers in New South Wales and Queensland in a metropolitan and a regional setting, using data collected in late 2020. The influence of the number of days WFH is identified as an important influence on the number of one-way weekly trips for various trip purposes, which together with socioeconomic, geographic and attitudinal variables enable us to gain an understanding of what is driving levels of trip-purpose-specific travel during the pandemic. Elasticities and simulated changes are presented as a behaviourally rich way to understand the sensitivity of influences on the frequency of travel.

Keywords: COVID-19; commuting trips; non-commuting trips; work from home; metropolitan and regional areas; workers and non-workers, elasticities

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1 Introduction

COVID-19 has had a significant impact on how countries operate in various settings. In relation to work, there has been a substantial increase in working from home (WFH), which has had a range of impacts on people's lives. While travel to and from the workplace has been affected by the pandemic, so has travel for other purposes (for example, going to the supermarket or to the doctor). As part of a larger study focussed on revisions to strategic transport models to accommodate WFH as a growing alternative to commuting mode choice (Hensher, Beck, et al., 2021; Hensher, Balbontin, et al., 2021), we need to recognise that changes in commuting activity as a result of increased WFH will also have an impact on the amount of non-commuting travel activity. With WFH changing the hours that many people actually work, including staggered working hours where commuting to the office occurs, the entire seven days of the week and weekend become candidate times for travel that pre-COVID-19 would have been more constrained as workers commuted five days a week and typically worked a 9 to 5 day, with variations around this common time slice.

The main objective of this paper is to get a better understanding on the main drivers for commuting and non-commuting travel activity, and to identify the extent to which WFH, respondents' characteristics and attitudinal variables play a role in defining it. This paper focusses on developing a series of models that use data collected during late 2020 in Australia (New South Wales and Queensland) in order to understand the relationship between working from home, perceptions about COVID-19, and one-way weekly trips for six trip purposes for working people. Other studies on the impact of COVID-19 in Australia have focused on commuting (Beck et al., 2020; Beck & Hensher, 2020; Hensher, Wei, et al., 2021). However, there is still a gap to fill in terms of the impact of COVID-19 and non-commuting trips, and how they might have an influence on the overall transport network – particularly in local and suburban areas where many of these non-commuting trips occur – and are of interest to transport authorities and policy makers. This is further compounded by the lack of clarity prior to COVID-19 as to whether telecommuting and personal travel are complements or substitutes (Kim et al., 2015; Zhu, 2012; Zhu et al., 2018) moreover how this behaviour might manifest during the COVID-19 period.

For each trip purpose, a negative binomial regression model is estimated, in which the dependent variable is the number of one-way weekly trips, a count variable. The candidate explanatory variables include sociodemographic characteristics of the participants (i.e., age, income, gender, profession), residential and work location (i.e., regional / suburban dummy variables), proportion of days worked from home relative to total days worked in the last week, and variables that represent the perception of COVID-19. For the latter, factor analysis is undertaken to combine responses to attitudinal questions that refer to the concern for COVID-19 in the life of each person and their community, the response of the authorities, and how comfortable they feel using public transport. An important objective of this study is to identify what are the systematic drivers influencing commuting and non-commuting travel behaviour for workers, non-workers and users in both regional and metropolitan areas during COVID-19, where working from home and bio-security concerns more generally are having a noticeable impact on travel behaviour.

The paper is organised as follows. The next section provides a brief background of other studies that have looked at the effects of COVID-19 on travel behaviour. Section 3 describes the data used in this study, followed by the methodology used. Section 5 presents the model results as well as a number of interesting mean direct elasticities. The next section presents simulated scenarios to analyse the level of sensitivity of the one-way weekly trips by purpose type; and the last section summarises the main findings.

2 Background

Since early 2020 when the COVID-19 pandemic spread across the world, many organisations and individuals have embarked on research designed to gain a better understanding of the impact that COVID-19 has had on the way we gave about our daily activities. The interest herein is on understanding the impact of COVID-19 travel behaviour, with the growth in working for home as an alternative to commuting in particular. Hensher, Beck, et al. (2021) collected data in early 2020 in Australia to understand the number of one-way commuting trips by car and public transport in Australia given the disruptions caused by COVID-19. Their findings suggest that the increase in WFH has had a major impact on travel behaviour and needs to be embedded in future revisions of strategic transport model systems. Beck & Hensher (2020) analyse the implications on travel behaviour in Australia by mid-2020. Their findings suggest that by mid-2020, travel activity had started to slowly return to normal in Australia, in particular by private car and for trips related to shopping and social/recreation. However, work from home prevailed and respondents had a positive opinion towards it. Beck et al. (2020) look at WFH in more detail, finding that the role of the employer is very important and determines how many days people are working from home. They also find that WFH is generally higher in metropolitan areas and households with higher income levels, which is probably related to the nature of employment.

Hensher, Balbontin, et al. (2021) formalise the relationship between WFH and commuting by day of the week and time of day using data collected in late 2020 in Australia. They use a mixed logit choice model to identify the influence of different explanatory variables such as income, age, concern about the use of public transport, among others, in the choice to WFH or to commute by different modes and at different times of the day. Their very high aggregate level results show that the adjustments of WFH should be around 0.3 and 0.4 representing the probability to WFH relative to commuting in any mode of transport.

Zhang et al. (2021) undertook a worldwide expert survey during the early stages of COVID-19 to understand the effect on travel. Their findings confirm that public transport usage decreased significantly, and most of the modal shift was to active transport followed by car, especially in Europe. Balbontin et al. (2021) compare travel behaviour in different countries around the world but using an online panel survey in Australia, South Africa and different countries in South America. Their results suggest a dramatic decrease in the use of public transport, but most of the participants had moved to private car, followed by active modes (bicycle and walk). Their results indicated a high incidence of WFH, either mandatory or by choice. Barbieri et al. (2021) study individual mobility patterns for all transport modes in ten countries on six continents. Their results show a substantial reduction in the frequency of commuting and non-commuting trips in all modes. The authors study the risk perception of using different modes of transport using three Likert-type queries. Their results suggest that socio-economic inequality and morbidity are related to health risks and also to perceived risks.

The Australian evidence aligns well with a recent USA study by Barrero et al. (2021) who surveyed more than 30,000 USA residents over multiple waves in 2020 to investigate whether WFH will stick, and why. That found that 20 percent of full workdays will be supplied from home after the pandemic ends, compared with just 5 percent before, of which 2 days a week is not uncommon. They provide five reasons for this large shift: better-than-expected WFH experiences, new investments in physical and human capital that enable WFH, greatly diminished stigma associated with WFH, lingering concerns about crowds and contagion risks, and a pandemic-driven surge in technological innovations that support WFH. The consequences are that employees will enjoy large benefits from greater remote work, especially those with higher earnings; the shift to WFH will directly reduce spending in major city centres by at least 5-10 percent relative to the pre-pandemic situation; data on employer plans and the relative productivity of WFH imply a 5 percent productivity boost in the post-pandemic economy due to re-optimized working arrangements; and only one-fifth of this productivity gain will show up in conventional productivity measures, because they do not capture the time savings from less commuting. Contrasts with developing economies have been studied in Balbontin et al. (2021) who investigated the relationship between WFH and commuting activity in South Africa, and five South American capital cities (i.e., Buenos Aires, Bogotá, Lima, Quito and Santiago) in August-December 2020, using questions derived from the Australian study. The number of days working from home has more variation across countries, where the lowest is in Australia with 1.63 average days WFH, followed by South Africa with 2.31 days; and the highest is Argentina with 3.43 days WFH followed by Chile with 3.19 days.

There is still much more to be done on the longer-term impacts of COVID-19 on travel behaviour. To the best of our knowledge, this is the first study that analyses the implications of COVID-19, from a WFH perspective but also from an attitudes and perceptions perspective, for both commuting and non-commuting travel behaviour, including workers, non-workers, metropolitan and regional areas.

3 Data description

The data used in this study was collected through an online survey in two states in Australia: New South Wales (NSW) and Queensland (QLD), in late 2020. The survey included questions on employment status, socio-demographics, work from home experience, travel behaviour, and attitudinal questions towards working from home, COVID-19, community and government response, among others, and was answered by adults only (18 years or older). Additional information was included in the data, such as distance between residential and main work location using home and workplace postcodes reported in the survey[17]. This paper focuses on understanding the effect of COVID-19 on respondents' travel behaviour for people currently employed and not employed. Six different purpose types are considered in this study: (1) commuting trips; (2) work-related trips; (3) education/childcare trips[18]; (4) shopping trips (i.e., food and general shopping); (5) personal business trips; and (6) social recreation trips. The commuting and work-related trips are only valid when a respondent is currently employed, referred to as workers; otherwise, he/she is a non-worker. Moreover, commuting trips refer to trips made from home to the office and back home, while work-related trips refer to trips made during the workday (e.g., visiting clients, delivering packages, meetings, among others). The analysis includes respondents that live in metropolitan areas – namely, in the Greater Sydney Metropolitan Area (GSMA) in NSW[19], and in Southeast Queensland (SEQ[20]) in QLD – and respondents that live in regional areas in both NSW and QLD[21]. Figure 1 profiles the average number of one-way weekly trips by purpose type and employment status in the metropolitan and regional areas of NSW and QLD.

[17] Census information and other neighbourhood information (such as employment rates in area) were included but they were not statistically significant when explaining the number of trips by different purposes.
[18] Includes all trips to childcare, schools or higher education (e.g., universities). These trips were combined because they represent a relatively low number of trips, as graphically shown in Figure 1.
[19] This includes, Sydney, Newcastle, Wollongong/Illawarra, Central Coast,
[20] This includes Brisbane, the Sunshine Coast and the Gold Coast.
[21] The regional areas in Queensland are Townsville, Cairns Toowoomba, Bundaberg, Gladstone, Mackay and Rockhampton. In NSW the regional Centres included are Wagga Wagga, Port Macquarie, Coffs Harbour, Tamworth, Armidale, Orange, Bathurst, Dubbo, Parkes and a number of smaller locations.

The majority of one-way weekly trips are commuting trips; they are higher in regional areas where we have observed far less days WFH. The second highest average number of trips is for shopping, followed by social/recreation activity. The number of trips with an education/childcare purpose are significantly lower for non-workers compared to workers in regional areas; the same relationship is true in metropolitan areas but the difference between workers and non-workers is small. The average number of personal business trips and social/recreation trips in regional areas are greater for non-workers, but in metropolitan areas they are higher for workers. The average number of shopping trips is slightly higher for non-workers in metropolitan areas, and almost the same in regional areas, compared to workers. The average for personal business trips is higher for workers relative to non-workers in all areas except regional NSW.

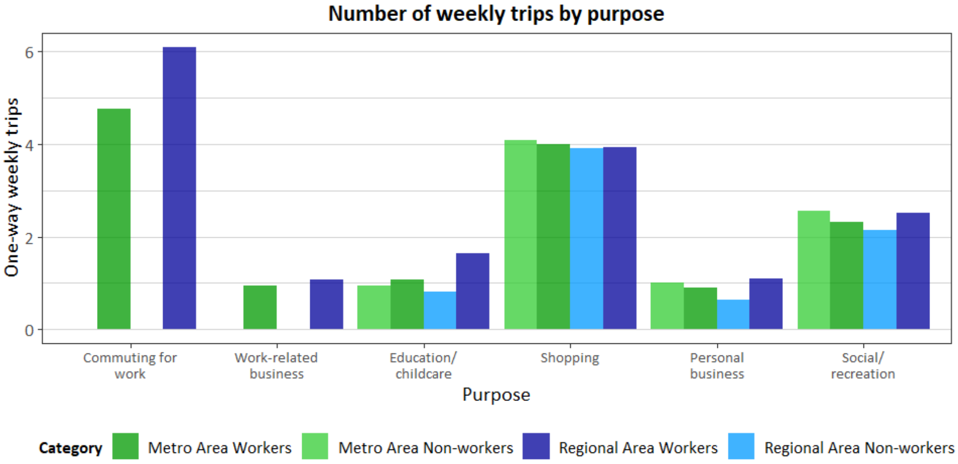

Figure 1: Average number of weekly trips by purpose in September 2020

A summary of the non-attribute variables investigated as sources of variation on trip purposes are summarised in Table 1. As expected, income is significantly lower for non-workers than workers, while age is also higher for non-workers than workers. The proportion of days worked from home in a 7-day week is significantly higher in metropolitan areas (0.35) than in regional areas (0.14). Figure 2 shows the average number of days worked and WFH before COVID-19 in 2019 and last week in September 2020. As can be seen, there is a significant increase in the number of days WFH in metropolitan areas from 0.84 to 1.66 days, while in regional areas the average of number of days WFH remains lower than 1. The total number of days worked decreased in metropolitan and regional areas.

Table 1: General descriptive statistics – mean (standard deviation)

	Metropolitan Area		Regional Area	
	Non-workers	Workers	Non-workers	Workers
Age (years)	58.62 (17.04)	40.15 (13.42)	57.27 (17.14)	38.62 (13.48)
Gender female (0,1)	62%	64%	62%	68%
Number of adults in household	1.57 (0.75)	1.68 (1.01)	1.58 (0.85)	1.66 (0.98)
Number of cars in household	1.30 (0.77)	1.64 (0.94)	1.59 (1.14)	2.05 (1.02)
Number of cars per adult in household	0.94 (0.64)	1.14 (0.75)	1.12 (0.79)	1.42 (0.78)
Number of children in household	0.75 (1.17)	1.11 (1.35)	0.90 (1.36)	1.18 (1.48)
At least one child in primary school (0,1)	-	22%	-	23%
Personal income ('000AUD$)	35.68 (32.63)	78.14 (51.03)	32.42 (27.58)	67.31 (46.31)
Proportion of days WFH	-	0.35 (0.43)	-	0.14 (0.30)
Number of days WFH	-	1.66 (2.12)	-	0.61 (1.40)
Distance from home to office (kms)	-	19.48 (32.47)	-	18.38 (28.66)
Occupation clerical and administration (0,1)	-	20%	-	22%
Occupation sales (0,1)	-	11%	-	9%
Occupation labour (0,1)	-	6%	-	5%

Occupation manager (0,1)	-	14%	-	12%
Industry category retail (0,1)	-	18%	-	7%

	Metropolitan Area		Regional Area	
	Non-workers	Workers		Non-workers
Used car to go to work last week[22] (0,1)	-	69%	-	93%
Used train/light rail to go to work last week[5] (0,1)	-	12%	-	-
Used bus to go to work last week[5] (0,1)	-	6%	-	1%
Prior to COVID-19 used car to go to work (0,1)	-	63%	-	93%
Prior to COVID-19 used train/light rail to go to work (0,1)	-	20%	-	-
Prior to COVID-19 used bus to go to work (0,1)	-	9%	-	2%
Brisbane (0,1)	18%	21%	-	-
Central Coast (0,1)	12%	7%	-	-
Located in the state of NSW (0,1)	64%	62%	76%	30%
Located in the state of QLD (0,1)	36%	38%	24%	70%
Number of observations	**269**	**627**	**141**	**311**

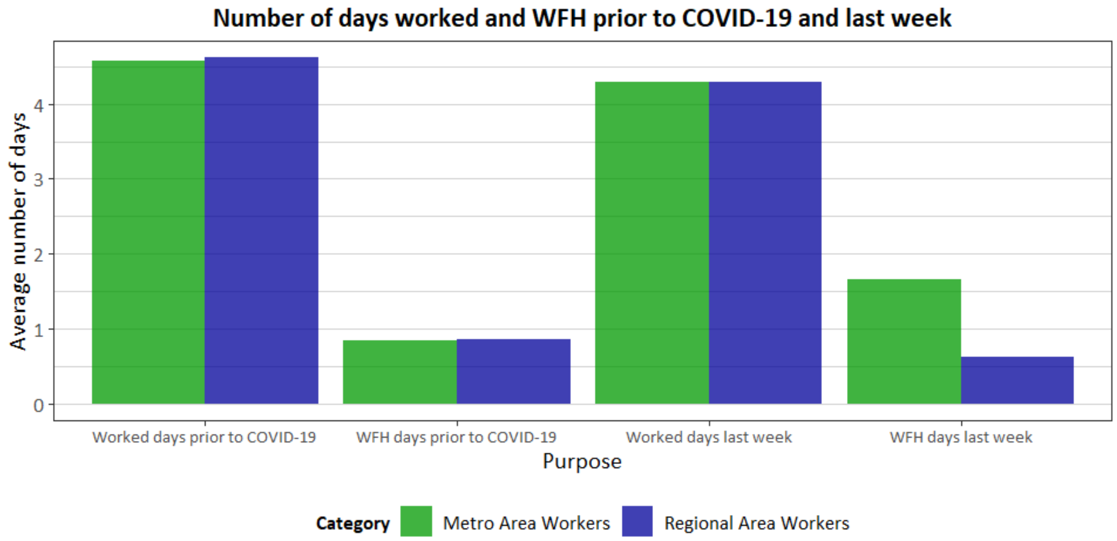

Figure 2: Average number of days worked and worked from home prior to COVID-19 and last week[5]

4 Methodology

The purpose of this study is to understand how the number of one-way trips for different purposes are affected by the COVID-19 pandemic. The proportion of work being done from home is an observable variable that is directly related to COVID-19. However, there are other underlying attitudes towards COVID-19 that might be influencing travel behaviour. Factor analysis is used as a data reduction tool to synthetise different statements that were included in the survey to understand respondents' perceptions and attitudes towards COVID-19.

A negative binomial regression model is estimated for the number of one-way weekly trips for each purpose type, location (metropolitan or regional area) and working status in late 2020. In total, 16 models were estimated for the workers in both metropolitan and regional areas and 12 for non-workers (which do not consider commuting or work-related trips). The dependent variables, the number of one-way weekly trips for each purpose, are non-negative discrete

[22] The concept *last week* was used in the survey to ask for travel behaviour in the week prior to the survey, which was collected in September 2020.

count values, with truncation at zero, which are defined as a discrete random variable, y_i, observed over one period of time. The negative binomial regression probability is given by equation (1).

$$P(y_i = k \mid \mu_i) = \frac{\exp(-\mu_i)\cdot \mu_i^{k}}{k!} \qquad k = 0,1,... \tag{1}$$

In a negative binomial model, the conditional mean of y_i is defined as follows:

$$\mu_i = E(y_i = k \mid x_i) = \exp(\beta' x_i) \tag{2}$$

And the conditional variance, which exceeds the conditional mean, includes a dispersion parameter estimate θ as follows:

$$Var(y_i = k \mid x_i) = \mu_i(1+\mu_i/\theta) > E(y_i = k \mid x_i) \tag{3}$$

The prediction rate or expected frequency of the number of days WFH was calculated as a function of different explanatory variables, shown in equation (4).

$$\mu_i = \exp\left(\beta_0 + \sum_n \beta_n \cdot z_n \cdot d_a + \sum_m \beta_m \cdot x_m \cdot d_a + \sum_f \beta_f \cdot x_f + \varepsilon\right) \tag{4}$$

where β_0 represents the constant; z_n represents respondents socio-demographics (e.g., age, gender, income); x_m other respondents' characteristics such as distance from home to work, mode used, etc.; d_a dummy variables associated to each area; x_f represents the factor attributes to underlying attitudes towards COVID-19; and the β represent the parameter estimate associated to each of the variables.

The marginal effects in this nonlinear model specification are presented in equation (5).

$$\text{Marginal Effects} \Rightarrow \frac{\partial E(y_i \mid x_i)}{\partial x_i} = \beta_i \cdot \mu_i = \beta_i \cdot E(y_i \mid x_i) \tag{5}$$

The direct point elasticities are presented in equation (6).

$$\text{Elasticity} \Rightarrow \frac{\partial E(y_i \mid x_i)}{\partial x_i} \cdot \frac{x_i}{E(y_i \mid x_i)} = \beta_i \cdot x_i \tag{6}$$

The direct point elasticity formula indicates that a one percentage change in the i^{th} regressor, *ceteris paribus*, leads to a one percentage change in the rate or expected frequency of $\beta \cdot x_i$. In contrast, where a variable is a dummy variable (1,0), a one percentage change is inappropriate, and a direct arc elasticity form is used as given in equation (7).

$$\begin{aligned}\text{Arc Elasticity} &\Rightarrow \frac{E(y_i \mid x_1) - E(y_i \mid x_2)}{x_1 - x_2} \cdot \frac{(x_1 + x_2)/2}{\left(E(y_i \mid x_1) + E(y_i \mid x_2)\right)/2} \\ &= \frac{E(y_i \mid 1) - E(y_i \mid 0)}{E(y_i \mid 1) + E(y_i \mid 0)}\end{aligned} \tag{7}$$

The arc elasticity interpretation is equivalent to the direct elasticity presented in equation (6) but it has to be multiplied by 100 to represent a 100% change (from 1 to 0, or 0 to 1).

In the survey, respondents were asked to answer several attitudinal questions that referred to their concern about using public transport (PT), their attitude towards working from home (WFH), their concern about health, among others. The first step was to use the Kaiser-Meyer-Olkim (KMO) test to measure sampling adequacy (Kaiser & Rice, 1974) and the Bartlett's Test of Sphericity (Bartlett, 1951) – both of which suggested that a factor analysis may be useful with our data. Parallel analysis is used to identify the number of factors to be used, which is used to compare the size of the eigenvalues with those identified by a set of data of the same size generated randomly (Horn, 1965). The attitudinal questions that refer to work from home are only valid for those respondents that are currently employed, so a separate analysis was performed for these questions for workers only. The parallel analysis results suggested that 5 factors should be considered for all the sample, and 1 for workers in relation to the WFH attitudinal questions. Having defined how many factors should be retained, the method of extraction used was maximum log-likelihood with oblique rotation. This method was used over restricting the factor to be orthogonal because attitudes are rarely statistically independent. The six factors extracted were the following:

1. WFH lovers: positive attitude towards WFH, which is only appropriate for workers.
2. Authorities and community's response supporters: respondents that believe the authorities and community response towards the pandemic has been appropriate.
3. Social meeting lovers: respondents that feel comfortable having social meetings with friends, visiting restaurants and pubs, gyms and exercise groups, among others.
4. All meeting lovers: respondents that feel comfortable having any type of meeting, including music events, watching live entertainment, among others,
5. Concerned about health: respondents that are concerned about theirs and others health and general COVID-19 implications.
6. Concerned about public transport: people that are concerned about hygiene and the number of people in public transport due to COVID-19.

The attitudinal questions defining each factor and their weights are presented in Tables 8 to 13 in the Appendix. The first factor representing WFH lover that is related to workers only, is described by questions describing how productive they feel working from home, if they have everything they need (appropriate space, equipment, etc.), if they are able to balance their personal life with their work, if they would like to have more flexibility in their work times in the future, among others. The higher weights in the second factor, related to support towards the authorities and community's response to the crisis, refer to the response of other people to COVID-19 (if they have been appropriately self-distancing, self-isolating, etc.), and if the response of the wider community and government has been appropriate.

The third and fourth factors refer to how comfortable respondents feel with meeting. The third factor refers to people that mainly feel comfortable meeting with friends, visiting restaurants and going to shops (represented by the highest weights), referred to as social meeting lovers. The fourth factor refers to people that mainly feel comfortable going to music events or watching professional sports, which represent larger events, referred to as all meeting lovers. Even though these factors might seem similar, the parallel analysis and extraction method suggest that they should be considered separately, suggesting they represent different respondent's profile. This suggest that people that feel comfortable meeting their friends do not necessarily feel comfortable going to massive events such as music concerts, and vice-versa.

The fifth factor refers to health concern and is defined by how a person thinks about COVID-19 as a serious public health concern which requires drastic measures to be taken. The last factor relates to a concern about the use of public transport (PT), defined by the concern about hygiene and the number of people using PT.

5 Model Results

5.1 Models for Workers in Metropolitan Areas

The model results for workers in metropolitan areas are presented in Table 2. It is important to mention that the commuting model was only estimated for those respondents that worked outside the home for at least one day (e.g., commuted) as their behaviour is significantly different from those that never commuted, so it is not appropriate to model them together. The parameter estimates suggest that different sociodemographic characteristics explain commuting and non-commuting travel behaviour for metropolitan workers. For example, income has a positive influence on social recreation trips for all regions. The number of children in a household has a negative influence on work-related trips, but a positive influence on education and shopping trips for all regions. Results show that the proportion of days WFH has a negative influence on commuting and work-related trips, as expected, but a positive influence on the number of shopping trips. As people work more days from home, they also tend to increase their shopping weekly trips in metropolitan areas.

The factor related to the social meetings loving attitude suggests that people that feel comfortable going to social meetings tend to do more shopping, personal business and social/recreation trips, but less education trips. This may be in part due to ease with education can be undertaken online in contrast to the other trip purposes where face to face interaction is more important. Respondents that feel comfortable going to all meetings (including massive gatherings), tend to do more work-related, shopping and social/recreation trips but less commuting trips, possibly because it is easier to WFH in contrast undertaking the other purposes in the home. The interaction between commuting by car and being concerned about health had a positive influence on commuting trips and social/recreation trips, suggesting that those that are concerned about health and used the car to commute tend to do more of these trips relative to those that do not use the car to commute or are less concerned about health. Respondents concerned about the use of public transport tend to do less social/recreation trips.

Clearly, what we have is evidence of a significant amount of preference heterogeneity in trip making behaviour linked to socioeconomic characteristics and attitudinal positions. The ability to link particular trip making across all trip purposes as commuting activity changes due to the growing incidence of WFH, enables planners to gain a richer picture of the quantum of trips on the roads and on public transport.

5.2 Models for Workers in Regional Areas

The results for regional area worker models are presented in Table 3. Income has a positive influence on the number of commuting and work-related trips for both states, and a negative influence on personal business trips in QLD. The number of children has a negative influence on the amount of commuting and a positive influence on the number of education trips. The proportion of days WFH has a negative influence on the number of commuting and work-related trips, and a positive influence on the number of social/recreation trips. The interaction term between WFH lovers and the proportion of days WFH has a negative influence on social/recreation trips. That is, respondents that WFH more often tend to do more social/recreation trips, but if they are WFH lovers they tend to do less trips than those that do not enjoy WFH as much.

Table 2: Model estimates for respondents currently employed (workers) located in metropolitan areas – mean (t value)

Metropolitan workers	Commute	Work-related	Education	Shopping	Personal business	Social/ recreation
Constant	2.401 (17.98)	0.168 (0.53)	-0.728 (1.56)	1.366 (15.92)	-0.132 (0.43)	0.658 (6.67)
Age (years)	-0.009 (3.08)		-0.041 (3.85)		-0.013 (1.94)*	
Gender female (0,1)		-0.602 (2.46)	0.400 (1.62)*			
Personal income ('000AUD$)						0.002 (2.38)
Number of children in household		-0.216 (2.08)	0.534 (4.45)	0.075 (2.88)		
At least one child in primary school (0,1)			1.344 (4.21)			
Number of cars per adult in household	0.113 (2.16)	0.671 (3.57)	0.532 (3.18)		0.230 (1.90)*	
Distance from home to office (kms)	-0.002 (1.39)*	0.006 (1.81)*	-0.013 (1.91)*	-0.003 (2.35)		
Proportion of days WFH	**-0.986 (6.06)**	**-0.766 (2.67)**		0.127 (1.47)*		
Occupation clerical and administration (0,1)		-0.407 (1.34)*				
Used car to go to work last week (0,1)	-0.338 (3.70)	-0.533 (1.97)		-0.133 (1.60)*	0.325 (1.61)*	
Work located in CBD area (0,1)				0.149 (1.61)*		
Brisbane (0,1)						-0.258 (1.98)
Factor analysis: social meetings			-0.162 (1.65)*	0.129 (3.58)	0.202 (2.68)	0.361 (6.32)
Factor analysis: all meetings	-0.050 (1.64)*	0.192 (2.05)		0.095 (2.86)		0.172 (3.27)
Factor analysis: public transport concerned						-0.153 (2.78)
Interaction between factor concerned about health and use of car to go to work last week[5]	0.069 (1.55)*					0.106 (1.56)*
Dispersion parameter	2.114 (10.16)	0.148 (8.39)	0.201 (7.50)	1.956 (10.87)	0.281 (8.55)	0.818 (10.70)
Restricted log-likelihood	***-1,677.13***	***-1,252.83***	***-1,430.93***	***-938.71***	***-1,051.40***	***-1,669.38***
Log-likelihood at convergence	**-1,303.78**	**-656.24**	**-606.46**	**-1,530.34**	**-753.93**	**-1,243.48**
AIC/n	**5.60**	**2.13**	**1.96**	**4.91**	**2.42**	**3.99**
Sample size	***469***	***627***	***627***	***627***	***627***	***627***

Note: The commuting model only considers those individuals that commute sometimes. Respondents that never commuted (i.e., worked from home every day) had a different behaviour, so could not be modelled together.

Note: All parameters are statistically significant with a 95% confidence level, except those identified with a * that are statistically significant with an 83% confidence level. They were kept in the model since they represent important variables that are likely playing an important role in decision-making.

Table 3: Model estimates for respondents currently employed (workers) located in the regional area – mean (t value)

Regional workers	Commute	Work-related	Education	Shopping	Personal business	Social/ recreation
Constant	1.932 (13.21)	0.160 (0.38)	-0.663 (1.36)	1.492 (9.04)	0.821 (2.13)	1.136 (6.84)
Age (years)	-0.008 (2.83)		-0.022 (2.18)			
Gender female (0,1)		-0.779 (2.21)	0.845 (3.02)	0.141 (1.48)*		
Personal income ('000AUD$)	0.004 (3.82)	0.006 (1.71)*				
Personal income in QLD State ('000AUD$)					-0.004 (1.60)*	
Number of children in household	-0.051 (1.95)*		0.709 (6.50)			
At least one child in primary school (0,1)			0.549 (1.52)*			
Number of cars per adult in household						-0.156 (1.59)*
Distance from home to office (kms)			-0.010 (1.59)*			-0.004 (1.38)*
Proportion of days WFH	**-0.908 (3.64)**	**-1.414 (2.41)**				**1.749 (1.90)***
Industry category retail (0,1)		-1.144 (2.39)				
Used car to go to work last week (0,1)					-0.689 (1.73)*	
Used car to go to work last week in QLD State (0,1)	0.169 (1.98)					
Prior to COVID-19 used car to go to work (0,1)				-0.261 (1.58)*		
Factor analysis: authorities and community response in QLD State	0.110 (2.22)					
Factor analysis: authorities and community response in NSW State	-0.109 (1.72)*					
Factor analysis: social meetings		0.265 (2.04)		0.061 (1.79)*	0.143 (1.67)*	0.169 (2.93)
Factor analysis: all meetings in NSW State	-0.090 (1.93)*					
Factor analysis: concerned about health	-0.341 (2.29)					0.108 (1.74)*
Factor analysis: concerned about health in QLD State		0.269 (1.59)*				
Interaction between factor WFH lover and proportion of days WFH						-1.699 (2.33)
Dispersion parameter	4.598 (5.96)	0.162 (6.04)	0.324 (6.20)	2.967 (6.65)	0.373 (6.37)	0.841 (7.79)
Restricted log-likelihood	***-897.41***	***-672.33***	***-861.89***	***-818.60***	***-577.74***	***-860.37***
Log-likelihood at convergence	***-776.01***	***-346.62***	***-417.27***	***-739.84***	***-425.95***	***-638.42***
AIC/n	***5.51***	***2.28***	***2.73***	***4.79***	***2.77***	***4.16***
Sample size	***286****	***311***	***311***	***311***	***311***	***311***

Note: The commuting model only considers those individuals that commute sometimes. Respondents that never commuted (i.e., worked from home every day) had a different behaviour, so could not be modelled together.

Note: All parameters are statistically significant with a 95% confidence level, except those identified with a * that are statistically significant with an 83% confidence level. They were kept in the model since they represent important variables that are likely playing an important role in decision-making.

The factor results suggest that people that have greater support for the government and wider community's response to COVID-19 in QLD tend to do more commuting trips while in NSW fewer commuting trips. People that feel comfortable going to social meetings tend to do more work-related, shopping, personal business, and social/recreation trips; while people that feel comfortable going to all meetings (including massive gatherings) tend to do fewer commuting trips and more social/recreation trips in both states. Respondents that are more concerned about their health tend to do more work-related trips in QLD area. Again, like metropolitan evidence, there exists a significant amount of heterogeneity in the influencing variables across the trip purposes, with this evidence being important in identifying patterns of trip making behaviour for particular origin-destination pairs during the COVID-19 period as WFH levels change in part linked to reduced levels of commuting. However, unlike metropolitan areas, commuting levels have not declined much at all, with WFH not having a statistically significant influence for three of the six trip purposes.

5.3 Models Non-workers Metropolitan Areas

The model results for non- workers in metropolitan areas are summarised in Table 4. The results show that, for example, income has a positive influence for social/recreation trips. Age has a negative effect on the number of education, shopping and personal business trips. The factors' results suggest that people who feel comfortable going to social meetings tend to undertake more education, shopping and social/recreation trips, while people that feel comfortable going to larger gatherings (all meetings) tend to do more shopping trips. Individuals that are concerned about the bio-security associated with public transport tend to do less shopping, personal business and social/recreation trips.

Table 4: Model estimates for respondents not currently employed (non-workers) located in metropolitan areas – mean (t value)

Metropolitan non-workers	Education	Shopping	Personal business	Social/ recreation
Constant	2.457 (2.84)	2.081 (8.27)	0.167 (0.28)	0.445 (2.26)
Age (years)	-0.054 (4.28)	-0.009 (2.89)	-0.016 (1.77)*	
Gender female (0,1)	-1.305 (2.97)	-0.200 (1.78)*		
Personal income ('000AUD$)				0.005 (1.68)*
Number of children in household	0.702 (4.58)	0.158 (3.69)	-0.306 (1.94)*	-0.139 (1.57)*
Number of cars per adult in household			0.883 (3.31)	0.392 (2.48)
Located in the state of NSW (0,1)		-0.177 (1.63)		
Factor analysis: social meetings	0.598 (3.29)	0.241 (4.24)		0.292 (3.56)
Factor analysis: all meetings		0.108 (1.94)*		
Factor analysis: public transport concerned		-0.121 (2.38)	-0.280 (2.07)	-0.208 (2.52)
Dispersion parameter	0.156 (4.41)	2.320 (6.71)	0.210 (5.90)	0.565 (7.57)
Restricted log-likelihood	***-621.49***	***-800.52***	***-555.45***	***-854.00***
Log-likelihood at convergence	***-216.34***	***-646.65***	***-316.14***	***-539.19***
AIC/n	***1.65***	***4.87***	***2.40***	***4.06***
Sample size	***269***	***269***	***269***	***269***

Note: All parameters are statistically significant with a 95% confidence level, except those identified with a * that are statistically significant with an 85% confidence level. They were kept in the model since they represent important variables that are likely playing an important role in decision-making.

5.4 Models Non-workers Regional Areas

The model results for non-workers in regional areas are presented in Table 5. The results show that, income has a positive effect on social/recreation trips. Age has a positive influence on the number of personal business trips. The factors' results show that people in QLD that support authorities and community's response to COVID-19 tend to do fewer education trips. People that feel comfortable going to larger gatherings (all meetings) tend to have a lower number of shopping and personal business trips.

Table 5: Model estimates for respondents not currently employed (non-workers) located in the regional area – mean (t value)

Regional non-workers	Education	Shopping	Personal business	Social/ recreation
Constant	-4.963 (4.54)	1.423 (8.47)	-2.305 (2.90)	0.888 (2.76)
Age (years)			0.027 (2.11)	
Gender female (0,1)	1.620 (1.50)*	0.299 (1.99)		
Personal income ('000AUD$)				0.010 (2.04)
Number of children in household	1.419 (6.57)			
Located in the state of NSW (0,1)		-0.392 (2.41)		-0.697 (2.13)
Factor analysis: authorities and community response in QLD State	-1.745 (3.85)			
Factor analysis: all meetings		-0.095 (1.70)*	-0.409 (2.51)	
Dispersion parameter	0.202 (3.30)	2.177 (5.21)	0.261 (3.53)	0.422 (5.34)
Restricted log-likelihood	***-277.95***	***-410.42***	***-192.23***	***-408.70***
Log-likelihood at convergence	***-90.36***	***-337.63***	***-135.34***	***-260.30***
AIC/n	***1.35***	***4.86***	***1.98***	***3.75***
Sample size	***141***	***141***	***141***	***141***

Note: All parameters are statistically significant with a 95% confidence level, except those identified with a * that are statistically significant with an 85% confidence level. They were kept in the model since they represent important variables that are likely playing an important role in decision-making.

5.5 Elasticities

We have calculated the point and arc direct elasticities for, which represent the relationship between the expected frequency of the number of weekly one-way trips and the statistically significant influences, as an informative way of identifying the sensitivity of trip frequency to levels of each explanatory variable. All elasticities are relatively inelastic. Table 6 presents the elasticities for workers in metropolitan areas and regional areas, while Table 7 presents the elasticities for non-workers in metropolitan areas and regional areas.

The elasticity of age in the commuting trips model is of -0.346 in metropolitan areas and -0.315 in regional areas, which indicates, *ceteris paribus*, that a person 10% older is (e.g., 24 years old relative to 20 years old) undertakes 3.5% fewer one-way weekly commuting trips in metropolitan areas and 3.2% fewer in regional areas. Given that elasticities are unitless and hence directly comparable, we can see that the elasticities associated with age create the greatest behavioural change across three trip purposes with a number of relatively high elasticities for some variables in some trip purpose models. Age has a significantly higher influence on non-workers education and personal trips. A person who is 10% older is likely to do 16.3% less education trips if he/she is a metropolitan area worker; 8.6% if he/she is regional area worker; and 31.5% if he/she is a non-worker in a metropolitan area compared to someone 10% younger. This provides evidence that older people not currently employed are significantly less likely to undertake education trips than those currently employed, particularly if they live in metropolitan areas.

Similarly, a person who is 10% older than someone else is likely to undertake 5.2% less personal business trips if he/she is a metropolitan area worker; 9.6% less if he/she is a non-worker in a metropolitan area; and 15.5% more personal business trips if he/she is a non-worker in regional areas. This suggests that older respondents not currently employed tend to undertake more personal business trips in regional areas, relative to younger respondents. This relationship is opposite in regional and metropolitan area workers and metropolitan area non-workers, where older respondents tend to do less personal business trips than younger respondents.

Table 6: Elasticities for the models of workers

		Commute	Work-related	Education	Shopping	Personal business	Social/ recreation
Metropolitan	Age (years)	-0.346		-1.631		-0.522	
	Gender female (0,1)		-0.292	0.197			
	Personal income ('000AUD$)						0.186
	Number of children in household		-0.240	0.592	0.084		
	At least one child in primary school (0,1)			0.586			
	Number of cars per adult in household	0.133	0.765	0.606		0.262	
	Distance from home to office (kms)	-0.034	0.119	-0.259	-0.068		
	Proportion of days WFH	-0.132	-0.270		0.045		
	Occupation clerical and administration (0,1)		-0.201				
	Used car to go to work last week (0,1)	-0.169	-0.261		-0.066	0.161	-0.005
	Work located in CBD area (0,1)				0.075		
	Brisbane (0,1)						-0.128
Regional	Age (years)	-0.315		-0.860			
	Gender female (0,1)		-0.371	0.399	0.071		
	Personal income ('000AUD$)	0.228	0.409			-0.182	
	Number of children in household	-0.060		0.840			
	At least one child in primary school (0,1)			0.268			
	Number of cars per adult in household						-0.222
	Distance from home to office (kms)			-0.191			-0.076
	Proportion of days WFH	-0.056	-0.194				-0.042
	Industry category retail (0,1)		-0.517				
	Used car to go to work last week (0,1)	0.082					
	Prior to COVID-19 used car to go to work (0,1)				-0.130		
	Located in the state of NSW (0,1)	0.007					

Table 7: Elasticities for the models of non-workers

	Metropolitan non-workers	Education	Shopping	Personal business	Social/recreation
Metropolitan	Age (years)	-3.146	-0.553	-0.963	
	Gender female (0,1)	-0.573	-0.100		
	Personal income ('000AUD$)				0.161
	Number of children in household	0.524	0.118	-0.228	-0.104
	Number of cars per adult in household			0.829	0.368
	Located in the state of NSW (0,1)		-0.088		
Regional	Age (years)			1.547	
	Gender female (0,1)	0.670	0.149		
	Personal income ('000AUD$)				0.332
	Number of children in household	1.278			
	Located in the state of NSW (0,1)		-0.193		-0.335

The number of cars per adult in the household has a significant impact on commuting and non-commuting travel behaviour, particularly for workers in metropolitan areas. A metropolitan area worker that lives in a household with two cars per adult compared to one car per adult (a 100% increase) tends to do, on average, 13.3% more commuting trips, 76.5% more work-related trips, 60.6% more education trips, and 26.2% more personal business trips. These results suggest that an increase in the number of cars is related to more non-commuting trips, and slightly more commuting trips, for workers in metropolitan areas. In regional areas, a worker in a household with two cars per adult compared to one car tends to do 22.2% less social/recreation trips. The elasticities for the dummy variables should be interpreted slightly different. In the case of gender, the results show that women (dummy equal to 1) who are metropolitan workers on average, undertake 29.2% less work-related trips than men; and 19.7% more education trips. In regional areas, women who work tend to have 37.1% less work-related trips than men; 39.9% more education trips; and 7.1% more shopping trips. Women not currently employed in metropolitan areas, on average, undertake 57.3% less education trips than men; and 10.0% less shopping trips. In regional areas, women not currently employed tend, on average, to undertake 67% more education trips than men, and 14.9% more shopping trips. These results reveal gender differences across the different areas and employment status, mainly related to a significantly higher number of education trips except for metropolitan non-workers; and a significantly lower number of work-related trips. In addition to the elasticities, the behavioural sensitivity of the number of one-way weekly trips will be analysed in the next section using simulated scenarios for each country.

6 Simulations

Different scenarios were simulated that represent the behavioural sensitivity of the number of one-way weekly trips by purpose due to variations in the proportion of days WFH, distance from home to work and age. These explanatory variables did not have a statistically significant impact on all trips purposes' models, so only the statistically significant relationships will be analysed below. Figure 3 presents the simulation results for changes in the proportion of days WFH on the weekly one-way trips made by workers in metropolitan and regional areas. In both locations, the number of commuting trips decrease as the proportion of days WFH increases, as expected. Work-related trips also decrease but at a slower rate when the proportion of days WFH increase. In metropolitan areas, the number of shopping trips increases as the proportion of days WFH increases. In regional areas, there is a significant increase in the number of social/recreation trips as the proportion of days WFH increase. What these findings suggest is that there is an identified increase in shopping trip activity when WFH increases and its associated reduction in commuting in metropolitan areas, and in regional contexts social/recreation trips are impacted by the WFH increase.

The distance from home to work simulation results, presented in Figure 4, suggest that people that work further from where they live in metropolitan areas, tend to do less commuting, shopping and education trips, but more work-related trips. It is important to note that the average number of commuting and shopping weekly trips is significantly higher than the education and work-related trips. In regional areas, people that work further from where they live tend to do less social/recreation and education trips. These results show the impact of a respondents' quantum of commuting trips on their non-commuting travel behaviour, suggesting that metropolitan area workers that have a longer commuting trips usually do less of these trips, but also less shopping and education trips, and slightly more work-related trips. Workers in regional areas that have longer commuting trips tend to undertake less social/recreation and education trips.

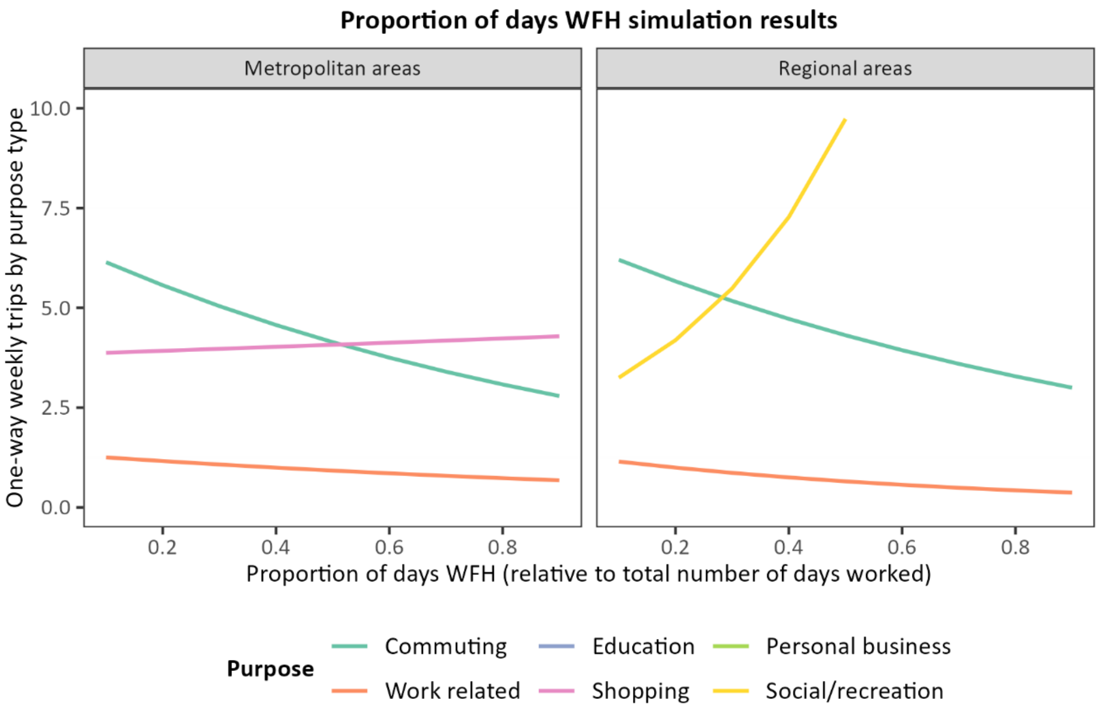

Figure 3: Proportion of days WFH simulation results

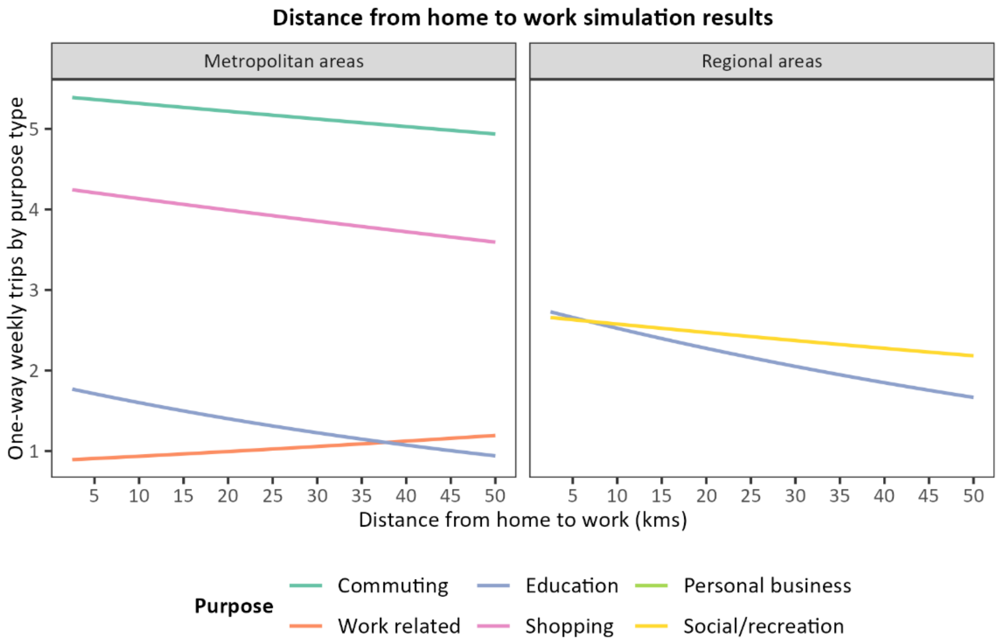

Figure 4: Distance from home to work simulation results

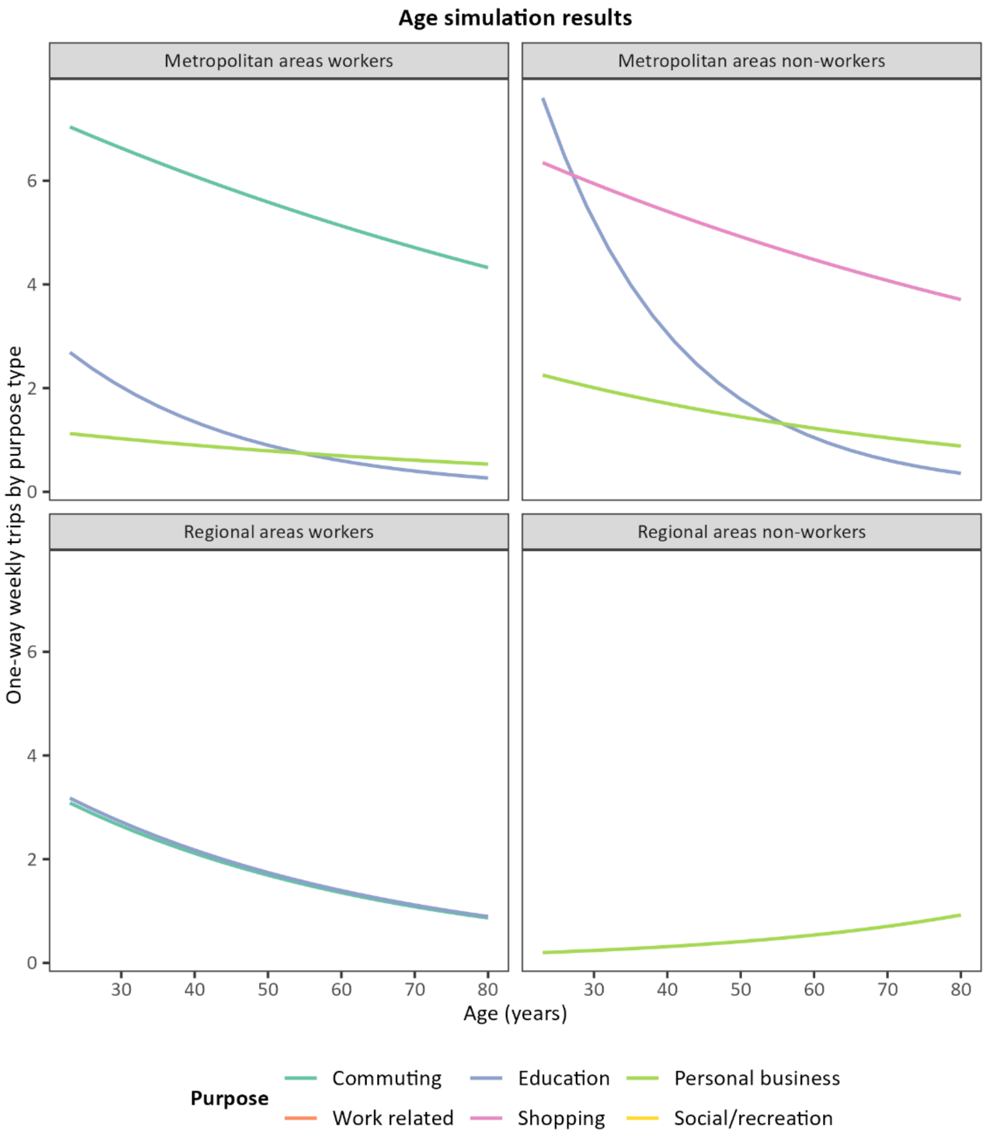

Figure 5: Age simulation results

Age simulation results are presented in Figure 5 and show that in metropolitan and regional areas, workers tend have fewer commuting trips as they age. These results should be interpreted in the light of the pandemic, as COVID-19 presents a higher health risk for older people, which is likely to affect their travel behaviour. For both workers and non-workers in metropolitan and workers in regional areas, older people tend to do less education trips – but the rate of decrease is higher for non-workers in metropolitan areas. Personal business trips seem to decrease as people get older, except for non-workers in regional areas, which increase significantly as people age. The number of shopping trips tend to decrease for older non-workers in metropolitan areas, whereas it is not significant in regional areas, nor for workers in metropolitan areas.

7 Conclusions

This study's focus is to understand the impact of COVID-19 on commuting and non-commuting travel behaviour. The impact of COVID-19 is measured through the proportion of days WFH, which has increased significantly, especially in metropolitan areas, as a result of this health crisis, and through respondents' perceptions and attitudes towards COVID-19. This data in this study includes respondents from metropolitan and regional areas in two states in Australia, QLD and NSW, and includes workers and non-workers. A separate model is estimated for different trip purposes: commuting, work-related, education/childcare, shopping, personal business and social/recreation.

To include the underlying attitudes towards COVID-19, factor analysis was used, and six factors were extracted that represent WFH loving attitude, support towards authorities and wider community response, social meeting lovers, all meeting lovers (including massive gatherings), health concerned, and public transport concerned. These factors were included as explanatory variables in negative binomial regression models, along with respondents' socioeconomic characteristics, other characteristics related to their work (e.g., distance from home to work) and location variables. The results suggest that attitudes towards COVID-19 have a significant influence on commuting and non-commuting travel activity. In metropolitan areas, people that WFH more often are less likely to undertake commuting trips, but if they love WFH to some extent then they are more likely to have commuting trips than individuals who do not love WFH. Workers that are concerned about the use of public transport due to COVID-19 are less likely to do work-related and social/recreation trips in metropolitan areas, and non-workers who are concerned are less likely to do shopping, personal business or social/recreation trips in metropolitan areas. In arriving at these findings, we have to recognise the real possibility that additional constraints that are not under the control of an individual may be at play such as less work for work-related travel and fewer people asking someone to visit them.

The results show that the proportion of days WFH has a significant impact on travel behaviour. As expected, it produces a reduction in the number of commuting and work-related trips in metropolitan and regional areas. Moreover, it generates an increase in shopping trips in metropolitan areas, and an increase in social/recreation trips in regional areas. These findings suggest that with an increase in WFH, there is an increase in non-commuting travel activity – which might have an influence particularly in local areas, since it is likely that people will stay around their neighbourhoods for much of this non-commuting travel activity. One limitation of this study is that there may be built environment factors that influence the behaviour of respondents in significant ways. Such perceptions/evaluations of amenity were not collected in the survey on which this study is based, and it would be interesting to compare these findings with future research including these variables. Moreover, future research could focus on estimating number of trips by purpose in a single model identifying the relationship between all of them and not only related to the proportion of WFH using, for example, a multiple discrete continuous extreme value model (MDCEV).

The findings in this study can be used as a guideline as to the impact of COVID-19 on weekly travel behaviour for commuting and non-commuting trips and to suggest changes to be made to strategic transport models where trip frequency by purpose and location is relevant. The impact of COVID-19 is measured both in terms of the proportion of days worked from home instead of the office, but also in terms of the attitudes and perceptions of COVID-19 in daily life. These measures affect workers and non-workers and people more generally in metropolitan and regional areas. The long-term impacts of COVID-19 are yet to be seen – and in the long-term it would be interesting to revisit and compare these models - but it is expected that working from home will prevail where possible, as it has proven to have advantages in terms of time-use, productivity and life balance. It could be argued that if increased rates of WFH remain - which seems likely – it could result in increased movement in local areas. This would mean that we would need to rethink infrastructure provision in those areas (e.g., footpaths, road quality, traffic management, traffic calming, active transport amenity) with a more localised focus. In addition, this local infrastructure is typically only funded by local governments, which may struggle for funding, so the financial arrangements will also need consideration. Health concerns might also have a long-term effect, even after we have overcome this pandemic or learnt to live with it in a fully vaccinated setting. This study suggests that WFH, health concerns and general attitudes towards COVID-19 play an important role in all-purpose mobility trips and not just commuting activity.

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Appendix Paper

Table 8: Survey questions associated with the factor WFH lovers

Survey question	Weight
How productive do you think you have been in the last week[5] whilst working from home?*	0.94
I have appropriate space to work from home**	0.97
I am able to find a balance between paid work and unpaid work (e.g. housework, yardwork, childcare)**	0.97
I am able to find a balance between time spent on work and time spent not working**	0.96
I have everything I need to be able to work from home successfully**	0.97
I still require equipment / technology to be able to complete work from home as well as I would like**	0.83
Working from home has been a positive experience for me**	0.98
I would like to work from home more often in the future**	0.96
I would like to have more flexible starting and finishing times in the future**	0.95
I would commute at less busy times in the future if I could**	0.94

*Scale: A lot less productive (1), A little less productive (2), About the same (3), A little more productive (4), A lot more productive (5)
**Scale: Strongly disagree (1), Disagree (2), Somewhat disagree (3), Neither agree nor disagree (4), Somewhat agree (5), Agree (6), Strongly agree (7)

Table 9: Survey questions associated with the factor authorities and community's response supporters

Survey question	Weight
The Federal government response to Covid-19 has been appropriate	0.60
The State government response to Covid-19 has been appropriate	0.49
The response of business to Covid-19 has been appropriate	0.59
The response of the wider community to Covid-19 has been appropriate	0.72
People have been appropriately social distancing as a measure to combat Covid-19	0.78
People have been appropriately self-isolating as a measure to combat Covid-19	0.78
I trust governments to respond to Covid-19 in the future	0.67
I trust business to respond to Covid-19 in the future	0.72
I trust other people to respond to Covid-19 in the future	0.79

Scale: Strongly disagree (1), Disagree (2), Somewhat disagree (3), Neither agree nor disagree (4), Somewhat agree (5), Agree (6), Strongly agree (7)

Table 10: Survey questions associated with the factor social meeting lovers

Survey question	Weight
If someone asked you to each of the following, how comfortable would you feel about undertaking these day-to-day activities at the moment?	
Meeting with friends	0.86
Visiting restaurants	0.81
Going to the shops	0.79
Going to the movies	0.49
Going to pubs or bars	0.50
Gyms and exercise groups	0.38

Doctor's appointments	0.54
Schooling and/or childcare	0.40
Attending work functions	0.46

Scale: Very uncomfortable (1), Uncomfortable (2), Somewhat uncomfortable (3), Neither (4), Somewhat comfortable (5), Comfortable (6), Very comfortable (7)

Table 11: Survey questions associated with the factor all meeting lovers

Survey question	Weight
If someone asked you to each of the following, how comfortable would you feel about undertaking these day-to-day activities at the moment?	
Going to the movies	0.41
Going to pubs or bars	0.42
Gyms and exercise groups	0.46
Watching professional sport	0.73
Music events	0.94
Watching live entertainment	0.95
Schooling and/or childcare	0.36
Playing organised sport	0.54
Attending work functions	0.44

Scale: Very uncomfortable (1), Uncomfortable (2), Somewhat uncomfortable (3), Neither (4), Somewhat comfortable (5), Comfortable (6), Very comfortable (7)

Table 12: Survey questions associated with the factor concerned about health

Survey question	Weight
Covid-19 will affect the way people travel*	0.39
The Federal government response to Covid-19 has been appropriate*	0.39
Covid-19 is a serious public health concern*	0.81
Combatting Covid-19 requires drastic measures to be taken*	0.83
On a scale of 1 (extremely low risk) to 10 (extremely high risk) how much of a threat do you think Covid-19 is to the following?	
My health**	0.42
The health of someone I know**	0.50
The health of the general public**	0.57
The health of the economy**	0.31

*Scale: Strongly disagree (1), Disagree (2), Somewhat disagree (3), Neither agree nor disagree (4), Somewhat agree (5), Agree (6), Strongly agree (7)
**Scale from 1 (extremely low risk) to 10 (extremely high risk)

Table 13: Survey questions associated with the factor concerned about PT

Survey question	Weight
Imagine you had to catch public transport tomorrow, what would be your level of concern about hygiene be?	0.94
Imagine you had to catch public transport tomorrow, what would be your level of concern about the number of people using public transport?	0.93

Scale: Not at all concerned (1), Slightly concerned (2), Somewhat concerned (3), Moderately concerned (4), Extremely concerned (5)

Appendix T. Paper #16: Characterizing public transport shifting to active and private modes in Brazil during the COVID-19 pandemic

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Abstract

The COVID-19 pandemic has produced a significant reduction in the number of trips by public transport worldwide. In this paper, we study the pandemic's impact on travel behaviour in four major cities of Brazil: São Paulo, Rio de Janeiro, Belo Horizonte and Porto Alegre. We analyze the shift in public transport use towards private and active transport due to pandemic impacts - assuming a comparative advantage in the shift to active transport. We conducted surveys in these cities considering elements of modal perception and activity patterns regarding the change from public transport to other modes. We used a SEM-MIMIC model to analyse and understand the information obtained in this study, allowing us to estimate people shifting choices for all cities. We found that comfort with leisure activities and increased subjective well-being positively influenced shifting to active modes, while community's response perceptions influenced shifting to private modes. This paper provides a novel understanding for the modal shift in these Brazilian cities due to the COVID-19 pandemic and gives relevant information on the variables that determine changes at the regional level.

Keywords: Coronavirus; COVID-19; Public transport; Modal shift; Perception; Brazil

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1 Introduction and background

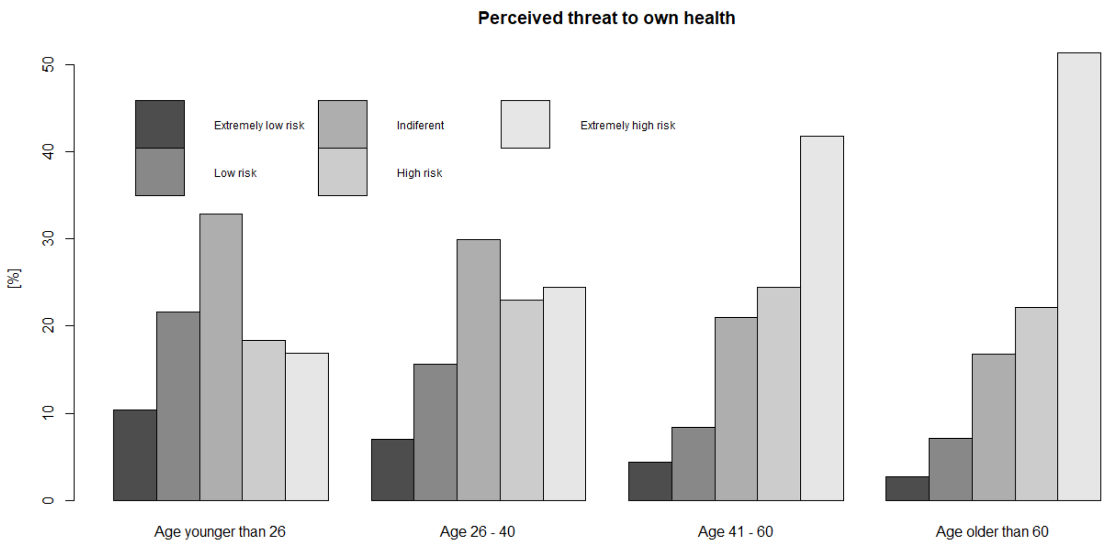
The impact of COVID-19 on travel behaviour has been analyzed during the pandemic in various contexts (Abdullah et al., 2020; Beck and Hensher 2020; Cartenì et al., 2021; Neuburger & Egger, 2020; Tirachini & Cats, 2020; Wen et al., 2021) through studies that have updated the impacts of the global health crisis. Although the effects on the use of public transport after the pandemic are still unknown, the necessary social distancing associated with mitigating the risk of contagion, has resulted in an important reduction in the use of public transport (De Vos, 2020). This fall in ridership could lead to an increase in trips by modes that allow avoiding close contact with other people, such as private vehicles and bicycles.

However, changes to these two modes may have quite different impacts. The relationship between the benefits and costs of car versus bicycle use has been studied (Ogilvie et al., 2004). It is also well documented how car use contributes to air pollution, risks and damages associated with road safety. On the contrary, cycling not only generates few negative externalities for others but also improves physical activity (Zapata-Diomedi et al., 2017), well-being (Larouche et al., 2020; Singleton, 2019), and people’s mental health (Wild & Woodward, 2019).

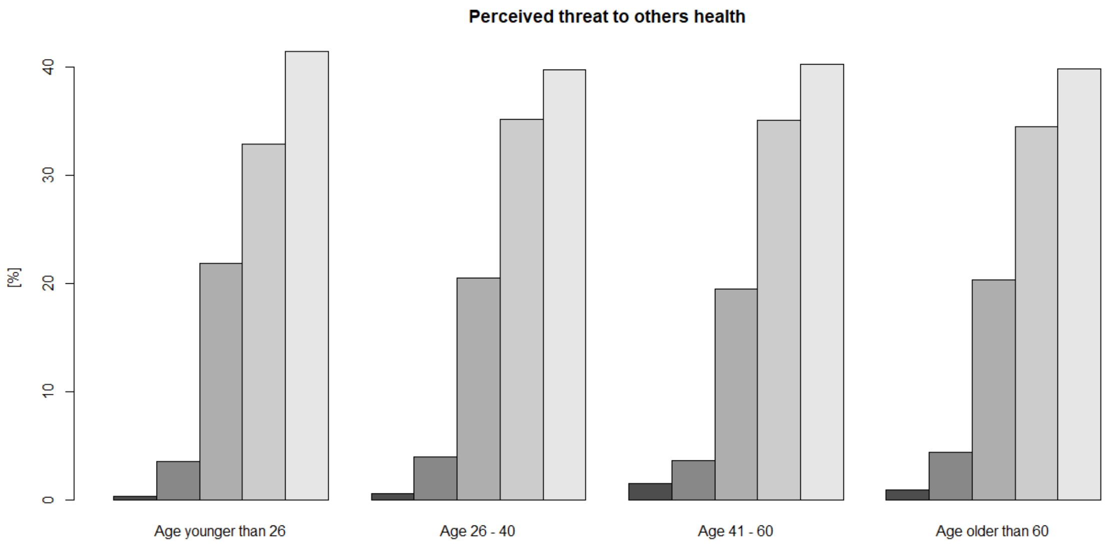
This study adds to previous research developed for different Latin American cities (Vallejo-Borda et al., 2021). Among the reasons for focusing on Brazil are the socio-demographics as the most populated and extended country of the region, and the particular stance taken by its federal and local governments to deal with the health crisis (Werneck & Carvalho, 2020).

In this paper, we analyze the modal change in four of the major cities in Brazil, one of the most controversial Latin American countries due to the high number of cases and the type of institutional measures used to face the pandemic. According to the World Health Organization (2021), in March 2021, Brazil was the second country worldwide in terms of total confirmed cases and deaths, after the United States, with over 1,300 confirmed deaths per million inhabitants. Although this mortality rate is in the World top 30, it is comparable to that of other countries in South America, such as Argentina, Colombia or Chile.

The four major Brazilian cities studied, include two megacities (São Paulo and Rio de Janeiro) and two large state capitals (Porto Alegre and Belo Horizonte). We examined in detail the public transport shifting to active and private modes during the pandemic. From the collected data, it was possible to identify the perceived threat level to people’s health. As presented in Figure 1(a), when we asked about their own health, the perceived threat depends on age. However, as shown in Figure 1(b), when asking about other people’s health, the perceived risk is similar among all ages.



(a)



(b)

Figure 1. Perceived threat to (a) own health and (b) other people health

The first case of COVID-19 in Brazil was diagnosed on February 25th, 2020. From that moment, and like other countries in the region, the municipal and federal governments adopted a series of measures to prevent the spread of this virus. According to official reports, the circulation of people, both in Sao Paulo and Rio de Janeiro, decreased by 75%-80% during March 2020, partially recovering to 50% of pre-pandemic mobility in April 2020 (Siciliano et al., 2020). The recommendations for social distancing and reduced activities have decreased, even though the number of cases have been increasing. As of March 2021, the country had reached a peak of new infections, reporting more than 80,000 daily cases on average (Johns Hopkins University, 2021). Furthermore, several Brazilian cities have reduced their public transport fleet, which has worsened the agglomeration and capacity constraints on public transport, making it harder to secure social distancing. Even though this measure has an economic root, decreasing the frequency of buses increases the risk of contagion (Rede de Pesquisa Solidária, 2020).

Recent studies (Boisjoly et al., 2017; Pereira, 2019) have shown that Sao Paulo and Rio de Janeiro have dominating central locations in terms of accessibility to closer destinations. This geographical disposition means a high probability of generating and exporting cases to other neighboring geographic regions, such as the South-East and South regions of Brazil, where Belo Horizonte and Porto Alegre are located (Coelho et al., 2020).

Table 1 provides basic information about the impact of COVID-19 for the cities and states where they are located. Except for Belo Horizonte, all cities belong to states that have a higher death rate than the national average.

Table 1. Main information about COVID-19 for selected cities/states, data from April 2021

State / *City*	**State population (A)**	**Confirmed cases**	**Confirmed deaths (B)**	**Death rate / 100,000**	**State death rate / Country death rate**
Rio de Janeiro	17,366,189	737,844 (B)	43,965 (B)	253.2	1.33
Rio de Janeiro		258,038 (C)	23,710 (C)		
São Paulo	46,289,333	2,888,158 (B)	95,532 (B)	206.4	1.08
São Paulo		1,043,263 (D)	27,194 (D)		
Rio Grande do Sul	11,422,973	966,895 (B)	24,753 (B)	216.7	1.14
Porto Alegre		141,246 (E)	4,333 (E)		
Minas Gerais	21,292,666	1,351,739 (B)	33,401 (B)	156.9	0.82
Belo Horizonte		176,029 (F)	4,295 (F)		

Data sources:

A Instituto Brasileiro de Geografia e Estatistica (IBGE). https://www.ibge.gov.br/cidades-e-estados. Data retrieved on April 30th, 2021.

B Coronavirus Brasil. https://COVID.saude.gov.br/. Data retrieved on April 30th, 2021.

C Painel Rio COVID 19. https://experience.arcgis.com/experience/38efc69787a346959c931568bd9e2cc4. Data retrieved on April 30th, 2021.

D Cidade de Sao Paulo. Boletim Diário COVID-19 N°399. https://www.prefeitura.sp.gov.br/cidade/secretarias/upload/saude/20210429_boletim_COVID19_diario.pdf. Data retrieved on April 30th, 2021.

E Prefeitura de Porto Alegre. Transparência COVID-19, Painel Saúde. https://infografico-COVID.procempa.com.br/ Data retrieved on April 30th, 2021.

F Prefeitura de Belo Horizonte, Secretaría Municipal de Saúde. Boletim Epidemiológico e Assistencial N°258/2021. https://prefeitura.pbh.gov.br/sites/default/files/estrutura-de-governo/saude/2021/boletim_epidemiologico_assistencial_258_COVID-19_29-04-2021.pdf. Data retrieved on April 30th, 2021.

Given that Brazil has a federal government structure, not only the national government but also state and municipal authorities may introduce regulations to mitigate the impact of COVID-19. In this context, state and local governments implemented different measures to contain the spread of the virus. In the states under study, the measures included: school and university suspensions as of March 2020, general quarantines in the states of Rio Grande do Sul and São Paulo, and quarantines for risk groups in Rio de Janeiro and Minas Gerais (Santos de Silva et al., 2020).

Table 2 presents the main transport-related measures adopted by state and local authorities to mitigate the virus's impact in the cities analyzed.

Table 2. Transport-related measures in selected cities

City	Rio de Janeiro	São Paulo	Porto Alegre	Belo Horizonte
Public transport				
Mandatory face masks in public transport	x (from May 6, 2020)	x (from May 4, 2020)	x (from May 11, 2020)	x (from May 23, 2020)
Suspension of discount fares for students	x (March, 2020)	x (March, 2020)	x (March, 2020)	
Closure of BRT lines or stations	x (from March to June 2020)			x (April 2020)
Reinforced bus service to/from hospitals		x	x	x
Restriction on cash payment			x	
Crowding restriction	2 pax/ m2 (set in June, 2020)	Seated-only (set in June, 2020)	Maximum # of standing passengers (modified in October 2020)	Maximum # of standing passengers (set in May 2020)
Other modes				
Temporary lanes for non-motorised transport				x
Driver's license expiration extension	x	x	x	x
Temporary lift of on-street parking fares ("zona azul")	(no "zona azul")	around health facilities (from March to December 2020)		around health facilities (from March 2020)
On-street parking prohibitions			x (July-August, 2020, except parking around hospitals, "zona azul" only)	
Temporary lift of car use restrictions	(no previous restrictions)	x (from March to May 2020)	(no previous restrictions)	(no previous restrictions)

Data Sources:

Sao Paulo:
https://www.prefeitura.sp.gov.br/cidade/secretarias/transportes/servicos/index.php?p=295489
https://jornalbicicleta.com.br/2020/07/15/sao-paulo-nao-tera-ciclovias-emergenciais-mas-belo-horizonte-ja-tem/
https://www.saopaulo.sp.gov.br/spnoticias/renovacao-da-cnh-pode-ser-feita-pelos-canais-digitais-do-poupatempo/
https://g1.globo.com/sp/sao-paulo/noticia/2020/06/05/prefeitura-de-sp-determina-que-onibus-circulem-apenas-com-capacidade-maxima-de-passageiros-sentados.ghtml
Rio de Janeiro:
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Porto Alegre:
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https://saude-admin.rs.gov.br/upload/arquivos/202005/12091118-55-240.pdf
https://www.detran.rs.gov.br/cnhs-vencidas-na-pandemia-deverao-ser-renovadas-ao-longo-de-2021
https://mobilidadeportoalegre.com.br/prefeitura-de-porto-alegre-publica-decreto-com-novas-restricoes-de-circulacao-na-cidade/
https://diariodotransporte.com.br/2020/10/05/porto-alegre-altera-limite-de-lotacao-dos-onibus-a-partir-desta-segunda-5/
Belo Horizonte:
https://prefeitura.pbh.gov.br/noticias/novas-ciclofaixas-criam-alternativa-de-mobilidade-na-capital-durante-pandemia

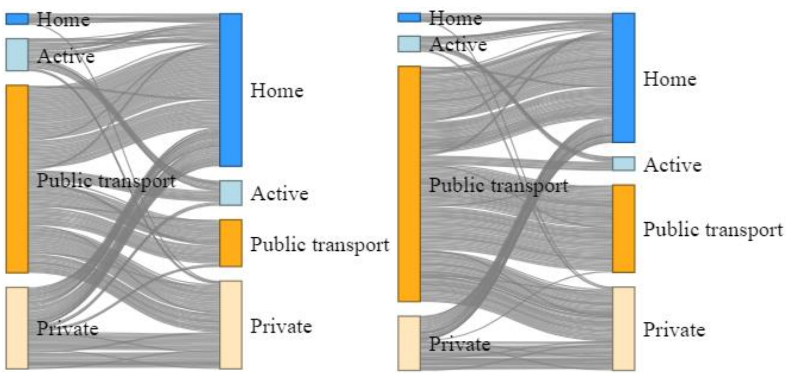
https://www.detran.mg.gov.br/sobre-o-detran/sala-de-imprensa/noticias/pcmg-restabelece-prazos-para-servicos-de-cnh-infracoes-e-veiculos
https://diariodotransporte.com.br/2020/04/10/prefeitura-de-belo-horizonte-suspende-tres-linhas-do-move-a-partir-de-segunda-13/

As a consequence of the pandemic, public transport usage has fallen sharply in the main cities of Brazil. That said, frequencies of buses and trains were also diminished, which generates agglomeration through crowding that increases the risk of contagion (Rede de Pesquisa Solidária, 2020). Note that public transport ridership in Brazil was already decreasing before the pandemic, with a reduction of 50% between 1994 and 2017 (Borges Xavier, 2020).

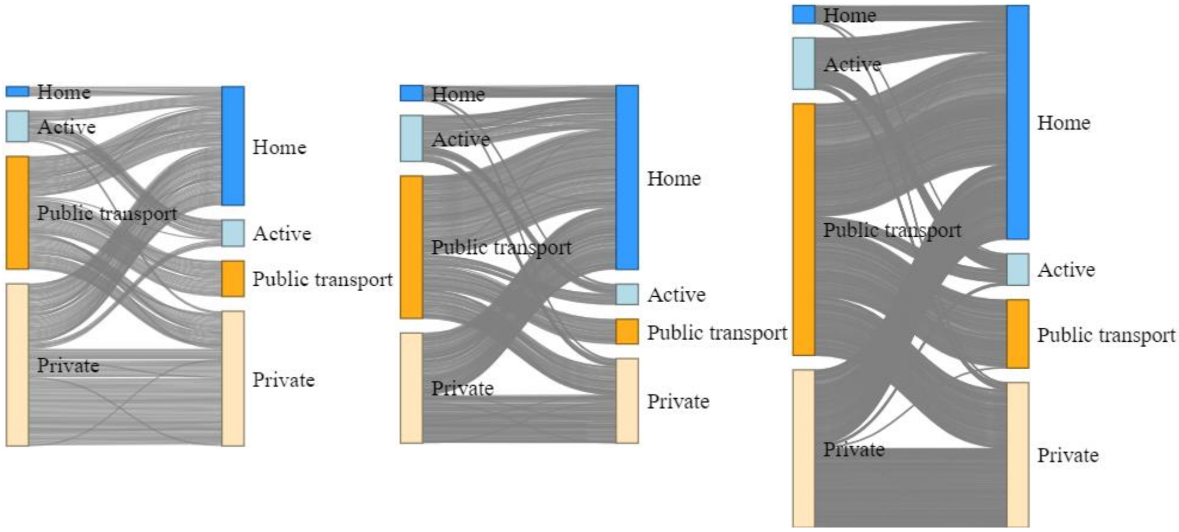
There is still no evidence about modal changes due to the effects of COVID-19 in Brazilian cities. However, international experience has shown that there has been a tendency to migrate towards private modes and active modes of transport due to the pandemic (Aloi et al., 2020; Bucsky, 2020; Meena, 2020; Beck and Hensher 2020). On the other hand, international experience has supported the use of active transport, particularly the bicycle, since it avoids the risk of contagion (Gutiérrez et al., 2020; Tirachini & Cats, 2020). Moreover, bicycle trips have other benefits, such as mental health, energy-saving, social and cultural (Arellana et al., 2020a;, 2020b; Deenihan & Caulfield, 2014; Götschi et al., 2016; Oja et al., 2011). However, in other contexts, the wide car availability and the fear of using public transport for hygiene and self-care measures, have increased car use as cities have come out of lockdown stages (Beck et al., 2020).

The Sankey diagrams in Figure 2 were developed using the R package “networkD3” (Allaire et al., 2017; R Core Team, 2020) from the surveys carried out in this study. In addition, we corrected the collected samples using gender and age variables for each city, using the “survey” package in R (Lumley, 2020; R Core Team, 2020).

As mentioned in recent studies (Aloi et al., 2020; Beck & Hensher, 2020; Bucsky, 2020), the negative impact on the use of public transport is also evident in the four Brazilian cities considered in this study. As shown in Figure 2, the vast majority of trips made by public transport shifted to other options in every city during the health crisis. About a third of trips tended to disappear in all cities due to the reduction of commuting trips, telecommuting and or staying at home. The case of Belo Horizonte reflects this last trend the most, since staying at home replaced almost half of the public transport trips. On the other hand, Sao Paulo and Rio de Janeiro presented the lowest reductions on public transport usage among the Brazilian cities studied.



(a) (b)



(c) (d) (e)

Figure 2. Modal shifting for (a) São Paulo, (b) Rio de Janeiro, (c) Belo Horizonte, (d) Porto Alegre, and (e) all cities

The scope of our work is to understand the travel behaviour motivations that led Brazilians to shift their trips from public transport to active modes and private-motorised vehicles during the COVID-19 crisis. By estimating Structural Equation - Multiple Indicator Multiple Cause (SEM-MIMIC) models, we sought to identify the types of users willing to change from public transport to individual modes such as cars, motorcycles and bicycles, as well as the attitudes towards risk perception, subjective wellness, and perception of government actions that may influence this behaviour.

This paper is the second that considers the surveys conducted between September 10th and November 10th, 2020, during the pandemic and particularly in Brazilian cities (cite ref). As the health crisis was still occurring, several short-term impacts have been addressed here. The collection of new data in the following months is always of interest to the authors, allowing the comparative study of the factors explored in this article with the new findings.

Our main contributions respond to the need for understanding the factors that contribute to a modal shift from public transport and towards private and active modes as a consequence of the pandemic. On the other hand, the study compares four Brazilian cities (two large and two medium-sized), all located along the country's southern coast—all receiving different federal authorities' responses regarding the health crisis and variations in their citizens' behaviour.

The rest of the paper is organized as follows. First, the methodology section provides the data collection details from the surveys in the four cities. Then, the results section shows the factors that affect mode shift from public transport to private and active modes, both directly and through latent variables. Finally, the study concludes with a discussion and conclusions regarding the research and general future research guidelines.

2 Methodology

2.1 Model development support

The COVID-19 outbreak impacted people's lives and how they used to interact with others (Blasco-Belled et al., 2020; Möhring et al., 2020). To understand shifting decisions from public transport modes to other modes, it is advisable not only to incorporate a classic explanation of these decisions by using attributes such as travel time, cost, and income level, but also to include subjective elements (e.g., perceptions). SEM-MIMIC models are able to include in a same model the classic objectively measured attributes and people's perceptions, through the use of latent variables, to explain individual choices (Vallejo-Bordaet al., 2020).

Latent variables refer to attributes that cannot be directly estimated but can be identified from questions that capture different people's perceptions. To capture people's perception about the public entities' response to COVID-19, it is crucial to consider the public entities' decisions limiting people displacements (Güner et al., 2020) and managing, in terms of communication and coordination, health capacity and contagious rates (Benítez et al., 2020). Perceptions about community response has also been essential during the COVID-19 outbreak, considering the different measures (e.g., face masks use) that individuals should follow (Güner et al., 2020; Marston et al., 2020).

The changes experienced by people during the COVID-19 outbreak resulted in an impact on personal subjective well-being (Blasco-Belled et al., 2020; Möhring et al., 2020). Nowadays, subjective well-being is used as an element to explain travel behaviour, and a thorough review of this concept can be found on Kahneman & Krueger (2006) and Dolan & White (2007), and more recently in Stanley et al (2021). Well-being in transport can be defined as the cognitive and affective evaluations of life that can capture the benefits of travel improvements (Ettema et al., 2011). Well-being in transport is commonly determined through a travel satisfaction survey (Bergstad et al., 2011), but there are other dimensions to approach the concept. For example, people using active transport modes have been reported higher rates of physical and mental health (Humphreys et al., 2013; Martin et al., 2014), happiness (Kroesen & De Vos, 2020), overall hedonic well-being (Singleton, 2019), satisfaction (Ettema et al., 2011; Olsson et al., 2013), and sociability (Wang & He, 2015). For this study, we are interested in capturing people's perceptions about the Brazilian federal government actions and the community response to COVID-19, about their comfort to perform leisure and life-related activities during the COVID-19 outbreak, and about their subjective well-being.

2.2 Data collection

The questionnaire used for this research is based on the work developed by Beck & Hensher (2020) and Beck et al. (2020). The questionnaire includes an initial section about travel activity and mode choices in both a typical week before and during the COVID-19 outbreak. Respondents are then asked about their employment, including the ability to work from home and their role at work. They are then asked about the potential impacts of COVID-19 in their lives, including questions related to ordinary activities changes (e.g., go shopping). Then, all respondents working from home are asked about that experience. Then, respondents are asked attitudinal questions and about perceptions of government, businesses, and people in general, to face the COVID-19 outbreak. Finally, respondents are asked to provide their socio-demographic information.

The original questionnaire was translated into Portuguese and contextualized for the four Brazilian cities (Rio de Janeiro, São Paulo, Porto Alegre and Belo Horizonte). After data cleaning, we finally obtained 1,518 valid surveys for this study (Rio de Janeiro 360; São Paulo 357; Porto Alegre 424; Belo Horizonte 377). The surveys were conducted between September 10th and November 10th, 2020; each survey lasted approximately 22 min with a completion rate of 50%. Table 3 shows a summary of the final sample.

Table 3. Basic socio-demographic data

City / indicator	Rio de Janeiro	São Paulo	Porto Alegre	Belo Horizonte	All cities
Gender identity					
Women	47.9%	59.6%	63.3%	55.3%	56.8%
Men	52.1%	40.4%	36.7%	44.7%	43.2%
Age					

First quartile	25.0	26.0	26.8	31.0	27.0
Median	32.0	33.0	34.0	42.0	34.0
Mean	35.4	35.7	37.0	42.1	37.6
Third quartile	43.0	44.0	45.0	53.0	47.0

In this paper, mode choice before and during the COVID-19 outbreak is explained through perception questions, respondent's socio-demographic information and indicators for time and cost savings. Table 4 presents the questions used to capture people's perceptions about the Brazilian federal government and the community response to COVID-19, their comfort to perform leisure and life-related activities during COVID-19 outbreak, and their subjective well-being. Then, Table 5 presents the objectively measured information collected in the survey.

Table 4. List of indicators and corresponding questions

Indicator	Question (possible answers)
Leisure activities comfort	
Going to pubs	How comfortable would you feel about completing these activities at the moment? (Very uncomfortable, Uncomfortable, Neither, Comfortable, Very comfortable)
Going to the movies	
Eating in restaurants	
Watching live entertainment	
Going to school	
Working out in the gym	
Playing sports	
Doctor's appointments	
Federal government response	
Appropriate federal government response	How much you agree or disagree with the following statements (totally disagree, disagree, neither disagree nor agree, agree, totally agree)
The federal government COVID-19 strategy was adequate	
I trust in the nation to affront COVID-19	
Community actions	
Adequate social distance	People have been appropriately social distancing as a measure to combat COVID-19 (totally disagree, disagree, neither disagree nor agree, agree, totally agree)
Adequate self-isolation	People have been appropriately self-isolating as a measure to combat COVID-19 (totally disagree, disagree, neither disagree nor agree, agree, totally agree)
Appropriate community response	The response of the wider community to COVID-19 has been appropriate (totally disagree, disagree, neither disagree nor agree, agree, totally agree)
Life-related activities comfort	
Meeting with friends	How comfortable would you feel about completing these activities at the moment? (Very uncomfortable, Uncomfortable, Neither, Comfortable, Very comfortable)
Meeting with relatives	
Attending work functions	
Subjective well-being	
Life is worth it	To what extent do you feel the things you do in your life are worthwhile? (not at all worth it, not worth it, indifferent, worth it, completely worth it)
Happiness	How happy did you feel yesterday? (completely unhappy, unhappy, neither unhappy nor happy, happy, completely happy)
Life satisfaction	How satisfied are you with your life nowadays? (totally dissatisfied, dissatisfied, neither dissatisfied nor satisfied, satisfied, totally satisfied)

Table 5. Objectively measured attributes

Variable	Options/unit
Gender identity	Woman, man
Age	[years]
Occupation	Employer, employee, self-employed, unemployed, student, retired, homemaker
Marital status	Single, living together (married, domestic partnership), union dissolved (divorced, separated), widowed
Household income level	<R$2090.00; R$2090.01 - R$3135.00; R$3135.01 - R$5225.00; R$5225.01 - R$6270.00; R$6270.01 - R$8360.00; R$8360.01 - R$10450.00; R$10450.01 - R$15675.00; R$15675.01 - R$20900.00; R$20900.01 - R$31350.00; >R$31350.00
Number of children at home	[number]
Travel duration prior to COVID-19	[minutes]
Travel duration during COVID-19	
Travel cost prior COVID-19	[Brazilian real, R$]
Travel cost during COVID-19	

2.3 Modelling approach

We aimed to explain mode shifting from public transport modes (e.g., BRT) to active (e.g., walk, bicycle) and private modes (e.g., car, motorcycle) using people's perceptions and their socio-demographic information. The dependent variables were obtained by comparing the respondent's mode choices in a typical week before COVID-19 with a week during the COVID-19 outbreak. In the cases that respondents' mode choice was public transportation in a typical week before the COVID-19 outbreak and mode choice was active or private during COVID-19, we assigned a value of 1 for the corresponding model; in other cases, we assigned a value of 0.

With the subjective information presented in Table 4, we developed an exploratory factor analysis (EFA) using a PROMAX oblique rotation method, allowing correlations between latent variables (Hair et al., 2014). The groupings presented in Table 4 were used as hypothetical latent variables. The EFA results helped us confirm the number through a screen test, keeping only the latent variables with eigenvalues greater than 1 (Vallejo-Borda et al., 2020). Besides, we calculated the Cronbach's alpha to measure the indicators' internal consistency for each latent variable, obtaining satisfactory results (i.e., higher than 0.6 for exploratory research, Hair et al., 2014); the results are presented in Table 6.

Table 6. Cronbach's alpha for hypothetical latent variables

Latent variable	Cronbach's alpha
Leisure activities comfort	0.82
Federal government response	0.84
Community actions	0.72
Life-related activities comfort	0.68
Subjective well-being	0.77

Using the hypothesised latent variables, we specified a SEM-MIMIC model (a generic structure is presented in Figure 3) considering the latent variables direct effects over the dependent variables and keeping only those with a 90% significant relation (i.e., absolute t-statistic values higher than 1.64). The objectively measured attributes (see Table 5) were used to define the dependent variable and the latent variables with a significant relationship over the dependent variable keeping only the significant relationships (i.e., absolute z-statistic values higher than 1.64).

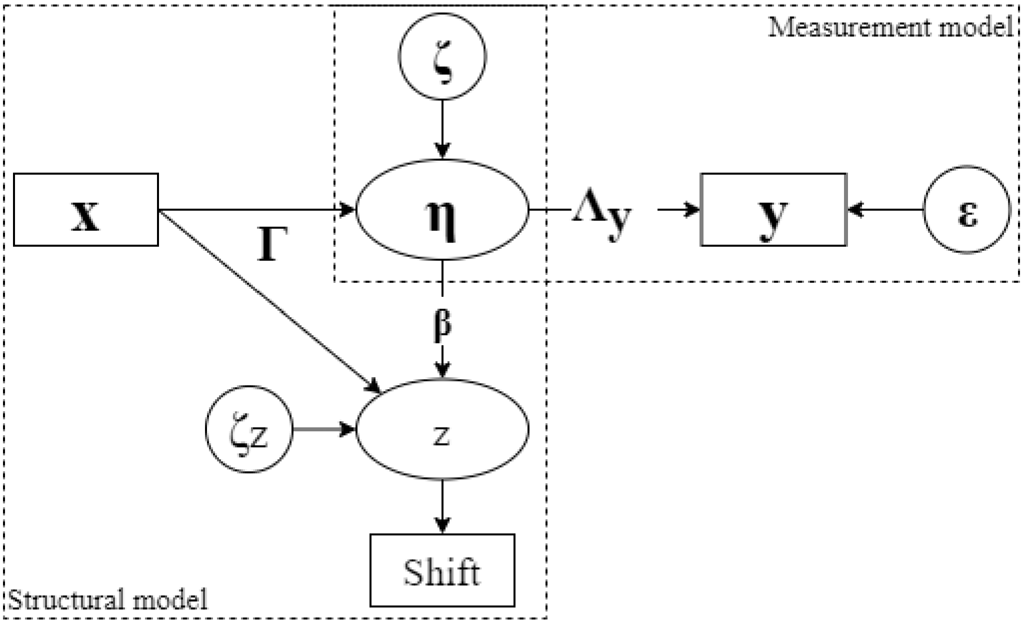


Figure 3. Generic SEM-MIMIC model

SEM-MIMIC models are composed of latent variables (η), indicators (**y**), and objectively measured attributes (**x**). The SEM-MIMIC structure has measurement equations (1) and the structural equations (2):

$$\boldsymbol{y} = \boldsymbol{\Lambda_y \eta} + \boldsymbol{\varepsilon} \tag{1}$$

$$\boldsymbol{\eta} = \boldsymbol{\Gamma x} + \boldsymbol{\zeta} \tag{2}$$

where:

y: vector of indicators used to identify each latent variable (i.e., the subjective information presented in Table 4).

$\boldsymbol{\Lambda_y}$: vector of coefficients indicating the change in the value of the indicators if there is a one-unit change in the latent variable (i.e., indicators weight).

$\boldsymbol{\eta}$: vector of latent variables.

$\boldsymbol{\varepsilon}$: error vector, associated with each indicator (assumed as normally distributed with an expected value of 0 and variance of 1).

$\boldsymbol{\Gamma}$: row vector of structural parameters indicating the change in the value of the latent variable if there is a one-unit change in the objectively measured attribute.

x: column vector of objectively measured attributes.

$\boldsymbol{\zeta}$: error vector associated with each latent variable (assumed as normally distributed with an expected value of 0 and variance of 1).

To estimate the model that explains the decision to shift from public transportation modes to active and private modes, we used the function “sem” of the R package “lavaan” (R Core Team, 2020; Rosseel, 2012). The shifting decision was defined as a binary variable (1 = shift, 0 = no shift), and we used diagonally weighted least squares to estimate the model parameters. To forecast the shifting decision, we calculated an unobserved variable z using (3) and compared the z value with the estimated threshold for each model.

$$z = \boldsymbol{\beta\eta} + \boldsymbol{\Gamma x} + \zeta_z \quad (3)$$

where:

$\boldsymbol{\beta}$: vector of parameters indicating the change in the value of z if there is a one-unit change in the latent variable

ζ_z: error associated with z (assumed as normally distributed with an expected value of 0 and variance of 1).

All the relationships assumed for the SEM-MIMIC model are considered simultaneously, and the entire model fit is evaluated using the goodness of fit indicators presented in Table 7 (Bollen, 2014; Hoyle, 2012).

Table 7. Goodness of fit indicators for the SEM-MIMIC model

Indicator	Explanation	Accepted threshold
$\frac{\chi^2}{DF}$	Measures the discrepancy between the sample and model covariance matrices corrected for degrees of freedom.	< 3.000
RMSEA	Determines the model fit to the covariance matrix of the sample with unknown coefficients.	< 0.060
SRMR	Calculates the square root of the difference between the sample and the hypothesised model covariance matrices' residuals.	< 0.080
CFI	Compares the proposed model with a non-correlated model between latent variables.	> 0.950

3 Results

The measurement model comprises the following five latent variables (in italics) explained by 20 indicators measured through the online survey in each city. The coefficients and significance associated with the relationship between the latent variables and indicators are presented in Table 8, and each latent variable is described below:

- *Leisure activities comfort* was the latent variable identified by the largest number of indicators: going to pubs, going to the movies, eating in restaurants, watching live entertainment, going to school, working out in the gym, playing sports, and doctor's appointment.

- *Federal government response* (related with how people perceived the government response to the outbreak) was identified from three indicators: appropriate federal government response, federal government COVID-19 strategy was adequate, and I have trust in the nation to face COVID-19.

- *Community actions* (as perceived by the respondent) was identified from three indicators: adequate social distance, adequate self-isolation, and appropriate community response.

- *Life-related activities comfort* was identified from three indicators: meeting with friends, meeting with relatives, and attending work functions.

- *Subjective well-being* was identified from three indicators: life is worth it, happiness, and life satisfaction.

Table 8. Parameters of the measurement model

Indicator	Estimate	Standard error	z value	p-value
Leisure activities comfort				
Going to pubs	1.000	na	na	na
Going to the movies	0.982	0.019	51.092	0.000
Eating in restaurants	0.908	0.017	52.274	0.000
Watching live entertainment	0.920	0.021	44.407	0.000
Going to school	0.828	0.018	45.069	0.000
Working out in the gym	0.824	0.021	39.841	0.000
Playing sports	0.698	0.022	31.660	0.000
Doctor's appointments	0.647	0.023	28.028	0.000
Federal government response				
Appropriate federal government response	1.000	na	na	na
The federal government COVID-19 strategy was adequate	0.951	0.016	58.754	0.000
I trust in the nation to affront COVID-19	0.723	0.018	40.141	0.000
Community actions				
Adequate social distance	1.000	na	na	na
Adequate self-isolation	0.813	0.034	23.796	0.000
Appropriate community response	0.556	0.028	19.739	0.000
Life-related activities comfort				
Meeting with friends	1.000	na	na	na
Meeting with relatives	0.861	0.047	18.465	0.000
Attending work functions	0.563	0.034	16.773	0.000
Subjective well-being				
Life is worth it	1.000	na	na	na
Happiness	0.983	0.026	37.490	0.000
Life satisfaction	0.911	0.028	32.347	0.000

na = not applicable

Following the procedure presented above, we estimated the SEM-MIMIC model to explain shifting from public transport to active modes during the COVID-19 pandemic. We found four latent variables and 12 objectively measured attributes explaining this decision. Figure 4 presents the structural model, and Table 9 shows the estimated coefficients for the significant relationships. The objectively measured attributes impacting the mode shifting decision directly are presented in bold.

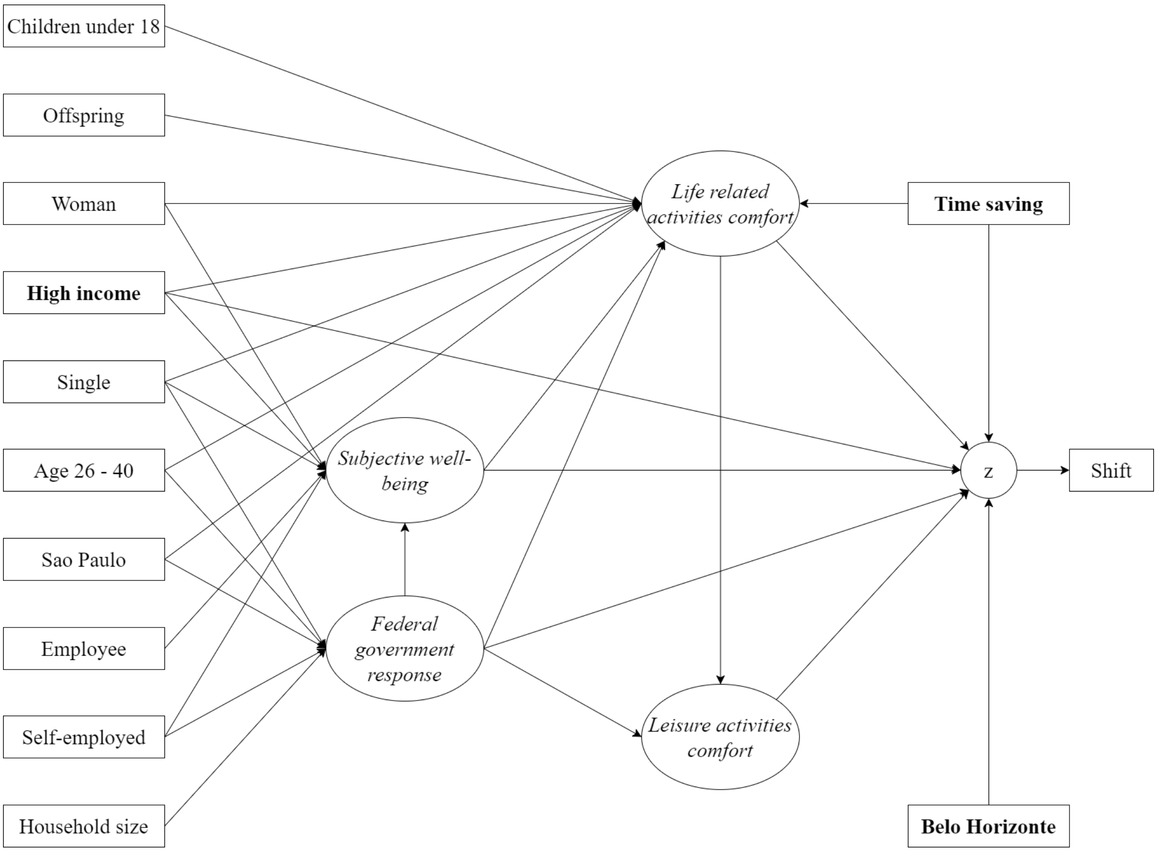


Figure 4. Public transport to active mode SEM-MIMIC model

Table 9. Parameters of the public transport to active mode structural model

Attribute	Estimate	Standard error	t value	p-value
Public transport to active mode				
0 | 1	1.595	0.373	4.274	0.000
Belo Horizonte	-0.909	0.475	-1.913	0.056
Time saving	-9.14×10^{-3}	3.87×10^{-3}	-2.363	0.018
High income	-0.505	0.268	-1.889	0.059
Leisure activities comfort	0.506	0.250	2.026	0.043
Life related activities comfort	-0.469	0.234	-2.003	0.045
Subjective well-being	0.306	0.106	2.871	0.004
Federal government response	-0.311	0.120	-2.582	0.010
Leisure activities comfort				
Life related activities comfort	0.815	0.027	29.753	0.000
Federal government response	0.161	0.023	6.977	0.000
Life-related activities comfort				
São Paulo	0.131	0.064	2.041	0.041
Time saving	-3.71×10^{-3}	8.30×10^{-4}	-4.475	0.000
Woman	-0.283	0.055	-5.178	0.000
Age 26 - 40	0.189	0.054	3.501	0.000
Single	0.201	0.062	3.225	0.001
High income	0.185	0.058	3.176	0.001
Offspring	-0.324	0.111	-2.911	0.004
Children under 18	0.335	0.111	3.030	0.002
Subjective well-being	0.087	0.035	2.450	0.014
Federal government response	0.340	0.028	12.049	0.000
Subjective well-being				
Woman	0.099	0.047	2.111	0.035
Single	-0.233	0.056	-4.148	0.000
Employee	0.230	0.056	4.075	0.000

Self-employed	0.253	0.078	3.257	0.001
High income	0.237	0.050	4.713	0.000
Federal government response	0.138	0.026	5.244	0.000
Federal government response				
São Paulo	-0.252	0.077	-3.251	0.001
Age 26 - 40	-0.393	0.065	-6.052	0.000
Single	-0.322	0.071	-4.558	0.000
Self-employed	-0.280	0.117	-2.400	0.016
Household size	0.050	0.022	2.316	0.021

Table 9 considers the direct effects over the choice and latent variables. However, there are indirect effects of the attributes that may affect the choice. In Table 10 the indirect and total effects of all attributes over the choice are shown, but considering only the significant attributes in Table 9.

Table 10. Direct, indirect and total effects of the public transport to active mode shift

Attribute	Direct	Indirect	Total
São Paulo	na	0.045	0.045
Belo Horizonte	-0.909	na	-0.909
Time saving	-9.14×10^{-3}	2.12×10^{-4}	-8.93×10^{-3}
Woman	na	0.046	0.046
Age 26 - 40	na	0.071	0.071
Single	na	-0.015	-0.015
Employee	na	0.069	0.069
Self-employed	na	0.134	0.134
High income	-0.505	0.061	-0.445
Household size	na	-0.010	-0.010
Offspring	na	0.018	0.018
Children under 18	na	-0.019	-0.019
Leisure activities comfort	0.506	na	0.506
Life related activities comfort	-0.469	0.412	-0.057
Subjective well-being	0.306	-0.005	0.301
Federal government response	-0.311	0.104	-0.207

na = not applicable

Similarly, we also estimated a SEM-MIMIC model to explain shifting from public transport to private modes during the COVID-19 pandemic. We found one latent variable and eight objectively measured attributes explaining this decision. Figure 5 presents the structural model, and Table 11 shows the estimated coefficients for the proposed relationships. The objectively measured attributes impacting the mode shifting decision directly are presented in bold, and the dotted lines represent the non-significant relationships.

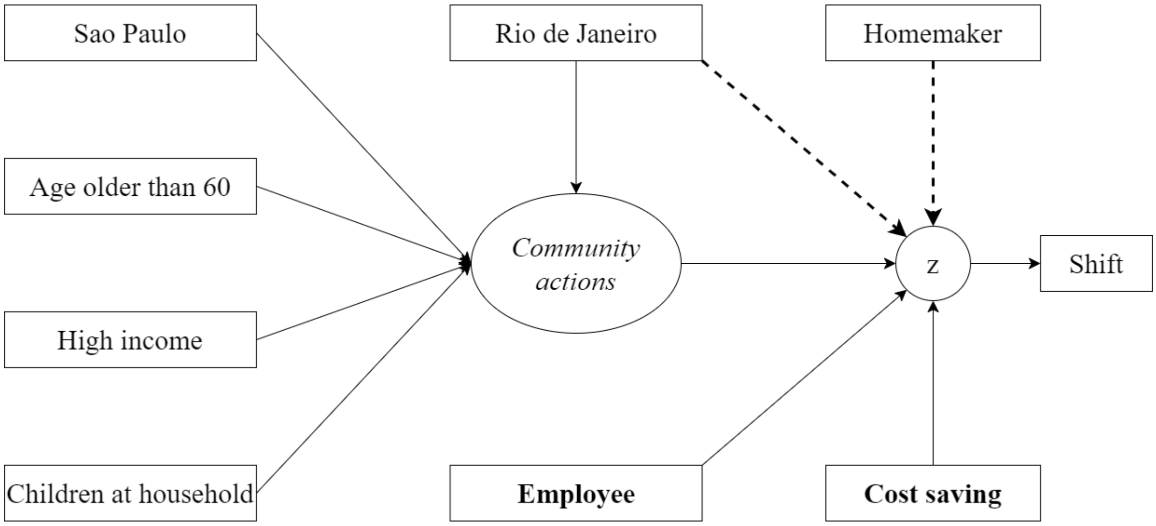


Figure 5. Public transport to private mode MIMIC model

Table 11. Parameters of the public transport to private mode structural model

Attribute	Estimate	Standard error	t value	p-value
Public transport to private mode				
0 | 1	1.665	0.116	14.353	0.000
Rio de Janeiro	0.187	0.121	1.547	0.122
Cost saving	-1.00×10^{-2}	7.03×10^{-4}	-14.244	0.000
Employee	0.506	0.111	4.576	0.000
Homemaker	1.307	0.820	1.594	0.111
Community actions	0.100	0.059	1.684	0.092
Community actions				
Rio de Janeiro	-0.274	0.065	-4.207	0.000
São Paulo	-0.176	0.068	-2.606	0.009
Age older than 60	0.361	0.106	3.399	0.001
High income	0.250	0.055	4.555	0.000
Children at household	0.145	0.041	3.545	0.000

Table 11 considers the direct effects over both community actions and choice. However, there are indirect effects of the attributes that may affect the choice. In Table 12 we present the indirect and total effects of all attributes over the choice but considering only the significant attributes in Table 11.

Table 12. Direct, indirect and total effects of the public transport to private mode shift

Attribute	Direct	Indirect	Total
Rio de Janeiro	na	-0.027	-0.027
São Paulo	na	-0.018	-0.018
Cost saving	-1.00×10^{-2}	na	-1.00x10-2
Age older than 60	na	0.036	0.036
Employee	0.506	na	0.506
High income	na	0.025	0.025
Children at household	na	0.014	0.014
Community actions	0.100	na	0.100

na = not applicable

Because of their satisfactory adjustment, no modifications were made to the resulting structural models in each case (see Table 13).

Table 13. Goodness of fit indicators of the final MIMIC models

	Accepted threshold (Table)	Shift to active	Shift to private
$\frac{\chi^2}{DF}$	< 3.000	2.297	1.558
RMSEA	< 0.060	0.029	0.019
SRMR	< 0.080	0.048	0.017
CFI	> 0.950	0.992	0.996

4 Discussion and Analysis

We have addressed the shifting decision from public transport to private and active modes by considering both traditional tangible attributes (e.g., time and cost) and subjectivity through people's perceptions. Schneider (2013) mentioned that active modes have many barriers to be selected, arguing that the decision to change from public transport to active modes is a bigger challenge than changing to private modes. Our results support this argument. We found that in our case the difficulty was due to the influence of the personal information. Shifting from public transport to active modes is influenced by different subjective elements, such as federal government response, subjective well-being, life-related activities comfort, and leisure activities comfort. On the other hand, the subjective elements influencing the shifting decision to private modes are only related to community actions against COVID-19, implying fewer barriers to making this change.

4.1 Shift from public transport to active modes

Migration from public transport to active modes, such as cycling and walking, was lower in Belo Horizonte than in the rest of the cities. This is manifested in our model by a significant direct effect captured through a dummy variable. This may be due to the relative scarcity of bicycle lanes in Minas Gerais's capital: according to Velasco et al. (2018), Belo Horizonte had fewer kilometres of bicycle lanes per inhabitant in 2018 than Sao Paulo and Rio de Janeiro, although somewhat more than Porto Alegre. Moreover, the steep topography of the city makes bike travel more difficult that in the other state capitals.

When considering the total effects of travel time on the migration to active modes, an increase is observed for the whole sample, without significant variations between cities. This is reasonable considering the expansion of the cities, which results in home-work trips that, in the case of Rio de Janeiro and Sao Paulo, can exceed 2 hours (Giannotti, 2020). On the other hand, there is a lower probability that high-income people migrate to active modes during the pandemic, which can be explained by their greater availability (or budget) to use other options such as cars or taxis.

Lastly, the switch to active modes is influenced by various subjective elements related to the pandemic's perception, which are indirectly associated with socio-demographic characteristics. In particular, those who have an inferior perception of the federal government's response to the pandemic are more likely to migrate to active modes: this pattern, which has also been observed in other Latin-American cities (Vallejo-Borda et al., n.d.), may be associated with a greater tendency to individualism and less trust in public entities in general.

The subjective information expressed through the latent variables indicates influences in the decision to shifting to active modes. A review of the literature suggests that the public entities' response to COVID-19 incorporates different measures that establish limits to people and their activities (Güner et al., 2020), representing many influences on people's decisions and perceptions. We found that perceptions about the federal government response against COVID-19 influence the decision to shift to active modes. In this case, the collected data reported a negative relationship between the perception of the federal government response and the decision to shift to active modes. In other words, perceiving better the federal government response represents a decrease in the probability of changing to active modes. Besides, this probability decrease grows when people feel comfortable developing life-related activities (e.g., meeting with friends or relatives). These results may be explained, considering that those perceiving better the most time-expended activities can be the ones with lower impacts in their daily activities. On the other hand, the relationship between comfort with leisure activities and the probability increase of changing to active modes, suggests that this kind of activity can encourage active modes choice.

When analyzing the individual dimension, particularly around gender, there is a negative influence on women's comfort in daily life activities when shifting from public transport to active transport. The modal shift towards using bicycle or walking might not necessarily be the main reason, but the lack of infrastructure (Lam, 2018), lack of facilities (Clark et al., 2021) or a cultural or social context associated with active transport practices (Aldred et al., 2016; Beecham & Wood, 2014). For example, this assumption corresponds when analyzing the perception associated with subjective well-being, which, according to our results, represents a higher probability of shifting to active modes. Women would be positively inclined to perceive subjective well-being when shifting from public transport to active transport (Mella Lira, 2020).

People with single marital status show a negative but significant inclination towards the modal shift towards active modes. Ageing between 26 and 40 years is a significant factor in analyzing the perception of comfort on life-related activities shifting to active modes. Despite the increasing diversity of bicycle and active transport user profiles, there is still a prevalence of the youngest adults' group within the shift to active travel. The latest could be explained by the versatility of factors impacting travel choice when travelling short distances (Simons et al., 2014). This has been as well contested in terms of safety with older cyclists that tend to be less risky when cycling (Useche et al., 2019).

The results show that occupation significantly influences subjective well-being, both in employed and self-employed - being expected that having a paid occupation would produce better well-being. The survey questions used in this study have not been specific in responding to the temporary nature or insecurity of permanence in jobs (as it could be further explored in Dawson et al. (2017) and Moscone et al. (2016)). However, regarding the self-employed, the literature has shown that, although this group tends to be less satisfied with income, they tend to be more satisfied with leisure time (van der Zwan & Hessels, 2019) - being relevant here to remark that recent research connects perceptions of leisure with the use of more active transport (Mouratidis, 2019).

Concerning the influence of household characteristics, the household size has proven to be connected with a positive response to the federal government, as well as when having children under 18 - according to Table 9. However, having children and large families tend to impact on shifting towards active modes negatively. Again, the lack of facilities, infrastructure, and safety might make parents more reluctant to choose active travel when having children.

4.2 Shift form public transport to private modes

The migration from public transport to private modes shows different relationships with trip and users characteristics. It was found that people shifting to private modes spend less time on their commute trips. This result is not surprising considering the reported reduction of trips representing less occupation of roads (Siciliano et al., 2020). It was also found that being an employee increases the probability of changing to private modes, which can be explained by a need to make commute trips and greater access to this kind of modes. When subjectivity is considered, a good perception of community actions against COVID-19 suggests an increase in the probability of changing to private modes. Güner et al. (2020) stated that community actions are fundamental to prevent COVID-19 spread, which at the same time decrease adverse effects in economic and society.

The results show that people over 60 years, people with high income and families with children at home tend to respond better to community actions. All these groups have a certain degree of 'vulnerability' to the individualization of daily activities. For example, older adults tend to require more assistance from the community where they live, so the organized community can provide them with security that state agencies or their closest relatives do not cover. Something similar happens with families with young children since the organized community's action can provide them with more security, especially in uncertainty contexts.

Transport-related social dilemmas, especially in low-income level neighborhoods, have been widely addressed in the literature in diverse contexts (Currie & Delbosc, 2011; Lucas, 2004, 2012; Oviedo & Sabogal, 2020). The problems at the local level and the strategies to claim spaces for communities in low-income neighborhoods seem to be rooted in the substantial socioeconomic income incidence (Francis et al., 2012). Daily mobility has an important effect on monthly family spending, which is expressed in a series of inequities, especially in contexts where there are significant gaps between high and low socioeconomic groups (Valenzuela-Levi, 2021). The pandemic has reinforced these inequalities (Mena et al., 2021). The results of this research show that there is a positive perception of community responses in shifting to private modes in Brazilian cities.

5 Conclusions and further investigation

This paper explains for the first time, through quantitative models, what are the socioeconomic and behavioural characteristics of people and their environment that explain the shift from public transport to motorised and active transport modes in four large Brazilian cities (São Paulo, Rio de Janeiro, Belo Horizonte and Porto Alegre) during the COVID-19 pandemic. A significant fall in public transport use was observed in the surveys carried out in these four cities, which corresponds to a global trend. Most of this decline corresponds to trips that are no longer made in a pandemic situation, such as work-related trips that have been avoided due to work from home. Among the trips that moved to other modes of transport, the switch to motorised modes, such as cars and motorcycles, was more frequent than to active modes, such as cycling and walking. This change was more profound in the smaller cities of the sample. This could be associated with a greater impact on the decrease in smaller cities' frequency of services. Future work may address in more detail the impact of the service level on the modal shift.

We explained the shifting decision from a structure composed of respondents' subjective and objective elements and used modes. This approach identified elements contributing (and counteracting) a modal shift from public transport to private and active modes, finding more subjective barriers on the modal shifting to active modes. This idea is supported by the latent variables found and the relationships between them in shifting to active modes. Contrary, shifting to private mode is significatively influenced only by one latent variable. Besides, it was found a difference in the latent variables not only by people characteristics but also depending on the locations.

The paper allows addressing community actions as determinants of responses, a fundamental issue in generating public policies and governance at the regional level. Although a previous study (Vallejo-Borda et al., n.d.) had already considered it a relevant factor, the current model places this factor as central in public transport to private mode shift. At the level of public transport changes to active mode, it is interesting to note that the essential factors cover a significant subjectivity spectrum - opposed to traditional research on transport models. Life-related activities, leisure, subjective well-being and authorities' responses have been some of the variables increasingly studied in recent years. Finding these variables seems sensible considering their relevance in theoretical discourse and the implementation of public policies.

Another future wave of surveys in these cities will help determine changes according to how the pandemic has progressed. The federal governments' responses will also change according to the cases' evolution, so we believe that there may be variations in perceptions regarding the authorities' response. It will be interesting to study in-depth comparisons of results in different Latin American cities (Vallejo-Borda et al., n.d.) concerning Brazilian cities. Although they have similar conditions, the number of cases and the pandemic management have differed in these Latin-American contexts. Understanding the changes and impacts in the long term is essential to gain experience and learning for future crises in the region. The data obtained in these surveys and the subsequent studies that may result from it allow comparison and the generation of critical thinking that allows the long-term analysis of the impacts of COVID-19 in the region.

As this paper was written, there was still little information on Brazilian cities' modal shift due to the pandemic. The data obtained from this study allow an analysis for each city, which can feed information on modal shifts and trends in transport modes, both for academic development and for supporting public policy.

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Appendix U. Paper #20: Restoring Confidence in Public Transport post Delta COVID-19 Lockdowns: Identifying User Segments and Policies to Restore Confidence

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Abstract

The COVID-19 pandemic has had a significant impact on the propensity to use public transport, with many countries seeing a decline in patronage to as low as 20% of the pre-pandemic levels. Although public transport use is recovering with 60% of pre-COVID-19 levels being a common statistic, there is a view that it could take many years to fully recover if at all. This paper presents evidence on societal perceptions and attitudes about the use and return to public transport that were obtained from surveys undertaken during COVID-19 at a period in early 2021 in which there were no lockdowns, and during a subsequent period of varying durations of lockdowns in the Greater Sydney Metropolitan Area and South East Queensland. Together with views on future plans, this paper offers policy useful evidence on the challenges that the public transport sector currently face, and are likely to continue to face, in developing a plan to support a return to using public transport. The focus of the paper is on an analysis of attitudinal and open ended qualitative responses using a mixture of descriptive interpretation and analytical methods of factor and cluster analysis to identify the spectrum of attitudes and concern about using public transport as a way of guiding future messaging.

Keywords: public transport; attitudes during lockdown; case study; factor analysis; cluster analysis

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1 Introduction

With the onset of the global COVID-19 pandemic in March 2020, public transport patronage in most jurisdictions worldwide collapsed, in many cases to as low as 20% of the pre-pandemic levels. The period since has been one of slow recovery that has been hampered by repeated lockdowns and on-going concerns around the safety of public transport. While several studies have specifically focussed on the relationship between level of concern with public transport and actual and intended use of public transport (see for example Jenelius and Cebecauer, 2020; Beck et al, 2021) less attention has been given to deriving segments of public transport user by level of concern.

This paper presents evidence from Greater Sydney Metropolitan Area (GSMA; comprising, Sydney, Newcastle and Wollongong) and South East Queensland (SEQ; comprising Brisbane, The Sunshine Coast and the Gold Coast) on societal perceptions and attitudes about the use and return to public transport. Results were obtained from surveys undertaken during COVID-19 in mid-2021 as two major metropolitan areas were in the very early stages of re-entering lockdowns. The two metropolitan areas provide an interesting contrast in terms of the influence of COVID-19 outbreaks and lockdowns on public transport patronage (Figure 1). By the first quarter of 2021, public transport use was returning in SEQ at a faster rate than in Sydney and had almost returned to pre-pandemic levels. In the GSMA, by end of March 2021 patronage overall had surpassed 70 per cent of the pre-pandemic level only to collapse again with the implementation of what became a 107-day lockdown from 26th June (by mid-July patronage had fallen to about 8% of pre-COVID levels - levels not seen since the 1800s). Also, in late June, South East Queensland was placed into a short snap lockdown.

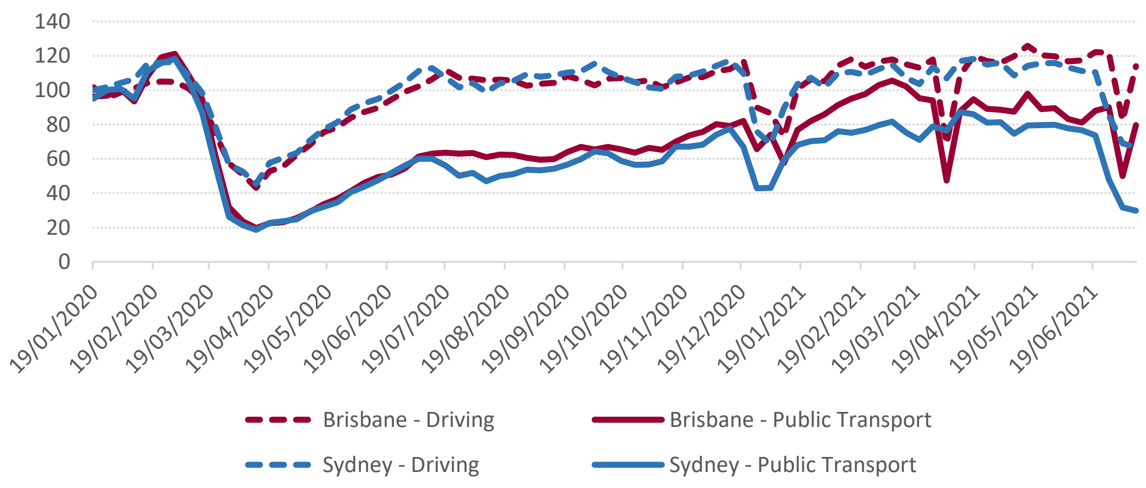

Figure 1: Apple Mobility Data on Driving and Public Transport Use

The paper is organised as follows. The next section provides the literature context with reference to measures that have been introduced to encourage confidence, and studies which have explored aspects of levels of concern and customer satisfaction with public transport during the pandemic. This is followed by a description of the sample used in the paper. Results presented identify levels of concern prior to the lockdown, concern about hygiene and numbers of users during the lockdown, and likelihood of use after the lockdown. A detailed examination of the concerns of workers identifies a number of different segments of public transport concern which are useful in determining where effort should be placed by operators and authorities in alleviating concerns associated with using public transport.

2 Public Transport and the Pandemic

The responses of public transport operators and authorities to the COVID-19 pandemic have been extensively documented (see for example, Beck et al. 2021; McKinsey & Company, 2021). Examples include: COVID-19 travel advice web pages and Apps and Journey planners with indications of safe passenger capacities on board; “on the ground” measures to support distancing measures, e.g., orderly queuing in stations and concourses and at station and in-vehicle signage such as “No dot, no spot” (as introduced in Sydney), as well as QR codes and stops, stations and in-vehicle. A strong visual presence of cleaning crews at stations and interchanges (with extra hours measured in hundreds of thousands) has been shown to be important. Operationally, there have been frequency changes in service levels. In some cities service levels were reduced, the New York subway service was cut by a quarter early in the first wave. In London the Waterloo and City Underground line which primarily caters for commuters was closed from March 2020 to June 2021 (TfL, 2021). Reductions in service frequencies, while implemented in response to falling demand, had a disproportionate impact on those who need to travel for essential purposes (De Vos, 2020).

A prolonged period of uncertainty inevitably impacts public transport patronage. Jenelius and Cebecauer (2020) note that the decline of public transport ridership can most likely be explained by both restrictions imposed by authorities and travellers' own choices. In seeking to understand the latter several studies have specifically focussed on the relationship between level of concern with public transport (primarily focussed on biosecurity) and actual and intended public transport use during the pandemic and in the “next normal”.

For the case of Australia, Beck et al. (2021), drawing on the findings of an ongoing country-wide study, report that concerns over bio-security issues around public transport are enduring and that even as COVID-19 restrictions are eased, both concern about crowds and hygiene have a significant and negative correlation with public transport use. Dong et al (2020) from a cross-sectional study in China conducted early in the pandemic, but at a time when the virus was considered to be under control (March 2020), confirmed that passengers’ feelings of safety enhanced their overall satisfaction with regard to public transport; in other words, perceived safety had a positive effect on overall satisfaction. They noted in particular that an individual’s subjective experiences and opinions on the pandemic were directly related to confidence in using public transport, thus emphasising the crucial role of operators and authorities in providing reassurance that public transport is safe to use.

Basu and Ferreira (2021), from their survey of 2,200 respondents in metropolitan Boston, report that one in five of zero-car households agreed that COVID-19 had enhanced their intention to purchase a car. They conducted follow-up interviews with ten previously zero-car owning households that had purchased a car subsequently and found that the major reasons for their decisions were primarily threefold. These can be summarised as uncertainty around public transport service frequency; lack of trust in safety measures introduced by the transport authority; and fear of other passengers not adhering to the safety guidelines. This underscores the ongoing concern that many of those lost to public transport as a result of the virus will never return. For example, a study from Poland (Przybylowski et al, 2021) which surveyed 302 public transport users in Gdansk in May and June 2020, found that 25% of respondents did not plan to return to public transport as they doubted that the services will ever be safe.

Emphasising the influence of social distancing policies on everyday movements, De Vos (2020) notes that the very act of social distancing might negatively affect subjective well-being with calls on public transport operators to focus on creating ways to make use of public transport safe, since it is clear that people avoid using public transport when it is viewed as unsafe. In the longer-term, the public transport sector will need to consider ways of futureproofing against virus-driven stresses. Florida et al. 2020 suggest pandemic-proof infrastructure and transport management will likely include the continuation or further development of current measures such as touchless solutions, capacity monitoring and floor markings.

Given the above, it is important to gain a greater understanding of the factors affecting societal perceptions and attitudes about the use and return to public transport. This is the focus of the remainder of this paper which presents evidence from which a better understanding of different segments of public transport concern can be derived that can be used to inform future policy on addressing the challenges that the public transport sector currently faces.

3 Sample Description

The public transport data was collected as part of survey Wave 4a (of a series beginning in March 2020), conducted in early July (5th to the 7th) 2021, during a period when the Delta variant of COVID-19 had meant that the entire Greater Sydney Metropolitan Area had been in a lockdown for a period of a week (which ended up extending until October, a total of 107 days), and small outbreaks of Delta were occurring in Brisbane such that South East Queensland (from the Sunshine Coast through to Brisbane and the Gold Coast - SEQ) was also placed into a short snap lockdown as a circuit-breaker for transmission from 29th June – 3rd July.

The purpose of the survey was to look at the working from home experience during the latest period of restriction, to gain further understanding of how previous experiences during the pandemic affected preparedness for this lockdown, and whether there has been any change in attitudes and evaluation since the first lockdowns conducted in the previous year (2020). As such, complete data was only collected as an online survey from respondents who were working during the July lockdowns (with a view to collecting a sample of approximately 300 such respondents in each of SEQ and the GSMA respectively).

However, the overall public transport concern questions (prior to the lockdown, concern about hygiene and numbers of users during the lockdown, and likelihood of use after the lockdown) were asked of all respondents during the screening phase, with a total of 1,854 responses obtained (1,153 in SEQ and 701 in the GSMA). Limited demographic data was collected for the majority of these respondents, with only gender and age as part of the other screening questions. With respect to the number of respondents who qualified for the survey and thus from whom full information was collected, there were 329 in SEQ and 387 in the GSMA.

4 Analysis of All Survey Respondents

4.1 Concern about Public Transport

Concern about hygiene prior to the lockdown still existed, despite a prolonged period of almost extremely low daily case numbers which were mostly contained within hotel quarantine, but at levels well below that observed at the start of the COVID-19 pandemic in March 2020. The average level of concern prior to the lockdown in each jurisdiction was significantly higher in the GSMA (3.2) than in SEQ (2.9), on a 5-point scale[23] (Figure 2). Mirroring the more severe nature of the outbreak in the GMSA, level of concern about hygiene during the lockdown was also significantly higher in the GSMA (3.6) than SEQ (3.1), as was concern about crowds (GSMA = 3.6, SEQ = 3.1). On the other hand, perhaps also representing the greater experience with COVID-19 outbreaks in the GSMA but also the more reliance on the network,

[23] Note that all the results of the hypothesis testing discussed in-text in this paper are provided in Appendix 1, in order in which they are discussed, for reference.

the likelihood of using public transport after lockdown was on average higher in the GSMA (3.2 versus 2.9).

Within SEQ, the average concern about hygiene (3.2) and crowding (3.1) during the lockdown was higher than concern prior (2.9), but there was no difference in the level of concern during the lockdown between hygiene and crowds of other users. The same is true in the GSMA, with average concern being significantly heightened during the lockdown compared to prior (3.2), both with respect to hygiene (3.6) and crowds (3.6), with no difference in average concern during the lockdown with respect to hygiene or crowding.

Figure 2: Level of Concern and Likelihood of Use – All Respondents

Table 1 shows that in the SEQ, there was no difference in concern between males and females prior to the lockdown, but after the lockdown females were significantly more concerned about hygiene and crowds, and males were more likely to use public transport again after lockdown. The same pattern is observed in the GSMA, but females were also significantly more concerned prior to the lockdown. In SEQ there were no differences in concern by age or income, however in the GMSA younger respondents[24] report less concern about crowding and a higher average likelihood of using public transport after lockdown. There are also differences observed by income group[25] in the GMSA; lower income respondents reported significantly higher levels of average concern prior to the lockdown, and significantly lower likelihood of using after lockdown.

[24] Age was broken into three categories (18-34 yrs, 35-54 yrs, and 55+ yrs)
[25] Personal income was broken into three categories ($80k or less, $80k-150k, and more than $155k)

Table 1: Concern by Gender – All Respondents

		Male	Female	t-value
SEQ	Concern about Hygiene - Prior	2.73	2.93	1.941
	Concern about Hygiene - During	2.95	3.31	4.416
	Concern about Crowding - During	2.95	3.26	3.796
	Likelihood of Using – After	3.00	2.83	1.976
GSMA	Concern about Hygiene - Prior	2.90	3.29	3.697
	Concern about Hygiene - During	3.31	3.82	4.834
	Concern about Crowding - During	3.32	3.78	4.249
	Likelihood of Using – After	3.37	3.08	2.774

4.2 Barriers to Public Transport Use

Open-ended questions were asked of all respondents before those who were not working and/or who are not commuters were screened out (the primary focus of survey was to look at impact of lockdown on working from home experiences). The sample size of usable comments was 1,761 in total, 1,102 in from SEQ, and 659 from the GSMA. After rating their level of concern about hygiene on public transport and the numbers of people using the mode, respondents were asked what their main barriers were to using public transport at the present moment. There were two themes unrelated to specific barriers: respondents indicating they do not use public transport (without further explanation); or indicating they have no concerns about using public transport at the current time.

For those that are concerned, there were 14 themes emerging from the responses. Being "worried about COVID-19" was stated by a large number of respondents (particularly in NSW), and reference to the Delta variant was made several times. It should be noted that this category was only coded if the respondent made specific reference to COVID-19 in their reply. For example, if a respondent was concerned about other people not wearing a mask but did not state due to COVID-19 (or the virus, disease, pandemic or any other indication it was COVID-19 related) it was not coded. It is likely then, that this category is more common than Figure 3 indicates.

The inability to social distance, and the number of other public transport users not doing so, was also a concern, as was the cleanliness and hygiene status of public transport. With regards to cleanliness, reference was commonly made to the lack of overt sanitising services onboard and the large number of touch points that are required while using public transport (notwithstanding contactless ticketing). While the lack of enforcement of COVID regulations was explicitly mentioned as an issue by a small number of respondents, implicit in concerns about social distancing and mask wearing are concerns about others not following the rules or being made to follow them. Incorrect wearing of masks was as commonly stated a concern as people not wearing masks.

Concerns about the behaviour of other passengers mainly comprised of not being sure of where other people are from or where they have been, general distrust of the hygiene status of other people, and a very clear theme that many feel that people still use public transport when they should otherwise stay home because they are sick (coughing and sneezing, general germs and/or illness not just specific to COVID-19). This category could be described as a distrust of other people and generally thinking of other public transport users as inconsiderate of others. Though not mentioned by many, some were concerned about becoming a close contact and having to isolate for two weeks, and only a very small number of people stated that being forced to wear a mask was an issue affecting their use of public transport.

4.3 Action Required to Restore Confidence

After rating how likely they would be to use public transport after the lockdown, respondents were asked what measures would need to be taken in order to make them feel more confident about using public transport (Figure 4). The most important measure is ongoing cleanliness. Many respondents stated that they had to be able to see that it was being done (either having continuing cleaning being conducted, scented cleaning materials, even an information sheet in the vestibule that informed passengers of when the carriage or bus was last cleaned).

Limits on people using public transport and/or social distancing measures combined with ongoing use of masks were also a commonly stated measures that would increase confidence. Several respondents stated that more services were required to allow for distancing to occur. A smaller number of respondents explicitly stated they wanted more enforcement of regulations, but it should be noted that this response category was only coded if it was explicitly stated by the respondent. Thus, the number of respondents who would like this to occur could be higher, as it might be implicit that the more commonly stated measures of social distancing and mask wearing would need to be enforced.

Vaccination and/or low to no case numbers would be needed for some to return to using public transport. In responses, some suggested that vaccination be mandatory for travel on public transport, and others suggested that there be vaccinated only carriages made available. Respondents in the GSMA were slightly more likely to state that no cases/vaccination would be important, along with ongoing use of masks and social distancing policies. Findings from the Transport Opinion Survey (March 2021), a regular national survey of public opinion on transport-related issues in Australia, found that over 20 percent of Australians will not return to public transport until they or their close household members have been vaccinated. Respondents in SEQ state that having sanitiser stations or antibacterial wipes available for passengers would make them feel more confident, many stating they would be happy to wipe down their own seat if they had wipes.

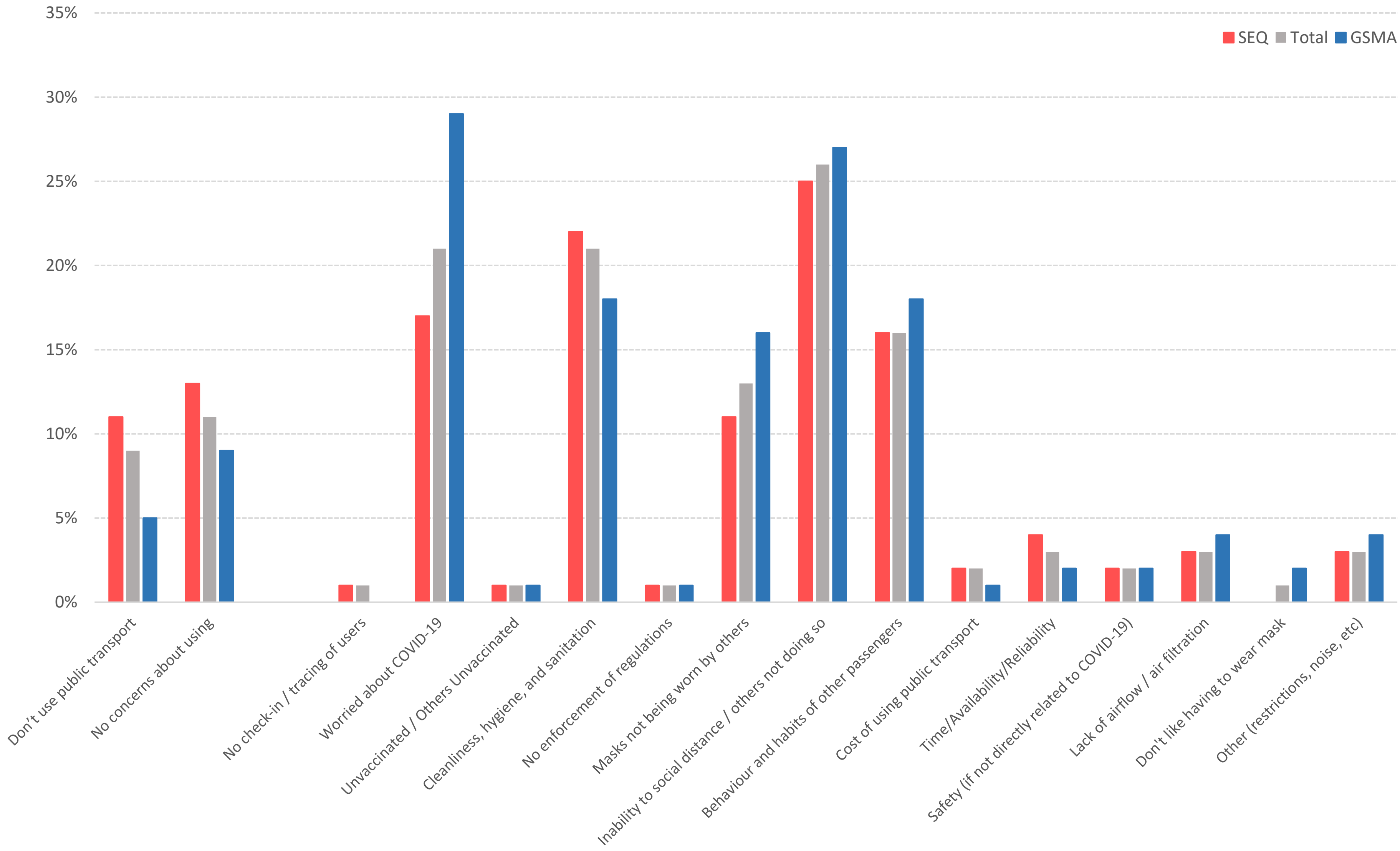

Figure 3: Commonly Stated Barriers to Public Transport Use

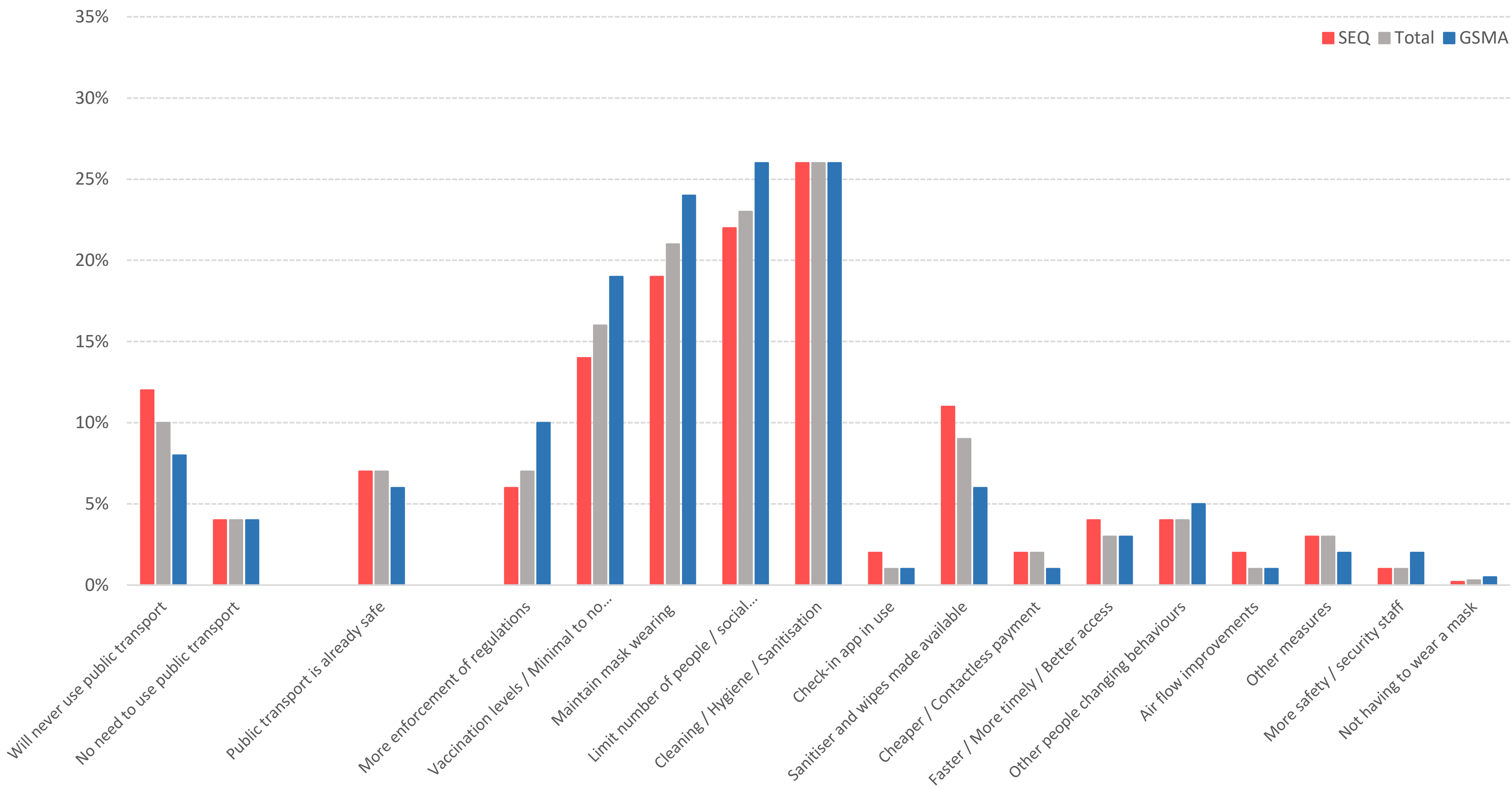

Figure 4: Measures to Increase Confidence in Public Transport

Though only a small percentage, one measure that would make people feel more confident (particularly given it was a common barrier to use) is behavioural change in other passengers, such as staying at home when sick, proper coughing/sneezing behaviours, even an onboard advertising campaign / posters onboard to emphasise the importance of people doing the right thing by others. Interestingly, airflow improvements did not feature very prominently amongst the responses, given knowledge of how important this is in reducing risk from the virus (Morawska and Milton, 2020).

5 Detailed Examination of Concerns of Workers

5.1 Concerns about Public Transport among Workers

The objective of the survey was to capture experiences and attitudes towards working from home during the most recent lockdown, as part of a longitudinal study on working from home and commuting being conducted over 2020 and 2021 (see Beck and Hensher 2020a-b, Beck and Hensher 2021a-b). Given budget and time constraints, a sample of approximately 300 respondents was targeted in SEQ and the GSMA, with reference to those people working, in particular typical commuters who have an office job, where they would be able to work from home during the lockdown restrictions. The ultimate sample size for each region was 329 in SEQ and 387 in the GSMA. While these completes are mainly commuters, commuters do represent the largest component of peak demand. Similar patterns were observed within those respondents who completed the full survey. Concern in the GSMA was on average significantly higher both prior to the lockdown and with respect to hygiene and crowding and during the lockdown; however, those in the GSMA stated a significantly higher likelihood to use public transport post the lockdown than those in the SEQ (Figure 5).

Figure 5: Level of Concern and Likelihood of Use – Completes Only

Within SEQ, the level of concern expressed about both hygiene and crowding is significantly higher during the lockdown than before, as expected. There is no difference between the concern about crowding and hygiene during the lockdown within the SEQ. Within the GMSA, the same is found with respect to heightened concerns about hygiene and crowding, but concerns about hygiene are significantly higher than crowding during the pandemic. Within SEQ, there are no differences across gender, age or income. In the GSMA, however, females are significantly more concerned on all dimensions and are less likely to use public transport after lockdown; lower income respondents were more concerned about public transport prior to the lockdown, and younger people are more likely to use public transport after the lockdown.

Table 2: Correlation of Concern Scores – Completes Only

		Concern about Hygiene - During	Concern about Crowding - During	Likelihood of Using - After
Concern about Hygiene - Prior - SEQ	Corr.	0.719	0.635	-0.151
	Sig	0.000	0.000	0.003
Concern about Hygiene - Prior - GSMA	Corr.	0.712	0.650	-0.142
	Sig	0.000	0.000	0.010

There is no difference in concern expressed by white- or blue-collar occupations in either region, nor between those who are “typical commuters” who commute between home and an office versus other types of workers. Unsurprisingly, in both SEQ and the GSMA, concern during the lockdown is significantly related to level of concern prior to the lockdown, and heightened concern prior to the lockdown also translates to lower likelihood of use after the lockdown ends (see Table 2). Finally, in terms of working from home, higher relative productivity has a significant and positive relationship with concern about public transport prior to the lockdown, and concern about hygiene during the lockdown within SEQ; and is significantly and positively related to concern about hygiene during the lockdown on the GSMA.

5.2 Barriers to Use and Actions to Restore Confidence

With regards to the open-ended responses, a larger number of workers in the GSMA stated they are worried about catching COVID-19 on public transport to those in SEQ, which is not surprising given the relative case numbers at the time and the growing realisation of the seriousness of the outbreak. Workers in the GMSA are also slightly more concerned about their ability to maintain social distancing while on public transport, and about the behaviour of other passengers who they may be traveling with (Figure 6). Overt and regular cleaning along with enough space to social distance are the two most stated strategies that are required to increase confidence about using public transport (Figure 7); this is particularly true in the GSMA. Also in the Sydney region, the use of masks and having high vaccination levels and/or low case numbers is also more commonly cited as a requirement than in the SEQ.

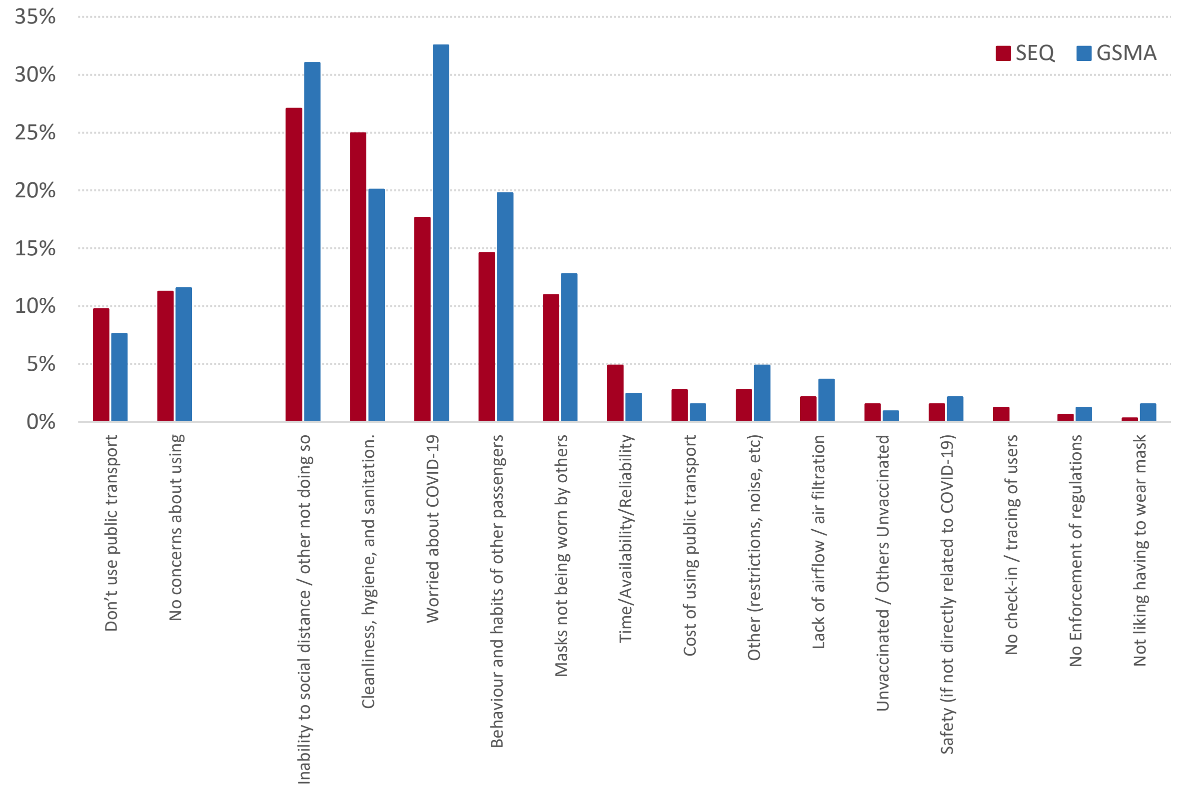

Figure 6: Barriers to Use of Public Transport – Workers

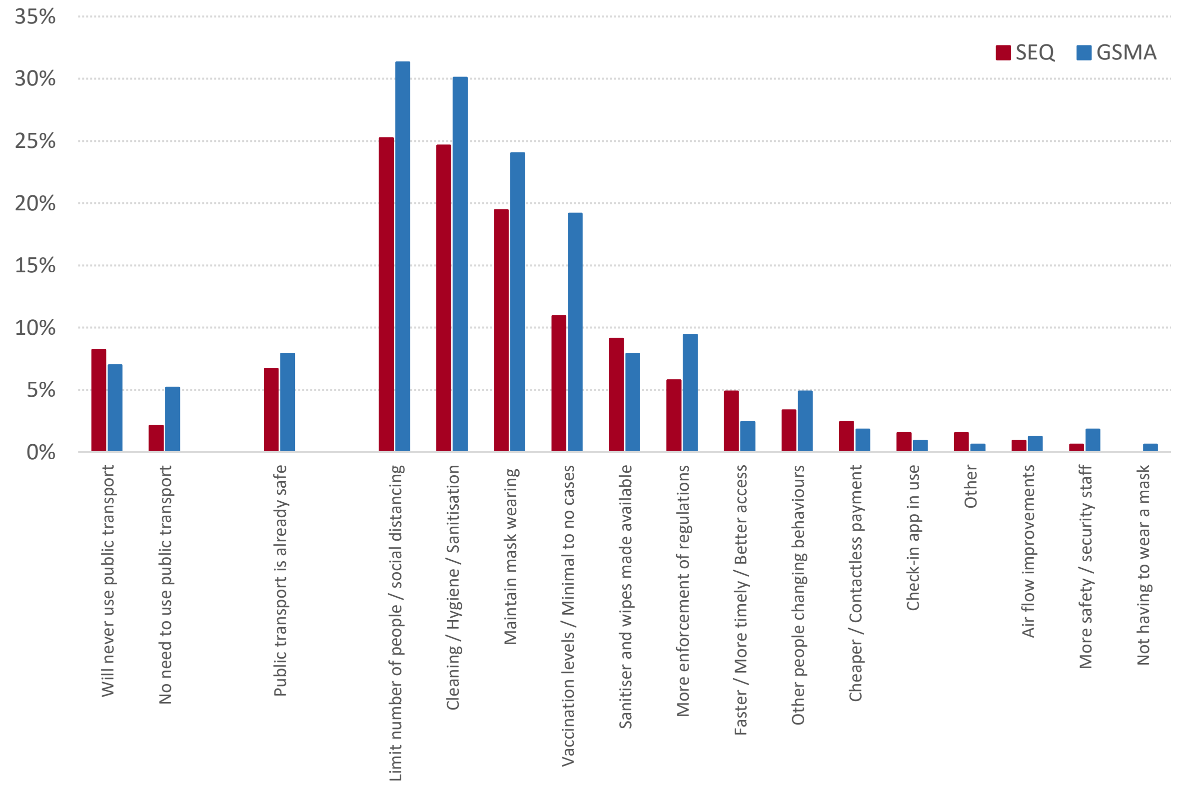

Figure 7: Measure to Increase Confidence in Public Transport – Workers

5.3 Relating Attitudes to Levels of Concern

5.3.1 Exploratory Factor Analysis on Attitudes

Respondents were given a battery of attitudinal statements covering four broad topics: attitudes towards working from home; how comfortable they felt completing selected day-to-day activities; their overall attitude to the way in which the pandemic has been handled; and their attitudes towards COVID-19 vaccination. In total there are 42 attitudinal statements, so exploratory factor analysis was conducted to reduce this to the underlying psychological constructs driving responses to the attitudinal indicators.

This was undertaken for SEQ and the GSMA respondents separately and the factor analysis results (KMO and Bartlett's Test) indicate that three of the four attitudinal subsets were meritorious for factor analysis, the exception being the vaccination attitudinal scale which was passable in both regional samples. Appendix A2 summarises the results of the factor analysis for each set of attitudinal questions.

- With respect to attitudes towards working from home, in SEQ the nine attitudinal statements reduced to two underlying constructs: experience with working from home ($WFH\_Experience_{SEQ}$) and the impact of working from home on commuting (WFH_Travel_{SEQ}). In the GSMA, the work from home attitudes reduced to one global construct (WFH_All_{GMSA}).

- For comfort in completing day-to-day activities, in SEQ the 13 statements can be reduced to one underlying construct ($Comfort\_All_{SEQ}$), whereas in the GSMA there are two dimensions: comfort with activities involving large gatherings ($Comfort\_Large_{GSMA}$); and an underlying dimension that is driving attitudes towards necessary activities ($Comfort\_Needs_{GSMA}$).

- On the 13 attitudinal statements related to the impact of, and response to, COVID-19 in SEQ, there are two drivers: the response of institutions and people to COVID-19 ($COVID\_Response_{SEQ}$) and the impact COVID-19 will have ($COVID\_Impact_{SEQ}$). In the GSMA, perhaps in response to the level of community transmission occurring at the time of data collection, there are three underlying drivers: the response of institutions ($COVID\_Institution_{GSMA}$); the response of the community ($COVID\_Community_{GSMA}$); and the impact of COVID-19 ($COVID\_Impact_{GSMA}$).

- For the seven attitudinal responses gauging attitudes towards vaccination, both in SEQ and the GSMA, these responses are driven by two underlying latent constructs: vaccination being needed and impactful ($Vacc\_Needed_{SEQ}$, $Vacc\_Needed_{GSMA}$); and concerns about the vaccination ($Vacc\_Concern_{SEQ}$, $Vacc\_Concern_{GSMA}$).

Factor scores were calculated using the regression method for use in further analysis, and the interrelationships between attitudes and concern about public transport differ between SEQ and the GSMA, so results are presented in sub-sections specific to each region.

5.3.2 Attitudes and Concern in SEQ

Within SEQ, neither $WFH\_Experience_{SEQ}$ nor WFH_Travel_{SEQ} were correlated with the level of concern about public transport prior to the lockdown, concern about hygiene or crowds during the lockdown, nor likelihood to use public transport after the lockdown ended. Unsurprisingly, $Comfort\_All_{SEQ}$ had significant negative correlations with concern prior, concern about hygiene and crowds during the lockdown and is positively correlated with the likelihood of using public transport after lockdown; more comfort around completing activities is associated with lower concern about public transport and a greater likelihood of using public transport after the lockdown. Scores for *COVID_Response*$_{SEQ}$ were negatively correlated with concerns about hygiene during the lockdown; indicating that those that thought the response of institutions were appropriate were less concerned. Scores for *COVID_Impact*$_{SEQ}$ were positively correlated with concern prior, hygiene and crowding concern during lockdown, and negatively correlated with likelihood of use after lockdown; indicating those that felt COVID-19 has a bigger impact on society and the economy are more concerned about public transport and are less likely to use public transport when the lockdown ends.

Lastly, on attitudes towards vaccination, *Vacc_Needed*$_{SEQ}$ is positively correlated with concern about hygiene during the lockdown; indicating that those who feel people who believe the vaccine to be needed and impactful are more concerned about using public transport. The *Vacc_Concern*$_{SEQ}$ variable is also positively correlated with concern about hygiene and crowding during the lockdown. Interestingly, vaccination attitudes are not correlated with the intention to use public transport after lockdown, possibly because the number of people vaccinated was increasing exponentially despite the fact that 59% of respondents indicated that they were currently unvaccinated, 25% had received one vaccination injection, 17% had received both doses. Being vaccinated or not has no impact on concern about public transport nor on likelihood to use for those in the SEQ.

5.3.3 Attitudes and Concern in the GSMA

Within the GSMA we see a difference between attitudes and concern in using public transport. In the GMSA, the single *WFH_All*$_{GMSA}$ latent variable that is driving evaluation of working from home attitudes, is positively correlated with concern about hygiene and crowding during the pandemic; indicating those with a more positive work from home experience are more concerned with public transport overall. The *Comfort_Large*$_{GSMA}$ construct is negatively correlated with concern prior to the lockdown, concern about hygiene and crowding during lockdown, and positively correlated with likelihood to use public transport after lockdown; indicating that those who express more comfort in engaging in activities involving larger groups of people are less concerned about public transport and more likely to use it. The same pattern is observed for the *Comfort_Need*$_{GSMA}$ latent construct with concern prior, about hygiene and crowding during lockdown, and likelihood to use public transport after lockdown. With regards to attitudes towards the impact of COVID-19 and the response towards the pandemic, only the *COVID_Impact*$_{GSMA}$ construct is correlated with concern about using public transport, specifically those who believe that COVID-19 has a larger impact on society and the economy are also more concerned about public transport prior to the lockdown, and towards hygiene and crowding during the lockdown.

In the GMSA, vaccination attitudes play a larger role than in SEQ, with the *Vacc_Needed*$_{GSMA}$ construct being positively correlated with prior concern, and hygiene and crowding concern during lockdown; those who feel the vaccine is needed and impactful express higher concern about using public transport. The *Vacc_Concern*$_{GSMA}$ latent variable is positively correlated with prior concern only. Again, it is interesting to note that vaccination attitudes are not correlated with intention to use public transport after lockdown. It should be noted that 60% of respondents indicated that they were currently unvaccinated, 26% had received one vaccination injection, 14% had received both doses. Being vaccinated or not has no impact on concern about public transport nor on likelihood to use for those in the GSMA; it is relevant to note though that this was early in the Delta outbreak and the virulence of the virus strain was probably not yet appreciated.

5.4 Segments of Concern and Likely Use

To better understand different segments of public transport concern that exist within the two metropolitan regions, the four measures of concern (prior to the lockdown, hygiene and crowding during lockdown, and likelihood to using public transport after lockdown) were jointly analysed in a *k*-means clustering process whereby *n* observations are partitioned into *k* clusters, with each observation belonging to the cluster with the closest cluster average. This process allows for the identification of non-overlapping segments of respondents in the data such that each respondent belongs to only one cluster. To determine the appropriate number of clusters, multiple trials with different cluster numbers are implemented, ultimately seeking to identify the solution that provided the largest number of cluster segments while maintaining significant differences between the inputs across each cluster. As with the previous analysis, SEQ and the GSMA were analysed independently of each other, but in both regions, there were four clusters that best segmented respondents based on levels of concern and likelihood of use (see Appendix A3 for tables of average response for each statement).

5.4.1 Defining Segments in SEQ

For SEQ, the average response to each statement from respondents in each segment is significantly different to the average attitude expressed by all other segments, indicating strong discrimination between the segments. Figure 8 summarises each of the four clusters identified in SEQ. "*Heightened Concern Users*" whose level of concern with public transport prior to the lockdown, hygiene and crowding during, averages between somewhat to moderate concern, but whose intention to use public transport after the lockdown is between neutral and somewhat likely. This segment accounts for 34% of respondents. "*Cautious Users*" whose average concern with public transport prior to the lockdown, hygiene and crowding during, is around slightly concerned, but have a likelihood to use public transport after lockdown that is between somewhat and extremely likely. This segment is 18% of respondents. "*Confident Casuals*" who express the lowest level of concern and report a neutral average likelihood to use public transport after lockdown. This segment accounts for 21% of respondents. Lastly, "*Extreme Concern Avoiders*" account for 27% of the sample and are a group that report the highest levels of concern with public transport and the lowest intention to use after the lockdown.

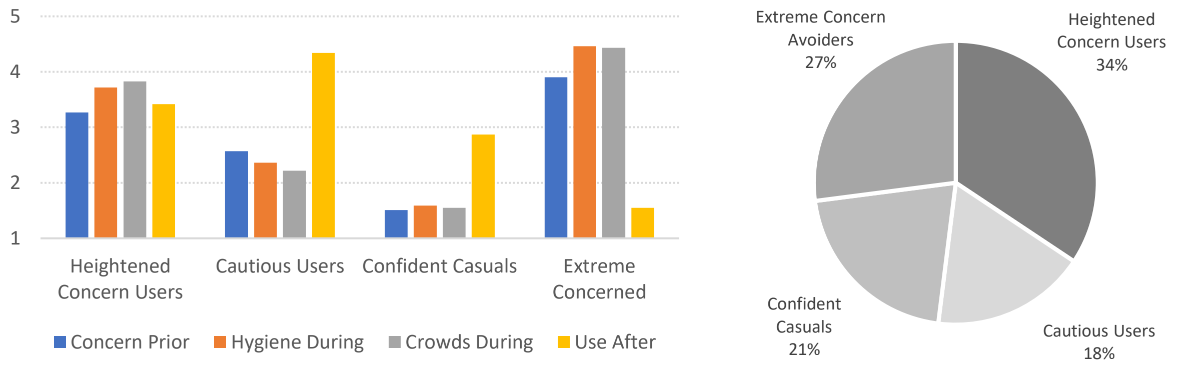

Figure 8: Segments of Concern in South East Queensland

Once the clusters were identified, further analysis was conducted to understand differences in characteristics. In South East Queensland, the composition of each segment was identical with respect to gender, proportion of "typical" commuters[26], occupation (white/blue-collar), age, income, possession of a driver's license, vaccination status, and productivity while working from home. In other words, socio-demographics do not explain differences in the segments, rather attitudes and behaviours are what delineates between the clusters. Table A4.1 (see Appendix A4) highlights the variables from the survey that differed significantly across the segments. Table 3 summarises the key components that define the make-up of each segment.

Table 3: Segments of Public Transport User by Level of Concern - SEQ

Heightened Concern Users 34%	Cautious Users 18%	Confident Casuals 21%	Extreme Concern Avoiders 27%
Uncomfortable completing day to day activities	Comfortable completing day to day activities	Comfortable completing day to day activities	Uncomfortable completing day to day activities
Heightened sense of COVID-19 risk to health and economy	Believe COVID-19 of to be less of a risk than other segments	Believe COVID-19 of to be less risk than other segments	Heightened sense of COVID risk to health and economy
Higher degree of anxiousness	Less positive about WFH experience	View COVID-19 as not as serious a health concern	Higher degree of anxiousness
Believe lockdown was implemented too slowly	Lower desire to WFH more in the future	Lower agreement with drastic actions to combat COVID-19	Agree more that people not isolating appropriately
Concerned about spread of COVID-19 on PT	More influenced by vaccine incentives	Lower belief in need to be vaccinated	Stronger belief in need for and efficacy of vaccination
Worried about cleanliness and distancing	Primarily worried about distancing	Likely to have no concerns about public transport	Believe lockdown was implemented too slowly
Need to observe cleaning taking place	What limits on users and regular cleaning	More likely to not be users of public transport	Concerned about spread of COVID-19 on PT
Want to know there is space for social distancing	Would also like sanitiser and wipes provided to passengers	Want better services in order to use public transport	Particularly worried about cleanliness
			Need vaccinations and/or minimal cases
			Need limits on people and regular visible cleaning

- "*Heightened Concern Users*" (34%) segment are generally uneasy about COVID-19 and the impact of the virus, as a result are anxious and worried about catching the virus on public transport. To avoid this, they would like to see observable cleaning being conducted on a regular basis and to know clearly that they will be able to social distance whilst onboard.

- "*Cautious Users*" (18%) express more comfort in being in public completing day to day activities, have a lower risk perception of COVID-19, are seemingly open to incentives to be vaccinated, and have a largest problem with distancing while on public transport. Interestingly, it is also this group that predominately wants to see sanitising facilities made available to passengers on board or at stops/stations.

[26] A "typical" commute is defined as someone who regularly travelled between home and an office or single work location (e.g., a warehouse, hospital). Given the sample focus, 70% of workers in the SEQ and 74% in the GSMA meet this definition.

- "*Confident Casuals*" (21%) are also comfortable being out and about, also have a lower relative risk perception of COVID-19, and thus have no concerns about using public transport other than wanting better access to services in order to use more frequently.
- "Extreme Concern Avoiders" (27%) are more concerned about COVID-19, exhibit higher levels of anxiousness, believe in vaccination and would need to see mass vaccination levels and or low/case numbers in particular, to be confident in using public transport again.

5.4.2 Defining Segments in the GSMA

In determining the clusters for the GSMA also using the four measures of concern about public transport, each segment displays an average score on these measures that are significantly different to the average scores by respondents in the other segments, with the exception of likelihood of future use of public transport, where there are only two groups of significantly different average likelihood of use score: users versus avoiders. Nonetheless, there is still strong discrimination between the segments. Figure 9 summarises each of the four clusters identified in the GSMA. The "*Unconcerned Users*" segment accounts for 23% of respondents and is comprised of those who have only slight concern about public transport, and a relatively high likelihood of using public transport after the lockdown. At 16% of the sample, "*Cautious Avoiders*" are those with slight to somewhat concern about public transport but are somewhat unlikely to use after lockdown. "*Very Concerned Users*" account for 29% of respondents and have moderate concern about public transport but are also likely to use these modes again after lockdown. Finally, the largest segment identified are the "*Extreme Concern Avoiders*" who have moderate to extreme concern about public transport and report being somewhat unlikely to use the mode again once the lockdown ends. Interestingly, and unlike SEQ, there is no segment that is extremely unlikely to use public transport, possibly explained by the size of the network in Sydney and the greater role public transport plays in moving people.

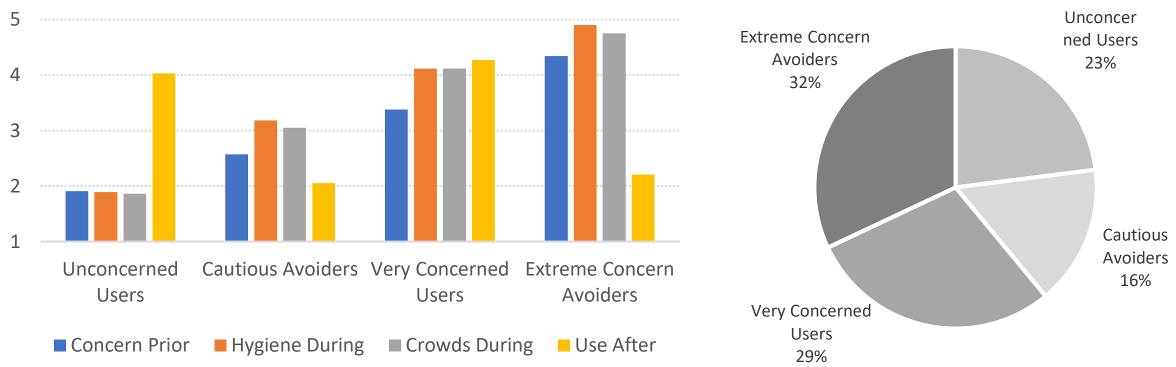

Figure 9: Segments of Concern the Greater Sydney Metropolitan Area

Similarly to SEQ, socio-demographics are largely the same within each segment (reinforcing that attitudes and behaviours differentiate between the clusters), however in the GSMA data males are more likely to be "*Unconcerned Users*" and female "*Extreme Concern Avoiders*"; lower income respondents more likely to be in the "*Cautious Avoider*" segment and high income in the "*Very Concerned Users*"; and blue-collar workers are more likely to be in the "*Cautious Avoider*" segment as well. Table A4.2 (see Appendix A4) highlights the variables from the survey that differed significantly across the segments. Table 4 summarises the key components that define the make-up of each segment:

- "*Unconcerned Users*" are generally comfortable completing day to day activities, have a lower risk perception of COVID-19 than other segments, are less anxious, and generally believe public transport to be safe to use. A small percentage of this group don't like wearing masks.

- "*Cautious Avoiders*" are comfortable completing essential activities, believe COVID-19 will have a lesser impact relative to other segments, have found the work from home experience to be less positive, are less inclined to believe in vaccination compared to other segments, and need social distancing to be maintained along with thorough cleaning to be confident in using public transport.

- "*Very Concerned Users*" are uncomfortable in large group activities, feel COVID-19 will have a larger impact than other segments, are concerned about COVID-19 at the workplace, have found the work from home experience to be positive, believe the lockdown happened too slowly, seemed swayed by vaccination incentives, have a clear emphasis on the need for social distancing to be confident in using public transport

- "*Extreme Concern Avoiders*" have a more pronounced discomfort in interacting in large group environments and a higher perception of the overall risk of COVID-19. They are less likely to be swayed by incentives for vaccination, believe the lockdown happened too slow and have a very low likelihood of using public transport unless social distancing is strictly maintained, and cleaning is regular and observable.

Table 4: Segments of Public Transport User by Level of Concern - GSMA

Unconcerned Users 23%	**Cautious Avoiders 16%**	**Very Concerned Users 29%**	**Extreme Concern Avoiders 32%**
Higher proportion of males (relative to sample)	Higher proportion of blue-collar workers	Higher average incomes	Higher proportion of females
More comfortable completing large group activities	Lower average incomes	Uncomfortable completing large group activities	Uncomfortable completing large group activities
More comfortable completing needed activities	More comfortable completing needed activities	Higher attitude towards the impact of COVID-19	Uncomfortable completing needed activities
Lower attitude towards the impact of COVID-19	Lower attitude towards the impact of COVID-19	More concern about COVID-19 in the workplace	Lower attitude towards the impact of COVID-19
Allocate more commuting time saved to leisure/family	Lower relative agreement of WFH as a positive experience	WFH experience means better prepared to WFH	More concern about COVID-19 in the workplace
Low perception of risk of COVID-19 to own health	Lower belief that COVID-19 will affect how people travel	Heightened sense of COVID-19 risk to health and economy	Heightened sense of COVID-19 risk to health and economy
Lower degree of anxiousness	Less belief that combatting COVID-19 needs drastic action	View WFH as a positive experience	Less open to incentives for vaccination
More open to incentives for vaccination	Lower belief in vaccination	More open to incentives for vaccination	Believe lockdown happened too slowly
Have no concerns about using public transport	Most worried about inability to social distance on PT	Believe lockdown happened too slowly	More concerned about COVID-19 on public transport
Believe public transport to be safe already	Need social distancing and cleaning to be confident	Emphasis on social distancing to be confident in using PT	Need space for social distancing in order to use PT
		Still need cleaning to occur to be confident about using PT	Need observable cleaning to occur on public transport

6 Discussion and Conclusions

The focus of the paper has been to identify the spectrum of attitudes and concerns about using public transport in two metropolitan areas (GSMA and SEQ) using a mixture of descriptive interpretation and analytical methods of factor and cluster analysis. This section summarises the key findings and their relevance in developing plans to support a return to using public transport.

While concerns over the use of public transport remain, from the survey of all respondents we found evidence that the likelihood of using public transport after lockdown was on average higher in the GSMA than SEQ. This implies a potential learning experience since the GSMA has greater experience with COVID-19. A frequently stated barrier to public transport use was the inability to social distance and the number of other public transport users not doing so was also a concern, as was the cleanliness and hygiene status of public transport. The reference made to the lack of overt sanitising services onboard is an aspect that operators could address directly. Similarly, reducing the number of touch points required while using public transport should be a future focus. Enforcement of COVID regulations is important to citizens but responsibility for this remains something of a grey area. Generally, operators have found it easier to "enforce" social distancing than mask wearing (Dzisi and Dei, 2020).

A different pattern of attitude drivers and their differing relationships to public transport concern show different experiences with the virus within the two metro areas as shown by the segments of concern that emerge. Interestingly, with the exception of a limited number of variables in the GSMA, the segments of user concern revealed do not vary by socio-demographics, emphasising the potential challenges faced by public transport operators in responding to a pandemic that has affected all societal groups equally. Indeed, the predominant variables that enable operators to delineate between segments of concern are attitudes towards responses by institutions and the general public, vaccinations, public transport behaviour, and most crucially, what segments have identified as being important measures that would work towards restoring some degree of confidence in public transport.

To restore confidence in SEQ, it is likely that operators will have most success targeting those in the "Heightened Concerned User" segment (accounting for one third of potential users) through observable cleaning and sensible distancing measures. As vaccinations roll-out and efficacy becomes more certain, attempts could then be made to target the "Extreme Concern Avoiders". In the GMSA it is notable that 23% of respondents identify as "Unconcerned Users" giving operators some hope that patronage will return, but operators in this metropolitan area might seek to target the "Very Concerned Users" with the highlighted strategies in Table 4, particularly again as vaccination effectiveness emerges. It is interesting to note that in the two metropolitan region there are subtle different segments, suggesting that different policies may be required, but that the GSMA experience may give insight into what SEQ might experience should virus numbers grow.

When looking at factors of concern vaccination attitudes (at the time of survey) were not linked to future use of public transport directly in either location, although it remains to be seen if that becomes of more importance now that vaccinations rates of 90% have been achieved. The only factors correlated with future use of public transport are level of comfort in completing day to day activities; this again likely represents a more positive attitude associated with living with the virus.

As noted earlier, while several studies have specifically focussed on the relationship between level of concern with public transport and actual and intended use of public transport, less attention has been given to deriving segments of public transport user by level of concern.

Thus, the development of market segments is useful in determining where effort should be placed by operators and authorities in alleviating concerns associated with using public transport during lockdown and as we learn to live with COVID-19. Findings indicate that while attitudes and concern are different, and these attributes are related in different ways, ultimately the same set of strategies to restore confidence in public transport will generally work for those with extreme aversion, but more importantly for those in the middle who are willing to use, but have concern about COVID-19 and the risk public transport poses.

For a large percentage of people it seems like distancing and really quite observable cleaning will be needed. As noted vaccination attitudes are not linked to future use directly, so it seems this form of deterrent needs to prove itself. Unless there is a long period of time with control or (no) case numbers, or the vaccine proves its effectiveness in suppressing numbers and in particular hospitalisations, cleaning and distancing is the policy that should be promoted by public transport operators. This is typified by the dominant “Heightened Concern Users” segment in SEQ who would like to see observable cleaning being conducted on a regular basis and to know clearly that they will be able to social distance whilst onboard. Similarly, in GSMA the “Cautious Avoiders”, while comfortable completing essential activities, need social distancing to be maintained along with thorough cleaning to be confident in using public transport. However, by late 2021 NSW has relaxed distancing measures with public transport capacity raised to 75% and a reliance on people to use common sense when it comes to distancing. Whilst this is consistent with a return to normality there remains the risk of disenfranchising those vulnerable users who need public transport. That both locations have an “Extreme Concern Avoiders” segment who are highly unlikely to use public transport unless social distancing is strictly maintained, and cleaning is regular and observable, suggests that this is where the focus of awareness campaigns that “public transport is safe” needs to be.

Ultimately, to paraphrase Jenelius and Cebecauer (2020), the return to public transport ridership will most likely be influenced by both restrictions imposed by authorities and travellers' own choices; this implies the need to be responsive to the concerns of travellers.

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Appendix Paper #20 A1

Table A1: Results of Hypothesis Testing (discussion in text)

Test	Statistic	Value	Sig
GSMA vs SEQ prior concern	t-value	4.352	---
GSMA vs SEQ crowding concern	t-value	7.227	---
GSMA vs SEQ hygiene concern	t-value	7.158	---
GSMA vs SEQ usage likelihood after	t-value	4.201	---
SEQ hygiene concern vs prior concern	t-value	9.972	---
SEQ crowding concern vs prior concern	t-value	8.385	---
SEQ hygiene concern vs crowding concern	t-value	1.201	---
GSMA hygiene concern vs prior concern	t-value	12.489	---
GSMA crowding concern vs prior concern	t-value	10.979	---
GSMA hygiene concern vs crowding concern	t-value	0.862	---
GSMA Age vs crowding concern	F-value	3.632	0.027
GSMA Age vs usage likelihood after	F-value	6.685	0.001
GSMA Income vs prior concern	F-value	3.283	0.039
GSMA Income vs usage likelihood after	F-value	3.079	0.047
GSMA vs SEQ Workers prior concern	t-value	2.814	---
GSMA vs SEQ Workers hygiene concern	t-value	4.752	---
GSMA vs SEQ Workers crowding concern	t-value	3.950	---
GSMA vs SEQ Workers usage likelihood after	t-value	2.467	---
SEQ Workers hygiene concern vs prior concern	t-value	5.373	---
SEQ Workers crowding concern vs prior concern	t-value	4.784	---
SEQ Workers hygiene concern vs crowding concern	t-value	0.074	---
GSMA Workers hygiene concern vs prior concern	t-value	9.832	---
GSMA Workers crowding concern vs prior concern	t-value	7.314	---
GSMA Workers hygiene concern vs crowding concern	t-value	2.131	---
GSMA Female Workers prior concern	t-value	2.500	---
GSMA Female Workers hygiene concern	t-value	4.218	---
GSMA Female Workers crowding concern	t-value	3.608	---
GSMA Female Workers usage likelihood after	t-value	1.993	---
GMSA Income vs prior concern	F-value	3.287	0.038
GMSA Age vs usage likelihood after	F-value	3.341	0.031

Table A1 (cont.): Results of Hypothesis Testing (discussion in text)

SEQ WFH productivity and prior concern	corr.	0.153	0.031
SEQ WFH productivity and hygiene concern	corr.	0.165	0.020
GSMA WFH productivity and hygiene concern	corr.	0.144	0.035
$Comfort\_All_{SEQ}$ vs prior concern	corr.	-0.325	0.000
$Comfort\_All_{SEQ}$ vs hygiene concern	corr.	-0.432	0.000
$Comfort\_All_{SEQ}$ vs crowding concern	corr.	-0.436	0.000
$Comfort\_All_{SEQ}$ vs usage likelihood after	corr.	0.196	0.000
$COVID\_Response_{SEQ}$ vs hygiene concern	corr.	-0.118	0.034
$COVID\_Impact_{SEQ}$ vs prior concern	corr.	-0.182	0.000
$COVID\_Impact_{SEQ}$ vs hygiene concern	corr.	-0.291	0.000
$COVID\_Impact_{SEQ}$ vs crowding concern	corr.	-0.269	0.000
$COVID\_Impact_{SEQ}$ vs usage likelihood after	corr.	-0.127	0.022
$Vacc\_Needed_{SEQ}$ vs hygiene concern	corr.	0.115	0.036
$Vacc\_Concern_{SEQ}$ vs hygiene concern	corr.	0.116	0.036
$Vacc\_Concern_{SEQ}$ vs crowding concern	corr.	0.117	0.034
WFH_All_{GMSA} vs hygiene concern	corr.	0.171	0.012
WFH_All_{GMSA} vs crowding concern	corr.	0.166	0.015
$Comfort\_Large_{GSMA}$ vs prior concern	corr.	-0.247	0.000
$Comfort\_Large_{GSMA}$ vs hygiene concern	corr.	-0.344	0.000
$Comfort\_Large_{GSMA}$ vs crowding concern	corr.	-0.310	0.000
$Comfort\_Large_{GSMA}$ vs usage likelihood after	corr.	0.139	0.006
$Comfort\_Need_{GSMA}$ vs prior concern	corr.	-0.172	0.000
$Comfort\_Need_{GSMA}$ vs hygiene concern	corr.	-0.232	0.000
$Comfort\_Need_{GSMA}$ vs crowding concern	corr.	-0.247	0.000
$Comfort\_Need_{GSMA}$ vs usage likelihood after	corr.	0.108	0.035
$COVID\_Impact_{GSMA}$ vs prior concern	corr.	0.143	0.005
$COVID\_Impact_{GSMA}$ vs hygiene concern	corr.	0.251	0.000
$COVID\_Impact_{GSMA}$ vs crowding concern	corr.	0.240	0.000
$Vacc\_Needed_{GSMA}$ vs prior concern	corr.	0.144	0.005
$Vacc\_Needed_{GSMA}$ vs hygiene concern	corr.	0.180	0.000
$Vacc\_Needed_{GSMA}$ vs crowding concern	corr.	0.189	0.000
$Vacc\_Concern_{GSMA}$ vs prior concern	corr.	0.133	0.009

Appendix Paper #20 A2

Table A2.1: Working from Home Factor Loadings

Attitudes toward Working from Home	SEQ		GSMA
	WFH_Experience	*WFH_Travel*	*WFH_All*
WFH has been a positive experience for me	**0.764**	0.351	0.7750
Like to WFH more often in the future	**0.766**	0.400	0.8170
Like more flexible starting and finishing times in the future	0.218	**0.830**	0.7220
Commute at less busy times in the future if I could	0.112	**0.846**	0.5180
Appropriate space to work from home	**0.726**	0.267	0.7430
Find a balance between paid work and unpaid work	**0.851**	0.112	0.8230
Balance time working versus not working	**0.847**	0.056	0.8020
Appropriate equipment / technology to WFH	**0.869**	0.166	0.7700
Overall I have everything I need to WFH well	**0.877**	0.136	0.7990

		SEQ	GSMA
KMO Test of Sphericity		0.877	0.864
Bartletts	Chi-square	2210.732	121.533
	Sig.	0.000	0.000

Table A2.2: Comfort with Activities Factor Loadings

Comfort with Activities	SEQ	GSMA	
	Comfort_All	*Comfort_Large*	*Comfort_Needs*
Meeting with friends	0.715	0.222	**0.847**
Visiting restaurants	0.846	0.456	**0.775**
Going to the shops	0.819	0.376	**0.804**
Going to the movies	0.78	Cross-loaded so removed	
Going to pubs or bars	0.888	**0.706**	0.563
Gyms and exercise groups	0.836	**0.775**	0.358
Doctor's appointments	0.685	0.332	**0.685**
Attending professional sporting events	0.886	**0.843**	0.33
Attending music events	0.875	**0.896**	0.286
Attending live entertainment	0.888	**0.897**	0.315
Attending schools and/or childcare	0.799	Cross-loaded so removed	
Playing organised sport	0.855	**0.762**	0.379
Attending work functions	0.574	**0.739**	0.454

		SEQ	GSMA
KMO Test of Sphericity		0.949	0.945
Bartletts	Chi-square	4557.517	5151.777
	Sig.	0.000	0.000

Table A2.3: Attitudes towards COVID-19 Factor Loadings

Attitudes toward COVID-19 Impact and Response	SEQ		GSMA		
	COVID_Response	*COVID_Impact*	*COVID_Institution*	*COVID_Community*	*COVID_Impact*
COVID-19 will continue to affect the way people travel	0.019	**0.677**	-0.031	0.080	**0.648**
Federal government response to COVID-19 has been appropriate	**0.596**	0.226	**0.846**	0.147	0.048
State government response to COVID-19 has been appropriate	*Cross-loaded so removed*		**0.827**	0.138	0.182
Business response to COVID-19 has been appropriate	**0.685**	0.29	**0.672**	0.331	0.159
Wider community response to COVID-19 has been appropriate	**0.817**	0.118	*Cross-loaded so removed*		
COVID-19 is a serious public health concern	0.088	**0.864**	0.272	-0.026	**0.869**
Combatting COVID-19 requires drastic measures to be taken	0.143	**0.856**	0.267	-0.008	**0.814**
People appropriately social distancing to combat COVID-19	**0.819**	-0.118	0.354	**0.796**	-0.061
People appropriately self-isolating to combat COVID-19	**0.824**	-0.114	0.392	**0.761**	-0.059
Trust governments to respond to COVID-19 in the future	**0.72**	0.334	**0.784**	0.308	0.167
Trust business to respond to COVID-19 in the future	**0.735**	0.274	*Cross-loaded so removed*		
Trust other people to respond to COVID-19 in the future	**0.825**	-0.058	0.400	**0.721**	0.022
Go to work from time to time to avoid too much social isolation	*Cross-loaded so removed*		-0.186	**0.554**	0.358

		SEQ	GSMA
KMO Test of Sphericity		0.839	0.836
Bartletts	Chi-square	2210.732	2763.677
	Sig.	0.000	0.000

Table A2.4: Attitudes towards Vaccination Factor Loadings

Attitudes toward Vaccination	SEQ		GSMA	
	Vacc_Needed	*Vacc_Concern*	*Vacc_Needed*	*Vacc_Concern*
People have a duty to protect themselves and others	**0.757**	-0.007	**0.773**	0.115
I believe in vaccinations and science	**0.870**	-0.220	**0.827**	-0.364
Vaccinations help stop the spread of the virus	**0.824**	-0.244	**0.810**	-0.380
I am concerned about the safety of the vaccine in its development	-0.205	**0.899**	-0.061	**0.913**
I am concerned about the potential side-effects of vaccines	-0.173	**0.911**	-0.012	**0.914**
I just want life to return to normal as quickly as possible	**0.473**	0.385	**0.477**	0.236
People should get vaccinated against COVID-19	**0.399**	-0.232	**0.395**	-0.334

		SEQ	GSMA
KMO Test of Sphericity		0.679	0.681
Bartletts	Chi-square	937.905	1120.611
	Sig.	0.000	0.000

Appendix Paper #20 A3

Table A3.1: Cluster Averages for SEQ

	Heightened Concern Users	Cautious Users	Confident Casuals	Extreme Concern Avoiders	F	Sig.
n allocated	34%	18%	21%	27%	**F**	**Sig.**
Concern Prior	3.27	2.57	1.51	3.90	99.379	0.000
Hygiene During	3.72	2.36	1.59	4.46	233.253	0.000
Crowds During	3.83	2.22	1.55	4.43	270.741	0.000
Use After	3.42	4.34	2.87	1.55	99.907	0.000

Table A3.2: Cluster Averages for GSMA

	Unconcerned Users	Cautious Avoiders	Very Concerned Users	Extreme Concern Avoiders	F	Sig.
n allocated	23%	16%	29%	32%	**F**	**Sig.**
Concern Prior	1.91	2.57	3.38	4.34	99.379	0.000
Hygiene During	1.89	3.18	4.12	4.90	233.253	0.000
Crowds During	1.86	3.05	4.12	4.75	270.741	0.000
Use After	4.03[b]	2.05[a]	4.27[b]	2.21[a]	99.907	0.000

Appendix Paper #20 A4

Table A4.1: Cluster Composition in South East Queensland

SEQ CLUSTER COMPOSITION	Heightened Concern Users	Cautious Users	Confident Casuals	Extreme Concern Avoiders	F-stat / Chi-square	Sig.
Comfort_All$_{SEQ}$	-0.57	0.64	0.53	-0.40	9.266	0.000
Concern about COVID-19 in workplace	2.9	2.0	1.6	3.0	33.080	0.000
Hours of work per week during lockdown	33.1	27.8	34.9	31.9	2.706	0.045
Risk of COVID-19 to my health	6.3	5.1	4.2	6.5	16.777	0.000
Risk of COVID-19 to health of someone known	7.2	6.2	5.1	7.2	14.293	0.000
Risk of COVID-19 to the general public	7.1	6.2	5.1	7.1	18.618	0.000
Risk of COVID-19 to the economy	8.1	7.2	7.3	7.7	3.361	0.019
How anxious did you feel yesterday	4.6	3.6	4.1	5.0	3.343	0.020
Work from home has been a positive experience	5.7	5.0	5.7	5.9	2.872	0.038
I would like to work from home more often	5.7	5.0	5.8	5.7	2.773	0.043
Community response to COVID-19 appropriate	4.7	5.0	4.5	4.3	2.778	0.401
COVID-19 is a serious health concern	6.0	5.9	5.2	6.3	8.926	0.000
Combatting COVID-19 requires drastic measures	5.7	5.3	4.7	5.8	8.502	0.000
People appropriately self-isolating	4.3	4.6	4.5	3.8	3.483	0.016
Trust others to respond in the future	4.6	4.7	4.5	4.0	3.391	0.018
Go to work to avoid isolation	5.0	5.3	4.6	4.6	3.021	0.022
People have a duty to protect themselves & others	6.0	6.1	5.6	6.3	4.815	0.003
I believe in vaccinations and science	5.9	6.3	5.6	6.2	4.268	0.003
Vaccinations stop spread of virus	5.6	6.0	5.3	5.9	3.387	0.018
Vaccination Incentive - Travel within Australia	3.4	3.9	3.1	3.5	2.941	0.034
Vaccination Incentive - Travel International	3.3	4.1	3.1	3.3	4.789	0.003
Speed at Which Lockdown was Implemented						
Lockdown happened to quickly	9%	9%	19%	7%	20.211	0.017
Timing of lockdown appropriate	43%	55%	44%	38%		
Lockdown happened to slowly	47%	29%	29%	49%		
Lockdown is not needed	2%	7%	9%	6%		
Barriers to the Use of Public Transport						
No concerns about using	4%	16%	33%	0%	51.329	0.000
Worried about COVID-19	20%	7%	12%	27%	11.938	0.008
Cleanliness, hygiene, and sanitation	31%	16%	4%	39%	30.430	0.000
Inability to social distance / others not doing so	30%	40%	9%	29%	17.189	0.001
Behaviour and habits of other passengers	15%	16%	4%	21%	9.130	0.028
Don't use public transport	5%	7%	22%	8%	14.731	0.002
Lack of airflow / air filtration	0%	0%	0%	8%	19.287	0.000
Strategies to Increase Confidence in Public Transport						
Will never use public transport	4%	7%	16%	9%	8.952	0.030
Public transport is already safe	3%	10%	17%	1%	21.273	0.000
Vaccination levels / Minimal to no cases	7%	10%	7%	19%	8.798	0.032
Limit number of people / social distancing	34%	28%	10%	25%	12.732	0.005
Cleaning / Hygiene / Sanitisation	29%	26%	10%	29%	10.129	0.017
Sanitiser and wipes made available	6%	21%	7%	8%	11.435	0.010
Faster / More timely / Better access	2%	7%	13%	1%	15.525	0.001
Other people changing behaviours	7%	2%	0%	2%	8.069	0.045

Table A4.2: Cluster Composition in the Greater Sydney Metropolitan Region

GSMA CLUSTER COMPOSITION	Unconcerned Users	Cautious Avoiders	Very Concerned Users	Extreme Concern Avoiders	F-stat / Chi-square	Sig.
Female	44%	59%	61%	68%	12.417	0.006
White-collar	91%	79%	89%	92%	7.935	0.047
Personal Income ($,000)	95.4	77.9	102.4	80.8	3.4	0.019
Comfort_Large$_{GSMA}$	0.59	0.00	-0.22	-0.50	6.884	0.000
Comfort_Need$_{GSMA}$	0.48	0.51	0.17	-0.13	2.723	0.044
COVID_Impact$_{GSMA}$	-0.20	-0.47	0.42	0.25	3.876	0.009
Saved commute time allocated to leisure (%)	66%	46%	52%	47%	3.016	0.031
Concern about COVID-19 in workplace	2.0	2.5	3.2	3.5	36.663	0.000
WFH experience means better prepared to WFH	3.8	3.6	4.0	3.9	3.556	0.015
Risk of COVID-19 to my health	4.1	5.6	6.5	6.6	28.064	0.000
Risk of COVID-19 to health of someone known	5.2	6.4	7.4	7.4	22.658	0.000
Risk of COVID-19 to general public	5.3	6.2	7.2	7.3	26.187	0.000
Risk of COVID-19 to the economy	7.2	7.4	7.8	8.1	4.064	0.007
How anxious did you feel yesterday	3.5	5.0	5.0	4.8	5.791	0.001
Work from home has been a positive experience	5.3	4.9	5.7	5.3	2.714	0.046
COVID-19 will affect the way people travel	5.7	5.2	5.8	5.9	5.989	0.001
COVID-19 is a serious public health concern	5.2	5.0	6.0	6.1	14.865	0.000
Combatting COVID-19 requires drastic action	4.9	4.8	5.9	5.8	14.798	0.000
People have a duty to protect themselves & others	5.8	5.4	6.1	6.2	7.058	0.000
I believe in vaccinations and science	5.7	5.1	5.9	5.9	5.868	0.001
Vaccinations stop spread of virus	5.5	5.1	5.8	5.8	3.353	0.019
Concerned about potential vaccine side-effects	4.5	5.0	5.0	5.2	2.797	0.040
Vaccination Incentive - Attend large groups	2.9	2.6	3.1	2.6	3.965	0.009
Vaccination Incentive - Travel within Australia	3.4	2.9	3.6	3.2	3.607	0.014
Vaccination Incentive - Travel International	3.4	2.7	3.7	3.2	6.355	0.000
Vaccination Incentive - Tax rebate or stimulus	3.2	3.1	3.8	3.1	4.788	0.003
Speed at Which Lockdown was Implemented						
Lockdown happened to quickly	8%	10%	6%	4%	23.683	0.005
Timing of lockdown appropriate	39%	34%	39%	35%	23.683	0.005
Lockdown happened to slowly	42%	41%	53%	58%	23.683	0.005
Lockdown is not needed	11%	15%	2%	3%	23.683	0.005
Barriers to the Use of Public Transport						
No concerns about using	32%	7%	2%	3%	67.321	0.000
Worried about COVID-19	17%	21%	35%	33%	10.904	0.012
Others not wearing mask	8%	2%	15%	14%	9.459	0.024
Inability to social distance / others not doing so	11%	26%	35%	30%	16.134	0.000
Behaviour and habits of other passengers	4%	13%	14%	30%	26.908	0.000
Don't use public transport	10%	15%	2%	4%	14.017	0.003
I have to wear a mask	4%	2%	0%	0%	10.121	0.018
Strategies to Increase Confidence in Public Transport						
No need to use public transport	3%	16%	2%	2%	25.149	0.000
Public transport is already safe	26%	2%	2%	0%	66.511	0.000
Limit number of people / social distancing	17%	21%	40%	25%	15.761	0.001
Cleaning / Hygiene / Sanitisation	16%	20%	34%	29%	10.315	0.016

Appendix V. Paper #30: The Impact that COVID-19 and working from home has had on the amount of main location office space retained and the future use of rented satellite offices

David A. Hensher
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Matthew J. Beck

Abstract

Despite the extensive amount of research on the impact that the COVID-19 pandemic has had on significant changes in the location at which work takes place, especially working from home (WFH), there is very little systematic consideration given to the relationship between the substantial increase in WFH and the responses taken by organisations in reviewing their office (work space) capacity needs in the future, including a switch of the mix of utilising work space in the main office(s) and satellite office locations. Using data from 459 businesses for three periods for pre-COVID-19, April 2022 (25 months after the outbreak of the pandemic) and stated intentions for 2023, we develop a random effects regression model for the Greater Sydney Metropolitan Area in which we identify some of the influences on the downsizing or not of the main office(s) work space, and comment on what we see as the most likely scenario for WFH and work space in the main office and rented satellite office space under the 'next normal'. The findings can be used to inform future commuting travel as well as changes in land use activity at specific locations, including possible reallocation of existing office space to other activity uses.

***Keywords**:* COVID-19; work space downsizing; working from home; satellite offices; elasticities, random effects regression

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1 Introduction

After two years of the COVID-19 pandemic, we are beginning to see a growing number of structural changes in the workplace that look like becoming key features of a 'next normal'. While we will live with a quantum of uncertainty on what is increasingly referred to as 'a return to the office', the evidence is mounting almost daily to suggest that the pre-COVID-19 work environment has changed forever, and for many good reasons supported by a significant number of employers and employees (Barrerro et al. 2021, Beck and Hensher 2021, 2021a, Beck and Hensher 2022, Hensher et al. 2022a).

Hensher et al. (2022), in analysing data collected in Australia at four points in time between March 2020 and July 2021, offer signals as to what are important drivers of the main influences on structural change that occurred during the ongoing pandemic which is crystallised in a desire to work from home. As long as unchanged (or even increased) productivity is seen as a positive outcome of working from home, especially by employers, who increasingly recognise the lifestyle and wellbeing benefits to their employees (something that will inevitably be built into employment contracts going forward), and that a preference of workers to continue to work from home remains, given the many benefits on balance that have been recognised, the 'next normal' will almost certainly be linked to the delivery of structural change centred around WFH.

At the same time, we are seeing businesses review their workspace requirements at their main office location (linked in part to WFH), with some being closed temporarily, while other organisations have downsized their space or planning on doing so when leases are renewed. Complementing this space review is a consideration of the role that other office space associated with renting at a satellite office[27] (by the hour or day, for example) might play, which is likely to be closer to where employees live, enabling some amount of working from home and/or return to the main office to be transferred to this alternative location, which we refer to increasingly as working near home (WNH). The satellite office offers a respite to both the long commute and being at home for extended periods, especially where work-related facilities at home are somewhat limited.

There is very little published research, despite extensive media commentary, on the relationship between working from home and changes that are occurring in the amount of office space that will be needed in the 'next normal', and how much of this space will be obtained through renting of space in satellite offices in contrast to the main office location. The question we are interested in is the extent to which levels of working from home and increased use of rented satellite office space will be linked to changes in the amount of workspace required at the main office that was used pre-COVID-19. We collected data in April 2022 from a sample of organisations in the Greater Sydney Metropolitan Area (GSMA) to enable us to estimate a random effects regression model on data from the pre-COVID-19 period, April 2022 and a period associated with looking ahead to 2023, that can shine a light on the links between

[27] A satellite office is a branch of a company that's physically separate from the organisation's main or primary office and can be located in a different country or on the other side of town. A satellite office can range in size from a single desk for an individual employee to a workspace housing many workers. Lately their usefulness has grown to accommodate trends around flexible working, creating convenience for a company's remote employees, help cut down on busy commutes, and reduce the number of workers in the main office at any one time. See https://www.wework.com/ideas/workspace-solutions/flexible-products/what-is-satellite-office

working from home and changes in workspace requirements today and in the future compared to pre-COVID-19.

The paper is structured as follows. We begin with a review of the evidence, largely from media and consultancy reports, on what changes are occurring and anticipated in the property market associated with office downsizing and /or relocation. We then provide a descriptive overview of the new survey data, collected as an online panel from a sample of individuals who have relevant knowledge of an organisations office location and sizing plans in the GSMA, distinguishing the Sydney Central Business District from other locations. A random effects regression model is estimated to account for the three periods, where the dependent variable is the percentage change in workspace at the main office location in April 2022 and in 2023 compared to the level (set at 100%) pre-COVID-19. The findings are discussed, including elasticity estimates associated with each of the three periods. The concluding section discusses what the evidence suggests for policy settings associated with transport, land use, property development and leasing.

2 Key Insights from the Literature

The Reserve Bank of Australia (RBA) in August 2021 indicated that from 2020 to 2021, the commercial property market in Australia has declined in terms of the demand for office and retail space due to staff shifting to working from home and an increase in online shopping. Except for industrial properties such as warehouse space, other commercial properties have increased vacancy rates since the pandemic. The demand for office space, especially in large cities like Sydney and Melbourne, has declined since 2020. The occupancy rates of office space have varied between 10% and 30% below the pre-COVID-19 levels in all cities.

Recent data released by the Property Council of Australia (PCA) show that the overall Australian office vacancy rate in January 2022 is 12.1%, compared to about 8% pre-COVID in January 2020[28]. However, the demand for the premium end of office leases, like quality towers, is still strong, with the vacancy rate reduced from 5.5% to 4.9% (Cummins 2022 and also Figure 2 and Table 2 below). The PCA data for early 2022 also show that for the first time in two years, the demand for offices has started to increase instead of decrease, indicating the beginning of a possible recovery[29]. There are growing office leasing enquires in capital cities, led by Sydney[30]. From March 2022 or over the peak of the outbreak of the Omicron variant, workers started to spend some time in the office while remaining working remotely on other days (Beck and Hensher 2022a). In the three Central Business Districts (CBDs) of Sydney, Melbourne and Canberra, workers only occupy 32% to 45% of the workspace, with others working remotely (Williams 2022). A USA survey by PwC suggests that some businesses have already cut back on their real estate needs, as WFH re-imagines how they get work done, and where that work takes place (PwC, 2021).

The challenges facing the commercial property industry are not just about recovery but also accommodating the evolving requirements of a hybrid work pattern, which is unlikely to change soon. For example, office spaces have been reconfigured to have more room for in-person collaboration, compensating for the lack of this function while working from home (Williams 2021). Some commercial property owners have set up new divisions to focus on these tasks, offering tenants new amenities such as wellness centres. Despite the higher vacancy rate during the pandemic, the commercial real estate sector has not seen a decline in investment,

[28] https://research.propertycouncil.com.au/data-room/office
[29] Vij et al. (2022) report that 5.2% of sampled individuals who are managers (807) work for a company that would consider reducing its office space,
[30] https://www.commo.com.au/news/2022/02/03/pca-office-vacancy-statistics-cbre/1643850982

exacerbating the potential oversupply of office space, although this is expected to result in lower rents in the short to medium term at least. A recent market figure suggests that over AUD$70 billion in investment has entered this sector, with $21 billion in office properties (Cummins 2022).

For employers, the decisions for workers and workspace are related. On the one hand, they need to work out the ongoing work arrangements and the support plan for working from home. On the other hand, they need to decide whether to maintain, increase or decrease, the existing workspace, or decentralise the workspace. Because of the length of many current office leases, these changes may take some time to resolve (Lenaghan 2021).

Naor et al. (2022) study the effects of the pandemic in Israel, with evidence indicating a decline both in procuring office space and its price per square metre. Employee productivity while WFH remains relatively high despite home distractions, with a forecast of a continuous shift to hybrid work mode after the pandemic.

There are clear advantages of the hybrid work form such as commuting time savings and work/life balance (Bloom et al. 2009, Hensher and Beck 2022). It has been widely acknowledged that supporting the hybrid work form is important for staff retention in the new "normal" workplace. For workers, after two years of working from home most of the time, some may never return to the past routine of working five days in an office. Not only do employees support it, but business leaders such as the CEO of Telstra have publicly endorsed it as the new way going forward. Flexibility is here to stay' and 'employers who offer a balance of WFH and in office will attract more high quality employees' (The Future of Office Space Summit, 17 Feb 2021)[31]. According to the Productivity Commission, the types of work that can be done at home are about 35% of all work activities, and the other 65% must be done on site, but this may change over time (Ziffer 2022). The Chair of the Productivity Commission's in Australia has stated that 'the five-day office week is dead, long live the hybrid model'[32].

In the long term, it is still unclear whether and to what extent office space requirements at the firm level will decline due to the hybrid work arrangement, with many industry experts being cautious in referencing a permanent decline in office space. First, there are signs that the demand is increasing for Central Business District offices. Second, many businesses are expanding post-COVID-19 and may need more space to accommodate more employees (although see Table 1). Third, larger organisations, including government departments and banks, have not yet decided to reduce office space; however in contrast, many small to medium businesses have decided to reduce office space since the pandemic (Harley 2022 and Table 2 below). Ramani and Bloom (2021) conclude that within large US cities, households, businesses, and real estate demand have moved from dense central business districts (CBDs) towards lower density suburban zip-codes. They label this the "Donut Effect" reflecting the movement of activity out of city centres to the suburban ring. This aligns with a growing interest in satellite office use.

By contrast, Delventhal et al. (2020) have argued that increased adoption of remote working arrangements is likely to lead to a further centralisation of employment. They base this position on three main factors driving this reallocation. First, employers can access the labour of telecommuters even if they are located far from where they live; hence employment shifts from locations which are less productive but closer to workers' home location, toward locations closer to the core which have higher exogenous productivity and benefit from greater productivity spillovers. Second, the reallocation of residents increases demand for floorspace in peripheral locations and reduces it in the core, creating a cost incentive for jobs

[31] https://futureplace.tech/future-of-office-space-summit-post-event-session-recordings/
[32] https://www.smh.com.au/business/companies/the-five-day-office-week-is-dead-long-live-the-hybrid-model-says-productivity-boss-20210706-p587d4.html

to move in the opposite direction. Third, the fact that telecommuters require less on-site office space further increases the cost-efficiency of firms in core locations with high productivity but high real estate prices. The hybrid WFH model can accommodate a mix on increased centralisation and decentralisation with a metropolitan area, in recognising this broader benefits from an employer's perspective, where physical connectivity (the commonly cited agglomeration benefit) is important despite digital agglomeration satisfying a growing number of connectivity needs in the business supply chain.

Regardless of whether the demand for commercial properties is increasing, the impact of the pandemic on commercial properties cannot be ignored. KPMG surveyed decision-makers of the twelve largest commercial property tenants, and the findings revealed some critical insights to guide how commercial properties might have to change in the future, including dropping the one-size-fits-all workplace, allowing hybrid workplaces and employee working flexibility, enhancing data and technology, and changing traditional offices to collaboration hubs[33].

This brief overview of how office space downsizing, growth and potential repositioning is occurring since the beginning of the pandemic illustrates the need to establish the extent to which there is a systematic relationship between three key elements of the structural change associated with a 'next normal', namely how the incidence of working from home and interest in substituting satellite office use may provide informative signals on the expected demand for work space in the future at the primary office location(s) associated with the pre-COVID-19 period. This evidence has important implications on the movement of employees as commuters and users of the many services associated with the living supply chain (e.g., morning coffee, lunches etc.), which are suffering at present, especially in CBDs. Anecdotally, as of April 2022 we are seeing a significant return of people traffic to the CBD of Sydney, but not as workers, rather to enjoy the interactions associated with shopping, restaurants and associated activities. Meanwhile the office blocks remain very empty.

3 Descriptive Overview of the Data

We drew a random sample of 500 organisations in the GSMA with a quota sample of 100 businesses in the Sydney CBD. There was no quota sampling of organisation size. The data source was an online panel provided by Pure Profile in which we sought to identify participants who have relevant knowledge of their organisations office location and sizing plans. A screening question was used to ensure that whoever we spoke to was working in the same organisation pre-COVID-19 and today, and that they had awareness (and ideally decision making capacity) in sharing with us information on the organisation's workspace plans, actual and anticipated, as well as the WFH and WNH activity. The survey took around 10 mins to complete. The final useable sample was 459, with the balance of data deemed unreliable for a number of key reasons including outlier responses to key questions.

A descriptive profile of the data over the three periods is summarised in Table 1 with accompanying graphs (Figures 1, 3 to 7) showing the distribution of the main variables in the sample. We see a drop in the number of employees during the pandemic compared to pre-COVID-19 with evidence (Figure 1) of some small recovery starting to occur. The percentage of working days that are worked from home (Figure 5) has significantly increased, as expected, during the pandemic, with evidence, on average, suggesting little change between April 2022 and the expected level in 2023. Employer support for WFH has more than doubled compared to pre-COVID-19 which, as we know, is crucial to the continuing support and success of a hybrid working model (Beck and Hensher 2022). The percentage of workspace has declined (Figure 3) to an estimate that aligns well with the broader findings in the literature of around

[33] https://home.kpmg/au/en/home/insights/2021/05/commercial-real-estate-future-of-work.html

70-80% of pre-COVID-19 levels. Interestingly, cost savings were only seem as a definite consideration by 26% of the organisations, with 11% indicating a definite no, and the balance (63%) not having sufficiently considered it to date.

Table 1. Descriptive profile of key data items across three periods

Before COVID-19	**Mean**	**STD**	**Min**	**Max**
Number of working days	4.4	1.3	0	7
Percentage of days WFH	20.5	32.5	0	100
Employer supported WFH days	1.3	1.7	0	5
Employee Numbers	847	4081	0	50000
Commuting time in minutes	35	25	0	180
April 2022	**Mean**	**STD**	**Min**	**Max**
Number of working days	4.1	1.4	0	7
Percentage of days WFH	35.5	37.5	0	100
Employer supported WFH days	2.8	1.4	0	5
Employee Numbers	711	3654	0	45000
Workspace change at main office location(s) (% compared to 100% Pre-COVID-19)	72	36	0	150
Commuting time in minutes	31	23	0	150
In 2023	**Mean**	**STD**	**Min**	**Max**
Number of working days	4.1	1.4	0	7
Percentage of days WFH	35.2	35.7	0	100
Employer supported WFH days	2.5	1.5	0	5
Employee Numbers	728	3643	0	45000
Workspace change at main office location(s) (% compared to 100% Pre-COVID-19)	80	32	0	200
Percent of employees will start working at satellite offices if satellite office will be used (160 of 459 orgs)	41.8	25.3	1	100
Commuting time in minutes	31	23	0	150
Other Contextual Data	**Mean**	**STD**	**Min**	**Max**
Accommodation & food services	0.031	-	0	1
Administrative & support services	0.037	-	0	1
Arts & recreation services	0.026	-	0	1
Construction	0.057	-	0	1
Education & training	0.153	-	0	1
Electricity, gas, water & waste services	0.017	-	0	1
Financial & insurance services	0.052	-	0	1
Health care & social assistance	0.107	-	0	1
Information media & telecommunications	0.031	-	0	1
Manufacturing	0.033	-	0	1
Professional, scientific & technical services	0.137	-	0	1

Public administration & safety	0.037	-	0	1
Rental, hiring & real estate services	0.015	-	0	1
Retail trade	0.107	-	0	1
Transport, postal & warehousing	0.048	-	0	1
Wholesale	0.022	-	0	1
Main work office - Sydney CBD %	26.6		0	1
Well informed about business work space plans *	72	-	0	0

The distribution of the size of the sampled businesses, defined by the number of employees, is given in Figures 1 and 2, and Table 2 where the latter is presented by five firm sizes. Relative to 100% pre-COVID-19, very large firms with 1,000 plus employees have reduced workspace much less than firms with less than five employees, which aligns well with what is suggested in Section 2 (Harley 2022) where larger organisations have not yet decided to reduce office space since the pandemic in contrast to many small to medium businesses. In aggregate, the average number of employees per firm has declined in April 2022 compared to pre-COVID-19 and is 83.9% of pre-COVID-19 levels; however we are starting to see a small increase to 85.9% in 2023. It is also likely that larger firms have been able to better weather the financial impacts of COVID-19 as compared to smaller businesses, who may also rent office space over shorter leases.

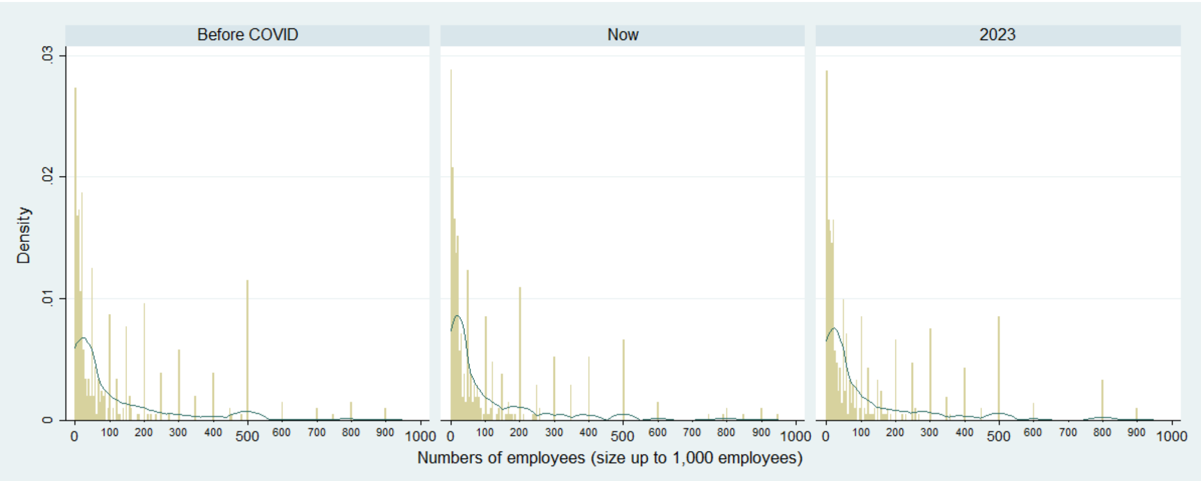

Figure 1. The distribution, by period, of the number of employees in each organisation in the GSMA sample (density refers to the frequency probability of such organisations)

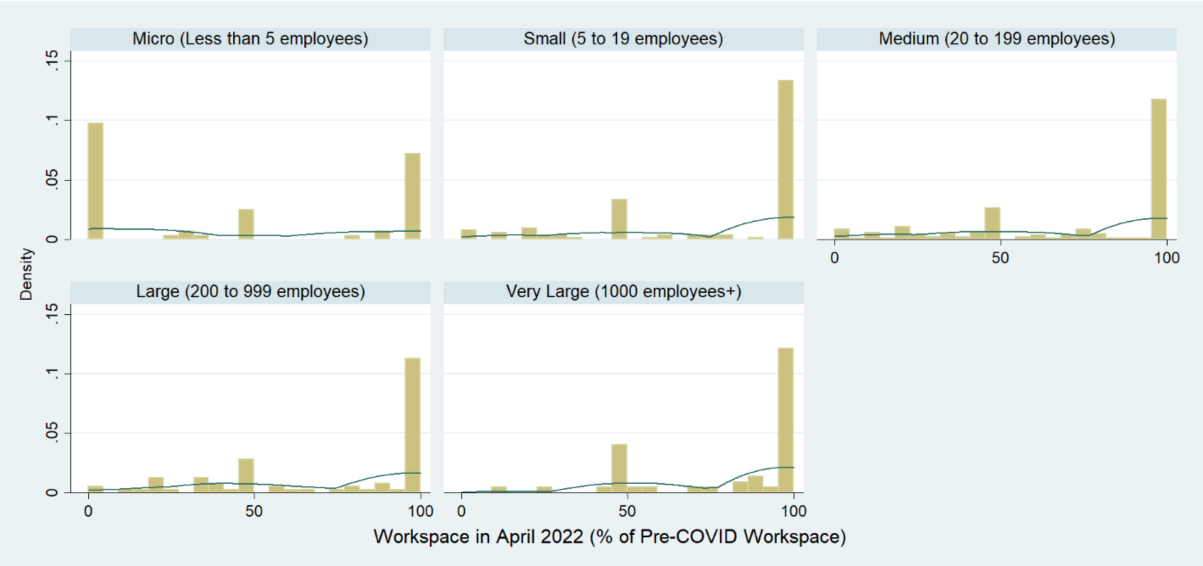

Figure 2. The distribution of main location office space in 2022 compared to Pre-COVID-19 by organisation size

Table 2. Workspace in April 2022 (% of Pre-COVID-19 workspace) by organisation size

Organisation size	**% of sample**	**Mean**	**STD**	**25th percentil e**		**median**	**75th percentil e**
Micro (less than 5 employees)	12.4%	44.9	44.9	0		35	100
Small (5 to 19 employees)	22.7%	77.2	32.1	50		100	100
Medium (20 to 199 employees)	37.5%	74.7	33.8	50		100	100
Large (200 employees)	17.6%	74.9	32.5	50		100	100
Very large (1000 employees+)	9.9%	82.0	24.9	52.5		100	100
Total	100.0%	72.3	35.5	50		100	100

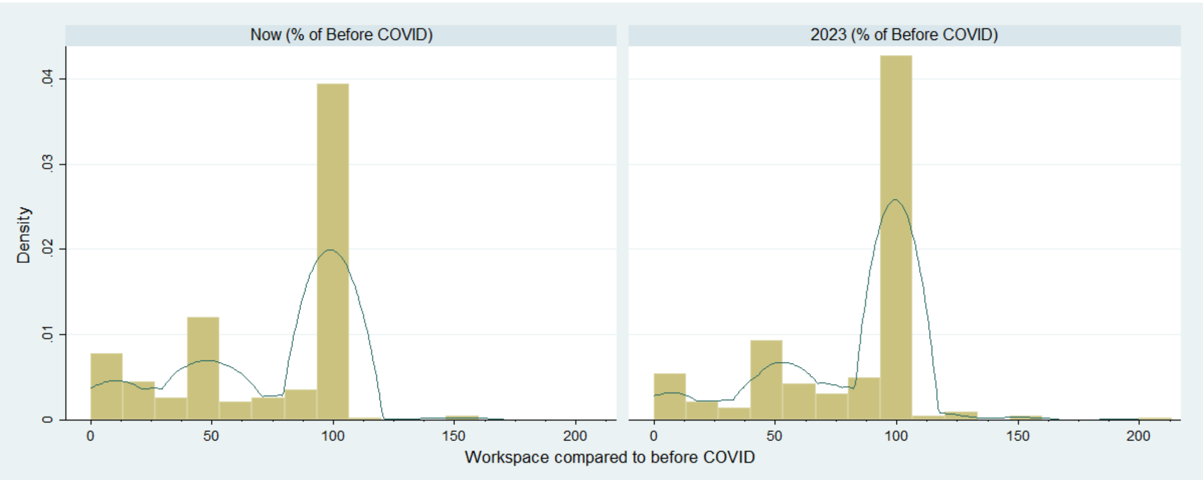

Figure 3. The distribution, by period, of the percentage of work space change in April 2022 and 2023 compared to pre-COVID-19 in the GSMA

Figure 4. The distribution, by period, of the number of working days in the GSMA

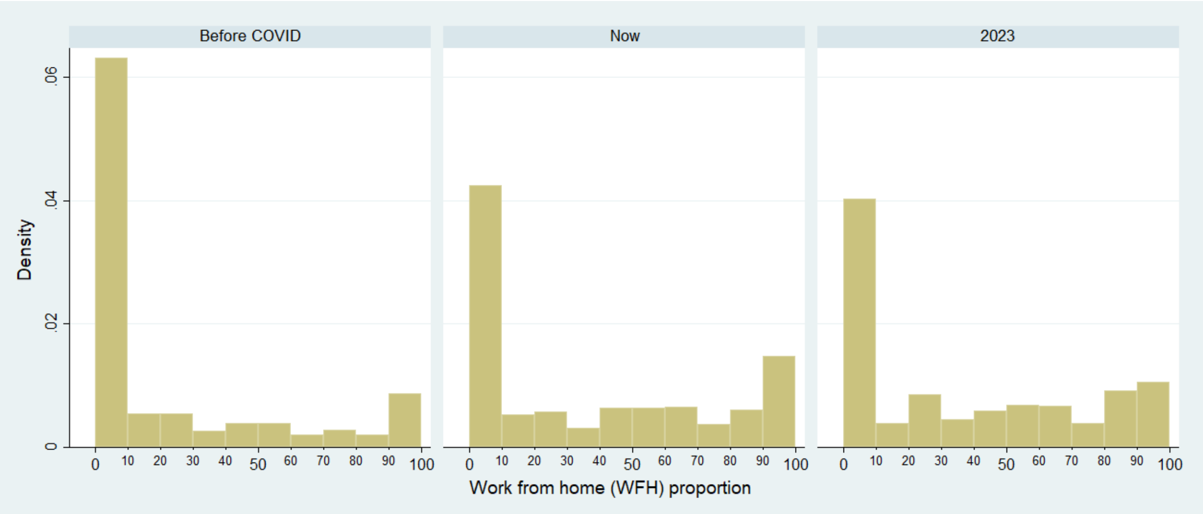

Figure 5. The distribution, by period, of the percentage of working days that are worked from home in the GSMA

We investigated the prospect of more employees starting to work at satellite offices (in space which is shared with others or rented for your organisation only) instead of the main office they went to before COVID-19. In 2023, it is anticipated that some amount of work will occur at a satellite location which we suggest is relatively closer to an employee's home than the Pre-COVID-19 office location; we call this 'Working near Home'. 34.72% of the sampled organisations (Figure 6) indicated that they will use satellite offices which represents an average 14.34% of staff in the future working in a satellite office or, on average one in 6.7.

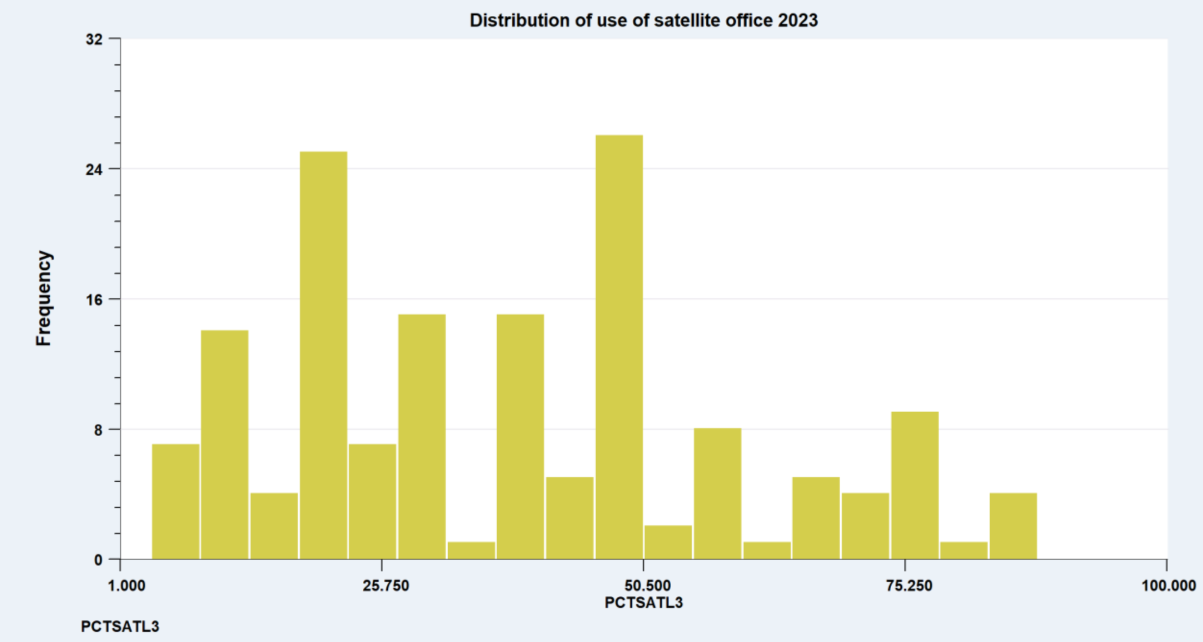

Figure 6. The distribution, by period, of the percentage of employees in 2023 who will start working at satellite offices if satellite office will be used (160 of 459 organisations)

3.1 Distinguishing the Sydney Central Business District and Other Locations

There has been a lot of interest in how the Central Business Districts of major cities have been impacted by the pandemic during lockdowns and periods of relaxation and removal of restrictions. It is well known that the decline in office workers, many of whom are in occupations that are more amenable to working from home (Hensher et al. 2022, 2022a), has been tumultuous in the CBDs compared to other locations, and this is indeed shown by the findings of our survey. In April 2022, at the time of the survey, noting that in Sydney at this point in time, vaccination rates including booster shots, sits at around 90% of the eligible population and there are no restrictions at all on the movement or gathering of people other than compulsory masks on public transport, the percentage of days WFH was 50% (2.5 days a week) where the main office is in the CBD and 28.5% (1.4) where the main office is in other locations (Figure 7). The percentage of employees WFH on any one day in 2023 is expected to be 46.4% for the CBD (i.e., 2.3 days per week) and 29.8% at other locations (i.e., 1.5 days per week), suggesting a slightly lower incidence of WFH in the Sydney CBD in the next year.

This mirrors the relative difference in the percentage of workspace change compared to pre-COVID-19 (100%) of 67% in the Sydney CBD and 73.4% in other locations, with this becoming in 2023, an estimated 72.4% and 81.7% respectively (Figure 8). We see some anticipated recovery towards pre-COVID-19 levels, however even the higher average estimate of 81.7% aligns well with what many pundits are suggesting for the number of workers in the CBD at any one time, namely 80%.

One of the most interesting new measures of influence on the main office work space is the growing interest in utilising space in satellite office locations, on a pay for usage basis (Figure 9). Surprisingly, the finding is very similar for both businesses located pre-COVID-19 in the Sydney CBD and at other locations, at around the 14.3%, which tends to suggest that the interest in using satellite office space is very generic by location and is linked to what we call working near home in contrast to working at home, reducing the frequency, distance and stress associated with daily commuting.

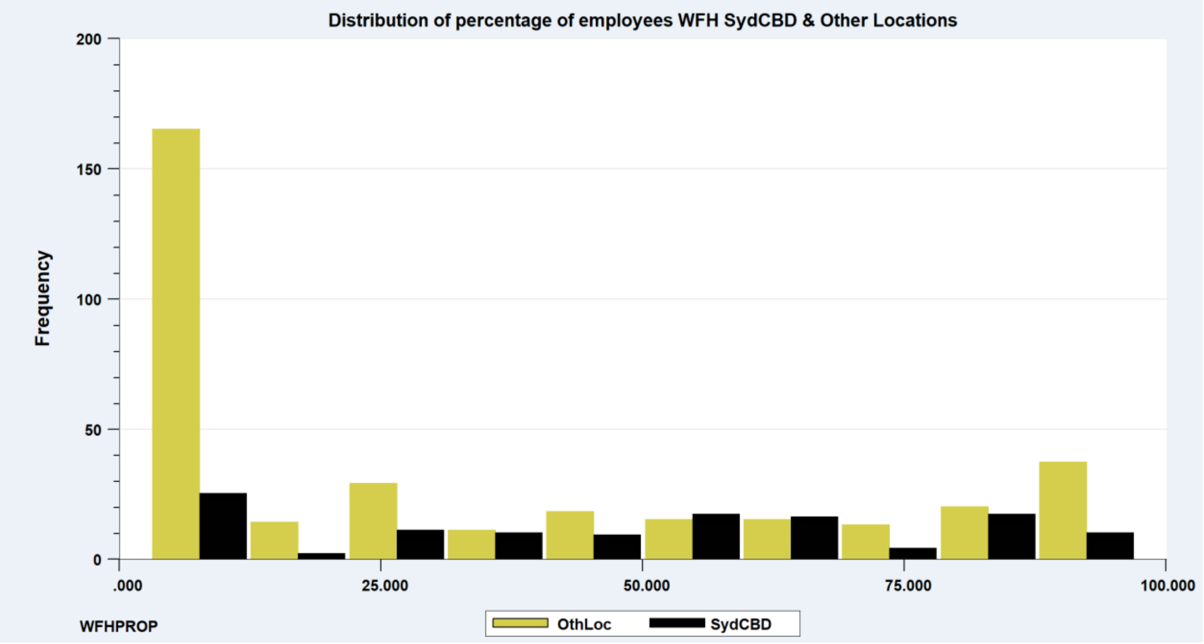

Figure 7. The frequency distribution of percentage of employees working from home in 2023 (horizontal axis) where the main office is in the CBD or at other locations

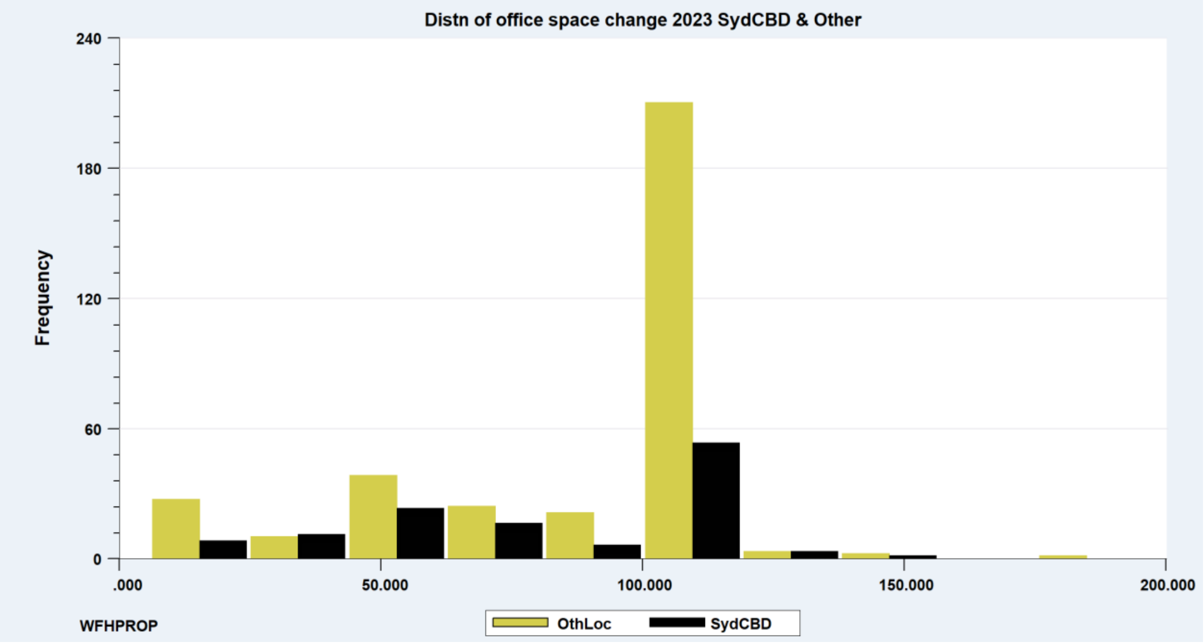

Figure 8. The frequency distribution of percentage of main location office space change in 2023 (horizontal axis) compared to Pre-COVID-19 where the main office is in the CBD or at other locations

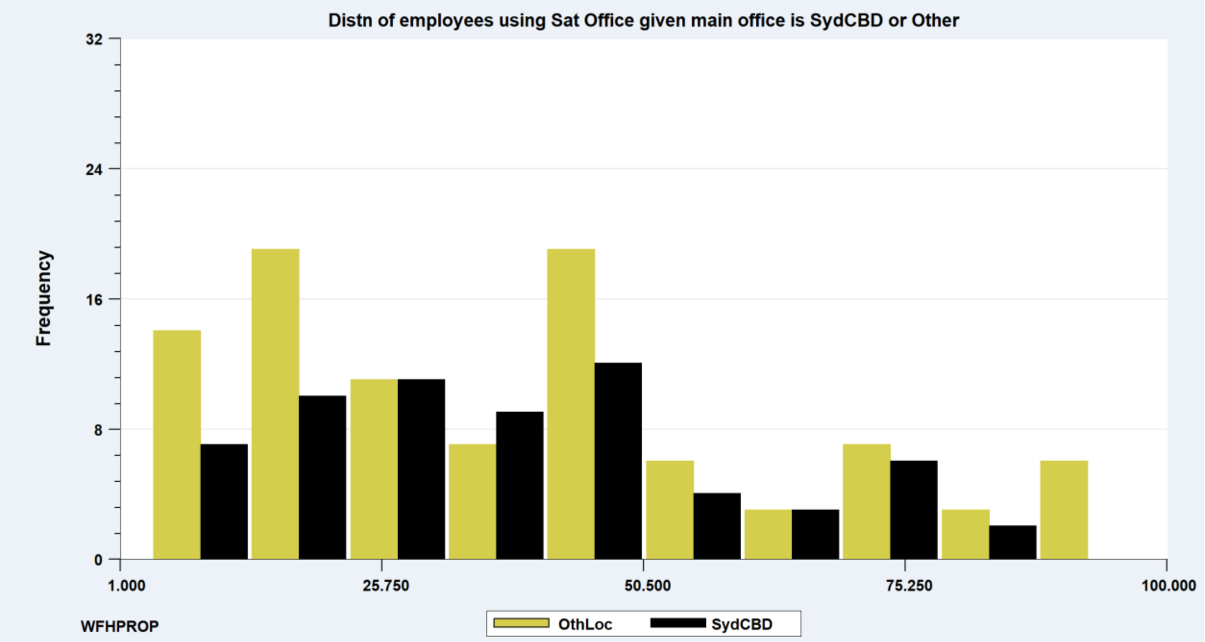

Figure 9. The frequency distribution of the percentage of employees in 2023 (horizontal axis) who will start working at a satellite office if a satellite office will be used whose current main office is the Sydney CBD or another location

4 Model of Influences on Changing Work Space Capacity

In this section we propose and estimate a regression model where the dependent variable is the percentage change in workspace at the main office location in April 2022 and in 2023 compared to the level (set at 100%) pre-COVID-19. We use a random effects (RE) regression model to account for data obtained from three periods.

4.1 The Random Effects Regression Model

Also called a variance components model, a RE regression model is a statistical model where the model parameters are random variables and which assumes that the data being analysed are drawn from a hierarchy of different populations whose differences relate to that hierarchy. We also have a set of candidate explanatory variables which we are interested in seeing what role they might play in influencing the workspace capacity in each of the three periods. To have the parameter estimates associated with these explanatory variables vary across periods, we interact them with period-specific dummy variables. The standard one-way random effects model (REM) is given in equation (1).

$$y_{it} = \alpha + \boldsymbol{\beta}'\mathbf{x}_{it} + u_i + \varepsilon_{it} \quad (1)$$

The variation across groups (*i* organisations) or time (i.e., *t* periods) is captured in simple shifts of the regression function. These models are the random effects models characterised by μ_i being uncorrelated with x. ε_{it} is the unobserved error across all periods and organisations. Under this assumption, the model can be estimated consistently by ordinary least squares. This model assumes that:

$Cov(u_i, x_{it}) = 0$ for all t, and $E[u_i \mid x_{it}] = 0$, $Var[u_i \mid x_{it}] = \sigma_\mu^2$, $Cov(\varepsilon_{it}, u_i \mid x_{it}) = 0$. The random effects model is a generalised regression model. It is homoscedastic, as all disturbances have variance $Var[\varepsilon_{it} + u_i] = \sigma^2 = \sigma_\varepsilon^2 + \sigma_\mu^2$. But, for a given *i*, the disturbances in different periods are correlated because of their common component, u_i, and $Corr\left[\varepsilon_{it}+u_i,\varepsilon_{is}+u_i\right]=\rho=\sigma_{\mu}{}^{2}/\sigma^{2}$. The efficient estimator is generalised least squares.

4.2 Results of Random Effects Model

The final model developed for the GSMA (459 organisations) is summarised in Table 3, where the dependent variable is the percentage change in the workspace of the main office in April 2022 and 2023 relative to 100% for Pre-COVID-19. Direct average elasticities derived from the model are given in Table 4. This model was selected after an extensive assessment of numerous socioeconomic, attitudinal and travel-related candidate variables.

The total variance of error consists of the variance of error between the periods for all organisations, ε_{it}, and within organization, μ_i. The results show that the variance within a time period is the dominant variance. This implies that COVID-19 is the dominant force and cause for businesses changing workspace, and differences of workspaces are not due to differences among other factors. This will give confidence for recovery once the pandemic is 'over'. Eventually, the before COVID-19 workspaces may recover to some extent given that COVID-19 is the dominant reason. However, such recovery will take time, shown by the closeness of current workspace and expected 2023 workspace levels and the growing evidence that WFH to some extent is here to stay as a non-stigmatised model of hybrid working. The model findings align well with the general direction of the empirical evidence from market monitoring, set out in Section 2.

The findings from the workspace random effects regression model suggest that during the pandemic, as measured in April 2022, two years on from the beginning of the outbreak of COVID-19, the increased incidence of WFH has, *ceteris paribus*, resulted in a reduction in the amount of workspace in the main office location throughout the GSMA. Taking the 35% of working days as being WFH now compared to 20% pre-COVID-19 for the organisations in the sample (see Table 1), we have a 14% absolute greater incidence of WFH or a 70% increase, and given the direct point elasticity of 0.059 (Table 4), this equates to a 4.13% decrease in the average amount of office space at the main workplace location. In 2023 we see a similar anticipated further change in the incidence of WFH but a higher direct point elasticity of -0.0676 resulting in a 4.72% decrease in the average amount of office space at the main workplace location. Hence there is close to a 5% reduction in leased or owned office space.

With many businesses supporting WFH on average one to three days a week and slowly introducing staggered (flexible) working hours, the reduction in office space is still much lower than the number of employees returning to the office and a continuing low occupancy rate, reported as 41% for Sydney[34]. Our survey suggests that the total drop in office workspace or office vacancies is close to an average of 28% in April 2022, and expected to be 21% in 2023. This suggests some recovery of space being leased or owned, and the full recovery to the pre-COVID-19 office occupancy level most likely taking much longer, and hence the decrease due to WFH is only one reason for the reduction of office capacity, representing 25% of the reason in 2023.

At the same time, in 2023 it is anticipated that some amount of work will occur at a satellite office location (14.34%) which we suggest is relatively closer to an employee's home than the Pre-COVID-19 office location. The mean elasticity estimate of 0.0198 indicates that, *ceteris paribus*, a 10% increase in the employees using a satellite office results in a 0.198% reduction

[34] https://www.commercialrealestate.com.au/news/workers-trickle-back-to-offices-but-cbds-remain-critically-underpopulated-1130458/

in the percentage change in the expected amount of workspace at the main office location in April 2022.

Table 3. Summary of GSMA random effects models for all three periods of data

Variable	Acronym	Units	Parameter estimate	t-value	95% confidence interval	
Pre-COVID-19:						
Number of employees	EMPNUM1	number	0.0187	2.80	0.0056	0.318
Percent of days working that are WFH	WFHP1	%	0.1384	2.73	0.039	0.238
April 2022:						
Percent of days working that are WFH	WFHP2	%	-0.3236	-7.91	-0.404	-0.243
2023:						
Percent of days working that are WFH	WFKP3	%	-0.3732	-8.92	-0.455	-0.291
Percentage of employees using a satellite office	PCTSATL3	%	-0.0089	-2.96	-0.147	-0.003
Context Variables:						
Industry = education and training	EDUC	1,0	-7.4322	-2.61	-13.01	-1.867
Industry = Real Estate	REALEST	1,0	-23.018	-2.76	-39.34	-6.69
Constant			88.871	53.2	-39.34	-6.691
Random effects*:						
Var (ε)			1427.57			
SD (ε)			37.78			
Var (μ)			0.2698			
SD (μ)			0.5195			
Corr [v(i,t),v(i,s)]			0.00019			
R-squared			0.13			

* Variances computed using ordinary least squares (OLS) and least squares dummy variable (LSDV)

Table 4. Summary of mean point and arc elasticity estimates
Computed by average over sample observations
(t-value in parenthesis)

Influence	Mean Elasticity
Percent of days working that are WFH (WFHP1)	0.0095 (2.97)
Percent of days working that are WFH (WFHP2)	-0.0590 (5.95)
Percent of days working that are WFH (WFHP3)	-0.0676 (6.45)
Percentage of employees using a satellite office	-0.0198 (3.16)
Number of employees	0.0098 (3.03)

5 Conclusions

There are many ongoing challenges to governments, to the broad base of employers, and even to households, as they work out how best to encapsulate the non-stigmatised WFH future (Beck and Hensher 2020). The implications for funding of infrastructure, re-prioritising land use plans, growing new office settings which include satellite offices, and what the future office environment might be are profound (Ramani and Bloom 2021).

This paper has identified how working from home and a growing interest in the use of satellite offices impacts on the amount of primary office space likely to be required (or preferred) in the near future as we seek out evidence on what the ‘next normal’ may look like in the office property market. The findings from our survey of 459 organisations, and its reflection in a random effects regression model, align extremely well with the reported changes occurring in the Sydney market. Given this alignment, it is plausible that the model will give good insights into what may happen to work space under different levels of working from home (measured as a proportion of days worked from home rather than a number of days measure).

We analyse the change in work space over a range of different WFH proportions, in respect of WFH (Figure 10) and use of satellite offices (Figure 11) on the quantum of main office space. The range of the percentage of days working that are WFH that we assessed suggests a potential drop in the amount of office space required at the main office of between 85.2% and 62.8%. If we work with what appears to be the most likely scenario of one to two days WFH per week for many occupations, our model predicts a reduction in the percentage of office space compared to pre-COVID-19 of 79.6% for an average of one day WFH and 72.1% for an average of two days WFH. The decline of 20% to 28% in 2023 relates reasonably well to an occupancy rate in February 2022 of 18% for the Sydney metropolitan area (Williams 2022).

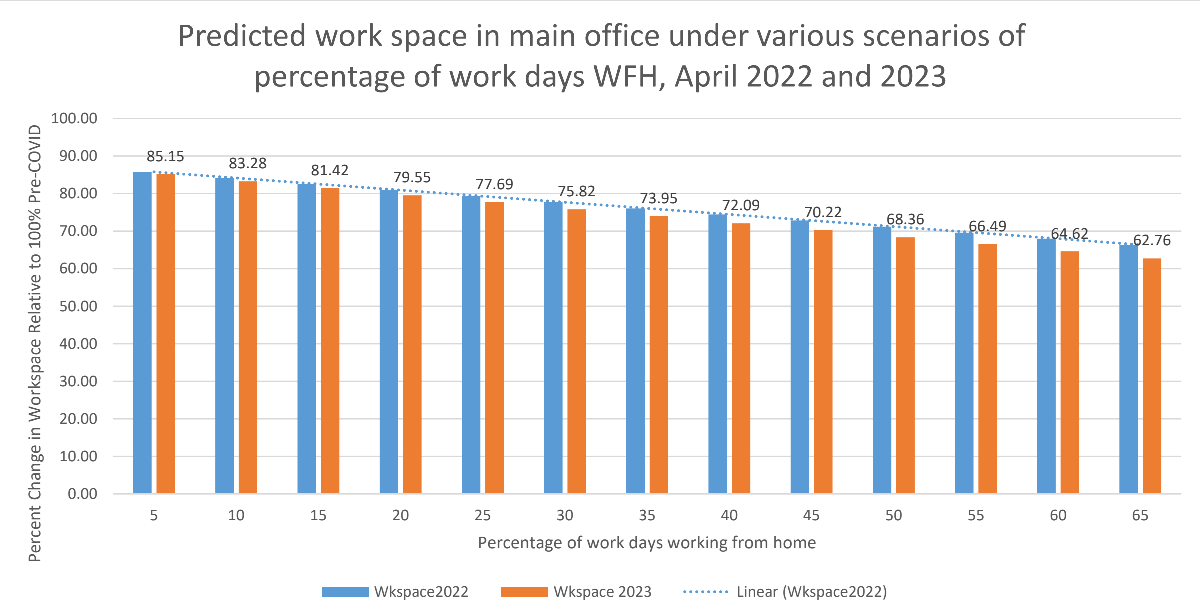

Figure 10. The expected influence of WFH levels on required office space in the main location in April 2022 and 2023

Figure 11 suggests that the growth in the use of satellite offices changes very little the quantum of main office space that is likely to be in place in 2023. The predicted impact at the mean of the likely use of satellite offices is close to 74%, which is the same range as the likely impact of WFH in Figure 10, reinforcing a view that the decrease in office space in the immediate future relative to the period just before the onset of COVID-19 is around 75%. We might speculate that some employees will use combinations of all three locations – the main office, the satellite office and WFH, adding some variety to their more flexible lifestyles. If true, to some degree, this may explain why we do not anticipate a significant change in the amount of main office workspace as satellite office use grows.

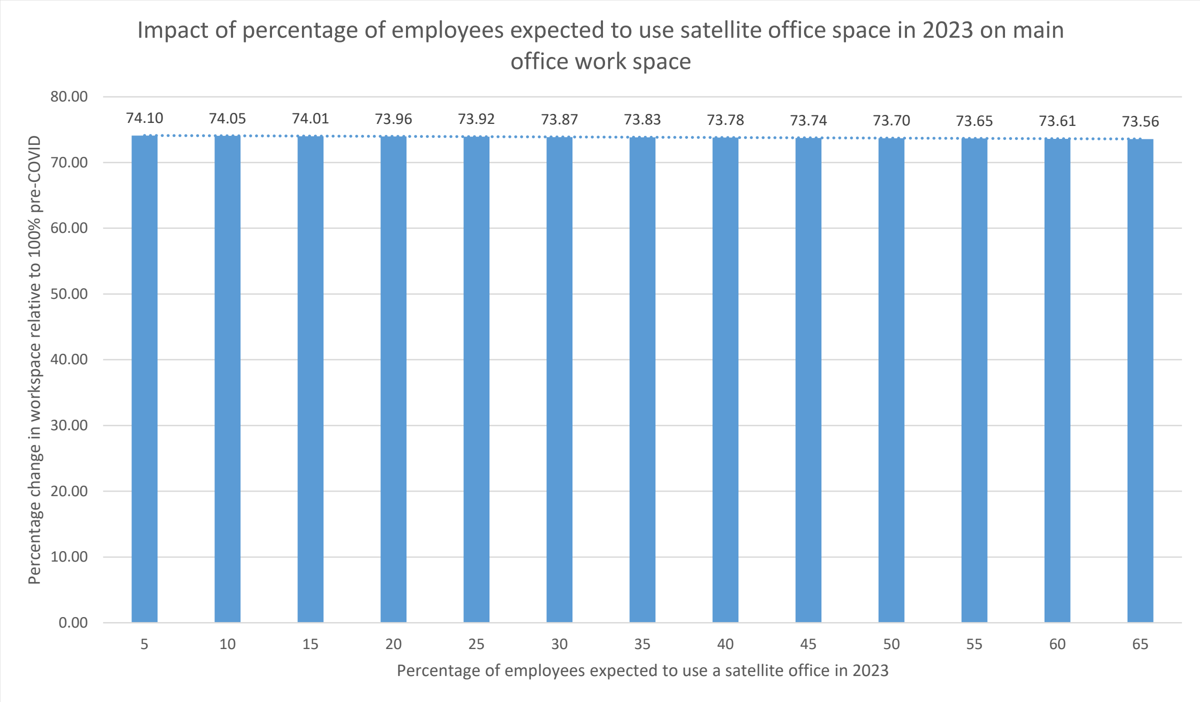

Figure 11. The expected influence of employees using a satellite office on required office space in the main location in 2023

These findings are significant in assessing policy settings that government needs to consider with respect to initiatives designed to manage changing demands on servicing various locations throughout the GSMA, especially infrastructure and ways to support businesses in delivering benefits to society as a whole. With WFH being seen as one of, if not the most, impactful transport policy instrument available for many years, the policy settings that flow from this WFH and WNH 'next normal' are expected to include infrastructure investments that align more with suburban investments to benefit walking and cycling and the broader agenda of the 20 minute city where reduced commuting distances become a greater priority. Importantly the changed profile of commuting may look more like reduced frequency over a week while preserving much of the longer distance commute over fewer days while either avoiding commuting at all on some days or commuting to a close by satellite office. These structural changes are evolving and look like becoming a permanent fixture of the mobility land use scape.

We recognise that this is a first attempt (indeed one of the first in the academic literature) to examine the impact of COVID-19 on work space volume decisions. It is likely that, after two years of "experimentation" with working from home, and with businesses now seeing largely unchanged productivity despite the challenges of the pandemic, decision makers are likely beginning to think more concretely about the size of main physical workplace that will be required in the future. As such, it is important that research in this area begin as it has been relatively overlooked, but will also be an important determinant into future travel patterns within urban areas and indeed the composition and reimaging of many office-dense city environments. In ongoing research, we are taking the evidence and model from this paper and building it into an integrated transport and land use model system for the GSMA, called MetroScan. We have already built WFH into Metroscan (Hensher, Wei and Liu 2022), but need to adjust the occupancy levels of employees in the office and workspace at each location in the GSMA.

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Appendix W. Paper #17: How has COVID-19 impacted on the propensity to Work from Home? An assessment over four time periods between March 2020 and June 2021

David A. Hensher
Matthew J. Beck
Camila Balbontin

Abstract

The COVID-19 pandemic has had a seismic impact on the world of work, with working from home (WFH) being a non-marginal structural response that looks like establishing itself, without stigma, as part of the 'next normal' pattern of work activity. With growing support and preference revelation from both employees and employers, we might anticipate a settling in of WFH around one to two days a week, varying by occupation depending on the ability to work remotely. Although there are a growing number of studies that have analysed data collected at a point in time or over time during the pandemic, there is dearth of analysis that treats the waves of collected data as a repeated cross section that is jointly modelled to assess systematically, the changing roles of various influences on the proportion of working days that are worked from home. This paper estimates random effects regression models for the Greater Sydney Metropolitan Area and South East Queensland over four waves of data collected in 2020 and 2021. By jointly estimating four waves of data within a single modelling framework, we are able to track the changing roles of the influences found to be statistically significant across the waves. The elasticity outputs reveal how these influences impact on the propensity to WFH, giving clues on whether we are starting to see a stabilisation of WFH activity that can be reflective of a 'new normal'.

***Keywords**:* COVID-19, working from home, Australian metropolitan experience, four waves, elasticities, random effects regression, new normal

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1 Introduction and Key Insights to Date

The interest in the impact that COVID-19 is having, and will likely continue to have, is unabated. Zhang and Hayashi (2022) reviewed the numerous papers that have been published in the first two years of the pandemic (up to March 11, 2022), and synthesised the key contributions, where the focus was on the impact on passenger transport, immediate measures taken to cope with the pandemic, how individuals and organisations adapted their travel activity in particular, and what this might mean from a policy position going forward in the future for all stakeholders. At the centre of much of the growing number of contributions is the changing nature of a real world experiment which has turned out to have many unintended positive consequences for both employees and employers, and has resulted in what may be the greatest transport policy level for desirable change we have seen for many years.

This change is especially noticeable in terms of benefits experienced by many (but not all) workers who have been able to work from home (WFH). There is a ground swell of evidence emanating from numerous studies in many countries that flexibility is here to stay, and that employers who offer a balance of WFH and in office will attract more high-quality employees. There is a noticeable increase in support from employers for work/leisure life balance of employees. About 75% of the increase in WFH will likely be permanent, with one in five workdays being from home post-COVID-19[35]. One of the most striking takeaways from the increase in WFH over the last two years is its persistence, without stigma.

We also see continuing nervousness about using public transport[36], and more generally any shared form of transport with strangers, which has resulted in part at least, in increased ownership of private cars (often as a first time purchase of a car), which has increased car use, but noticeably with a flattening of the traditional peaks and growth in off-peak road traffic, in part linked to greater flexibility in when non-commuter travel can occur. With reduced commuting activity by each worker, the cost and time outlays in commuting take on a new set of values in terms of sensitivity to outlays that were previously over five days a week and are now much less; consequently there is an expectation that commuters will be less sensitive to parking and fuel/toll prices. In addition, some of the retained commuting activity where an employer has reduced their office space footprint (saving on lease and other costs), will be translated into the growth of work in satellite offices located closer to home. This is a nice association with the idea of a 15-20 min city, where much of previous activity that denied this outcome was commuting-related. Furthermore, the reduction in office space capacity is resulting in many employers rethinking when staff need to be in the office on the commuting days, which spills over to staggered working hours leading to an increase in single-occupant car use where car sharing was previously feasible for common spans of working hours.

The land use implications are also quite striking, with WFH associated with what is referred to as the 'suburbanisation effect'. With more time spent working at home, activities outside of the house are more likely to occur at the local level. With reduced commuting, suburbs will become more popular as activity centres, but the downtown centres will still remain important locations

[35] https://www.bloomberg.com/news/articles/2022-02-28/remote-work-seen-more-persistent-than-u-s-city-planners-expect, 28 February 2021.

[36] Car and freight travel have reached pre-pandemic levels, but public transit and passenger rail are not expected to recover fully. Americans' preferred means of travel were shifting away from public transit before the pandemic, and these changes accelerated during the pandemic and afterwards. Americans prefer the flexibility and safety of cars rather than group travel, where they risk catching COVID. TomTom, which provides traffic information and navigation systems, estimates that traffic is higher midday than before the pandemic, and slightly lower during peak hours. See https://www.forbes.com/sites/dianafurchtgott-roth/2022/03/31/out-with-buses-in-with-rideshare/?sh=2a0dea23328d

for not just business but entertainment and accommodation, which we refer to as downtown activity precincts (in contrast to reference to a central business district).

Figure 1, based on data collected in late 2021[37], shows how the time reallocated from reduced commuting is used on work and leisure-related activities. For the GSMA (NSW), 23% of all time saved is associated with leisure activities undertaken in the home, 18% being household tasks (i.e., chores), and 9% is associated to leisure outside of the home, i.e., a total of 50% of the saved time is allocated to leisure activities plus household tasks. The equivalent percentages for SEQ (Qld) are 17.5% for leisure activities in home, 19% for household tasks, and 11% for leisure activities outside home, i.e., 47.5% of all saved time is allocated to leisure plus household tasks in SEQ. The out-of-home activity adds additional traffic onto the road network in particular although some of this travel is local and increasingly by active modes.

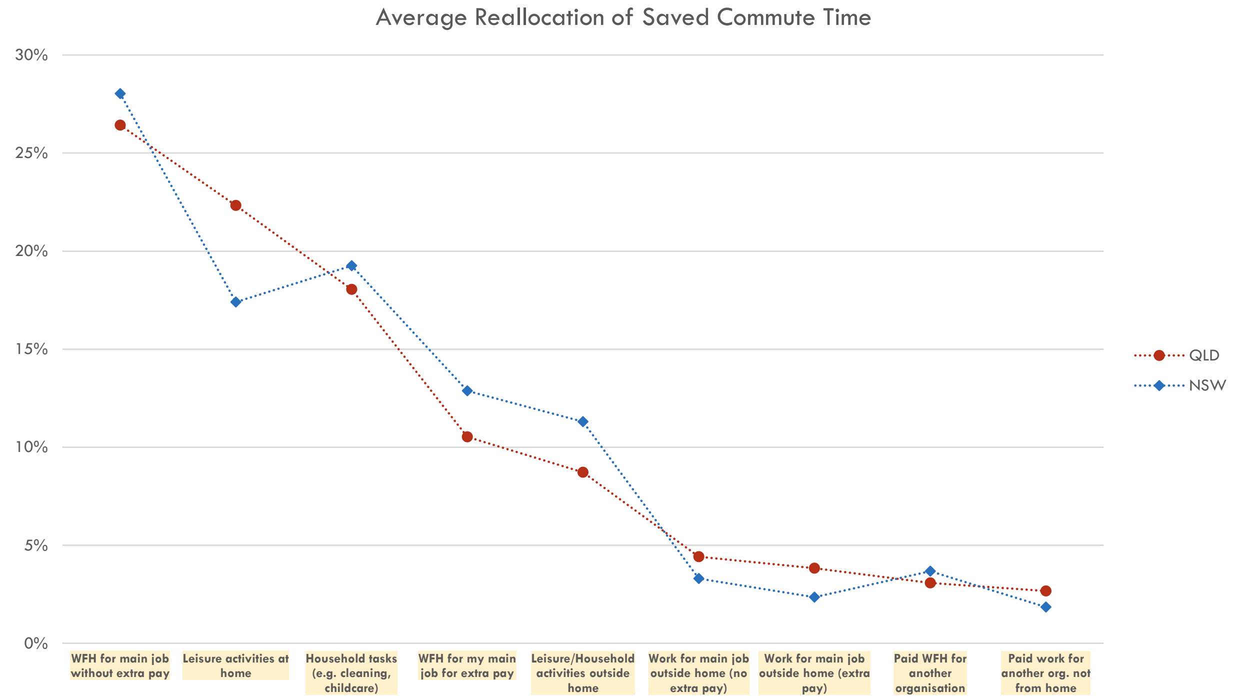

Figure 1. The breakdown of the allocation of saved commuting time within leisure and work in the GSMA and SEQ

Ramani and Bloom (2021) find that in dense US cities, households, businesses, and real estate demand have moved from central business districts towards lower density suburban areas, labelling the phenomenon the "Donut Effect" reflecting the movement of activity out of city centres to the suburban ring. While many have speculated that WFH might result in people moving out of a city altogether, this US study does not find evidence for large-scale movement of activity from large US cities to smaller regional cities or towns. This might be explained by the growing evidence that working patterns will increasingly be hybrid, with workers commuting to their business premises typically three days per week.

Delventhal and Parkhomenko (2022) suggest that there are at least four views on WFH now and in the future. First, WFH during the pandemic is a transitory phenomenon, and that once people are allowed to and feel safe they will return back to the office. Second, Individuals have experienced through WFH a shock to preferences. Barrero et al. (2021) suggest that

[37] This data was collected after waves 1-4 but is sufficiently relevant telling the story on activities undertaken as a result of reduced commuting activity that we have included it in this paper. See Beck and Hensher (2022c) for analysis of data collected after Wave 4.

working from home was always great but that social norms and stigma limited it; and that we now observe a positive change in attitude by the average worker towards WFH after having actual experience with WFH. Third, events of the past two years may amount to a technology shock, with the early months after March 2020 seeing a burst of innovation directed at making remote work, work. Digital software was widely adopted, new policies and procedures were put in place, and individuals and organisations did a great deal of learning by doing, all on top of a sizeable investment in remote-complementary physical capital. Fourth, it could be that the work mode is a coordination game with multiple equilibria if everyone is in the office, but if enough people go remote, workers prefer to WFH. They suggest that the most feasible explanation of increased and continued WFH is due to a preference shock, something we also find in the modelling undertaken in this paper.

The traditional thinking, highly associated with predict and provide, is now better aligned with vision and validate, since not only are the new opportunities preferred and supported by most areas of society, they come on top of the broader environment challenges that are looming large in climate change which has resulted in changes in weather patterns accompanied by increased periods and severity of drought and floods. Hensher et al. (2022) show in an integrated transport and land use model system that the levels of WFH observed in the GSMA in mid-2021 have resulted in a 10 percent reduction in CO_2 emissions from land transport, both passenger and freight. This is significant and unlikely to be achieved by any single transport initiative with the possible exception of road pricing reform (Hensher et al, 2021c, 2022b).

The paper is structured as follows. The next section provides a brief literature review on the impact that WFH is having on travel activity, noting that we and others have covered much of this material extensively in many other publications. This is followed by a descriptive overview of the four wave data sources collected from March 2020 to May 2021, and then we propose a model framework centred on a random effects regression model. The findings from model estimation for the two geographical jurisdictions of our focus, the Greater Sydney Metropolitan Area and South East Queensland, are presented and discussed together with the informative elasticity estimates. The paper concludes with a synthesis of the main findings and future research themes.

2 Descriptive Overview of the Data

The data has been collected throughout Australia at four points in time since the pandemic took hold in March 2020 (Figure 2). The four waves are associated with periods of lockdown and easing of lockdown, enabling us to capture the influence that degrees of severity of restrictions had on the propensity to work from home, either under a compulsory mandate of government or by choice. Wave 1 was collected in the first two weeks of April 2020 when much of Australia was in lockdown, with restrictions being eased from late April onwards into May with dates varying by State. When we commenced Wave 2 in the middle of May most restrictions had eased (with nationally only 100 deaths from COVID-19, heavily linked to cruise ships) with schools reopening and limits of the number of people that could gather in public places, restaurants, religious locations, and parties. Beck and Hensher (2020, 202a) discuss the impacts on work productivity, support from employers for WFH where it is possible not to have to be on-site, and a large number of other responses related to bio-security concerns in using public transport and other shared modes such as ride share, and attitudes towards working from home in the future after these new forced experiences.

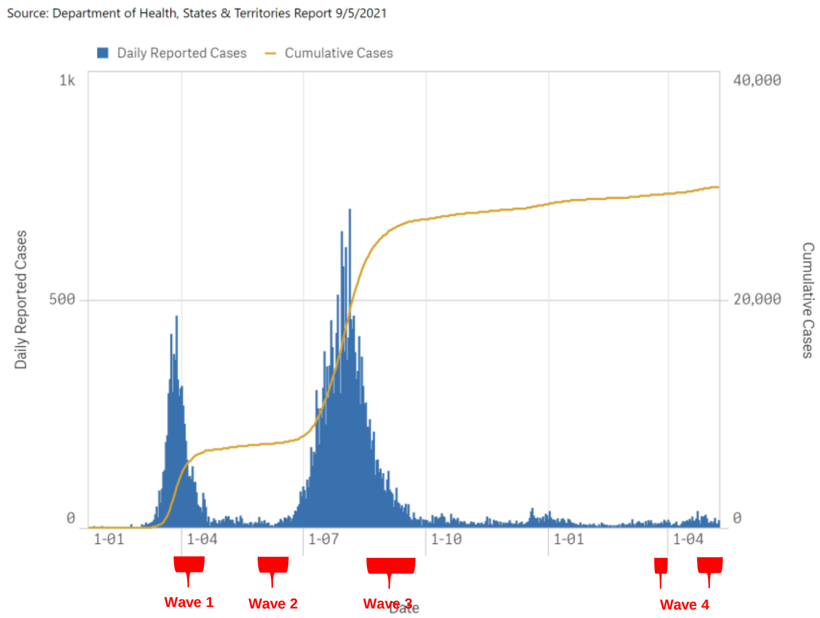

Figure 2. The timing of the four waves of data collection in 2020 and 2021.

Wave 3 was collected over an extended period between early August and mid-October 2020 where we witnessed state border closures, a severe lockdown in Victoria but increasing easing of restrictions in other States. Full details are provided in Beck and Hensher (2021, 2021a), with a descriptive comparison of Waves 1 to 3, and a focus on the changing dynamics of travel activity, concern with public transport, and attitudes surrounding activity given the perception of risk of COVID-19, as well as the level of public support for regulatory intervention and restrictions on movement. Hensher et al. (2022) proposed a new way of integrating the choice between WFH and commuting into a strategic transport model system with a mapping equation to identify the influences on the probability of WFH at an origin-destination level for both the Greater Sydney Metropolitan Area and South East Queensland. Wave four was in the field during April-May 2021, during a period where we had started to see most restrictions removed, except for State border closures and international travel unless by exception permission, just prior to an extended lockdown in NSW and Victoria when the Delta virus took hold. We had anticipated that the data from Wave 4 would represent a period of accumulated experience with lockdowns and easing of restriction and a period of reflection on experience with WFH (see Hensher et al. 2022b). This was indeed a period of significantly reduced restrictions, which was before an unexpected growth in people catching COVID as a result in the main of the Omicron strain of the virus (Beck and Hensher 2022c).

A descriptive profile of the data over the four waves is summarised in Table 1 for the two geographical jurisdictions we are investigating in this paper, namely the Greater Sydney Metropolitan Area (GSMA) and South East Queensland (SEQ). We limit the table to those variables that we have found to have a statistically significant impact on the incidence of WFH in one or more waves of data in each location. Some data items were not collected across all four waves, due in part to the journey of exploration and identifying some new data items as we progressed through the waves. Employer perceived productivity in Wave 4 was asked but unfortunately a coding error resulted in this data item being ignored by too many eligible respondents who should have answered it.

Table 1. Descriptive profile of key data items across Waves 1 to 4 for the GSMA and SEQ

	Wave 1		Wave 2		Wave 3		Wave 4	
	GSMA	**SEQ**	**GSMA**	**SEQ**	**GSMA**	**SEQ**	**GSMA**	**SEQ**
Survey period	30 March – 15 April 2020		23 May-15 June 2020		4 August-10 October 2020		April-May 2021	
Number of workers	82	63	120	44	413	332	421	334
Proportion of Work Days that are WFH	0.595 (σ=0.463)	0.644 (σ=0.467)	0.591 (σ=0.469)	0.417 (σ=0.476)	0.410 ((σ=0.442)	0.368 (σ=0.434)	0.313 (σ=0.421)	0.271 (σ=0.405)
Age	44.5 (σ=14.2)	46.4 (σ=11.5)	42.3 (σ =13.3)	42.1 (σ=11.7)	40.4 (σ = 13.5)	40.5 (σ =13.8)	41.5 (σ=14.7)	42.7 (σ=13.9)
Male	74.4%	38.1%	30%	31.8%	41.1%	30.1%	47.3%	42.2%
Manager	3.7%	0%	1.7%	4.5%	16.2%	12.3%	19.2%	12.3%
Professional	54.8%	49.2%	45%	27.3%	30.8%	31.6%	28.7%	27.8%
Like to WFH more in future	43.9	55.6%	42.5%	27.2%	39.5%	37.9%	n/a	n/a
Number of days WFH in future	1.89 (σ=1.8)	2.04 (σ=1.9)	2.29 (σ=2.0)	1.95 (σ=2.0)	1.74 σ=1.9)	1.9 (σ=2.0)	1.51 (σ=2.1)	1.31 (σ=2.1)
My work cannot be done from home	n/a	n/a	n/a	n/a	14.8%	16.6%	46.7%	52.1%
Total weekly one-way commuting trips	5.69 (σ=4.6)	4.39 (σ=5.8)	6.84 (σ=7.1)	5.48 (σ=5.2))	5.32 (σ=8.6)	5.29 (σ=6.0)	5.92 (σ=7.3)	5.98 (σ=6.4))
Distance to work from home	n/a	n/a	n/a	n/a	18.4km (σ=19.4)	16.9 km (σ=17.4)	19.8km (σ=19.6)	20.9 km (σ=20.5)
Employee perceived more productive	n/a	n/a	n/a	n/a	21.3%	20.5%	16.2%	9.3%
Employee perceived same productivity	n/a	n/a	n/a	n/a	20.3%	21.9%	14.0%	15.3%
Employer perceived more productive	20.7%	38.1%	17.5%	20.45%	27.8%	31.9%	n/a	n/a
Employer perceived same productivity	35.4%	31.7%	45.8%	50%	42.1%	40.1%	n/a	n/a

The proportion of working days that are worked from home in the GSMA vary from a high average of 0.595 in Wave 1 to a low average of 0.313 in Wave 4, with the range for SEQ being greater from a high of 0.644 in Wave 1 and a low of 0.271 in Wave 4. The distributions are shown in Figures 3 and 4. There is a clear trend towards a reduced number of days WFH from the beginning of 2020 until mid-2021, which is an important finding, but one that raises the question as to whether we have arrived at a level of WFH that is likely to become the 'next normal', showing an average of 1.3 to 1.5 days per week in wave 4 for the two locations. This is a question for ongoing research to see if the evidence in mid-2021 is reinforced in 2022 after a period of severe lockdowns in late 2021.

The average number of one-way weekly commuting trips is relatively stable over time, in a range from 6.84 to 4.39 which is typically of an average of two to three days commuting per week; although the standard deviations suggest a noticeable spread across the samples for each wave and location.

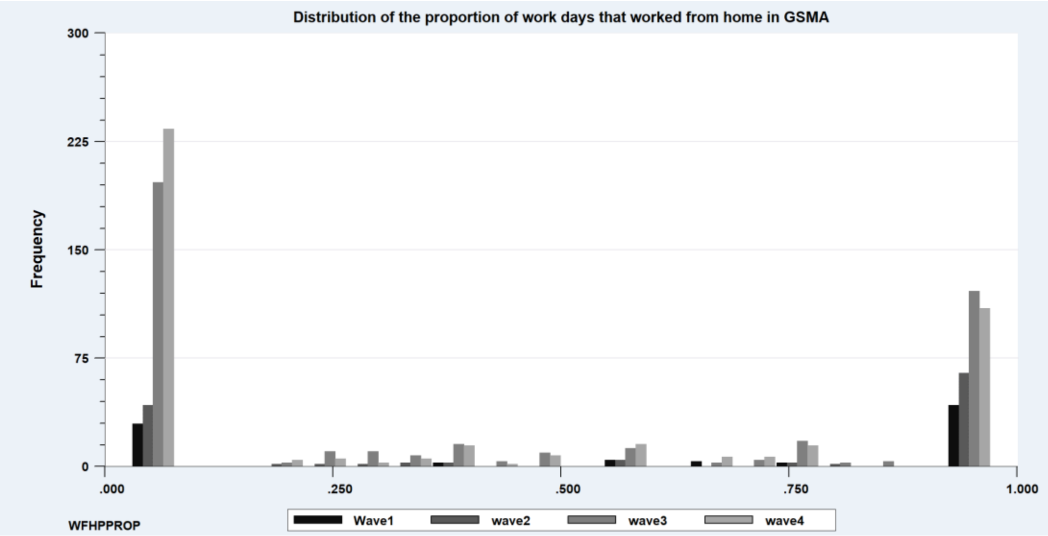

Figure 3. The distribution, by Wave, of the proportion of work days that were worked from home in the GSMA

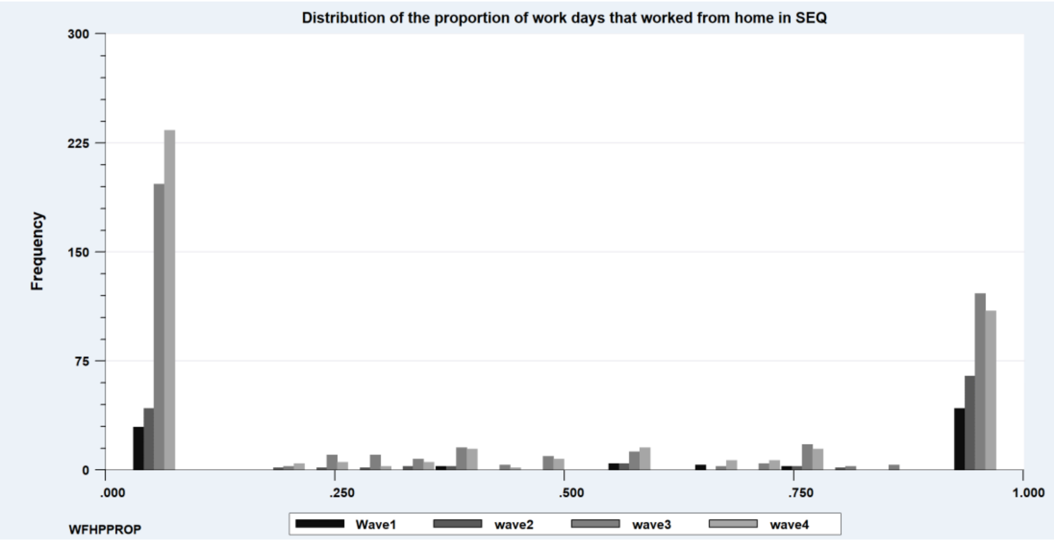

Figure 4. The distribution, by Wave, of the proportion of work days that were worked from home in the SEQ

One of the most interesting and behaviourally relevant findings is the coalescing of agreement on the level of perceived productivity of workers as reported by both employees and employers. Figure 5 shows the difference of the employer minus the employee perception of greater productivity, with zero referring to agreement on the level, which dominates the findings. We know from this data, summed across all waves and data reported elsewhere, that employers who were not supportive of WFH prior to COVID-19 were surprised and pleased to see that WFH was increasingly associated with greater employee productivity. This evidence has contributed to a growing view that WFH, to some extent, is here to stay and as a significant structural change, will lead to a major rethink by government and industry on what policies should be put in place to support what is shaping up to be a significant unintended positive consequence of the pandemic that is also seen as a new reflection on the redesign of organisations to accommodate a situation where people are seen as more than workers but as people with lives that can creatively benefit organisations who start to reflect of this.

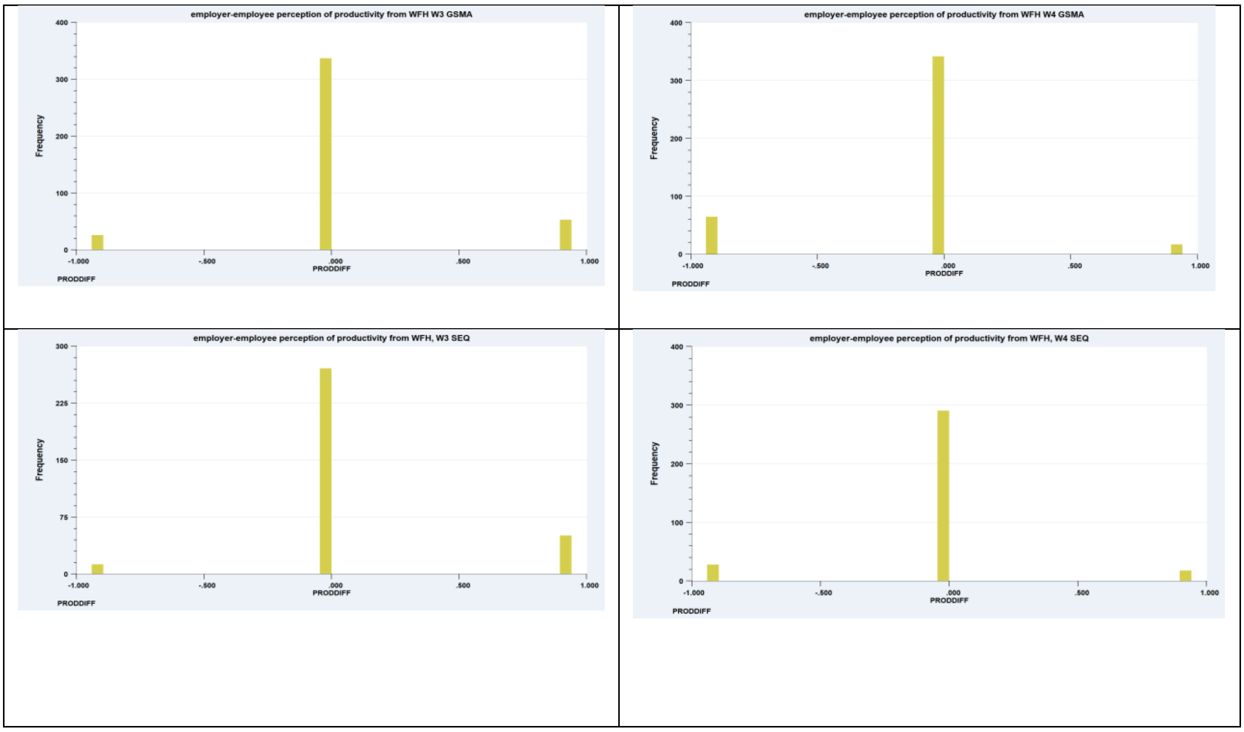

Figure 5. The difference between employee and employer perceptions of greater productivity while WFH

Another data item of particular interest is respondent preferences for days to WFH going forward (Figures 6 and 7). This was at high when asked in Wave 1 and slowly reduced to an average of 1.51 days per week for the GSMA and 1.31 days per week for SEQ. This evidence aligns well with what is the average of 1.3 to 1.5 days per week in wave 4 for the two locations. This may be suggesting that we are close to identifying the incidence of WFH in the ‘next normal’ as workers process their accumulated experiences and settle on a regular WFH profile.

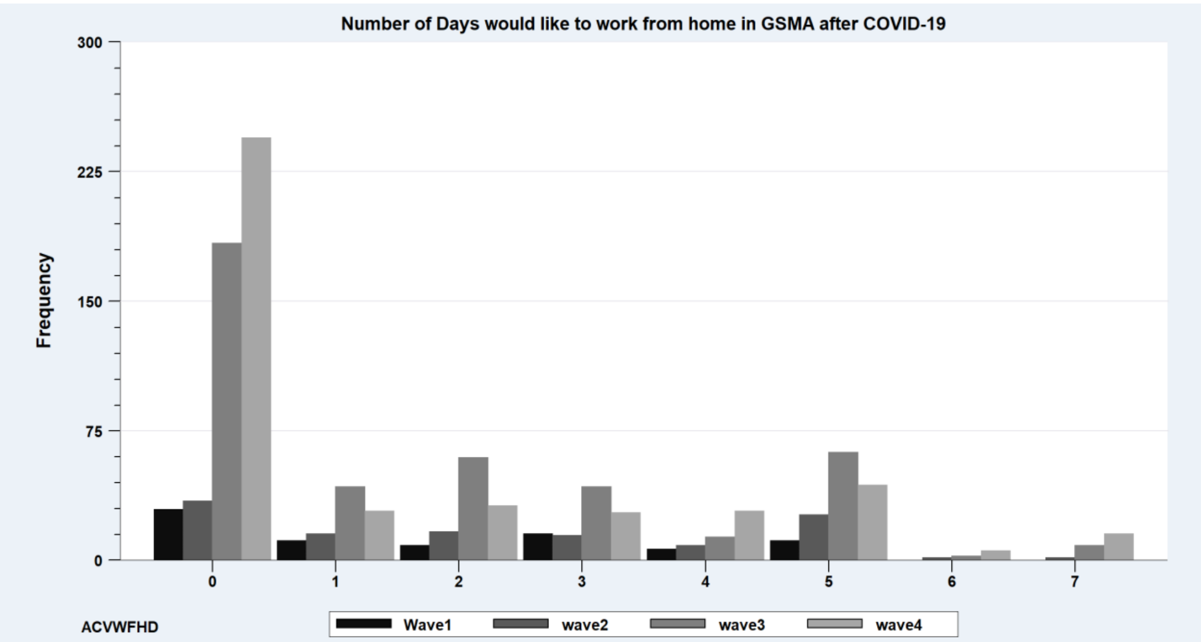

Figure 6. The preferred numbers days working from home in the future

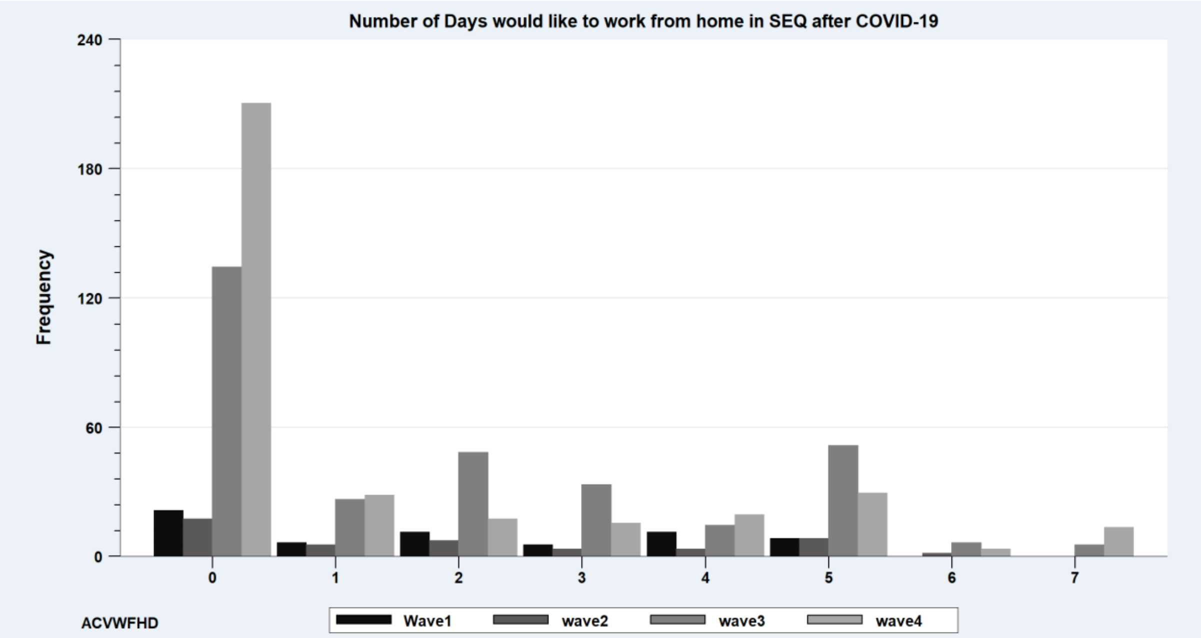

Figure 7. The preferred numbers days working from home in the future

3 Methodology

We use a random effects regression model to account for data obtained from four waves of repeated cross-section surveys, assumed to be random in order to account for random effects. Random effects are especially useful when we have uneven sampling across levels as is the case with our four waves. We also have a set of candidate explanatory variables which we are interested in seeing what role they might play in influencing the proportion of work days that are worked from home each of the four waves of data. To have the parameter estimates associated with these explanatory variables vary across periods, we interact these variables with period dummy variables. The standard one-way random effects model (REM) is given in equation (1).

$$y_{it} = \alpha + \boldsymbol{\beta}'\mathbf{x}_{it} + \varepsilon_{it} + u_i + w_t \qquad (1)$$

The variation across groups (individuals) or time (i.e., data waves) is captured in simple shifts of the regression function – i.e., changes in the intercepts. These models are the random effects models characterised by u and w being uncorrelated with x. Under this assumption, the model can be estimated consistently by ordinary least squares. The fundamental part of the random effects model is a one-way common effects specification,

$$y_{it} = \alpha + \boldsymbol{\beta}'\mathbf{x}_{it} + \varepsilon_{it} + u_i \qquad (2)$$

where $Cov(u_i, x_{it}) = 0$ for all t, and $E[u_i \mid x_{it}] = 0,\ Var[u_i \mid x_{it}] = \sigma_\mu{}^2,\ Cov(\varepsilon_{it}, u_i \mid x_{it}) = 0$. The random effects model is a generalised regression model. It is homoscedastic, as all disturbances have variance $Var[\varepsilon_{it} + u_i] = \sigma^2 = \sigma_\varepsilon{}^2 + \sigma_u{}^2$. But, for a given *i*, the disturbances in different periods are correlated because of their common component, u_i, $Corr[\varepsilon_{it} + u_i, \varepsilon_{is} + u_i] = \rho = \sigma_\mu{}^2 / \sigma^2$. The efficient estimator is generalised least squares.

4 Model Results

Separate models developed for GSMA (1036 respondents) and SEQ (773 respondents) are summarised in Table 2[38], where the dependent variable is the proportion of days worked per week that are worked from home. These models were selected after an extensive assessment of numerous socioeconomic, attitudinal and travel-related variables.

Table 2 Summary of GSMA and SEQ random effects models for all waves of data
n/s = not statistically significant

Variable	Acronym	Units	Parameter estimate (t-value)		95% confidence interval	
			GSMA	**SEQ**	**GSMA**	**SEQ**
Wave 2	Wave2	1,0	0.0928 (5.71)	0.4579 (3.1)	0.3478-0.7115	0.1685-0.7473
Wave 3	Wave3	1,0	0.0755 (3.44)	-0.0104 (0.23)	0.0325-0.1184	-0.0986-0.779
Wave 4	Wave4	1,0	0.1913 (2.2)	0.0571 (0.90)	0.0293-0.3532	-0.0673-0.1815
Wave 1:						
Age of respondent	Age1	years	0.0038 (3.98)	0.0044 (4.42)	0.0019-0.0056	0.0024-0.0063
Professional	Dprof1	1,0	0.3065 (5.18)	0.1582 (2.57)	0.1905-0.4224	0.0375-0.2790
Like to WFH more often in future	WFHFrag1	1,0	0.5345 (8.84)	0.6442 (9.79)	0.4160-0.6530	0.5152-0.7732
Wave 2:						
Age of respondent	Age2	years	-0.0049 (-2.62)	-0.0075 (-2.18)	-0.0086-0.0012	-0.0141—0.0008
Professional	Dprof2	1,0	n/s	0.2725 (3.07)	n/s	0.0984-0.4466
Like to WFH more often in future	WFHFrag2	1,0	0.5866 (11.7)	0.7166 (8.29)	0.4880-0.6852	0.5472-0.8859
Wave 3:						
Age of respondent	Age1	years	n/s	0.0024 (2.35)	n/s	0.0004-0.0044
Professional	Dprof3	1,0	0.1122 (3.94)	n/s	0.0564-0.1680	n/s
Manager	DMngr3	1,0		-0.0805 (-1.88)		-0.1642-0.0033
Work cannot be done at home	EMVRet3	1,0	-0.0946 (-2.56)	n/s	-0.1671—0.0220	n/s
Employee productivity much more than pre-COVID-19	ProdMor3	1,0	0.2750 (5.66)	0.3110 (6.53)	0.179800.3702	0.2177-0.4043
Employee productivity same as pre-COVID-19	ProdSam3	1,0	0.3613 (8.63)	0.3922 (9.21)	0.2793-0.4434	0.3087-0.4756
Like to WFH more often in future	WFHFrag3	1,0	0.4503 (10.9)	0.3876 (9.59)	0.3692-0.5314	0.3083-0.4668
Wave 4:						
Male respondent	DMale4	1,0	n/s	0.0631 (2.28)	n/s	0.0090-0.1173
Distance from home to regular office	DistHmW4	kms	-0.0007 (-11.2)	-0.0008 (-10.4)	-0.0009—0.0006	-0.0009—0.0006
Work cannot be done at home	EMVRet4	1,0	-0.1604 (-4.87)	-0.0621 (-1.95)	-0.2249—0.0958	-0.1324-0.0082
Employee productivity much more than pre-COVID-19	ProdMor4	1,0	0.49021 (11.5)	0.4568 (8.05)	0.4066-0.5736	0.3467-0.5580
Employee productivity same as pre-COVID-19	ProdSam4	1,0	0.5293 (12.0)	0.5449 (11.8)	0.4429-0.6157	0.4544-0.6355
After COVID-19, preferred # days WFH	ACvWFHD4	Days per week	0.0376 (4.69)	0.0435 (4.58)	0.0219-0.0534	0.0249-0.0621
Random effects*:			**GSMA**	**SEQ**		
Var (ε)			0.0664	0.0618		
SD (ε)			0.2577	0.2486		
Var (μ)			0.0060	0.0029		
SD (μ)			0.0774	0.0539		
Corr [v(I,t),v(I,s)]			0.0828	0.0449		
R-squared			0.649	0.671		

[38] A combined model with a GSMA dummy variable associated with each wave was far less informative than separate models for SEQ and the GSMA.

Variable	Acronym	Units	Parameter estimate (t-value)		95% confidence interval	
			GSMA	SEQ	GSMA	SEQ
Lagrange Multiplier Test vs. RE Model:			0.43	0.33		
1 degrees of freedom, prob. value			0.512772	0.562839		

* Variances computed using ordinary least squares (OLS) and least squares dummy variable (LSDV)

We have endeavoured to account for all variables that are available from all waves, but a few variables are only available from Waves 3 and 4 (when we finally sorted out the list of data requirements). For example, employee perceived productivity is only collected in Waves 3 and 4. We did obtain employer perceived productivity of employees in all Waves but struggled to find any statistical significance except in Waves 1 and 3; however, employee perceived productivity is a good proxy given that employees and employers are well aligned.

The estimated random effects model suggest that the gains in statistical efficiency are very small compared to the traditional ordinary least squares regression model[39]. The most insightful output supporting this position is the Correlations (Corr[v(i,t),v(i,s)]) for the GSMA and SEQ of 0.0828 and 0.0449 respectively, which suggests that the waves are unlikely to impact on each other. This might be expected given we have a repeated cross section sample of unequal sizes and we have included wave-specific dummy variables to control for differences, at the mean, in unobserved influences, which clearly matter in the GSMA across all waves and less so for SEQ. The two models have overall explanatory power as reflected in the linear R^2 of 64.9% and 67.1% respectively for the GSMS and SEQ.

Specifically, we found few occupation dummy variables to be statistically significant, with professionals being the main significant occupation category, with manager status appearing only in wave 3 for SEQ. Age of the respondent is an important influence of the incidence of WFH, with a statistically significant presence in Waves 1 and 2 for the GSMA and SEQ, and wave 3 for SEQ. The sign, however, changes between the waves, with increasing age tending to increase the incidence of WFH in waves 1 and 3 and the reverse in wave 2.

Employee perceived productivity is a statistically significant influence in waves 3 and 4 for more productivity and the same productivity relative to pre-COVID-19, and we anticipate that this would also be significant in Waves 1 and 2 if it had been collected. The other influence of significance is future preference for working from home. We have two specifications, one related to a desire to work from home more often in the future, as a dummy variable ($WFHFrag_t$), and the number of days a respondent would like to work from home in the future (ACvWFHD4). We had to consider ACvWFHD4 on wave 4 since there was a coding error in the reference to the question for $WFHFrag_t$ which resulted it being avoided by many workers. We did, however, include ACvWFHD4 in waves 1-3 but found that $WFHFrag_t$ was statistically superior. A variable representing the dummy variable response that work cannot be done at home was available in waves 3 and 4, and was found to be statistically significant and of the expected negative sign for the GSMA in wave 3, and both locations in wave 4.

Commenting on the differences in parameter estimates is not behaviourally informative compared to the set of elasticities that can obtained. The elasticities calculated for each respondent and averaged are summarised in Table 3. We report the results for all the explanatory variables whose standard errors on a Delta test result in a statistically significant t-value at 95% confidence or better. They are either point or arc elasticities depending on whether the explanatory variable is continuous or discrete, and are defined as the relationship between the percentage change in an explanatory variable and the percentage change in the

[39] Available on request but most parameters are very similar to the random effects model.

proportion of work days WFH, *ceteris paribus*. As unitless metrics, they are directly comparable, and offer a preferred way to identify the greatest influences on changes in WFH.

There are interesting differences of influences between each wave as well as within the GSMA and within SEQ. We present the results in two ways: a ranking for the lowest (least elastic) to highest (most elastic) (column 2), and by the specific explanatory variable appearing in each wave and geographical jurisdiction (column 4). We also present this evidence in Figures 8-9.

Table 3 Summary of mean point and arc elasticity estimates

Influence	Elasticity	Influence	Elasticity
Emvret3 GSMA	-0.193	ACVWFH4 GSMA	0.0411
Age 2 GSMA	-0.065	Age 2 GSMA	-0.065
Age1 SEQ	0.039	Age1 SEQ	0.039
ACVWFH4 GSMA	0.0411	Emvret3 GSMA	-0.193
Prof3 GSMA	0.647	Prodmor3 GSMA	0.855
Prodmor3 GSMA	0.855	Prodmor3 GSMA	0.957
Prof1 GSMA	0.888	Prodmor3 SEQ	1.068
Prodmor3 GSMA	0.957	Prodmor4 GSMA	1.063
Prof2 SEQ	1.018	Prodmor4 SEQ	1.173
WFHFrag2 GSMA	1.06	Prodsam3 SEQ	1.145
Prodmor4 GSMA	1.063	Prodsam4 GSMA	1.086
Prodmor3 SEQ	1.068	Prodsam4 SEQ	1.25
WFHFrag1 GSMA	1.074	Prof1 GSMA	0.888
Prodsam4 GSMA	1.086	Prof2 SEQ	1.018
WFHFrag2 GSMA	1.113	Prof3 GSMA	0.647
Prodsam3 SEQ	1.145	WFHFrag1 GSMA	1.074
WFHFrag3 SEQ	1.157	WFHFrag1 SEQ	1.274
Prodmor4 SEQ	1.173	WFHFrag2 GSMA	1.113
Prodsam4 SEQ	1.25	WFHFrag2 GSMA	1.06
WFHFrag1 SEQ	1.274	WFHFrag2 SEQ	1.292
WFHFrag2 SEQ	1.292	WFHFrag3 SEQ	1.157

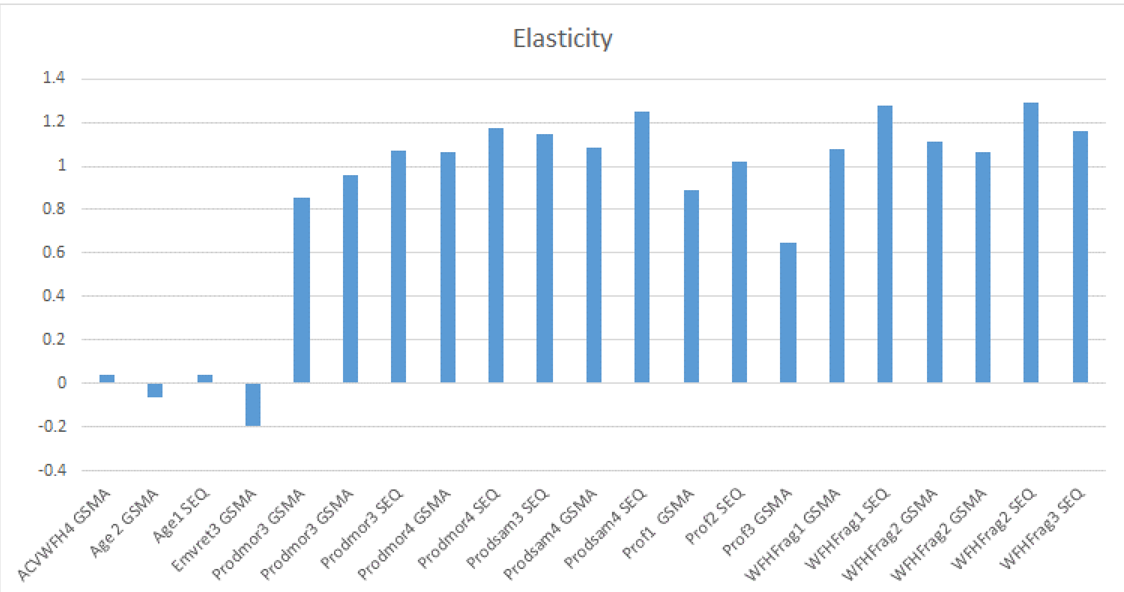

Figure 8. Direct point and arc mean elasticity estimates by variable-specific grouping

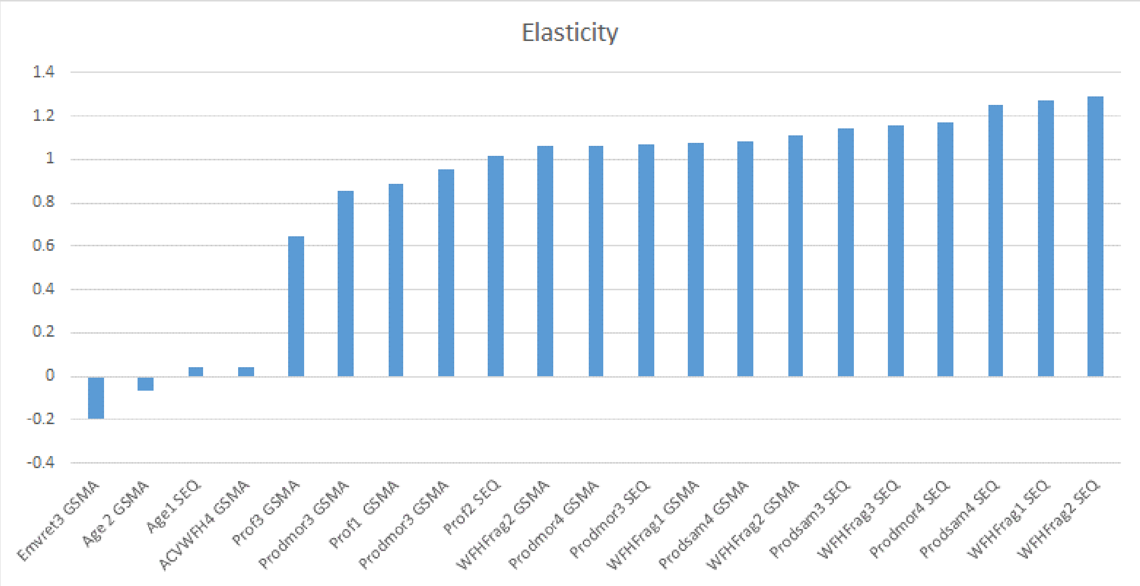

Figure 9. Direct point and arc mean elasticity estimates ranked by numerical value

A most interesting finding is that the direct elasticity of the proportion of weekly work days WFH with respect to employee perceived productivity is in the range of 0.855 to 1.173 for being more productive and 1.086-1.25 for the same level of productivity. These elasticities span a high relative inelasticity and a low relative elasticity. For example, if the average number of days WFH is 1.5, then the high end elasticity response of 1.173 in the SEQ (wave 4) will result in an average number of days WFH increasing to 1.76. Clearly there is a statistically significant and plausible behavioural link between the propensity to perceive a greater or same level of productivity when WFH compared to back in the regular office, and as arc elasticities we see that when a worker moves from a level of perceived productivity that is not higher to one that is higher, we obtain a 0.855% to 1.173% increase in the proportion of working days that are worked from home. As far as we know, these are the first elasticity empirics on this link. Interestingly the relative elasticity for being more productive goes up between Waves 3 and 4 for the SEQ and down for the GSMA, suggesting, on average, that the employee perception of greater productivity is starting to drop slightly in the GSMA, but is continuing to increase at what appears to be a greater rate in the SEQ.

We have a similar relative elastic finding for 'I would like to work from home more often in the future' ($WFHFrag_t$), in the range of 1.06 to 1.292. This is statistically significant in Waves 1 and 2 but not in waves 3 and 4. We see that when a worker indicates that they would like to work from home more often in the future, we obtain a 1.06% to 1.292% increase in the proportion of working days that are worked from home. As far as we know, these are the first elasticity empirics of this link. This preference has more or less flattened between Waves 1 and 2 for both the GSMA and SEQ. An alternative metric is the number of days 'after COVID-19' that an individual would like to WFH (ACVWFH). This was not found to be statistically significant in most waves and both locations with one exception, the GSMA in Wave 4 with a mean elasticity of 0.041. As a continuous variable that indicates, for example, that if we have a 10% increase in the number of days someone would like to WFH after COVID, we see a 0.41% increase in the proportion of weekly days working that are WFH.

In summary, the evidence across the waves suggests, *ceteris paribus*, that the improved productivity of employees as perceived by employees, which aligns well with employers views on employee productivity, is a very strong indicator of the success and desire to WFH more often than pre-COVID-19. We should suggest that this influence, together with a limited number of socioeconomic effects, provides rich support for a future of WFH, to some extent, that is on average 1 to 2 days a week, but even greater for some workers.

5 Conclusions

There is enough accumulating evidence in this study and indeed many other studies, that working from home will be embedded at the centre of the 'next' or 'new' normal. While the timing of this is not clear, in the sense of a stable level that can be used in future planning and proofing, there are signs that adjustments made through experience, often without choice, and through outcomes that have proven on balance to be very attractive to both employees and employers where on-site presence all of the working time is not necessary or valuable, will reinforce a regular pattern of WFH that is significantly greater than pre-COVID-19 levels. The often suggested metric of 1 to 2 days a week on average, seems to be reinforced by almost all studies.

This study has investigated how the move between waves of data as society has learnt to live with and adjust to COVID-19, and all of its associated health risks (in an almost fully vaccinated society such as Australia since November 2021), offers signals as to what are important drivers of a desire to work from home. As long as productivity is seen as a positive outcome of working from home, especially by employers, who also recognise the lifestyle and wellbeing benefits to their employees (something that will inevitably be built in to employments contracts going forward), and that a preference of workers to continue to work from home remains, given the many benefits on balance that have been recognised, the next normal will almost certainly be linked to the delivery of structural change centred around WFH.

There are many ongoing challenges to governments, to the broad base of employers, and even to households as they work out how best to encapsulate the non-stigmatised WFH future. The implications for funding of infrastructure, re-prioritising land use plans, growing new office settings which include satellite offices, and what the future office environment might be are profound. Individuals who commute less often may translate into a shrinking local revenue base and contribute to long-term fiscal challenges for local and State governments. Many cities have been bracing for this in their forward budgets; but their projections for the quantum of people who will continue to work from home is almost certain to underestimate the magnitude of the shift. Philadelphia, for example, assumed a permanent loss of 15% of the non-resident wage tax base in its projections, according to an analysis by the Philadelphia Office of the Controller last July. San Francisco, in a five-year financial plan published in January, estimates that office workers will permanently telecommute about 15% of the time in the fiscal year 2025-2026[40].

Ongoing research will investigate how the WFH profiling emerging for society as a whole might be embedded in the way organisations will see the need for a revised value proposition. The challenge is to identify the key characteristics of a future setting for work and transport practices that aligns with a desire to build an effective workplace environment that promotes a culture of collaboration, connecting with peers and to foster company loyalty while retaining the flexibility benefits of WFH. Better understanding the WFH environment will give more insight into potential spill over effects on home design, urban design and transport systems. Five distinct models seem to be emerging: (1) Office frequency and days fixed, a model that mandates certain days all employees are expected to be at the office; (2) Office frequency fixed but days of attendance flexible where companies require employees to attend the office for a specific number of days each week, but choose when those days are; (3) Workers' choice

[40] https://www.bloomberg.com/news/articles/2022-02-28/remote-work-seen-more-persistent-than-u-s-city-planners-expect, 28 February 2021.

which is the most flexible with employees having autonomy to choose where (and when) work is done; (4) Remote work only; and (5) Office work only.

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Appendix X. Paper #19: Accounting for the spatial incidence of working from home in an integrated transport and land model system

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Edward Wei
Wen Liu

Abstract
The COVID-19 pandemic has resulted in a seismic shift in the way in which work is conducted. Remote working or working from home is becoming a centrepiece of the next normal with strong support from both employers and employees. With reduced commuting activity associated with an expected 1 to 2 days working from home for many occupations and industries, associated with releasing commuting time to spend on other activities including changed levels and patterns on non-commuting travel, it is necessary, indeed essential, to allow for the incidence of working from home in integrated strategic transport and location model systems. In this paper we show the extent of changes in travel behaviour and the performance of the transport network before and after allowing for working from home which is more impactful than any new infrastructure project. The differences are significant and suggest that even within the existing modelling frameworks used pre-COVID-19, we need to make adjustments in the modal activity overall and by location. Using the MetroScan platform in the Greater Sydney Metropolitan area, we present a number of outputs to illustrate the significant impacts of working from home such as modal activity (total and shares), emissions, government revenues, and generalised cost of travel.

***Keywords**:* Working from home, impacts on travel demand and networks, integrated transport and land use strategic model system, emissions, MetroScan.

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1 Introduction

The extreme event, COVID-19, has resulted in a number of unintended consequences of which the extent and support for working from home (WFH) or remote working has been both surprising and generally welcomed by employees and employers. Since the beginning of the pandemic in March 2020, there has been a significant amount of WFH in lockdown and non-lockdown states in many countries. While we have seen a proliferation of descriptive assessments of the extent of WFH and the levels of support including productivity benefits, flexibility in work arrangements and general lifestyle benefits and costs (e.g., Beck and Hensher 2021a, 2021b, Barrero et al. 2020, Hill et al. 2010), there is a dearth of research that formally analyses, during the current pandemic period, the spatial relationship between WFH and the performance of the transport network, including trip making levels, travel times and emissions. Kim et al. (2015) is an example of such a modelling effort pre-COVID-19 when WFH (or telecommuting) was significantly less. Moeckel (2017) is the best example of an effort using an integrated transport and land use framework to account for working from home pre-pandemic, but the focus is only on the impact that WFH has on travel times within the transport model MATSim (www.matsim.org) as integrated with the land use model SILO (www.silo.zone).

To achieve an understanding of spatial variations and impacts of WFH, we use MetroScan, developed by the authors (Hensher et al. 2020), as a strategic-level transport and land use planning application system which allows for mapping of passenger and freight activity, as well as an endogenous treatment of the location of households and firms. We modify Metroscan to include the probability of WFH as obtained from an ongoing longitudinal research project that commenced in March 2020 and will continue through to 2023 (see Hensher et al. 2021). The longitudinal perspective is essential to gain an understanding of the changing state of WFH, and to be able to gain confidence in establishing a level of WFH that appears to be reliable in future investigations of its impact on travel behaviour and network performance.

The main model change involves using a mapping equation developed by Hensher et al. (2022) for the Greater Sydney Metropolitan Area (GSMA), that enables us to obtain an estimate of the probability of WFH (compared to commuting from a commuting mode choice and time of day model) at an origin-destination level, as determined by socioeconomic and other drivers which have been parametrised from the latest wave of longitudinal data (June 2021), and used with aggregate data describing each origin and destination. We also incorporate changes in the amount of non-commuting trip activity consequent on WFH through elasticity estimates obtained from a Poisson regression model of one way weekly trips for a number of trip purposes. In addition, we account for the influence that changing levels of commuting and non-commuting have on network travel times, supported by trip-purpose specific equations that relates pre-COVID-19 travel times to travel times with WFH during COVID-19. These equations are embedded in the traffic assignment algorithm to obtain revised travel times on the road network.

The paper is structured as follows. We begin with a summary overview of Metroscan as a way of setting out the framework within which we embed working from home. This is followed by the WFH modelling results used to obtain a mapping between location-specific influences on WFH and the probability of WFH. We then present the results associated with a base with and without WFH and the project application with and without accounting for WFH. A case study is then presented for an extension to a tolled motorway in Sydney, followed by the empirical results to show the influence on WFH compared to a new project treatment. We choose a number of key behavioural outputs to account for the impact of WFH such as levels of travel activity, modal shares, emissions and energy, revenues, modal generalised cost, and accidents. The paper concludes with comments on the future role of WFH in transport planning activity where we consider both ‘predict and provide’ and ‘vision and validate’.

2 The MetroScan Structure

One of the most important features of comprehensive land use and transport planning is an ability to identify candidate projects and policies that add value to the sustainable performance of transport networks and to the economy as a whole. There is a case to be made for having a capability to undertake, in a timely manner, a scan of a large number of potentially worthy projects and policies that can offer an understanding as well as forecasts of passenger and freight demand responses to specific initiatives. Such a framework would then be meaningful in the sense of offering outputs that are similar to those that are the focus of assessments that are typically spread over many months, if not years, on very few projects, which may exclude those which have the greatest merit. MetroScan, a strategic-level transport and land use planning application system allows for mapping of passenger and freight activity, as well as an endogenous treatment of the location of households and firms. In short, MetroScan is all-in-one assessment and scanning system enabling us to conduct quick predictions of the demand characteristics for cars, public transport, freight activities, and many other travel demand characteristics associated with a base and a project application.

Figure 1 shows how the macro generator works by taking inputs from existing transport models, such as the road and public transport network, and any OD matrices for the starting year to be used as a base, then uses the network travel times and distances by time of day. Characteristics of households, such as dwelling, household types, or car ownership, in synthetic data, carry sociodemographic and behavioural elements into the system. The scheme also uses some defaults for values and distributions to fill in gaps when input data or models do not support such information (e.g., population growth rate or inflation rate). One of the central features of the macro generator is the adoption of macrozones. These macrozones can be predefined using a standard zone definition (e.g., from the Australian Bureau of Statistics), but can also be manually defined in the system. The macro generator can aggregate any OD skims to the macrozone layer. If executed outside the system, this would be a difficult task that can require months to correct. MetroScan has this process automated so changes to any OD skim matrices can be contemplated on the macrozone level when a proposed initiative is being processed. To provide further background, the macro generator applies a data manager to manage imported networks from different origins, such as TRANSCAD, VISUM, EMME, CUBE, and other systems. While preserving the accuracy for fast scanning, the macro generator largely reduces many detailed zones to a manageable number of macrozones, including the ones made by users. By doing so, initiatives under investigation can be assessed very fast in order to generate forecasting results from travel demand and economic impact. A trade-off exists between computation time and accuracy due to the detailed level of the macrozone. For example, in Sydney, there are over 3,000 detailed zones in the transport network. In practice, we would apply 80 macrozones, which could satisfy both accuracies of forecasting and efficiency of the computation process. In reality, the forecasting results for major macro zones would also provide more meaningful and actionable insights for policymakers. Many strategic initiatives also start with higher levels of macrozones and request scanning results at the same level from travel demand to economic impact factors.

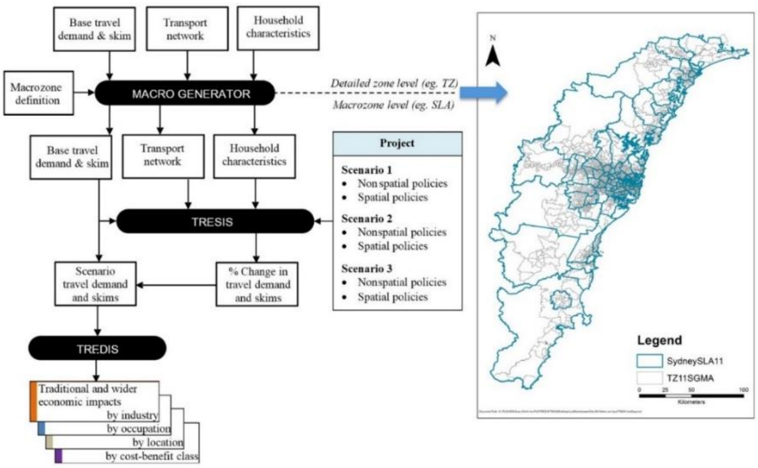


Figure 1. MetroScan framework.

MetroScan was designed to apply synthetic (or proto-typical) households as units to gain numerous responses to alterations in the system driven by both broad and in-depth policy measures. MetroScan applies a large number of choice models on both the macro and micro level, including behavioural aspects, providing more behavioural realistic market responses robust in contrast to traditional model systems (see Figure 2). This enables us to use Metroscan as both a vision and validate system as well as predict and provide system (Jones 2016). MetroScan processes and delivers results for different modes, travel purposes, and time-of-day choices for medium to long-term decisions up to 20 to 35 years (i.e., currently forecasting up to 2056). It also accounts for long-term decisions or choices on vehicle types, fleet size, vehicle technology, residential and work locations, job and firm growth areas, dwelling types, and many others. Besides forecasting commuting, non-commuting trips, such as personal business and social purposes, and business trips; light commercial vehicle and freight commodity models support business activity responses by location, volumes, and trips at macrozone levels. Further details are given in Hensher et al. (2020).

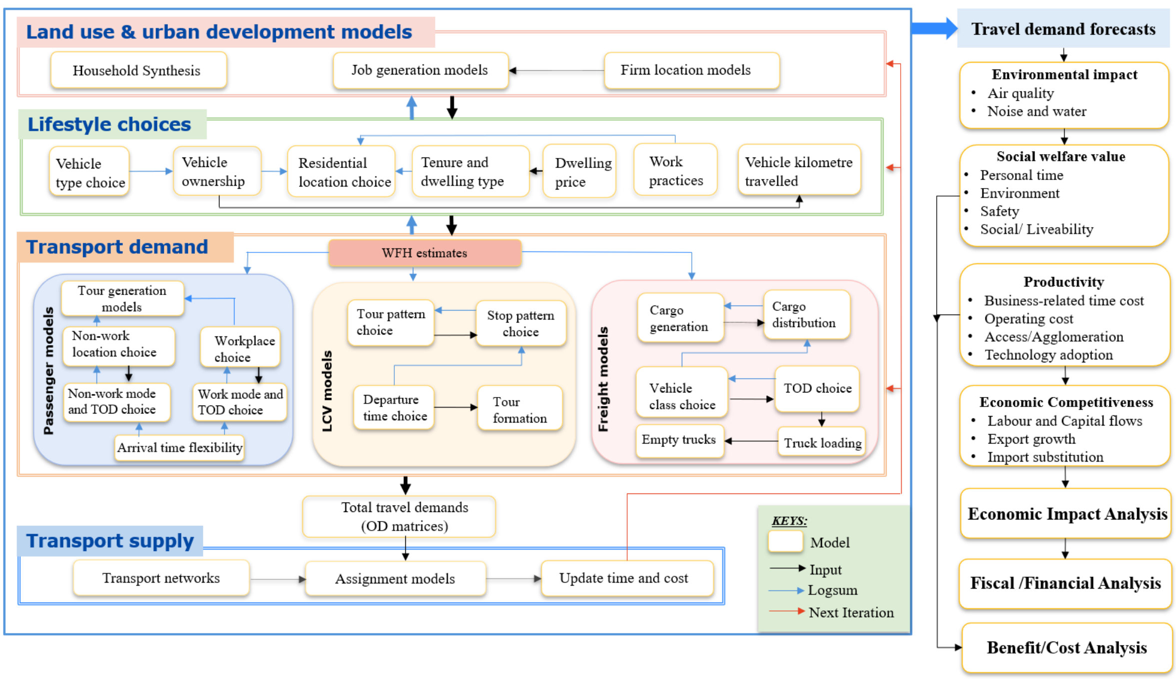


Figure 2. The demand-side behavioural model system for passenger, light commercial, and freight travel activity. Source: Hensher et al. (2020).

3 Identifying the Spatial Incidence of Working from Home and building it into MetroScan

The evidence on WFH is obtained from a separate model system developed as part of an ongoing research project on the implications of WFH on travel and location behaviour (see Beck and Hensher 2021, 2021a). The study area for this analysis was defined as the GSMA, stretching from Newcastle to Wollongong (Figure 3), with a wide range of socio-economic and traffic data being assembled for this area.

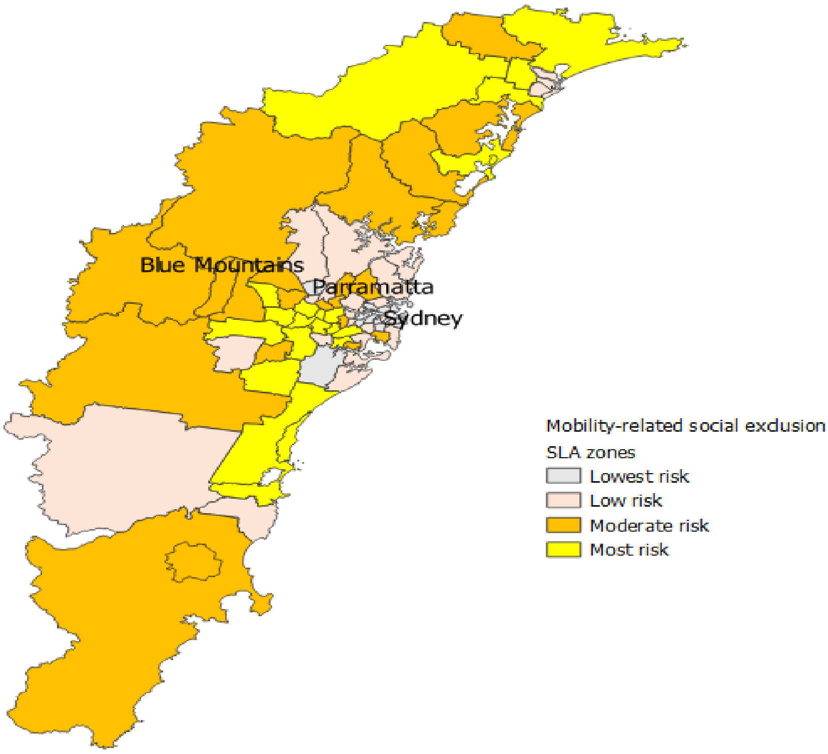


Figure 3: Sydney zones in MetroScan

Two models are used as the baseline for obtaining predictions of the probability of WFH on any day and the key influences of the obtained levels. We have presented the model structure in Hensher et al. (2022) using the data from the September 2020 time period (called Wave 3) in our ongoing longitudinal data collection in Australia. The commuter mode and time of day choice model with embedded WFH choice used in this paper is newly estimated using the June 2021 data (called Wave 4) given in Table 1 based on the structure in the top and bottom panels of Figure 4, and we refer readers to Hensher et al. (2022) for fuller details of the methods and interpretation of model results. In summary, we first estimate a commuter mode choice mixed logit model in which the choices are between no work, WFH and up to seven commuter modes for 7 days of the week and 4 times of day (Figure 4) on the sample of commuters, using equations 1- 5 as the utility expressions associated with each alternative. The implied value of in-vehicle travel time is $22.18/person hour. The estimated model enables us to obtain a prediction of the probability of WFH, and separating out the probability of no work, we obtain the probability of WFH compared to commuting at a particular time of day and day of week. This probability is then used in a mapping equation to identify sources of influence on the probability of WFH, given in Table 2. Descriptive data associated with both models is given in Appendix A.

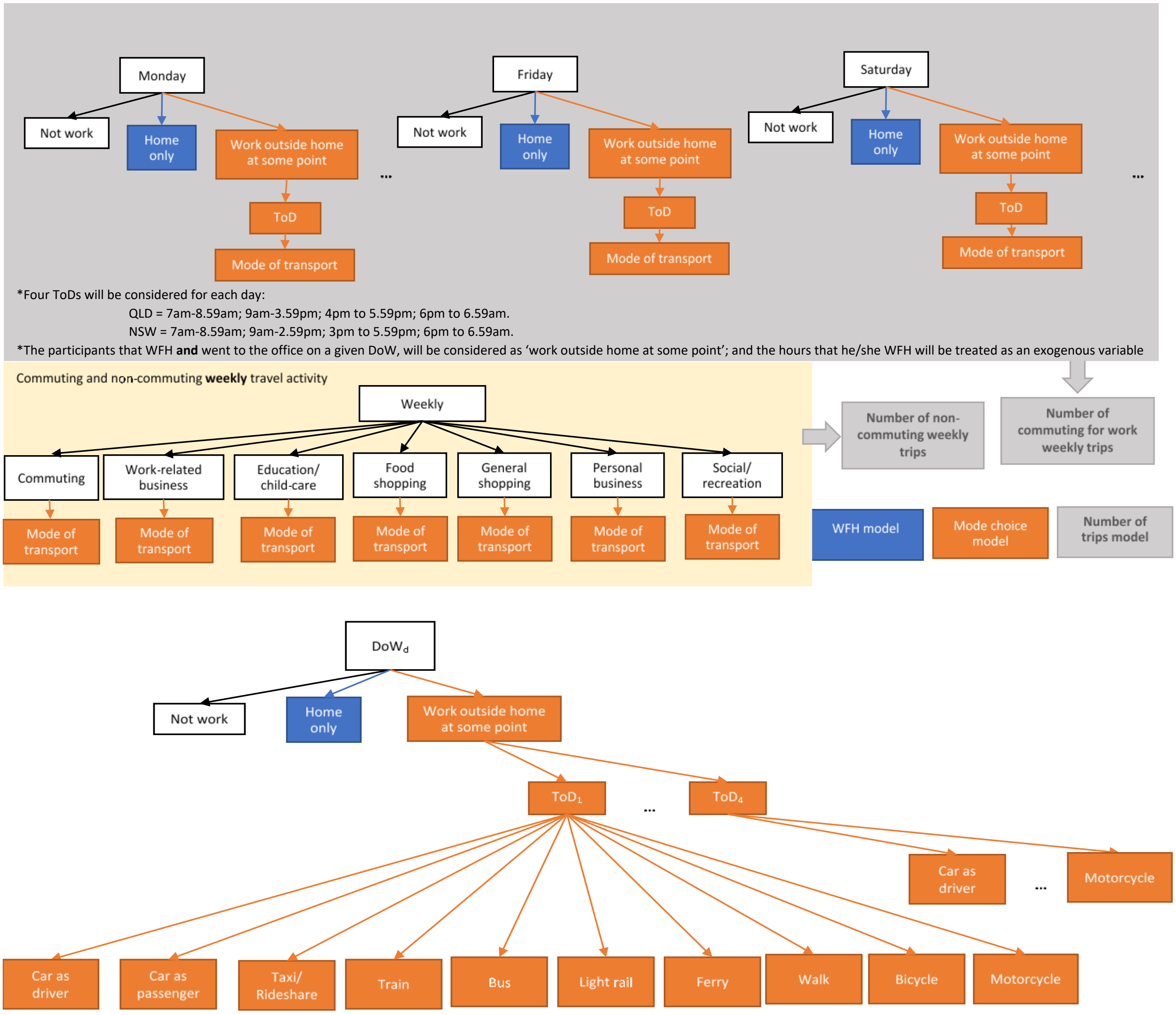


Figure 4: Model structure

The alternative of no work (alternative 1) is described by an alternative specific constant ASC and by respondents' socioeconomics z_n. The WFH alternative (alternative 2) is described by its alternative specific constant; respondents' socioeconomics; by dummy variables that represent each different day *d* of the week day_d; if the respondent works in the central business district area CBD_{work}; and by the distance from their home to their office $Dist_{Home-work}$. The utility functions are defined as follows:

$$U_{NoWork} = ASC_{NoWork} + \sum_n \beta_{NoWork,n} \cdot z_n \quad (1)$$

$$U_{WFH} = ASC_{WFH} + \sum_n \beta_{WFH,n} \cdot z_n + \sum_n \beta_{WFH,d} \cdot day_d + \beta_{WFH,CBD} \cdot CBD_{work} + \beta_{WFH,Dist} \cdot Dist_{Home-work} \quad (2)$$

where β represents the estimated parameters associated with the different attributes or characteristics. The utility functions for the modal alternatives (alternatives 3 to 42) are described by two alternative specific constants: one that refers to mode *m*, and one that refers to the time of day *t*. The utility function for the public transport modes is defined by travel time TT_{Mode_m}; access time AcT_{Mode_m}; egress time EgT_{Mode_m}; waiting time WT_{Mode_m} and fare $Fare_{Mode_m}$

, as shown in equation (3). Note that the parameter estimate β for access, egress and waiting times is generic[41].

$$U^{PT}_{Mode_m,ToD_t} = ASC_{Mode_m} + ASC_{ToD_t} + \beta_{Mode_m,TT} \cdot TT_{Mode_m} + \beta_{Mode_m,Cost} \cdot Fare_{Mode_m} + \beta_{Mode_m,AEWT} \cdot \left(AcT_{Mode_m} + EgT_{Mode_m} + WT_{Mode_m} \right) \quad (3)$$

The utility function for the car driver and motorcycle alternatives is described by travel time, fuel cost $Fuel_{Mode_m}$, parking cost $Park_{Mode_m}$, and toll costs $Toll_{Mode_m}$; as well as some socioeconomic characteristics[42], as presented in equation (4). Note that the parameter estimate β for fuel, toll and parking was estimated in the preferred model as generic[43].

$$U^{Car/moto}_{Mode_m,ToD_t} = ASC_{Mode_m} + ASC_{ToD_t} + \beta_{Mode_m,TT} \cdot TT_{Mode_m} + \beta_{Mode_m,Cost} \cdot \left(Fuel_{Mode_m} + Park_{Mode_m} + Toll_{Mode_m} \right) + \sum_n \beta_{Mode_m,n} \cdot z_n \quad (4)$$

The active modes (walk and cycling) and car passenger[44] alternatives are described only by the travel time, as presented in equation (5).

$$U^{Active}_{Mode_m,ToD_t} = ASC_{Mode_m} + ASC_{ToD_t} + \beta_{Mode_m,TT} \cdot TT_{Mode_m} \quad (5)$$

Table 1: Mixed Logit Model results for the GSMA, Wave 4 (June 2021)

Parameters	Acronym	Alternatives	Mean (std deviation)
Constants:			
ASC no work	ASC_NoWork	1	-
ASC work from home	ASC_WFH	2	-
ASC car driver/motorcycle	ASC_CarMoto	3, 12, 13, 22, 23, 32, 33, 42	-0.603 (3.28)
ASC car passenger	ASC_CarP	4, 13, 24, 34	-3.221 (14.19)
ASC taxi/ridesharing	ASC_Taxi	5, 15, 25, 35	-4.018 (6.66)
ASC public transport	ASC_PT	6-9, 16-19, 26-29, 36-39	-0.778 (3.69)
ASC active modes	ASC_Act	10, 11, 20, 21, 30, 31, 40, 41	-0.813 (3.50)
ASC ToD 1 and 3	ASC_T13	3-12, 23-32	0.216 (2.85)
ASC ToD 2	ASC_T2	13-22	-
ASC ToD 4	ASC_T4	33-42	0.451 (5.54)
Socio-economic variables:			
No Work - Age	Age_NW	1	0.021 (10.18)
Car driver - Number of cars in household	NCar_CarD	3, 13, 23, 33	0.155 (3.46)
WFH - Occupation professional (1,0)	OcProf_WFH	2	0.382 (3.03)
WFH - Occupation manager (1,0)	OcMng_WFH	2	0.574 (4.25)
WFH - Occupation clerical and administration (1,0)	OcAdm_WFH	2	0.623 (4.18)
WFH - Occupation blue collar worker (1,0)	OcBlCl_WFH	2	-0.670 (3.19)
Day of week:			
WFH - Monday dummy variable (1,0)	DMon_WFH	2	0.988 (6.96)
WFH - Tuesday dummy variable (1,0)	DTue_WFH	2	0.926 (6.47)
WFH - Thursday dummy variable (1,0)	DThu_WFH	2	0.700 (4.77)
WFH - Friday dummy variable (1,0)	DFri_WFH	2	0.717 (4.90)
Spatial location effects:			
WFH NSW - Wollongong residential location (1,0)	Woll_WFH	2	-1.234 (6.34)
WFH NSW - Newcastle residential location (1,0)	Newc_WFH	2	-0.868 (5.83)
WFH NSW - Central Coast residential location (1,0)	CentC_WFH		-0.780 (4.35)

41 They were estimated as specific first and the results suggested that they were not statistically different.
42 The respondents' socioeconomics were tested in different modes of transport, but they were statistically significant only in the car driver mode.
43 They were estimated as specific first and the results suggested that they were not statistically different.
44 We tested the option of including the costs associated with a car trip but they were always not significant, suggesting that car passengers do not usually pay for these costs and, therefore, are not part of their decision.

Parameters	Acronym	Alternatives	Mean (std deviation)
Modal attributes:			
Travel time all modes except active - *mean*	TT_CarPT	3-9, 12-19, 22-29, 32-39, 42	-0.010 (3.15)
- *standard deviation*			0.008 (3.15)
Travel time walking	TT_Walk	10, 20, 30, 40	-0.040 (4.00)
Travel time bicycle	TT_Bike	11, 21, 31, 41	-0.013 (1.65)
Cost all modes except car pax and active - *mean*	Cost_CarPT	3, 5-9, 12, 13, 15-19, 22, 23, 25-29, 32, 33, 35-39, 42	-0.024 (2.75)
- *standard deviation*			0.024 (2.75)
Access + egress + waiting time taxi/PT modes	TTAEW	5-9, 15-19, 25-29, 35-39	-0.017 (0.94)
Number of parameters estimated			**26**
Sample size			**2,975**
Log Likelihood at convergence			**-4,897.17**
Log likelihood at zero			**-11,119.57**
McFadden Pseudo R squared			**0.56**
AIC/n			**3.31**

Table 2: WFH probability mapping model results (linear regression with 0-1 constraint) for the GSMA – Wave 4 Note: confidence intervals are available on request

Variable	Mean (t test**)**
Constant	0.111 (21.69)
Socio-Economics	
At least one child in household attends primary school (1,0)	0.006 (2.29)
At least one child in household attends secondary school (1,0)	-0.010 (3.65)
Occupation Manager (1,0)	0.141 (28.26)
Occupation Professional (1,0)	0.107 (22.85)
Occupation Clerical and Administration (1,0)	0.148 (28.79)
Occupation Sales (1,0)	0.056 (11.11)
Occupation Community and Personal Services (1,0)	0.057 (10.44)
Occupation Labourer (1,0)	-0.019 (2.81)
Residential Location	
Home located in Newcastle (1,0)	-0.123 (46.95)
Home located in Illawarra (1,0)	-0.173 (56.53)
Home located in Central Coast (1,0)	-0.118 (39.76)
Workplace CBD of Sydney	
Work located in CBD area (1,0)	
Work located in Castle Hill area (1,0)	-0.043 (7.22)
Work located in North Sydney area (1,0)	0.066 (8.84)
Day of Week Commuting	
Monday dummy variable (1,0)	0.159 (47.56)
Tuesday dummy variable (1,0)	0.147 (44.40)
Thursday dummy variable (1,0)	0.105 (35.62)
Friday dummy variable (1,0)	0.108 (36.80)
Commuting Mode	
Main mode of transport to go to work now is PT (1,0)	0.010 (2.15)
Main mode of transport to go to work now is car driver (1,0)	-0.012 (4.67)
Number of weekdays commuting by Time of day	
Number of days a person commuted to work on ToD 1 (excluding weekends)	-0.013 (2.34)
Number of days a person commuted to work on ToD 2 (excluding weekends)	-0.015 (2.57)
Number of days a person commuted to work on ToD 3 (excluding weekends)	-0.026 (2.85)
Number of days a person commuted to work on ToD 4 (excluding weekends)	-0.028 (4.85)
Work place location characteristics	

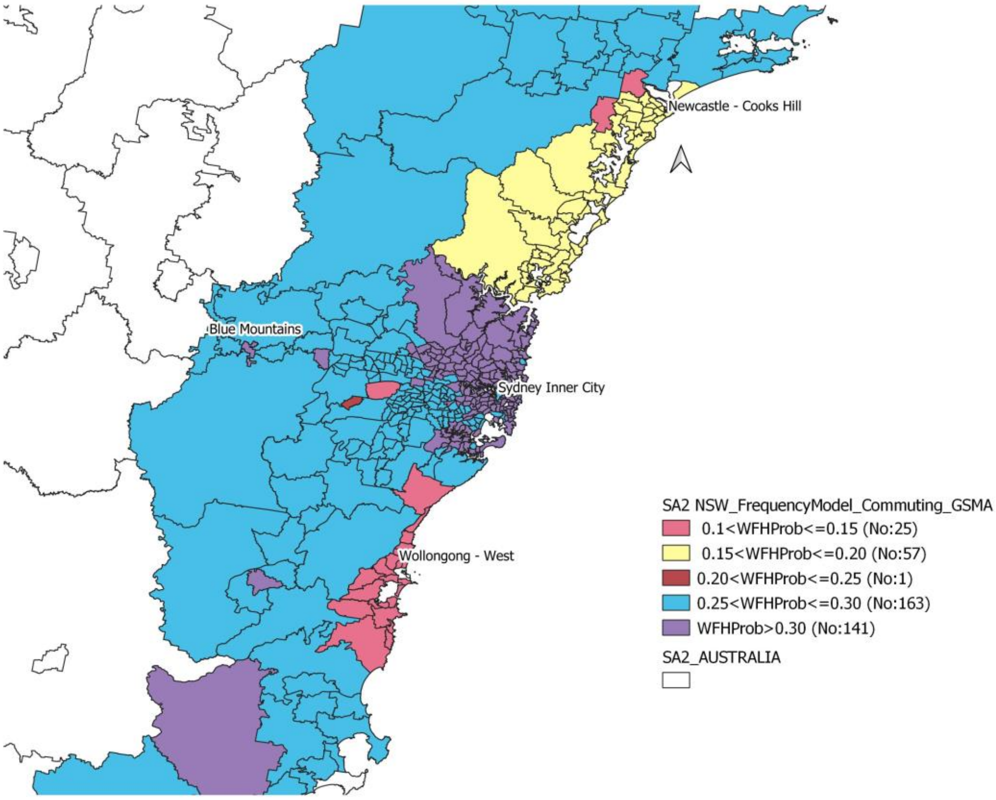
Variable	Mean (t test)
Number of persons with occupation professionals in each workplace location NSW	0.000 (3.70)
Number of persons with occupation machinery operators and drivers in each workplace location NSW	0.005 (3.25)
Number of jobs in work postcode for Industry category (TMR industry categories provided by TMR) for Qld and NSW	-0.001 (2.95)
Number of jobs in work postcode for other category (TMR industry categories provided by TMR) for Qld and NSW	-0.011 (3.88)
Number of employees in business 20-199	0.008 (3.57)
Travel time for commuting	
Average daily travel time getting to work by car driver, car pax and motorcycle considering number of days a person commuted	0.000 (8.84)
Average daily travel time getting to work by PT considering number of days a person commuted	0.000 (6.48)
Average daily travel time getting to work by taxi / ridesharing considering number of days a person commuted in these modes	0.002 (4.29)
Sample size	***2,261***
Adjusted R squared	***0.86***

The next task is to build the evidence on WFH into MetroScan. Adjustments are required for each and every origin-destination pair in the 80 by 80 matrix. This is where the mapping equation is used, with a number of crucial variables providing the differentiation for a given origin of the probability of WFH. The number of commuting trips associated with each OD pair is adjusted down by the probability of WFH associated with each of the modes in the mapping equation, obtained by applying the levels of all explanatory variables associated with each origin and destination zone including the travel times for each OD pair and additional dummy variables for car and public transport as the chosen commuting mode. In addition, we have accounted for the number of jobs by occupation and industry as well as job density at the destination in order to provide a way of identifying a distribution of probabilities of WFH associated with a given origin across all destinations. The other key drivers of WFH relate to the socioeconomic characteristics of individuals and their households as well as some broad geographical location dummy variables such as Newcastle, Wollongong and the Central Coast compared to the Sydney Metropolitan area (SMA). Within the SMA, we also account for high density suburban shopping and employment precincts such as Castle Hill in the northwest and North Sydney in the lower north shore.

We also need to correct the number of trips by non-commuting purposes, which was identified from Poisson regression models (See Appendix C and middle panel of Figure 4 above) for the relationship between the number of one-way weekly trips and explanatory variables (Table C1), of which one was the proportion of working days that are worked from home. We obtained the direct elasticity estimates for the number of trips with respect to WFH, given as equations (6a-6g).

Education trips=Original ED trips*(1 + 0.077*WFH) (6a)
Food shopping=Original FS trips *(1+ 0.066*WFH) (6b)
General shopping=Original GS trips*(1+ 0.091*WFH) (6c)
Personal business=Original PB trips*(1+0.085*WFH) (6d)
Social/Recreational=Original SR trips*(1+0.053*WFH) (6e)
Care visit=Original CV trips*(1+0.019*WFH) (6f)
Work related = Original trips*(1-0.374*WFH) (6g)

Figure 5 and the associated table shows the average estimates of the probability of WFH for all workers regardless of commuting mode for each of the 80 zones in Metroscan. In addition, it summarises the probability of WFH for workers who use car or public transport when they commute.



SLAName	MScanZon	WFHProb	WFHProb_Car	WFHProb_PT	SLAName	MScanZor	WFHProb	WFHProb_	WFHProb_PT
Botany Bay (C)	1	0.290	0.281	0.303	Penrith (C) - East	41	0.283	0.274	0.296
Leichhardt (A)	2	0.308	0.299	0.321	Penrith (C) - West	42	0.283	0.274	0.296
Marrickville (A)	3	0.308	0.299	0.321	Blacktown (C) - North	43	0.285	0.275	0.297
Sydney (C) - Inner	4	0.308	0.299	0.321	Blacktown (C) - South-East	44	0.285	0.275	0.297
Sydney (C) - East	5	0.308	0.299	0.321	Blacktown (C) - South-West	45	0.285	0.275	0.297
Sydney (C) - South	6	0.308	0.299	0.321	Hunter's Hill (A)	46	0.317	0.308	0.330
Sydney (C) - West	7	0.308	0.299	0.321	Lane Cove (A)	47	0.315	0.306	0.328
Randwick (C)	8	0.306	0.297	0.319	Mosman (A)	48	0.319	0.310	0.332
Waverley (A)	9	0.311	0.302	0.324	North Sydney (A)	49	0.320	0.311	0.333
Woollahra (A)	10	0.293	0.284	0.306	Ryde (C)	50	0.305	0.296	0.318
Hurstville (C)	11	0.295	0.285	0.307	Willoughby (C)	51	0.314	0.304	0.326
Kogarah (A)	12	0.293	0.283	0.305	Hornsby (A) - North	52	0.306	0.296	0.319
Rockdale (C)	13	0.290	0.281	0.303	Hornsby (A) - South	53	0.306	0.296	0.319
Sutherland Shire (A) - East	14	0.299	0.290	0.312	Ku-ring-gai (A)	54	0.317	0.308	0.330
Sutherland Shire (A) - West	15	0.299	0.290	0.312	The Hills Shire (A) - Central	55	0.306	0.297	0.319
Bankstown (C) - North-East	16	0.284	0.275	0.297	The Hills Shire (A) - North	56	0.306	0.297	0.319
Bankstown (C) - North-West	17	0.278	0.269	0.291	The Hills Shire (A) - South	57	0.306	0.297	0.319
Bankstown (C) - South	18	0.284	0.275	0.297	Manly (A)	58	0.304	0.295	0.317
Canterbury (C)	19	0.284	0.275	0.297	Pittwater (A)	59	0.304	0.295	0.317
Fairfield (C) - East	20	0.272	0.263	0.285	Warringah (A)	60	0.304	0.295	0.317
Fairfield (C) - West	21	0.272	0.263	0.285	Gosford (C) - East	61	0.166	0.157	0.179
Liverpool (C) - East	22	0.282	0.273	0.295	Gosford (C) - West	62	0.166	0.157	0.179
Liverpool (C) - West	23	0.285	0.276	0.298	Wyong (A) - North-East	63	0.166	0.157	0.179
Camden (A)	24	0.289	0.280	0.302	Wyong (A) - South and West	64	0.166	0.157	0.179
Campbelltown (C) - North	25	0.279	0.270	0.292	Cessnock (C)	65	0.150	0.141	0.163
Campbelltown (C) - South	26	0.279	0.270	0.292	Lake Macquarie (C) - East	66	0.043	0.034	0.056
Wollondilly (A)	27	0.293	0.284	0.306	Lake Macquarie (C) - North	67	0.043	0.034	0.056
Ashfield (A)	28	0.308	0.299	0.321	Lake Macquarie (C) - West	68	0.043	0.034	0.056
Burwood (A)	29	0.294	0.285	0.307	Maitland (C)	69	0.278	0.269	0.291
Canada Bay (A) - Concord	30	0.310	0.300	0.322	Newcastle (C) - Inner City	70	0.167	0.158	0.180
Canada Bay (A) - Drummoyne	31	0.310	0.300	0.322	Newcastle (C) - Outer West	71	0.167	0.158	0.180
Strathfield (A)	32	0.291	0.282	0.304	Newcastle (C) - Throsby	72	0.167	0.158	0.180
Auburn (A)	33	0.291	0.282	0.304	Port Stephens (A)	73	0.155	0.146	0.168
Holroyd (C)	34	0.280	0.271	0.293	Kiama (A)	74	0.120	0.111	0.133
Parramatta (C) - Inner	35	0.300	0.291	0.313	Shellharbour (C)	75	0.104	0.095	0.117
Parramatta (C) - North-East	36	0.300	0.291	0.313	Wollongong (C) - Inner	76	0.120	0.111	0.133
Parramatta (C) - North-West	37	0.300	0.291	0.313	Wollongong (C) Bal	77	0.120	0.111	0.133
Parramatta (C) - South	38	0.280	0.271	0.293	Shoalhaven (C) - Pt A	78	0.108	0.098	0.121
Blue Mountains (C)	39	0.295	0.286	0.308	Shoalhaven (C) - Pt B	79	0.108	0.098	0.121
Hawkesbury (C)	40	0.283	0.273	0.295	Wingecarribee (A)	80	0.293	0.283	0.305

Figure 5: WFH probability by Location June 2021

We see in Figure 5 that the highest incidence of working from home is predicted to occur in locations closer to the Centre of Sydney and generally in the wealthy locations where there is a higher accumulation of workers in professional and managerial occupations who are more likely to be able to WFH. The locations depicted with lower probabilities of WFH are heavily populated with blue collar workers and those who jobs prevent WFH. This evidence lines up well with that from other studies such as the recent Productivity Commission study (2021).

In addition to the adjustment of the number of commuting and non-commuting trips associated with modes and times of day, we also have to account for any changes in the travel times on the road network as a result of levels of WFH. The way do this is to use an adjustment equation for each and every trip purpose that adjusts the initial travel time before further traffic assignment[45]. The adjustment models are given in equations (7a-7c) where we initially obtained predictions of trips accounting for WFH (e.g., newavgtrips) and not accounting for WFH (oldavgtrtips), given the latter is resident in the network levels of performance data base, and then applied these formula to obtain travel times in the presence of the incidence of WFH. Importantly the travel times are adjusted as the number of trips varies.

new avgtime = base avgtime*(1+*0.3535*(newavgtrips/oldavgtrips - 1)) (7a)
new peaktime = base peaktime*(1+*0.739*(newpeaktrips/oldpeaktrips - 1)) (7b)
new offpeaktime = base offpeaktime*(1+*0.196*(newoffpeaktrips/oldoffpeaktrips - 1)) (7c)

4 Impact of accounting for WFH on the base or status quo situation

The starting position for assessing the impact of WFH is to compare a base or status quo situation where we ignore WFH (essentially a pre-COVID-19 situation with negligible WFH) to a base with WFH in mid-2021. The most interesting empirical evidence is summarised in Table 3 for the year 2023 with spatially distributed impact changes associated with residential and workplace locations, and with modal shares for all 80 zones summarised in Figures 6 to 8.

Overall, we see a 15.71% drop in the number of annual trips by car and public transport for all trip purposes, with the greatest decline being in public transport (~37%), which aligns well with the 65% estimate of return to using public transport in June 2021 just before an extended lockdown in the GSMA. This translates into a modal shift into the more bio-secure car compared to public transport, with car increasing from 91.33% to 93.53% for all trip purposes. This has resulted in an annual revenue loss to public transport of 36.93 %(from $1.482bn to $934m). Although the motorised modal share in favour of the car increased, there was a noticeable decline in car use which resulted in a reduction in fuel excise (10.72%), toll revenue (2%) and parking revenue (1.7%).

The generalised cost of public transport and car travel in $/person trip is based on all the components of time and cost and associated valuation given in Appendix B. It is a comprehensive set of factors fior main mode travel time, access and egress time, public transport headways, travel time variability, crowding on public transport, number of transfers and all cost components (fares, fuel, tolls, parking). There are noticeable decreases in generalised cost outlays associated with WFH, as might be expected where we account for the reduction in commuting travel as well as any changes in non-commuting as a result of WFH, of which some trip purpose activity might increase as a result of more flexible working arrangements. The extent of change associated with each trip purpose is discussed in Balbontin et al. (2021) for all trip purposes and Hensher, Beck et al. (2021) for details on commuting travel time and cost savings and how that saving is reallocated to work (paid and unpaid)and leisure). On average, we see a $1.06 decrease in the generalised cost for public

[45] MetroScan uses its own internal traffic assignment routines linked to the open-source traffic assignment platform PLANit (https://github.sydney.edu.au/PLANit), developed at ITLS (University of Sydney). The assignment configuration conducts a traditional static traffic assignment where route choice and network loading is done by deterministic user equilibrium (DUE) with the shortest path algorithm as Dijkstra one-to-all. Smoothing uses the method of successive averages (MSA) with the number of iterations user configurable; when set to 1 (default), DUE collapses to an all-or-nothing (AON) assignment.

transport and $3.01 for car travel, resulting in a weighted average reduction in the generalised cost of car and public transport of 13%.

Table 3: Summary of key MetroScan outputs with and without accounting for WFH, 2023

Modal Activity per annum (all trip purposes):	Base (before WFH)	Allowing for WFH	Percentage change
Car drive alone	3,063,173,050	2,723,910,852	-11.076
Car with passengers	1,650,606,668	1,344,940,034	-18.518
Bus	194,705,461	123,841,331	-36.396
Train	252,787,164	157,911,904	-37.532
Total motorised modes	*5,161,272,343*	*4,350,604,121*	*-15.707*
Modal shares (all trip purposes):			
Car drive alone	59.35%	62.61%	5.59
Car with passengers	31.98%	30.91%	-3.257
Bus	3.775	2.85%	-24.36
Train	4.90%	3.63%	-25.753
Passenger Vehicles:			
Total daily car kms	252,725,288	225,630,166	-10.72
Total revenue for PT use ($pa)	1,482,019,696	934,644,336	-36.934
Total revenue from parking ($pa)	302,715,424	297,595,277	-1.691
Total government revenue for GST	64,381,101,223	57,478,690,186	-10.721
Total revenue from toll roads ($)	867,317,568	849,985,927	-1.998
Total annual auto VKM ($)	9,165,032,041	8,182,432,845	-10.721
Total government revenue from fuel excise ($pa)	3,302,013,595	2,947,998,912	-10.721
Generalised cost per annum for PT ($pa)	9,726,699,697	5,824,402,874	-40.119
Generalised cost per annum for car ($pa)	104,504,496,348	85,685,930,808	-18.007
Generalised cost per person trip for PT ($)	21.726	20.669	-4.865
Generalised cost per person trip for car ($)	22.130	19.123	-13.588
Generalised cost per person trip car & PT ($)	22.095	19.223	-12.998
Freight Vehicles:			
Total government revenue from fuel excise ($pa)	1,162,090,474	1,168,269,296	0.532
Annual Total distance travelled Articulated	3,478,798,038	3,497,879,878	0.549
Annual Total distance travelled Rigid	2,331,654,333	2,343,466,600	0.507
Generalised cost per trip for freight ($)	126,303	123,487	0.532
Emissions and Pollution:			
Total CO_2 for passenger and freight movements	16,746,997,718	15,414,134,454	-7.959
Total CO_2 for passenger movements	12,432,062,391	11,099,199,128	-10.721
Total annual carbon dioxide for trucks	4,314,935,327	4,337,961,459	0.534
Total annual local air pollution costs for trucks	2,674,467,833	2,688,976,524	0.542

Emission impacts are of particular interest in a de-carbonisation world. We see an aggregate reduction in CO_2 of 7.96% for passenger and freight modes, of which passenger movements is the greatest contributor with a 10.72% reduction, but associated with a truck increase of 0.53%, the latter largely due to greater freight distribution during the pandemic including the growth in online shopping and delivery by light commercial vehicles.

Figures 6 and 7 show that there is a greater incidence of reduced trips associated with the incidence of WFH in locations close to the Central area of Sydney (but up to20 kilometres in most directions) including close by suburbs that are relatively wealthy and have a high proportion of people in occupations where WFH is feasible and achievable. While we see a consistent decrease in overall annual trips by all purposes this declines the further north and south where essential workers are more prevalent.

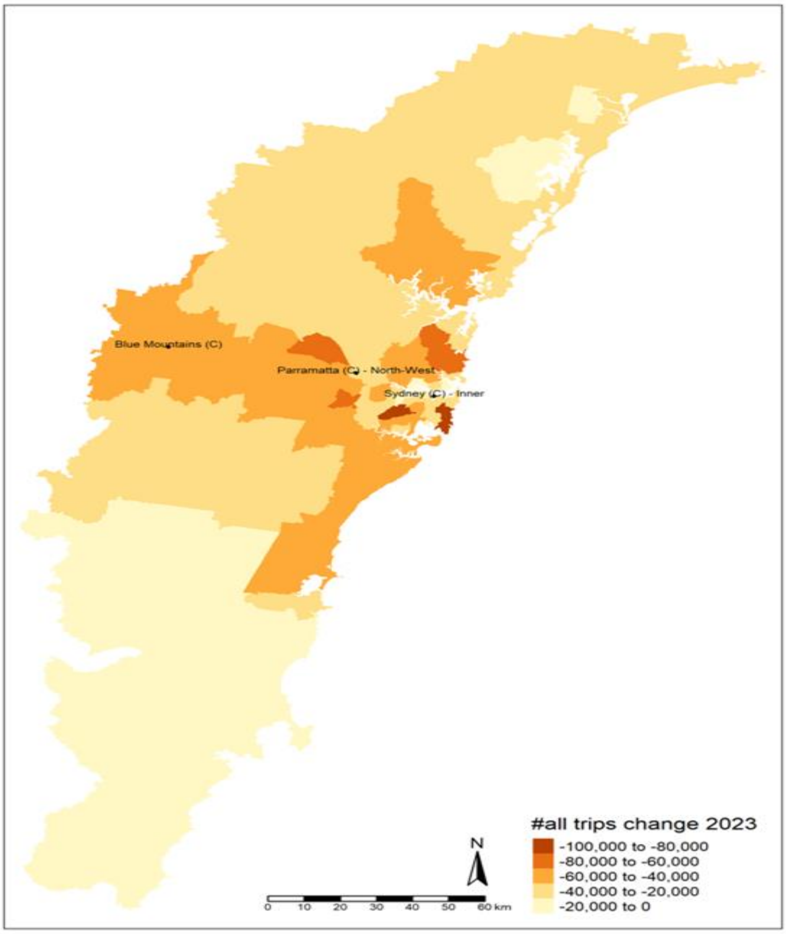


Figure 6: Impact of WFH on total trips 2023

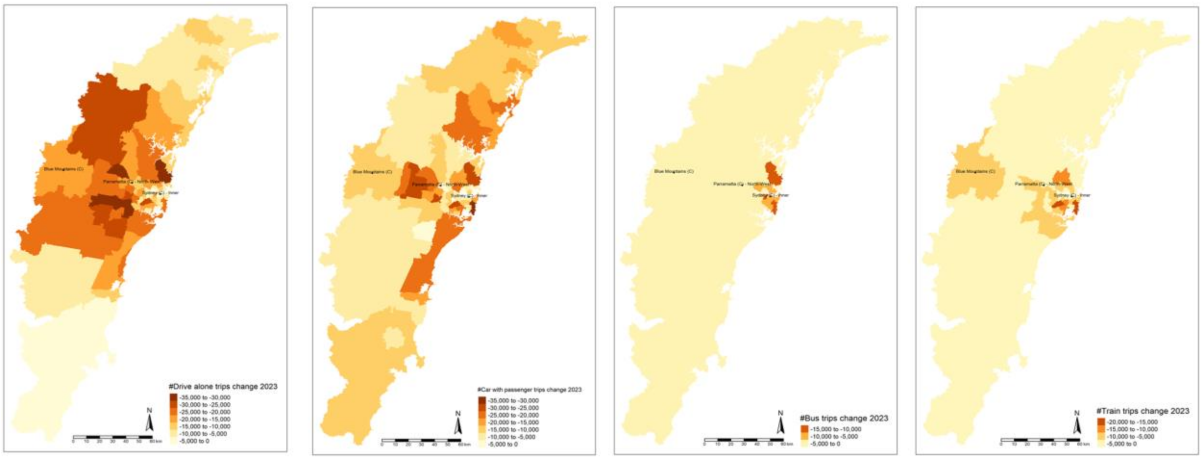


Figure 7: Impact of WFH on modal usage 2023

It is expected that WFH will impact of residential and workplace locations choices. In Metroscan this is influenced by changing levels of service associated with mode and time of days travel which results in a linked logsum (or expected maximum utility change) out of the mode and time of day model that is carried forward into location choice models representing changes in accessibility between each origin and destination zonal pair. These links are given in more detail in Figure 8, building on Figure 2.

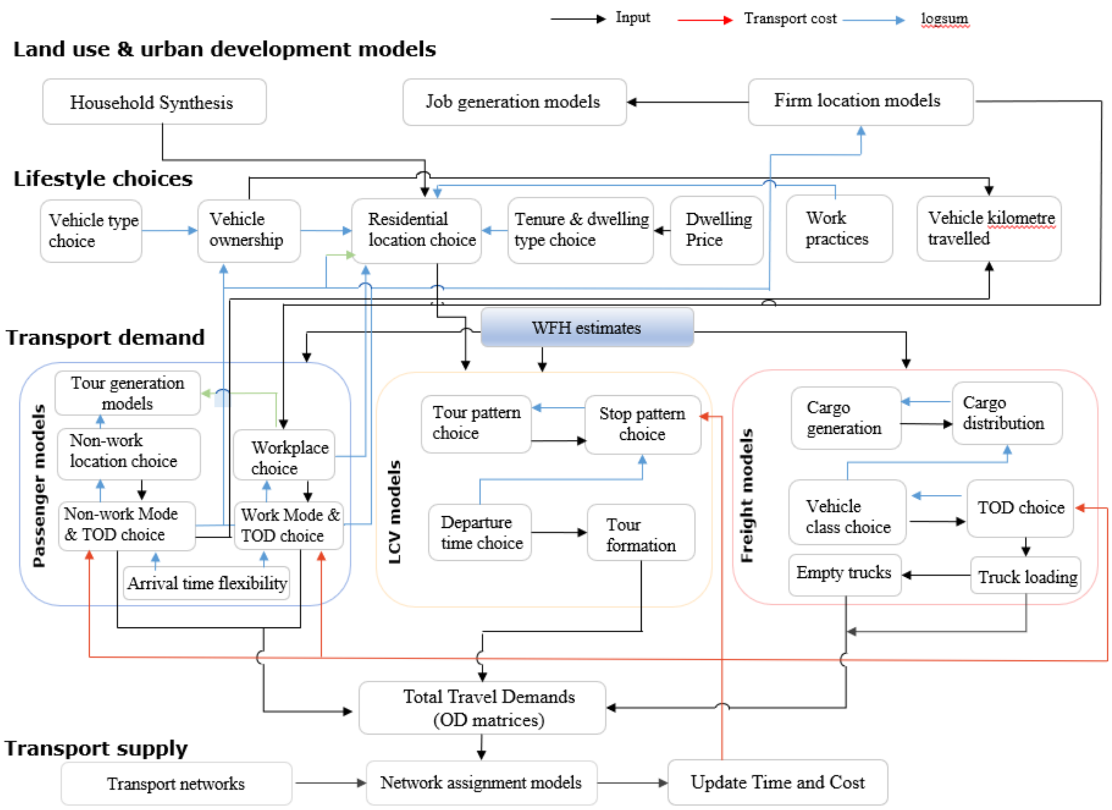


Figure 8: Tracing changes in accessibility on location responses

We can see the changes in workplace (left hand side) and residential (right hand side) locations as a result of increased WFH in 2023 and 2033. We present forecasts 12 years out as well as in 2023 to emphasise that these location adjustment take time and in the immediate years we anticipate relatively little change but more change in later years as people start to adjust their housing and job prospects. In general, we see growth of residential and workplace locations away from central areas within the GSMA which aligns with what is being shown in surveys of plans by employers and employees to move to satellite offices and reduced commuting travel and hence associated residential locations further out under the predicted suburbanisation trend (Beck and Hensher 2021b). But this takes time, and by 2033 we start to see significant reductions in people working in the central parts of Sydney, the Central coast and Newcastle as well as a start of a suburbanisation trend. Given the impacts that including WFH in a strategic transport and location model system has, the next task is to extend the analysis to an investment in a large piece of road infrastructure to see if the justification is tempered by the growth in WFH.

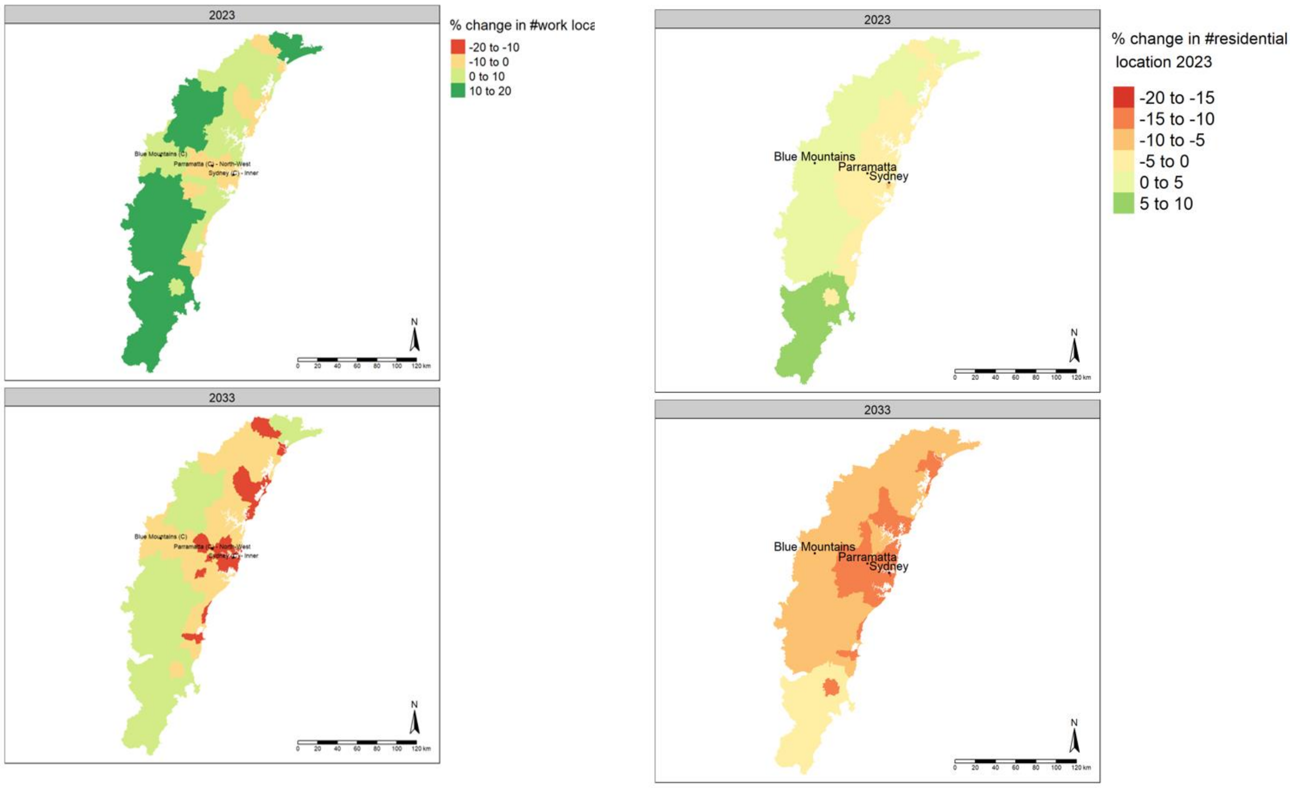


Figure 9: Impact of WFH on workplace and residential location

5 A Motorway Case Study

The Sydney case study selected is the M4 Outer Motorway upgrade (Figure 10) as representative of major road projects. This is a road widening project of around 37 kilometres in length, from the M4 East to the Nepean River, as shown in purple in Figure 9 (and between Parramatta and the Blue Mountains in Figure 3). This project is also estimated to have a capital cost of around $2.4 billion.

Figure 10: M4 Outer Motorway (Source: Western Sydney road alignments - M4 Motorway (Sydney) - Wikipedia

We have two scenarios of interest to compare with Table 3, namely the introduction of the M4 motorway before allowing for WFH and after allowing for WFH (Table 4), and the impact of the M4 when WFH is not considered at all (Table 5). In another paper, we report the results of this assessment where we ignore WFH (Stanley et al. 2021). While the impact on WFH or not in the presence of the M4 extensions is significant, a comparison between Table 3 and 4 suggests that the impact of the M4 investment on the overall performance of the network is negligible compared to the impact that WFH has, again reinforcing the enormous importance of WFH as a transport policy lever in obtaining significant positive change in network performance and emissions, despite the loss of public transport trips. Table 5 provides the comparison between investing in the M4 motorway and not doing so when we ignore WFH in our modelling and assumes the levels of WFH observed during the pandemic (at June 2021) did not occur. The most notable impact of the M4 in this setting is improvement in the generalised cost of freight vehicle movements (2.12%), associated in part with increased online shopping and the growth in demand of food etc.; otherwise it reinforces what is said above when comparing the evidence in Tables 3 and 4.

Table 4: Predicted impact of the M4 outer motorway before after allowing for WFH

Modal Activity per annum (all trip purposes):	In absence of WFH	Allowing for WFH	Percentage change
Car drive alone	3,066,126,672	2,726,835,198	-11.066
Car with passengers	1,649,450,071	1,343,773,199	-18.532
Bus	193,875,141	123,167,898	-36.471
Train	250,592,807	156,212,887	-37.663
Total motorised modes	5,160,044,691	4,349,989,182	-15.699
Modal shares (all trip purposes):			
Car drive alone	59.421	62.686	5.495
Car with passengers	31.966	30.891	-3.363
Bus	3.757	2.832	-24.621
Train	4.856	3.591	-26.05
Passenger Vehicles:			
Total daily car kms	252,750,626	225,563,693	-10.76
Total revenue for PT use ($pa)	1,472,595,406	927,225,202	-37.035
Total revenue from parking ($pa)	302,821,676	297,715,942	-1.686
Total government revenue for GST	64,387,555,812	57,461,756,289	-10.756
Total revenue from toll roads ($)	867,384,304	850,059,061	-1.997
Total annual auto VKM ($)	9,165,950,891	8,180,022,204	-10.756
Total government revenue from fuel excise ($pa)	3,302,344,641	2,947,130,397	-10.756
Generalised cost per annum for PT ($pa)	9,644,954,472	5,762,787,452	-40.251
Generalised cost per annum for car ($pa)	104,002,045,067	77,488,101,445	-25.494
Generalised cost per person trip for PT ($)	21.70	20.627	-4.945
Generalised cost per person trip for car ($)	22.055	19.036	-13.689
Generalised cost per person trip car & PT ($)	22.024	19.138	-13.104
Freight Vehicles:			
Total government revenue from fuel excise ($pa)	1,167,967,975	1,168,271,008	0.026
Annual Total distance travelled Articulated	3,496,949,142	3,497,885,167	0.027
Annual Total distance travelled Rigid	2,342,890,733	2,343,469,873	0.025
Generalised cost per trip for freight ($)	123.624	123.487	-0.111
Emissions and Pollution:			
Total CO2 for passenger and freight movements	16,770,147,304	15,433,897,013	-7.968
Total CO2 for passenger movements	12,433,308,779	11,095,929,173	-10.756
Total annual carbon dioxide for trucks	4,336,838,525	4,337,967,840	0.026
Total annual local air pollution costs for trucks	2,688,268,896	2,688,980,546	0.026

Table 5: Predicted impact of the M4 outer motorway compared to no project under no allowance for WFH

	Status Quo (no Projects)	M4 Motorway	Base vs M4 no WFH
Modal Activity per annum (all trip purposes):	Base (before WFH)	In absence of WFH	Percentage change
Car drive alone	3,063,173,050	3,066,126,672	0.096
Car with passengers	1,650,606,668	1,649,450,071	-0.070
Bus	194,705,461	193,875,141	-0.426
Train	252,787,164	250,592,807	-0.868
Total motorised modes	*5,161,272,343*	5,160,044,691	-0.024
Modal shares (all trip purposes):			
Car drive alone	59.350	59.421	0.120
Car with passengers	31.980	31.966	-0.044
Bus	3.775	3.757	-0.477
Train	4.900	4.856	-0.898
Passenger Vehicles:			
Total daily car kms	252,725,288	252,750,626	0.010
Total revenue for PT use ($pa)	1,482,019,696	1,472,595,406	-0.636
Total revenue from parking ($pa)	302,715,424	302,821,676	0.035
Total government revenue for GST	64,381,101,223	64,387,555,812	0.010
Total revenue from toll roads ($)	867,317,568	867,384,304	0.008
Total annual auto VKM ($)	9,165,032,041	9,165,950,891	0.010
Total government revenue from fuel excise ($pa)	3,302,013,595	3,302,344,641	0.010
Generalised cost per annum for PT ($pa)	9,726,699,697	9,644,954,472	-0.840
Generalised cost per annum for car ($pa)	104,504,496,348	104,002,045,067	-0.481
Generalised cost per person trip for PT ($)	21.726	21.7	-0.120
Generalised cost per person trip for car ($)	22.13	22.055	-0.339
Generalised cost per person trip car & PT ($)	22.095	22.024	-0.321
Freight Vehicles:			
Total government revenue from fuel excise ($pa)	1,162,090,474	1,167,967,975	0.506
Annual Total distance travelled Articulated	3,478,798,038	3,496,949,142	0.522
Annual Total distance travelled Rigid	2,331,654,333	2,342,890,733	0.482
Generalised cost per trip for freight ($)	126	123.624	-2.121
Emissions and Pollution:			
Total CO_2 for passenger and freight movements	16,746,997,718	16,770,147,304	0.138
Total CO_2 for passenger movements	12,432,062,391	12,433,308,779	0.010
Total annual carbon dioxide for trucks	4,314,935,327	4,336,838,525	0.508
Total annual local air pollution costs for trucks	2,674,467,833	2,688,268,896	0.516

6 Conclusions

The modelling capability developed and presented in this paper provides a behaviourally appealing way of recognising the incidence of working from home over a week and the appeal of embedding it into an integrated strategic transport and land use model system. The focus is on a capability to identify levels of WFH at a spatial level; in our model system it is an 80 by 80 origin-destination zonal level for the entire GSMA in NSW. The major changes that are associated with WFH are the quantum of commuting trips as well a non-commuting trips, where the latter is in part a response to more flexible working hours over a 24/7 week and the ability to undertake non-commuting trips when commuting travel time is 'saved'. Hensher et al. (2021) show that approximately 50% of the time reallocated from reduced commuting is used for leisure activities out of home and hence we see increased non-commuting trip making.

We have accounted for these changes and tracked them through Metroscan to obtain changes in travel times on the road network, which have impacts on many travel and locations choices, including over a 10 year period up to 2033, some amount of residential and workplace relocation (Figure 9). The feedback relationships between the full set of behavioural choices set out in Figures 2 and 8 enable us to gain a better understanding of just where changes in the probability of WFH have a spatial impact.

The most noteworthy changes in the transport sector as a result of the growing incidence of WFH, regardless on any proposed new transport initiatives, as identified in Metroscan, are reduced CO_2 emissions (up to 10%), close to a 13% reduction in the generalised cost of travel for all motorised modes, which is equivalent to an average saving of around $1 per person one-way trip, and a 16% reduction in total annual one-ways trips by all motorised modes with public transport having the greatest reduction of around 37%. Freight vehicle movement, however, has increased by half a percent which is substantial. When we introduce a project, the M4 outer motorway, the changes in key policy outputs are very small compared to the introduction of WFH in Metroscan.

In ongoing research, we are continuing to re-assess the evidence on the impact of WFH as we use the next waves of data collected to obtain new parameter estimates for mapping WFH with the variables describing each origin and destination. It is clear that WFH is possibly the most impactful, in a positive sense, transport policy lever we have had since the advent of the car. We are hoping to identify some stability in the estimates of the parameters as a way of giving us confidence that the 'next normal' under increased WFH is a solid reference point in going forward in analysis as part of both 'predict and provide' and 'vision and validate' (Jones 2016)[46]. While some authors have asked whether "predict and provide" might be a welcome casualty of COVID-19 and finally be replaced with a more holistic 'vision and validate' approach, focused on the kind of towns and cities we want to live in, and not ones that simply deal with residual traffic impacts, we would suggest that both perspectives have merit in a linked way. Specifically, the analytical tools that are commonly associated with 'predict and provide' should be repositioned to be responsible in recognising the types of initiatives that align with 'vision and validate', and hence can add value in understanding the varied sets of output results that can be used to judge a range of scenario-based futures where vison is key driver. The old 4-step model that is a villain in the 'predict and provide' armoury could well be replaced with tools such as Metroscan that provide enrichment support for obtaining relevant information of consequence on behavioural change.

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[46] 'Vision' is the setting out and planning from the outset what we want 'inspiring, sustainable growth' to look like. 'Validate' utilises exemplar design and modal shift forecasting techniques to test that vision, ensuring that our efforts will lead us to the best ways of eventually achieving it. This would envision, for example, what we want 'good growth' to look like, and use forecasting and design skills to test scenarios in order to identify the approach which will provide us with the best opportunity of achieving that vision.

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Appendix Paper A: Descriptive Statistics for the commuter mode choice and mapping equations

Table A1: Descriptive profile of respondents Wave 4 - mean (standard deviation)

Variables	GSMA
Age	41.54 (14.7)
Average personal annual income (AUD$000)	83.88 (52.8)
Number of people in the same house	3.21 (1.4)
Number of cars in your household	2.63 (1.0)
Number of children in household	0.66 (0.9)
Number of modes available	4.95 (2.7)
Proportion who used car as driver to commute prior to COVID-19	0.693
Distance from home to regular workplace location (kms)	19.95 (20.2)
Proportion of sample who are blue collar workers	0.154
Proportion of workers who have a high level of concern about using PT	0.379
Occupation professional (1,0)	0.287
Occupation manager (1,0)	0.192
Occupation sales (1,0)	0.095
Occupation clerical and administration (1,0)	0.181
Occupation community and personal services (1,0)	0.090
Occupation technology (1,0)	0.052
Occupation machine operators (1,0)	0.050
Occupation labourers (1,0)	0.052
NSW - Wollongong residential location (1,0)	0.138
NSW - Newcastle residential location (1,0)	0.192
NSW – Central Coast residential location (1,0)	0.119
QLD – Gold Coast residential location (1,0)	-
QLD – Sunshine Coast residential location (1,0)	-
Work located in CBD (1,0) (SEQ=4000, 4006 postcodes; GSMA = 2000, 2007, 2009 and 2011 postcodes)	0.128
Number of respondents	**421**
Number of observations (respondents-day of week)	**2,947**

Table A2: Mode characteristics Wave 4- mean (standard deviation)

Variables	GSMA
Travel time car driver (min)	29.24 (21.1)
Travel time car pax (min)	27.18 (19.2)
Travel time taxi/ride share (min)	25.56 (14.1)
Travel time train (min)	43.95 (34.3)
Travel time bus (min)	38.60 (29.5)
Travel time light rail (min)	47.50 (24.7)
Travel time ferry (min)	30.00 (10.0)
Travel time walk (min)	25.57 (16.9)
Travel time bicycle (min)	34.20 (29.4)
Travel time motorcycle (min)	36.67 (31.4)
Fuel car driver (AUD$)	3.85 (3.7)
Fuel car pax (AUD$)	3.40 (3.1)
Fuel motorcycle (AUD$)	1.60 (1.3)
Parking car driver (AUD$)	1.87 (7.4)
Parking car pax (AUD$)	0.17 (1.3)
Toll car driver (AUD$)	1.43 (9.0)
Toll car pax (AUD$)	0.25 (1.6)
Waiting time train (min)	7.67 (4.9)
Waiting time bus (min)	7.92 (5.1)
Waiting time light rail (min)	5.00 (0.0)
Waiting time ferry (min)	8.33 (2.9)
Egress time train (min)	9.56 (5.1)
Egress time bus (min)	8.08 (5.4)
Egress time light rail (min)	12.50 (3.5)
Egress time ferry (min)	5.67 (4.0)
Access time train (min)	13.43 (10.3)
Access time bus (min)	12.83 (16.1)

Variables	GSMA
Access time light rail (min)	8.50 (2.1)
Access time ferry (min)	20.00 (10.0)
Ride Share fare ($)	33.44 (31.1)
Train Fare ($)	6.56 (5.4)
Bus Fare ($)	4.81 (4.8)
Light Rail Fare ($)	21.00 (12.7)
Ferry Fare ($)	**6.50 20.4)**

Appendix Paper B: Generalised Cost and Emission Calculations

Public Transport Times

Bus Time=In Vehicle Time + 1.5*Egress Time + 4.1 *STD of In Vehicle Time +1.5*Access Time +1.65*STAND + 0.7* Peak Time Frequency (Headway Minutes)

Train Time=In Vehicle Time + 1.5*Egress Time + 4.1 *STD of In Vehicle Time +1.5*Access Time +1.65*STAND + 0.7* Peak Time Frequency (Headway Minutes) + 1.5*Transfer Times

GC for Bus and Train

$$BusGC = \sum_{i=1}^{6}\sum_{j=1}^{6} Bustime * VoT$$

$$TrainGC = \sum_{i=1}^{6}\sum_{j=1}^{6} Traintime * VoT$$

with i for the commuting, business, and other non-work trips, and j as 6 time of the day (TOD).

Car Peak Time and Car Off-Peak Times

Carotime = Off-Peak in vehicle time + 1.5 * Egress Time + 4.1*STD of In Vehicle Time

Carptime = Peak in vehicle time + 1.5 * Egress Time + 4.1*STD of In Vehicle Time

GC for Bus and Train

$$CarPGC = \sum_{i=1}^{6}\sum_{j=1}^{6} (Carptime * VoT \ + \ Other\ Costs)$$

$$CarOpGC = \sum_{i=1}^{6}\sum_{j=1}^{6} (Carotime * VoT \ + \ Other\ Costs)$$

Note: VOT is different for commuting and other purposes as noted in the following table and varies by purpose (i) and time of the day (TOD, j). The peak and off-peak times are weighted averaged based on the amount of peak and off-peak time to obtain the overall GC for car.

Public Transport	All by ToD				VoT weight	Row	VoT
Variable in these utility expressions	Bus	Train	Walk	Cycle			
INVTIME = in-vehicle time in minute	√	√	√	√	1	OD	17.72/57.49
EGGTIME = egress time in minute walking propn	√	√			1.5	O or D	
DEVTIME2 = std dev of door-to-door travel time in minute	√	√			4.1	OD	
ACCTIME = access time in minute walking propn	√	√			1.5	O or D	
FARE = PT fare (one way) in $	√	√			N/A	OD	
STAND = number of people stand on PT when boarding	√	√			1.65	OD	
PTFREQ = PT frequency (or headway) in minute	√	√			0.93 to 0.37*	OD	

Public Transport	All by ToD				VoT weight	Row	VoT
Variable in these utility expressions	Bus	Train	Walk	Cycle			
MABUS = access mode is bus (1/0)		√			N/A	O or D	
MEPT = egress mode is PT (1/0)					N/A	O or D	
TRANSFER = number of transfers		√			1.5	OD	
MACAR = access mode is car (1/0)	√	√			N/A	O or D	
* 5 min service =0.93, 10 min=0.83, 20 min=0.65, 30 min=0.52, 40 min= 0.44, 60 min = 0.37							
GC = sum of all after applying adjusted VoT to levels of each attribute							

Car	All by toD		VoT weight	Row	VoT
Variable in these utility expressions	Car DA	Car RS			
INVTIME = in-vehicle time in minute	√	√	1	OD	17.72/57.49
GGTIME = egress time in minute walking propn	√	√	1.5	O or D	
DEVTIME2 = std dev of door-to-door travel time in minute	√	√	4.1	OD	

Walk and Cycle	All by ToD		VoT weight		VoT
Variable in these utility expressions	Walk	Cycle		Row	
INVTIME = in-vehicle time in minute	√	√	N/A	OD	23.49
Using value of $3.25/trip travelling 8.3 mins on average, the VoT for walk per hour is $23.49 (3.25/8.3*60).					

Other costs include parking, toll, fuel, registration and maintenance costs are shown in the following table for each trip purpose.

	Km	trip parking cost	trip toll cost	Trip fuel cost	Rego	Maintenance	Total costs/trip	Weight based on trips
Commuting	15.7	$1.33	$1.02	$2.79	$0.94	$2.51	$8.59	0.17
Work related business	16.4	$1.39	$1.07	$2.91	$0.98	$2.62	$8.97	0.063
Education/childcare	6.3	$0.53	$0.41	$1.12	$0.38	$1.01	$3.45	0.1
Shopping	5.5	$0.46	$0.36	$0.98	$0.33	$0.88	$3.01	0.154
Personal business	7	$0.59	$0.46	$1.24	$0.42	$1.12	$3.83	0.055
Social/recreation	8.4	$0.71	$0.55	$1.49	$0.50	$1.34	$4.60	0.253
Serve passenger	5.8	$0.49	$0.38	$1.03	$0.35	$0.93	$3.17	0.182
Other	4.7	$0.40	$0.31	$0.83	$0.28	$0.75	$2.57	0.022
Weighted average total	**8.85**	**$0.75**	**$0.58**	**$1.57**	**$0.53**	**$1.42**	**$4.84**	

Other key assumptions used in MetroScan are given below.

	Commute		Non-commute		Business		Freight	LCV
	Car	PT	Car	PT	Car	PT		
VTTS per person ($/person hour)	17.72	17.72	17.72	17.72	57.48	57.48	31.05	25.41
Average vehicle occupancy	1.7		1.7		1.3		1	1
Value of travel time reliability (VoR) ($/person hour)*	30.12	Bus only	30.12	Bus only	97.72	97.72	52.79	52.79
Value of out-of-vehicle time ($/person hour)	26.58	26.58	26.58	26.58	57.48	57.48	N/A	N/A

	Commute		Non-commute		Business		Freight	LCV
	Car	PT	Car	PT	Car	PT		
CO_2 emissions (c/km)	2.66	15.61 bus; 0.8 rail; 32.69 light rail	2.66	15.61 bus; 0.8 rail; 32.69 light rail	2.66	15.61 bus; 0.8 rail; 32.69 light rail	3.67 rigid, 14.64 articulated	2.35
Air pollution (c/vkm)	3.37	37.9 bus; 4.99 rail; 41.42light rail	3.37	37.9 bus; 4.99 rail; 41.42light rail	3.37	37.9 bus; 4.99 rail; 41.42light rail	16.5 rigid, 65.82 articulated	7.56
Air pollution (c/pkm)	2.39	1.89 bus, 0.04 train, 0.64 LR	2.39	1.89 bus, 0.04 train, 0.64 LR	2.39	1.89 bus, 0.04 train, 0.64 LR	N/A	N/A
Carbon dioxide equivalent (CO2-e) $/tonne*	62.79							
Carbon monoxide (CO) $/tonne*	3.95							
Oxides of nitrogen (Nox) $/tonne*	2.503.55							
Particulate matter (PM10) $/tonne*	398,451.75							
Total hydrocarbons (THC) $/tonne*	1,254.41							
Fuel excise (proportion of fuel price)	0.416							

*Transport for NSW (2020)

Appendix Paper C: Poisson Regression Models for One-way weekly trips for each trip purpose

A Poisson regression model is estimated for the number of one-way weekly trips for each purpose type, location (metropolitan or regional area) and working status in June 2021. In total, 8 models were estimated for the workers in the GSMA. The dependent variables, the number of one-way weekly trips for each purpose, are non-negative discrete count values, with truncation at zero, which are defined as a discrete random variable, y_i, observed over one period of time. The Poisson regression probability is given by equation (C1).

$$P(y_i = k \mid \mu_i) = \frac{\exp(-\mu_i)\cdot \mu_i^k}{k!} \qquad k = 0,1,...$$

(C1)

The prediction rate, μ_i, is both the mean and variance of y_i and is defined as follows:

$$\mu_i = E\left(y_i = k \mid x_i\right) = \exp(\beta' x_i)$$

(C2)

The prediction rate or expected frequency of the number of days WFH was calculated as a function of different explanatory variables, shown in equation (C3).

$$\mu_i = \exp\left(\beta_0 + \sum_n \beta_n \cdot z_n \cdot d_a + \sum_m \beta_m \cdot x_m \cdot d_a + \sum_f \beta_f \cdot x_f + \varepsilon\right)$$

(C3)

where β_0 represents the constant; z_n represents respondents socio-demographics (e.g., age, gender, income); x_m other respondents' characteristics such as distance from home to work, mode used, etc.; d_a dummy variables associated to each area; x_f represents the factor attributes to underlying attitudes towards COVID-19; and the β represent the parameter estimate associated to each of the variables.

The direct point elasticities are presented in equation (C4).

$$\text{Elasticity} \Rightarrow \frac{\partial E\left(y_i \mid x_i\right)}{\partial x_i} \cdot \frac{x_i}{E\left(y_i \mid x_i\right)} = \beta_i \cdot x_i$$

(C4)

The direct point elasticity formula indicates that a one percentage change in the *i*th regressor, *ceteris paribus*, leads to a one percentage change in the rate or expected frequency of $\beta \cdot x_i$. In contrast, where a variable is a dummy variable (1,0), a one percentage change is inappropriate, and a direct arc elasticity form is used as given in equation (C5).

$$\text{Arc Elasticity} \Rightarrow \frac{E\left(y_i \mid x_1\right) - E\left(y_i \mid x_2\right)}{x_1 - x_2} \cdot \frac{\left(x_1 + x_2\right)/2}{\left(E\left(y_i \mid x_1\right) + E\left(y_i \mid x_2\right)\right)/2}$$

$$= \frac{E\left(y_i \mid 1\right) - E\left(y_i \mid 0\right)}{E\left(y_i \mid 1\right) + E\left(y_i \mid 0\right)}$$

(C5)

The arc elasticity interpretation is equivalent to the direct elasticity presented in equation (C4) but it has to be multiplied by 100 to represent a 100% change (from 1 to 0, or 0 to 1).

Table C1: Model estimates for respondents currently employed (workers) located in the GSMA – mean (t value)

GSMA workers	Commute	Work-related	Education	Food shopping	General shopping	Personal business	Social recreation	Visit sick/elderly
Constant	2.100 (61.04)	-0.109 (0.48)	-2.024 (7.87)	1.093 (13.70)	0.677 (5.18)	-0.426 (3.21)	0.246 (2.88)	-2.496 (6.09)
Age (years)		-0.007 (1.92)	0.007 (1.67)		-0.006 (2.02)			0.025 (3.75)
Gender female (0,1)	-0.226 (5.11)	-0.466 (4.03)	0.723 (6.82)					0.412 (2.18)
Personal income ('000AUD$)		0.003 (3.88)				0.004 (3.97)	0.003 (4.92)	0.005 (3.65)
Number of children in household			0.713 (18.96)	-0.098 (2.78)		-0.105 (1.66)	-0.113 (2.77)	
Number of cars per adult in household		0.162 (2.15)	0.456 (6.41)	0.117 (2.22)				
Distance from home to office (kms)				-0.004 (2.53)		-0.005 (1.62)		-0.016 (2.74)
Proportion of days WFH	-1.556 (19.33)		0.255 (2.30)			0.282 (1.93)	0.189 (1.91)	
Occupation clerical and administration (0,1)			-0.355 (2.35)				0.227 (2.48)	-0.687 (2.69)
Occupation sales (0,1)				-0.350 (2.88)				-2.724 (3.71)
Occupation blue collar (0,1)		0.480 (3.72)			0.250 (2.40)			
Used car to go to work last week (0,1)		-0.123 (2.10)		-0.075 (2.27)	-0.152 (3.38)	-0.134 (2.14)	0.138 (3.29)	-0.424 (4.12)
Newcastle (0,1)					0.240 (2.48)	0.358 (2.70)		1.411 (7.15)
Factor analysis: authorities and community response				0.067 (2.12)				0.261 (2.40)
Factor analysis: social meetings		-0.201 (4.97)	-0.123 (3.17)		0.119 (2.94)	0.114 (2.05)	0.179 (5.94)	0.183 (2.08)
Factor analysis: all meetings					0.152 (3.60)	0.099 (1.79)		0.529 (5.24)
Factor analysis: concerned about health	-0.129 (2.90)	-0.165 (2.89)						-0.275 (2.04)
Factor analysis: public transport concerned		0.123 (2.09)		0.079 (2.40)	0.152 (3.38)	0.139 (2.21)	-0.139 (3.30)	0.440 (4.25)
Interaction between factor concerned about health and use of car to go to work last week			0.000 (1.98)					
Interaction between factor concerned about health and proportion of days WFH							-0.144 (1.92)	0.669 (3.14)
Restricted log-likelihood	**-1,480.65**	**-747.09**	**-882.70**	**-972.78**	**-776.49**	**-598.61**	**-954.44**	**-428.88**
Log-likelihood at convergence	**-1,202.40**	**-680.28**	**-645.84**	**-954.15**	**-755.91**	**-577.15**	**-901.18**	**-356.08**
AIC/n	**6.20**	**3.54**	**3.36**	**4.93**	**3.92**	**3.01**	**4.67**	**1.90**
Sample size	**390**	**390**	**390**	**390**	**390**	**390**	**390**	**390**

Appendix Y. Paper #21: Exploring the link between working from home and how worthwhile the things that you do in life are during COVID-19

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Abstract

The COVID-19 pandemic has had a significant impact on the way we work and live, with working from home becoming more than the occasional desire but a regular feature of work and life. While an increasing number of research studies have promoted the virtues of what is often described as the positive unintended consequences of the pandemic, there are also downsides, especially during lockdown, that have broadly been described as impacting mental health and life's worth. In this paper we use data collected in New South Wales during September 2020 and June 2021, seven and 16 months after the pandemic began, to obtain an understanding of the extent to which the pandemic has impacted on how worthwhile things done in life are for workers. We investigate whether there is a systematic behavioural link with working from home, reduced commuting linked to distance to work, balancing work with non-work activities, and various socio-economic characteristics. The evidence suggests that the opportunity to have reduced commuting activity linked to working from home, increased work-related productivity and an improved balance between time spent on work and time spent not working, have all contributed in a positive way to improving the worth status of life, offsetting some of the negative consequences of the pandemic.

***Keywords**:* COVID-19; working from home; NSW experience; satisfaction with life; anxiety; ordered choice; reduced commuting; well-being

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1 Introduction

The COVID-19 pandemic, as forced onto society, has resulted in a large number of changes in the way we live and work. From a negative perspective, Dam et al. (2020) list a range of negative outcomes of the SARS-CoV-2 and COVID-19 pandemic such as duration of the lockdown, loss of freedom, boredom and frustration, social separation, inadequate lifestyle supplies, financial crisis, increased family issues and domestic violence, anxiety related to local news as well as rising case numbers, stigma, fear of contracting the disease, uncertainty about life, fear of losing closed ones and fear of death (thanatophobia). Despite the horrors of the virus, a number of positive outcomes have resulted which have delivered support from both employers and employees for more flexible working arrangements, including the greater incidence of working for home. Recently in Australia, we have seen that moderated behaviour has reverberated into periods of no lockdown, where people are self-regulating activity where the risk of transmitting and catching the virus has been deemed too risky.

Despite the overarching negatives of COVID-19, there have been some unintended positive consequences. There is a large literature that shows the benefits of reduced commuting which is one of the outcomes of the new paradigm of extensive working from home. From a health perspective, there have been a number of studies that have explored the impact of commuting. For example, Haefner et al. (2001) found that German commuters with a one-way trip time of 45 minutes or more had significantly higher levels of pain, dizziness, exhaustion and severe sleep deprivation than the sample group of non-commuters with an equivalent one-way trip time. Similarly, Stutzer and Frey (2007) found that people with long journeys to and from work are systematically worse off and report significantly lower life satisfaction, which is not explained by a compensation or benefit at the level of the household. Further examination of the German Socio-Economic Panel data from 2007 to 2013 provided contrasting results, revealing that longer commutes were only related to lower satisfaction with particular life domains, especially family life and leisure time, and that time spent on housework, childcare as well as physical and leisure activities mediated the association between commuting and well-being (Lorenz, 2018). Ingenfelt et al. (2019) found a non-linear relationship between the negative effects of commuting and the trip distance, suggesting that the negative effects of commuting are almost completely due to individuals who commute more than 80 kilometres daily one-way.

In the USA, Hoehner et al. (2012) found those with commuting trips exceeding a distance of 20 miles had on average a significantly higher levels of cholesterol, heart disease, stroke, blood sugar, and kidney disease (limited though due to the cross-sectional nature of the study and an inability to disentangle commuting time from correlations with sedentary behaviour). Kahneman and Krueger (2006) find that morning commuting is particularly unpleasant, with the degree determined by whether the person commutes alone or with another person, and suggest that interventions that reduce the amount of time spent commuting alone, such as congestion taxes and carpool subsidies, could possibly have a beneficial effect on individuals' emotional states. One UK study found that every extra minute of commute time reduces job satisfaction, reduces leisure time satisfaction, increases strain and reduces mental health, whereas working from home, walking to work and shorter commute times increase job satisfaction; and that shorter commute times make it more likely that an employee will stay with their job (Chatterjee et al. 2017). In an Australian context, it has been found that commuting distance has a direct impact on increased absenteeism after controlling for indirect effects (Ma and Ye 2019, Hensher et al. 2021).

The aforementioned savings in the time spent commuting have arisen because of the shelter at home, or work from home orders that have forced many organisations to adopt remote working at a much higher rate than many thought possible. Also a positive, Australian studies have found that productivity whilst working from home has remained largely unchanged compared to the regular work environment; although there are some occupations classes with increased productivity (Beck and Hensher 2020, 2020a,b, 2021). In the USA, studies have similarly shown that firms have not experienced productivity loses due to working from home (Bartik et al. 2020).

Given that remote working (flexible working, working from home, or whatever term you wish to use) will be a significantly greater proportion of the work mix moving forward, it is not surprising that research has explored the interplay between work and well-being during the COVID-19 pandemic. From a prevention perspective Alipour et al. (2021) found that working from home reduced SARS-CoV-2 infections and helped to protect firms from COVID-19 distress. With respect to indicators of negative working from home experiences, Xiao et al. (2021) find that decreased overall physical and mental well-being after working from home were associated with physical exercise, food intake, communication with co-workers, children at home, distractions while working, adjusted work hours, workstation set-up and satisfaction with workspace indoor environmental factors. Negatively perceived factors of working from home include lack of distinction between work and home life, poor eating habits, loss of self-discipline, absence of an IT department, longer working hours and frequent video calls (Statista, 2020). In four waves of data collection in France, Italy, Germany, Spain and Sweden, covering the period May–November 2020, Schifano et al. (2021) find that well-being is lowest among those who are not working at all, but is also lower for those who are working from home, in particular among those who are older, better-educated, and/or those with young children and those with more crowded housing. Mohring et al. (2020) find an overall decline in work satisfaction which is most pronounced for mothers and those without children who have to switch to short-time work. In contrast, fathers' well-being is less affected negatively and their family satisfaction even increased after changing to short-time work.

On the other hand, Birimoglu and Began (2022) find that working from home, while having challenges, also has favourable aspects if organisations can develop and maintain a good level of productivity and encourage staff to achieve the right level of work and life balance. In terms of promoting productivity in the working from home environment Hashim et al. (2020) highlight the importance of adequate ICT equipment and support. Interestingly, Butler and Jaffe (2021) found that simply reflecting on the benefits of being with family, more flexibility and on support of colleagues could provide greater levels of work satisfaction through the day. In a longitudinal study during the pandemic, Russo et al. (2021) find that social contacts predicted positively and could moderate stress which predicted an individual’s well-being negatively. They also found their sample of software engineers adapted to working from home over time and were able to do so productivity irrespective of predictor variables they attempted to use, highlighting the widespread success of the measure (although boredom and distraction did negatively impact productivity). For those employees that experienced lower work productivity, increased stress and poorer mental health, Toniolo-Barrios and Pitt (2021) recommended mindfulness techniques to help reduce negative outcomes and provide recommendations as to how to implement them. In spatial modelling of place use and well-being in Sweden, Samuelsson et al. (2021) found that easy access to natural settings supported well-being, irrespective of the population density of visited places, and highlighted how equitable access to natural settings can increase urban resilience towards pandemics. De Vos (2020) posits that walking and cycling can be important ways to maintain satisfactory levels of health and well-being.

One overarching concern that may exist, is how worthwhile individuals think the things that they do in life are, and how that might have changed in the face of the pandemic and resulting shock to work and activity. This is often raised in the broader literature, including the grey literature, with limited evidence on whether it is a serious issue adding to the sense of social alienation and well-being that was not there in the pre-COVID-19 period. If we can identify a link between this and what are identified as positive lifestyle outcomes of the pandemic such as reduced commuting, especially for longer distance commutes, increased flexibility in working arrangements and generally higher levels of productivity in working from home, then we should be able to establish whether individuals think that the things they do in life at present have changed for the better or worse in terms of worthwhileness, which is a useful proxy for some features of well-being.

In this paper, we draw on data obtained from the third wave undertaken in September 2020 and the fourth wave in June 2021 as part of an ongoing study of working from home and its implications for travel for residents in New South Wales (NSW) (see Figure 1). During this survey period NSW had experienced an extended run of low COVID-19 case numbers, almost exclusively limited to the hotel quarantine system, and thus life had largely returned to pre-COVID-19 conditions, albeit with workers having a far greater opportunity to continue to work from home to some extent, at levels much higher than before the pandemic.

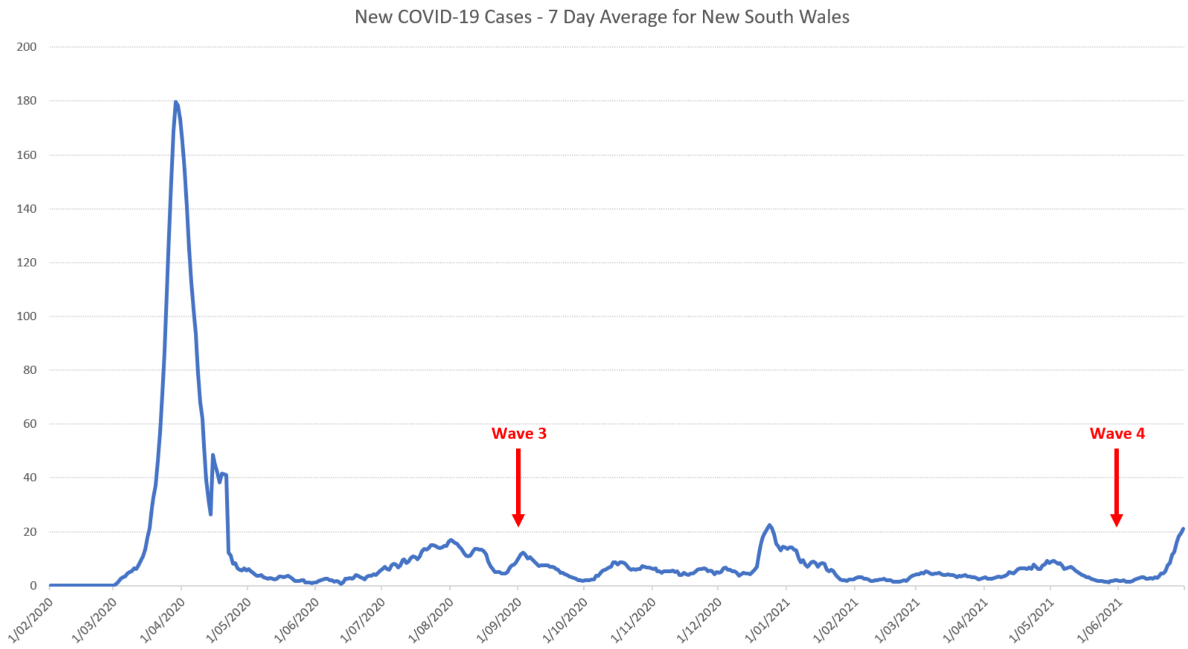

Figure 1. Overview of data collection time points

The paper is organised as follows. We begin with a descriptive overview of the data used to identify a number of soft variables pertaining to happiness, anxiety and life's worth which were collected during the 3rd and 4th waves of an ongoing survey. This is followed by a brief overview of the properties of the ordered logit choice model as an appropriate analytical setting when the dependent variable is an ordered rating scale. We then present the evidence from the estimation of the ordered logit model, focussing on the direct elasticity estimates associated with each explanatory variable at each level on the 11-point rating scale. These elasticity estimates provide the behaviourally rich evidence on the role of statistically significant influences on life's worth that are linked to the propensity to work from home, which is associated with increased work productivity, and reduced commuting activity as well as feelings of anxiety at the time of the surveys. We conclude with comments on the positive offsetting effects that have contributed to mitigating the negative impacts of influences that reduce the worth of life.

2 The Descriptive Setting

As part of an ongoing longitudinal survey designed to investigate changes in travel and working for home since the beginning the COVID-19 pandemic in March 2020, as the survey developed over time we began asking a short series of well-being questions identical to those used in the UK Office of National Statistics Annual Population Survey (ONS 2021), as part of their quarterly estimates of life satisfaction (in part so that subsequent comparisons in ongoing research between Australia and the UK could be made, especially given the very different experiences with COVID-19). The four questions used asked respondents to indicate: (i) how satisfied they are with life nowadays, (ii) how worthwhile they think things done in life are, (iii) how happy they felt yesterday, and (iv) how anxious they felt yesterday. Full details of the survey are provided in Beck and Hensher (2020a, 2021). A particular focus for the data collection has been New South Wales, given the overarching objective of the project funding data collection, with a view to understanding how commuting behaviour might change during the pandemic as well as in a living with a COVID-19 world. As such, there is also a greater focus on workers, their experiences with working from home, and how it has affected commuting mode and time choices. In this paper we focus on the interplay between working from home and these quality-of-life measures.

The four well-being questions are reported on a scale from 0 representing 'not at all' to 10 representing 'completely'. The sample average for each of the four states from both waves is presented in Figure 2 (with the 95% confidence interval shown by the error bars). There is a significant increase in overall satisfaction with life in Wave 4, along with the level of happiness felt, indicating that as people moved away from the initial peak of COVID-19 and life returned to some degree of normality, the mood of people improved; however, their overall level of anxiousness and perhaps more interestingly there perspective on how worthwhile the things they did in life were, remained unchanged between the two waves, potentially indicating that despite being less satisfied and happy, the sample still found worth in the activities and work being completed.

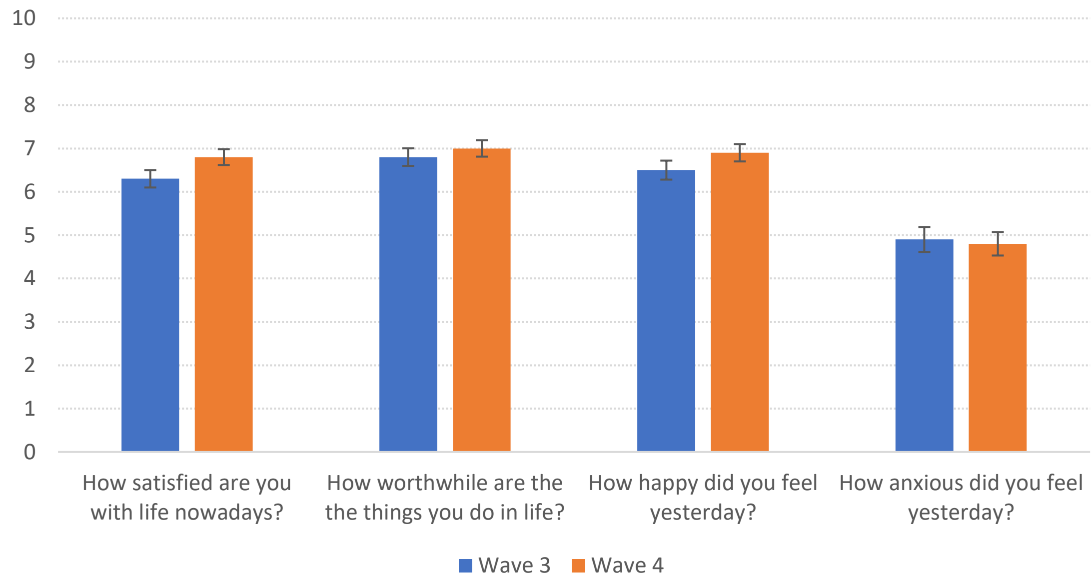

Figure 2. Sample Average Scores for Each Wave on Each Scale Item

Table 1 shows the partial Spearman's correlation matrix for each scale item within each wave of data collection. The correlation patterns are very similar: it can be seen that satisfaction with life, how worthwhile people find the things they do in life to be, and happiness all exhibit strong positive correlations, whereas they are negatively correlated with anxiousness. Perhaps interesting to note is that the weak correlations exhibited with anxiousness in Wave 3 all but disappear in Wave 4.

Table 1 Partial correlations between the four items

Wave 3	SatLife	SatWorth	SatHappy
SatLife	1		
SatWorth	0.75	1	
SatHappy	0.74	0.73	1
SatAnx	-0.23	-0.16	-0.32

Wave 4	SatLife	SatWorth	SatHappy
SatLife	1		
SatWorth	0.79	1	
SatHappy	0.74	0.74	1
SatAnx	-0.05	-0.07	-0.16

Given the high partial correlation amongst the first three questions across both waves, we focus on how worthwhile individuals think things done in life currently are, which we see as the most interesting question, although we investigate in the ordered choice model the relationship this variable has with anxiety. For this variable, given we also found no statistically significant difference between the responses obtained in the two time periods (see Figure 2), we pool the Wave 3 and Wave 4 sample for this statement. Figure 3 which shows the full distribution of responses for this statement in the pooled sample, as we as for each wave of data collection.

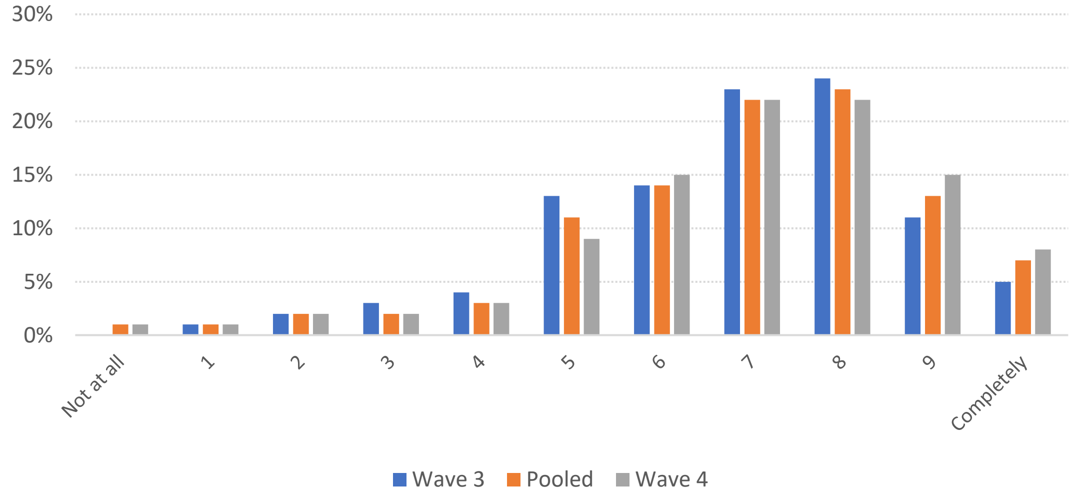

Figure 3. Distribution of the "how worthwhile are the things you do in life" statement

In the distribution presented in Figure 3, we see a right-skewed distribution with rating scores of 7 and 8 dominating. This already hints at evidence that satisfaction with life, in particular as people moved away from the initial peak of COVID-19 infections, was returning to some greater degree of positive 'normality', and was robust for those people who were still working during this period. However what interests us is investigating whether there is a systematic and statistically significant relationship between what the accumulating literature is suggesting are positive outcomes of the pandemic, centred on working for home and reduced commuting. We implement an ordered logit choice model on the 11-point scale to investigate the presence or otherwise of such a relationship.

3 The Ordered Logit Model

The response variable of interest is a rating scale of 11 levels which can be represented by an ordered choice model of the logit form. The ordered logit model explicitly recognises the ordinality of life satisfaction, and avoids arbitrary assumptions about scale. It does this by defining points on the *observed scale* as thresholds that recognise, in preference space, that the numerical levels of the dependent variable are not strictly linear (Zavoina and McElvey 1975; Greene and Hensher 2010). Formally, let Y_i^* denote an unobserved (or latent) continuous variable ($-\infty < Y_i^* < +\infty$), defined in utility space and $\mu_0, \mu_1, ..., \mu_{j-1}, \mu_J$ denote the threshold utility points in the distribution of Y_i^*, where $\mu_1 = -\infty$ and $\mu_J = +\infty$. Define Y_i to be an ordinal (observed) variable for life worth at present such that $Y_i = j$ iff $\mu_{j-1} < Y_i^* < \mu_j$; $j = 0,1,2,...,J$ response levels. Since Y_i^* is not observed, the mean and variance are unknown. We assume that Y_i^* has a mean of zero and a variance of one. To make the model operational, we need to define a relationship between Y_i^* and Y_i. The basic ordered choice model is based on a latent regression model given as equation (1).

$$Y_i^* = \beta' x_i + \varepsilon_i, \quad \varepsilon_i \sim F(\varepsilon_i | \theta), \ E(\varepsilon_i) = 0, \ Var(\varepsilon_i) = 1 \quad (1)$$

where θ collects the mean and threshold parameters. The observation mechanism results from a complete censoring of the latent dependent variable as follows:

$$\begin{aligned} Y_i &= 0 \text{ if } Y_i^* \le \mu_0, \\ &= 1 \text{ if } \mu_0 < Y_i^* \le \mu_1, \\ &= 2 \text{ if } \mu_1 < Y_i^* \le \mu_2, \\ &\ldots \\ &= J \text{ if } Y_i^* > \mu_{J-1}. \end{aligned} \quad (2)$$

The probabilities which enter the log likelihood function are given by equations (3).

$$\text{Prob}[y_i = j \mid x_i] = \text{Prob}(Y_i^* \text{ is in the } j\text{th range}) = F(\mu_j - \beta' x_i) - F(\mu_{j-1} - \beta' x_i) > 0, \ j = 0,1,...,J. \quad (3)$$

We also depart from the basic model to test for random thresholds and heterogeneity in the preferences associated with the explanatory variables (Greene and Hensher 2010). In order to model heterogeneity in the utility functions across individuals, we construct a hierarchical model in which the parameters vary randomly due to individual specific unobservables, v_i. The parameters appear as equation (4).

$$\beta_i = \beta + \Gamma v_i \quad (4)$$

Γ is a lower triangular matrix and $v_i \sim N[0,I]$. The parameter vector in the utility function, β_i is normally distributed across individuals with conditional mean

$$E[\beta_i | x_i] = \beta \quad (5)$$

and conditional variance

$$Var[\beta_i | x_i] = \Gamma I \Gamma' = \Omega. \quad (6)$$

The model is formulated with Γv_i rather than, say just v_i with covariance matrix Ω purely for convenience in setting up the estimation method. This is a random parameters formulation that is common with mixed logit models for unordered alternatives. In addition, the thresholds are modelled randomly and nonlinearly as

$$\mu_{ij} = \mu_{i,j-1} + \exp(\alpha_j + \delta' r_i + \sigma_j w_{ij}),\ w_{ij} \sim N[0,1] \quad (7)$$

with normalisations and restrictions $\mu_{-1} = -\infty$, $\mu_0 = 0$, $\mu_J = +\infty$. For the remaining thresholds, we have the form in (8).

$$\mu_1 = \exp(\alpha_1 + \sigma_1 w_{j1})$$
$$\mu_2 = [\exp(\alpha_1 + \sigma_1 w_{j1}) + \exp(\alpha_2 + \sigma_2 w_{j2})],$$
$$\mu_j = \left(\Sigma_{m=1}^{j} \exp(\alpha_m + \sigma_m w_{im})\right),\ j = 1,...,J-1$$
$$\mu_J = +\infty.$$

This formulation ensures that all of the thresholds are positive, preserves the ordering of the thresholds and incorporates the necessary normalisations. Most importantly, it also allows unobserved heterogeneity to play a role both in the utility function and in the thresholds. The model is fully consistent, in that the probabilities are all positive and sum to one by construction. If $\delta = 0$ and $\sigma_j = 0$, then the original model is returned, with $\mu_1 = \exp(\alpha_1)$, $\mu_2 = \mu_1 + \exp(\alpha_2)$. Note that if the threshold parameters were specified as linear functions rather than as in (8), then it would not be possible to identify separate parameters in the regression function and in the threshold functions. Finally, we allow for individual heterogeneity in the variance of the utility function as well as in the mean. The disturbance variance is allowed to be heteroscedastic, now specified randomly as well as deterministically. Thus,

$$\mathrm{Var}[\varepsilon_i | h_i, e_i] = \sigma_i^2 = \exp(\gamma' h_i + \tau e_i)^2 \quad (9)$$

where $e_i \sim N[0,1]$. Let $v_i = (v_{i1},...,v_{iK})'$ and $w_i = (w_{i1},...,w_{i,J-1})'$. Combining all terms, the conditional probability of outcome j is

$$\mathrm{Prob}[y_i = j \mid x_i, h_i, v_i, w_i, e_i] = F\left[\frac{\mu_{ij} - \boldsymbol{\beta}_i'\mathbf{x}_i}{\exp(\boldsymbol{\gamma}'\mathbf{h}_i + \tau e_i)}\right] - F\left[\frac{\mu_{i,j-1} - \boldsymbol{\beta}_i'\mathbf{x}_i}{\exp(\boldsymbol{\gamma}'\mathbf{h}_i + \tau e_i)}\right], \quad (10)$$

where it is noted, once again, both μ_{ij} and β_i vary with observed variables and with unobserved random terms. The log likelihood is constructed from the terms in (10). However, the probability in (10) contains the unobserved random terms, v_i, w_i and e_i. The term that enters the log likelihood function for estimation purposes must be unconditioned on the unobservables, and are integrated out, to obtain the unconditional probabilities in (11).

$$\mathrm{Prob}[y_i = j \mid x_i, h_i] = \int_{\mathbf{v}_i,\mathbf{w}_i,e_i} \left(F\left[\frac{\mu_{ij} - \boldsymbol{\beta}_i'\mathbf{x}_i}{\exp(\boldsymbol{\gamma}'\mathbf{h}_i + \tau e_i)}\right] - F\left[\frac{\mu_{i,j-1} - \boldsymbol{\beta}_i'\mathbf{x}_i}{\exp(\boldsymbol{\gamma}'\mathbf{h}_i + \tau e_i)}\right]\right) f(\mathbf{v}_i, \mathbf{w}_i, e_i)\, d\mathbf{v}_i\, d\mathbf{w}_i\, de_i. \quad (11)$$

$$\mu_{ij} = \left(\Sigma_{m=1}^{j} \exp(\alpha_m + \sigma_m w_{im})\right),\ j = 1,...,J-1. \quad (12)$$

4 Ordered Choice Model Results

A large number of ordered logit models were estimated to identify candidate influences on the probability of choosing a level on the rating scale associated with the worthwhile of things done in life. The descriptive profile of the statistically significant variables is summarised in Table 2 with the final ordered logit model in Table 3 where we have six statistically significant influences and the threshold parameters. We investigated preference heterogeneity associated with the explanatory variables and threshold parameters, but did not find any evidence to support this situation. The disturbance variance was not found to be heteroscedastic.

In developing the final ordered logit model, we initially had anticipated including the number of days working for home (mean of 1.88, SD of 2.12) or the proportion of days working from home as an explanatory variable[47]. Subsequently it became apparent that including the distance of the commuting trip and the productivity gain associated with working from home both represented the influence that working from home has on the worthwhile of things done in life.

Again, it is important to note that since we are interested in how working from home might impact on how worthwhile people find the things they are doing in life during the pandemic, this model is restricted to those who are employed. We acknowledge that being in employment or not is likely to have a significant impact on this statement, particularly if a person was made unemployed by the pandemic. We did explore the number of days worked as an explanatory variable (as a possible alternative to the number of days working from home, including distinguishing between zero and non-zero), but it was not statistically significant (r = -0.011, sig. = 0.460). Additionally, we also examined changes in the volume of work between Wave 3 and Wave 4 and find that there is no difference in the average response to life's worth if a person lost one or more days of work or not (6.8 vs 7.0; t = 0.911), nor is there any correlation between the change in the number of days worked in total (r = -0.036, sig. = 0.318).

Table 2. Descriptive Profile of Data

	Units	Mean	Standard Deviation
Worthwhile of things done in life	0 to 10 rating scale	6.922	1.984
Wave 3 (compared to Wave 4)	1,0	0.436	
Socio-economic:			
Age	years	40.34	13.36
Household size	number	3.03	1.37
Other influences:			
Distance of workplace for home	kilometres	20.35	24.79
Productivity working from home is much more than at the office	1,0	0.168	
How anxious did you feel yesterday? (0-10 scale)	number	4.75	2.81

Table 3. The Ordered Logit Model Results

Dependent variable: Worthwhile of things done in life	Parameter estimate (t-value)
Constant	4.192 (13.9)
Wave 3 dummy variable	-0.2272 (-1.62)
Socio-economic:	
Age	0.0141 (2.92)
Household size	0.1365 (2.93)
Other influences:	
Distance of workplace for home	-0.0007 (-2.64)
Productivity working from home is much more than at the office	0.3867 (2.15)
How anxious did you feel yesterday? (0-10 scale)	-0.0794 (3.32)
Threshold parameters:	
μ_1	0.9004 (4.76)
μ_2	1.5212 (9.37)
μ_3	1.9843 (14.3)
μ_4	2.4592 (20.9)
μ_5	3.3608 (37.9)

[47] We tested for a continuous variable, a series of dummy variables related to varying levels of working from home, and a logarithmic transformation, none of which were statistically significant in the presence of other significant influences. The partial correlation of the continuous working home variable with the dependent variable was 0.029.

μ_6	4.1221 (54.5)
μ_7	5.0757 (68.6)
μ_8	6.2279 (68.6)
μ_9	7.5215 (52.1)
Log-likelihood at convergence	-1545.94

Given the non-linear nature of the model, the estimated parameters are not appropriate sources of behavioural interpretation, and instead we calculate elasticities as a way of establishing the relationship between a change in the level of an explanatory variables and the probability of being on a particular level of worth in life scale. Beginning with the parameter estimates, one is typically interested in estimation of the parameters such as β in equation (11) which is directly associated with an explanatory variable, to learn about the impact of the observed explanatory variables on the outcome of interest. The generalised ordered choice model contains four points at which changes in observed variables can induce changes in the probabilities of the outcomes, in the thresholds, μ_i, in the marginal utilities, β_i, in the utility function, x_i and in the variance, σ_i^2. These could involve different variables or they could have variables in common. In principle, then, if we are interested in all of these, we should compute all the partial effects; however in the model in Table 3, only the partial effects converted to an elasticity for the x_i are used. The partial effect is shown in equation (13) which we multiply by the ratio of the level of x_i and the probability of choosing that level, to obtain the elasticity indicator.

$$\frac{\partial \text{Prob}(y_i = j \mid \mathbf{x}_i, \mathbf{z}_i, \mathbf{h}_i, \mathbf{r}_i)}{\partial \mathbf{x}_i} =$$
$$\int_{\mathbf{v}_i, \mathbf{w}_i, e_i} \left(\frac{1}{\exp(\boldsymbol{\gamma}'\mathbf{h}_i + \tau e_i)} \left\{ \begin{array}{l} f\left[\dfrac{\mu_{ij} - \boldsymbol{\beta}_i'\mathbf{x}_i}{\exp(\boldsymbol{\gamma}'\mathbf{h}_i + \tau e_i)}\right] - \\ f\left[\dfrac{\mu_{i,j-1} - \boldsymbol{\beta}_i'\mathbf{x}_i}{\exp(\boldsymbol{\gamma}'\mathbf{h}_i + \tau e_i)}\right] \end{array} \right\} (-\boldsymbol{\beta}_i) \right) f(\mathbf{v}_i, \mathbf{w}_i, e_i) d\mathbf{v}_i d\mathbf{w}_i de_i \tag{13}$$

In Table 4 and Figure 4, we summarise the direct elasticities associated with the relationship between the level of a statistically significant influence on life and the probability of how worthwhile a respondent thinks the things that they do in life are? The mean direct elasticity varies as we move from the low rating of 0 to the high rating of 10, and indicates how a percentage change in the level of a specific variable impacts on the probability of obtaining a particular rating level in terms of how worthwhile a respondent thinks the things that they do in life are? The elasticities associated with dummy variables recognise a 100% change.

We see quite significant differences in the probability of a particular rating level associated with the worth of things being done; for example age of a respondent has a mean elasticity that varies from -0.562 to 0.534 across the 11-point scale, which is the greatest range although the range of most of the explanatory variables is quite substantial.

Table 4. Direct Elasticities

Dependent variable: Worthwhile of things done in life scale	0	1	2	3	4	5	6	7	8	9	10
Age	-0.562	-0.55	-0.534	-0.512	-0.481	-0.402	-0.257	-0.04	0.224	0.428	0.534
Household size	-0.409	-0.402	-0.388	-0.373	-0.35	-0.292	-0.187	-0.029	0.163	0.312	0.388
Number of cars in household	0.307	0.304	0.296	0.285	0.27	0.217	0.132	0.009	-0.147	-0.253	-0.295
Distance of workplace for home	0.0142	0.0139	0.0135	0.0129	0.0122	0.0101	0.0065	0.001	-0.0057	-0.0108	-0.0135

Dependent variable: Worthwhile of things done in life scale	0	1	2	3	4	5	6	7	8	9	10
Productivity working from home is much more than at the office	-0.341	-0.335	-0.327	-0.316	-0.301	-0.26	-0.181	-0.049	0.138	0.308	0.407
How anxious did you feel yesterday?	0.369	0.362	0.351	0.337	0.316	0.264	0.168	0.027	-0.147	-0.282	-0.351

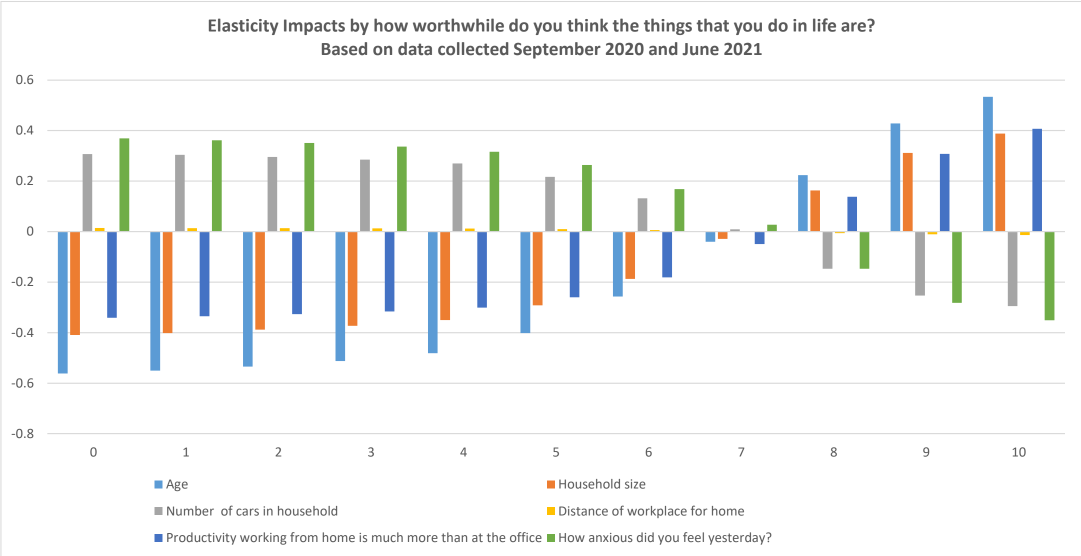

Figure 4. Distribution of direct elasticities across the 11-point scale for all explanatory variables

Three variables of particular interest (expanded in Figure 5) are the distance between the home and work place location (a mean of 20.4 kilometres), the incidence on working from home being much more productive than in the regular office location used pre-COVID-19 (a mean of 16.8%), and how anxious a respondent was during the pandemic period (a mean of 4.75 on the 0-11 scale).

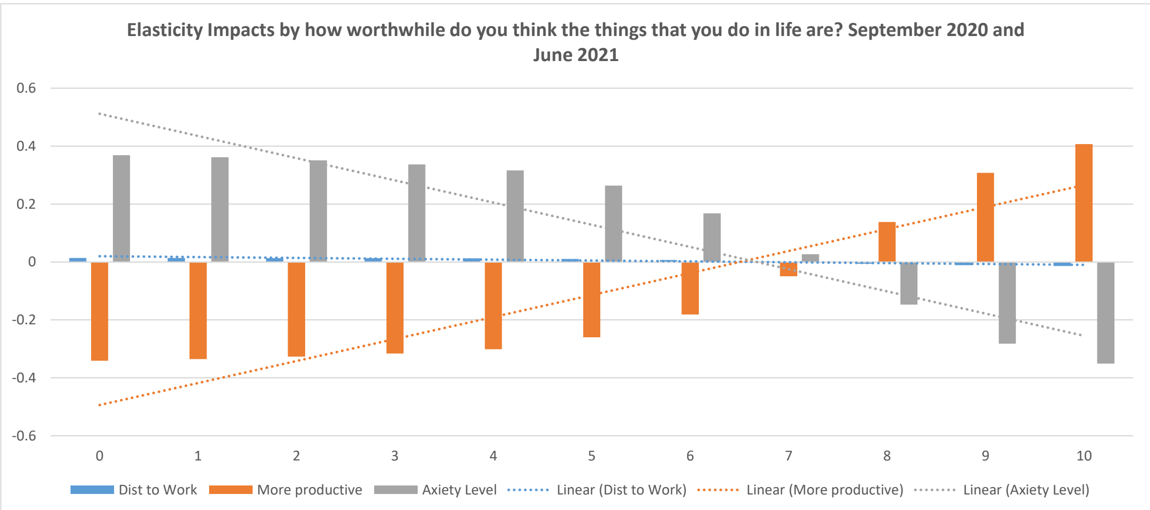

Figure 5. Distribution of direct elasticities across the 11-point scale for three key explanatory variables

The sign range from negative to positive, as we move through the 11-point scale, suggests that as the distance of a commute between home and work increases, as a percentage, it results in a respondent having a greater probability of feeling that things done in life are not being worthwhile at all or to a lesser degree, and the opposite probability lowering of a response on the worth of things done in life being completely or greatly worthwhile. This aligns well with evidence in Hensher et al. (2021a,b, 2022) on the influence that the longer commuting distance has on the increase in the probability of working from home. In contrast, as productivity as a result of working from home increases as a percentage change, *ceteris paribus*, the feeling that the worth of things done in life not being worthwhile at all or to a lesser degree (within the scale range of 0 to 8) decreases and the feeling that the worth of things done in life being completely or greatly worthwhile (in the 9 to 10 scale range) increases. Again, this aligns well with expectations that the work-leisure balance improves when there is greater flexibility in when and where to work (Hensher et al. 2021). The elasticity associated with the feeling of anxiety is of interest, suggesting that when you are much more anxious, compared to not being so at all, the probability of the feeling that the worth of things done in life being completely worthwhile reduce as might be expected.

5 Conclusions and Implications

The evidence in this paper suggests that the opportunity to work from home, which has resulted in increased work-related productivity and an improved balance between time spent on work, and time spent not working, has contributed in a positive way to improving the worth status of life, offsetting some of the negative consequences of the pandemic. This suggests that had the pandemic been associated with a requirement to continue commuting at the same level as pre-COVID-19, and hence no or a reduced ability to work from home and gain greater flexibility in work hours, the consequences on an individual's mental state may have been much worse, putting aside the greater risk of being exposed to the virus. Importantly there was no statistically significant relationship between anxiety and the extent of working from home, but we did initially find a positive relationship between working from home and the worth status of life, although in the presence of positive productivity gains (partial correlation of 0.78), the number of days working from home was marginally significant and not included in the ordered choice model[48].

What does this paper add to the literature? Importantly we promote a view that there have been unintended positive consequences of COVID-19 that have cushioned the severity of the pandemic to some degree, and that this should be recognised as an immediate benefit. More importantly, however, is the potential for longer term gain in well-being and lifestyle that may not have been offered up if life had continued along the journey associated with the pre-COVID-19 state of travel, commuting and associated pressures on the work-home balance. Given that it is likely that working from home will continue to feature as a greater proportion of where work is completed, it is crucial to develop and implement best practices for working from home to maintain a good level of productivity, achieve the right level of work and life balance and maintain a good level for physical and mental health.

In particular, we have shown that productivity in work can lead to a greater sense of worth and thus positive well-being outcomes. To work from home well, robust ICT infrastructure and digital literacy is important (Gupta 2020) particularly as the world is expected to focus even more on digitisation and technology after the pandemic (Gasser et al. 2020). As argued by Carnevale and Hatak (2020), organisations have to remain alert and adaptive to unforeseen events and find new solutions to challenges arising across many areas of their operations. They may need to find ways in which to give employees greater job autonomy and associated self-responsibility which positively impacts working from home (Shin 2004, Stiglbauer and Kovacs 2018), especially given that individual work personality can change (Dweck 2008, Tasselli et al. 2018).

[48] Adding in an interaction terms for positive productivity gain and number of days working from home resulted in a t-value of 0.36.

While we would have preferred that the virus had not taken hold, we must look forward to use this extreme event experience to obtain positive benefits to individuals, households and society more broadly. This position must recognise that mental health and well-being, including social exclusion has not gone away (see Stanley et al. 2021) and that it remains a high priority for governments as well as for business more generally; however let us recognise that some good has come out of the pandemic to provide some directions to better support well-being that were not on offer before COVID-19. The policy implication is very clear; namely, to continue to ensure that people can work from home successfully, and know they are making a contribution while doing so. Meaningful work provides meaning to life.

In ongoing data collection during the subsequent period(s) of Omicron, we will investigate the extent to which the very positive evidence in the first two years of COVID-19 (2020-2021) is seen to continue. 2022 is showing strong signs of new actions to live with COVID-19, despite Omicron tending to produce a new kind of lockdown, which we refer to as 'voluntary lockdown'; but what seems clear thus far is that the new levels of working from home appear set to continue as a result of this positive outcome to date.

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Appendix Z. Paper #22: How are life satisfaction, concern towards the use of public transport and other underlying attitudes affecting mode choice for commuting trips? A case study in Sydney from 2020 to 2022

Camila Balbontin
David A. Hensher
Matthew J. Beck

Abstract

COVID-19 had unprecedented consequences in our daily routines and habits. From a transportation context, there is the potential for unintended positive consequences on sustainability made possible by working remotely or from home (WFH) which reduced mobility significantly. However, there were some significant negative effects such as the increase of car use leading to congestion and erosion of sustainability gains. This paper uses data collected during the three years of the pandemic (2020, 2021 and 2022) in two metropolitan areas in Australia to estimate the changes in workers' daily decision to not work, WFH or to commute by different modes of transport. A hybrid choice model is estimated which includes three latent variables: life satisfaction, concern towards the use of public transport, and social-meeting loving attitude. Results suggest that WFH has settled as a valid and efficient alternative to a regular workplace, given the reduced stigmas employers increasingly support this flexible hybrid working model. Moreover, results show that the majority of these "saved" commuting trips were previously by car, and not by more sustainable options such as public transport and active modes. If respondents do not have the option to WFH and thus have to attend the workplace, the increase in commuting trips tends to be by car, despite evidence of some amount of return to public transport.

Keywords: Work from home; mode choice; public transport concern; life satisfaction; hybrid choice model

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1 Introduction

Habits are extremely difficult to change, especially those that we have been engaging in for years, but COVID-19 forced us to change some of them dramatically. From a transportation context, COVID-19 continues to have unprecedented consequences on mobility and mode choice. Whereas some of these consequences might have a positive effect on sustainable transport outcomes in the long-term – such as the possibility to work remotely or from home (WFH) - others have a significant negative effect – such as an increase in car use leading to congestion and subsequent emissions. Although the effects of the pandemic have slowly dissipated as vaccine rates grow and the use of restrictions and lockdowns wane, findings are suggesting that some pre-COVID behaviours are coming back but others seem to have stayed. Therefore, it is essential to analyse mobility patters in light of WFH and mode choice changes to determine if they are continuing to change, or stabilising over time, so that relevant authorities and communities can work together towards a more sustainable transportation future.

The data used in this study was collected in two metropolitan areas in Australia: The Greater Sydney Metropolitan Area (GSMA) located in New South Wales (NSW), and South East Queensland (SEQ) located in Queensland (QLD) and it includes participants that work at least one day a week given the objective to understand changing levels of commuting travel (i.e., to and from work) and the growth in WFH. The data includes three waves: the first one was collected between September-October 2020 when there were relatively minor restrictions within Australia but overseas trips were not allowed; the second one between March-May 2021, a period at the start of what would be the longest sustained period of lockdown in New South Wales (with relative freedoms still existing in Queensland throughout the same time period); and the third one between August-September 2022, a period with relatively minor restrictions in Australia.

A hybrid choice model is used to understand commuter mode choice including to WFH or not work on a particular day, where aside from including the modes' characteristics (e.g., travel time and cost) and participants' socioeconomic characteristics (e.g., age, gender and income), it also takes into account underlying attitudes that have a significant influence on individual preferences. Three latent variables are estimated and incorporated into the mode choice model: concern towards public transport use, life satisfaction, and social-meeting lovers. These underlying attitudes are explained by different socioeconomic and workplace characteristics, and are included in the mode choice model, which are estimated simultaneously. Different scenarios are simulated to quantify the impact of different variables in the probability to WFH, or to commute by different modes of transport.

The paper is structured as follows. The next section provides a brief overview of the literature. Section 3 details the methodology used in this paper, followed by a description of the dataset used. Section 5 presents the results of the hybrid choice models, and the next section presents the simulated scenarios. The paper ends with a discussion of the main findings and policy implications of this study.

2 Literature overview

The inclusion of latent variables in discrete choice models has been widely used in different contexts, with early application by Walker (2001) and Walker & Ben-Akiva (2002). Hensher et al. (2015) reviewed the various forms of the Hybrid choice model. Different studies have incorporated the use of latent variables to understand the role that underlying attitudes are playing in travel behaviour (Beck & Hess, 2017; Daly et al., 2012; Jensen et al., 2014; Kim et al., 2014; Morikawa et al., 2015; Prato et al., 2012). While there has been much literature on the impact that COVID-19 has had on transport networks and commuting, there is a smaller subset that has examined the role of attitudes on commuting mode choices, including working from home, within the framework of hybrid choice models.

Prior to COVID-19, a limited number of studies have looked at the role of latent variable in mode choice prior, with many focusing on attitudes towards more sustainable modes of transport. Sottile et al. (2019) study the influence of latent variables on the choice to cycle, specifically people's perception of the context and the bicycle as a viable mode of transport in European countries. Their results show that people that live in countries with more cycling infrastructure see cycling as a viable mode of transport for utilitarian purposes, compared to residents of countries with less cycling infrastructure. Their findings suggest that the decision to cycle requires a drastic change compared to the switch between traditional modes. Paulssen et al. (2014) study travel mode choices of German commuters including the influence of attitudes towards flexibility, comfort and convenience, and ownership. Their results show that these variables have a higher influence on mode choice than traditional service levels, such as travel time and costs. Specifically, they find that a 10% increase in positive attitudes towards comfort and convenience would reduce market share for car by 8.4%, while a 10% increase in car travel times would reduce car market share by only 0.9%. Their results suggest that such attitudes should be taken into account when creating policies to increase public transport use and reduce car use.

Thorhauge et al. (2020) undertook out a study in Copenhagen, Denmark to understand commuters' mode choice including latent variables that represent perceived mobility necessities (PMN), which represent how mobile respondents perceive their life/work/obligations. The authors include *activity complexity* as an explanatory variable, which measures the dispersion of activities. Their results suggest that people that have complex activity patterns, have a higher PMN and a higher probability of choosing the car and bike. Their results show that bike can play a similar role as car when appropriate infrastructure is provided, which is the case of Copenhagen. Muñoz et al. (2016) review the literature focused on understanding the role of latent variables in bicycle mode choice, and show that the attitudes towards safety, comfort, convenience, awareness, social norm and bicycle ability have a significant influence on the decision to cycle.

Since the start of 2020 the transportation literature has focused on understanding the effects that COVID-19 has had on commuter and non-commuter mode choice, particularly in changing habits. Aaditya & Rahul (2021) study the impacts of COVID-19 on mode choice in India through the incorporation of two latent variables: awareness of the disease and perception of strictness of lockdown. Their results show that awareness of the disease had a significant role in moving people away from public transport into their private cars, and perception of strictness of lockdown had a positive influence on public transport use.

Balbontin et al. (2022) study WFH and mode choice for commuters in metropolitan areas in Australia using the same dataset in this study but only for late 2020. The authors use a hybrid choice model including attitudes of WFH loving attitude and concern towards the use of public transport, focusing on the influences towards working from home. Their results show that people that have a higher level of concern towards the use of public transport are less likely to choose these modes of transport, and they tend to use the train/light rail less than the bus. The higher influence associated with train and light rail probably could be related to the fact that if there are more people waiting, the vehicles will be more crowded – and considering the train and light rail have a higher capacity of compartments relative to buses, the biosecurity risk associated with them might be higher. It could also be possible that, in both metropolitan areas, the train and light rail networks service suburban regions populated with greater number of workers who are more able to WFH. People that love to WFH are more likely to WFH. The results show that WFH loving attitude is positively influenced where the respondent has their own space to work from home and interestingly it is higher for people between 25-40 years old than for older respondents. Income seems to negatively affect the WFH attitude, as well as for respondents that work in labour. Using the same Australian data from 2020 to 2021, Hensher & Beck (2022) explore the link between working from home and how worthwhile are things that you do in life. They find that working from home, reduced commuting linked to distance to work and increased work-related productivity have contributed to life satisfaction, particularly on how worthwhile respondents feel their life is nowadays. This finding in part motivated the current study, which expands what has been previously found in Australia, but using three waves of data for years 2020, 2021 and 2022 to allow for a comparison of mobility changes since the start of the pandemic and understand how these patterns of behaviour have changed as the pattern of COVID-19 infection and restrictions have waxed and waned. In addition, it includes latent variables that represent underlying attitudes towards life satisfaction, concern towards the use of public transport and social-meeting loving attitude to provide a better understanding of the influence on working from home and mode choice.

3 Methodology

The hybrid choice model is formed by two models that are estimated simultaneously: (1) an ordered probit model that represent the latent variables, measured using attitudinal questions in the survey; and (2) a mixed multinomial logit model that represents the WFH/commute decision for each day of the week. The WFH/commute model considers three alternatives for each day of the week: not work, work from home, or work outside home. If someone decides to work outside home, the mode used is relevant in understanding individual commuting behaviour. The daily alternatives' structure is presented in Figure 1.

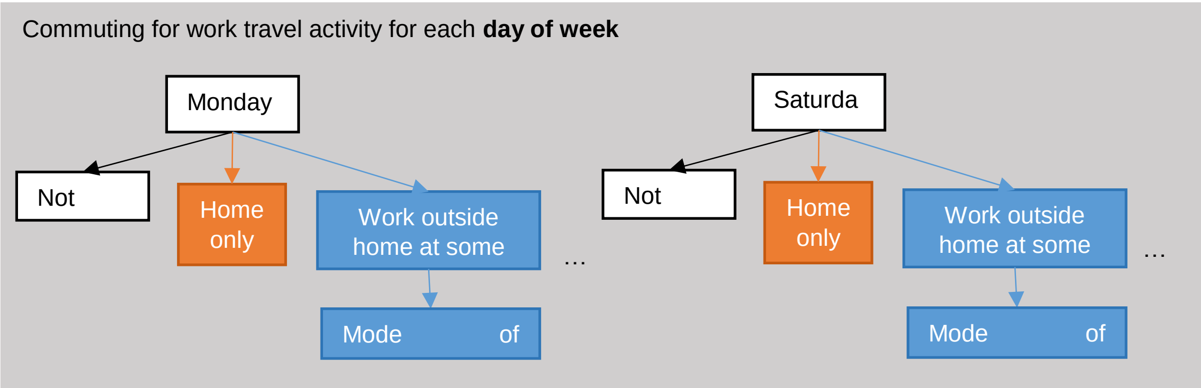

Figure 1. Individuals' daily alternatives' structure

For each day of the week, respondents can have up to 12 alternatives available, presented in Table 1. The alternatives available will depend on which modes of transport are available to the respondent for commuting, and if they can work from home.

Table 1. Alternative numbers per DoW

Alternative	Description
1	Not work
2	Work from home only
3	Work outside home - car driver
4	Work outside home - car passenger

Alternative	Description
5	Work outside home - taxi/rideshare
6	Work outside home - train
7	Work outside home - bus
8	Work outside home - light rail
9	Work outside home - ferry
10	Work outside home - walk
11	Work outside home - bicycle
12	Work outside home - motorcycle

The overall modelling framework is presented in Figure 2, showing the latent variable and the WFH/commute models. The structural and measurement equations of the latent variable model, as well as the WFH/commute mode choice model each have their own associated error term or disturbance: ω, υ and ε, respectively. The proposed WFH/commute mode choice model accounts for preference heterogeneity through error components (estimated as random parameters) and allows for the panel effect across the observations related to the same individual for different days of the week. This error component is alternative-specific, that is, there is a ε_{NoWork} for the no work alternative, and one $\varepsilon_{Commute}$ common for all the commuting modal alternatives. The second one creates a hierarchical structure allowing for a correlation between all commuting alternatives.

There is an additional error component considered, η_n, which takes into account the relationship between the structural equations and the WFH/commute mode choice model derived from using simultaneous estimation of the hybrid choice model, referred to as serial correlation (Bierlaire, 2016; Sottile et al., 2019). If this error term was not included, the simultaneous estimation would be assuming that the error terms involved in these models are independent. Serial correlation is taken into consideration by including an agent effect in the model specification, which is an error component in all the models involved (i.e., structural equations and mode choice).

The latent variables refer to variables that cannot be directly observed but are explained by certain indicators. Three latent variables will be considered: (1) Concern about using public transport (PT) to go to workplace due to COVID-19, X^*_{PT}; (2) Satisfaction with life, X^*_{LS}; and (3) Social-meeting lovers, X^*_{SM}. The linear structural equations of the latent variables are expressed as follows:

$$X^*_{PT} = \theta_{PT_0} + \sum_j \theta_{PT_j} \cdot Z_{qj} + \sum_j \theta_{PT_j} \cdot H_{qj} + \omega_{PT} + \eta_{PT} \tag{1}$$

$$X^*_{LS} = \theta_{LS_0} + \sum_j \theta_{LS_j} \cdot Z_{qj} + \sum_i \theta_{LS_i} \cdot H_{qi} + \omega_{LS} + \eta_{LS} \tag{2}$$

$$X^*_{SM} = \theta_{SM_0} + \sum_j \theta_{SM_j} \cdot Z_{qj} + \sum_i \theta_{SM_i} \cdot H_{qi} + \omega_{SM} + \eta_{SM} \tag{3}$$

Z_{qj} represents the j^{th} characteristics of respondent *q* (e.g., age, gender, income, occupation); H_{nj} represents attribute *j* of the home or work of respondent *q* (e.g., distance to work, travel time, has their own WFH space, mode used to go to work, location); and θ are the estimated parameters associated with each attribute which are specific to each latent variable. The latter represents the deterministic part of the linear structural equations, which allow for deterministic heterogeneity through the inclusion of socio-demographics and work/home characteristics. The disturbances of the linear structural equations are defined by ω, which are the error terms associated to each latent variable; and η is a part of the error term that takes into account serial correlation and is specific to each latent variable. The error terms ω and η are normally distributed with a mean of 0 and a standard deviation equal to 1, but they defer in that the second one will also be included in the choice model explained below (representing serial correlation) and that is why both can be estimated simultaneously.

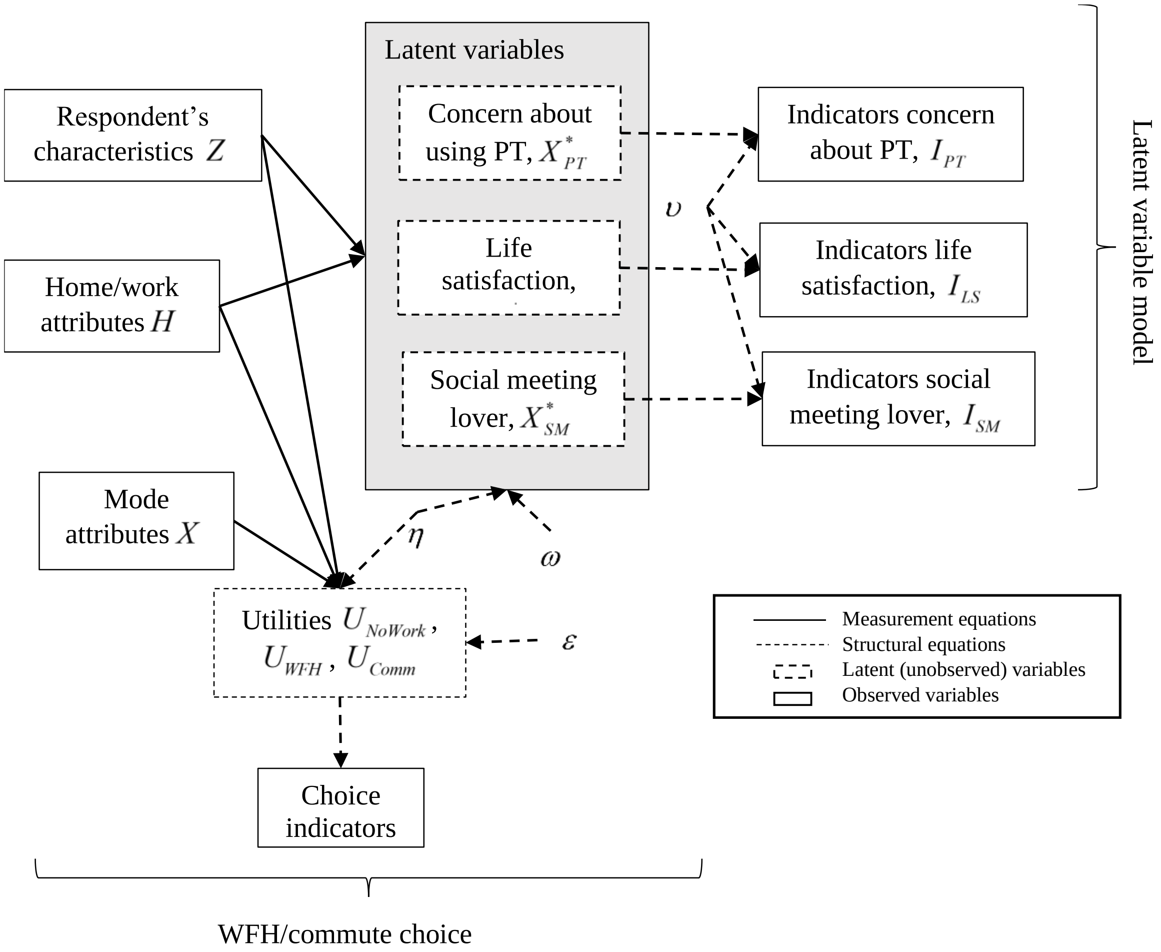

Figure 2. Hybrid model framework

The measurement equations of the latent variables are linear additive, as follows:

$$I_n = \alpha_n \cdot X_n^* + \upsilon_n \quad (4)$$

where I_n represents an indicator associated with the latent variable X_n^*; α are the parameters to be estimated; and υ_n the error term. The indicators are attitudinal questions asked in the survey, which are shown in Table 2 to 4. Given the high complexity in the estimation of hybrid choice models, an analysis was carried out to identify which attitudinal questions should be used as indicators for each latent variable. The attitudinal questions were chosen based on the results from a factor analysis and a correlation analysis between the responses to the different attitudinal questions. These indicators were measured on a Likert scale with 5 levels and for model estimation we define four parameters, τ_i. We assumed symmetry in the indicators, using two positive parameters as follows:

$$\begin{aligned} \tau_1 &= -\delta_1 - \delta_2 \\ \tau_2 &= -\delta_1 \\ \tau_3 &= \delta_1 \\ \tau_4 &= \delta_1 + \delta_2 \end{aligned} \quad (5)$$

The probability of a given response is given by an ordered probit model (Greene & Hensher, 2010), where the observed responses to the attitudinal questions and the measurement equations are related as follows:

$$Y_n = \begin{cases} 1 \text{ if } & I_n \leq \tau_1 \\ 2 \text{ if } & \tau_1 < I_n \leq \tau_2 \\ 3 \text{ if } & \tau_2 < I_n \leq \tau_3 \\ 4 \text{ if } & \tau_3 < I_n \leq \tau_4 \\ 5 \text{ if } & \tau_5 < I_n \end{cases} \quad (6)$$

Table 2. Indicators associated with the latent variable concerned about PT and workplace*

Acronym	Question
ACvConc	Imagine you had to catch public transport tomorrow, what would be your level of concern about hygiene be?
ACvCoNUs	Imagine you had to catch public transport tomorrow, what would be your level of concern about the number of people using public transport?
WkEnvCnc	How concerned are you today about Covid-19 and work, given the environment that you normally work in (i.e., before Covid-19)?

*Scale: Not at all concerned (1), Slightly concerned (2), Somewhat concerned (3), Moderately concerned (4), Extremely concerned (5)

Table 3. Indicators associated with the latent variable life satisfaction*

Acronym	Question
SatLife	How satisfied are you with your life nowadays?
SatWorth	How worthwhile do you think the things that you do in life are?
SatHappy	how happy did you feel yesterday?

*Scale from 1 (not at all) to 5 (completely)

Table 4. Indicators associated with the latent variable social-meeting lover*

Acronym	Question
ComFrnd	For each of the following day to day activities, if you had to complete them, how comfortable would you feel doing so at the moment? - Meeting with friends
ComRest	For each of the following day to day activities, if you had to complete them, how comfortable would you feel doing so at the moment? - Visiting restaurants
ComShop	For each of the following day to day activities, if you had to complete them, how comfortable would you feel doing so at the moment? - Going to the shops
ComDoc	For each of the following day to day activities, if you had to complete them, how comfortable would you feel doing so at the moment? - Doctor's appointments

*Scale: Very uncomfortable/uncomfortable (1), Somewhat uncomfortable (2), Neither (3), Somewhat comfortable (4), Very comfortable/comfortable (5)

Different utility function specifications were tested for the underlying attitudes and their effects in the alternatives, but only some of them were statistically significant. The specification presented in this section was preferred given the model results. The underlying latent attitudes, 'social-meeting lover' and 'life satisfaction', are included in the WFH alternative utility, as follows:

$$U_{WFH} = \beta_{WFH} + \sum_j \beta_{WFH_j} \cdot Z_{qj} + \sum_j \beta_{WFH_j} \cdot H_{qj} + \left(\beta_{SM_{WFH}} \cdot X^*_{SM} + \eta_{SM}\right) + \left(\beta_{LS_{WFH}} \cdot X^*_{LS} + \eta_{LS}\right) + \varepsilon_{WFH_q} \quad (7)$$

The latent variable 'social-meeting lover' is also included in the commuting alternatives by car and by active modes[49], which is represented for each mode *m* as follows:

$$U_{Car_m} = \beta_{Car_m} + \sum_j \beta_{mj} \cdot Z_{qj} + \sum_j \beta_{mj} \cdot H_{qj} + \sum_j \beta_{mj} \cdot X_{mjq} + \left(\beta_{SM_{Car}} \cdot X^*_{SM} + \eta_{SM}\right) + \varepsilon_{Car_{mq}} \quad (8)$$

$$U_{Act_m} = \beta_{Act_m} + \sum_j \beta_{mj} \cdot Z_{qj} + \sum_j \beta_{mj} \cdot H_{qj} + \sum_j \beta_{mj} \cdot X_{mjq} + \left(\beta_{SM_{Act}} \cdot X^*_{SM} + \eta_{SM}\right) + \varepsilon_{Act_{mq}} \quad (9)$$

The latent variable that represents concern towards the use of public transport is included in the commuting by public transport alternatives using a mode *m*-specific parameter estimate, β_{PTm}. The utility function for commuting by mode *m* is given by:

$$U_{PT_m} = \beta_{PT_m} + \sum_j \beta_{mj} \cdot Z_{qj} + \sum_j \beta_{mj} \cdot H_{qj} + \sum_j \beta_{mj} \cdot X_{mjq} + \left(\beta_{PT_m} \cdot X^*_{PT} + \eta_{PT}\right) + \varepsilon_{PT_{mq}} \quad (10)$$

The utility function of the *no work* alternative is given as equation (7):

$$U_{NoWork} = \beta_{NoWork} + \sum_j \beta_{NoWork_j} \cdot Z_{qj} + \varepsilon_{NoWork_q} \quad (11)$$

Respondents provided data on the choice made each day of the week, and hence there are seven choice sets per respondent. To recognise this, the error terms ε account for the panel structure of the data, i.e., varying across individuals but the same within individuals. The hybrid model was estimated simultaneously using the Apollo Software (Hess & Palma, 2019) and using a high-speed computer at the University of Sydney with 24 nodes.

4 Data

The data used in this study was collected using an online survey in two metropolitan areas in Australia: The Greater Sydney Metropolitan Area (GSMA) = and South East Queensland (SEQ) and it includes participants that work at least one day a week given the objective to understand commuting trips (i.e., to and from work).The data used includes three waves: Wave 3 was collected between September-October 2020 when there were relatively minor restrictions within Australia but overseas trips were not allowed; Wave 4 between March-May 2021, a period at the start of what would be the longest sustained period of lockdown in New South Wales (with relative freedoms still existing in Queensland throughout the same time period); and Wave 5 between August-September 2022, a period with relatively minor restrictions in Australia. Beck & Hensher (2021a, 2021b) report on the first two waves. Descriptives of the main characteristics used in the modelling are presented in Table 5. The majority of the variables are stable across waves, except for the number of days working from home only in a week at the time of the survey, which has declined across waves reaching its minimum in Wave 5 with 1 day a week from home, out of 4.36 days worked on average during a week. Wave 5 sample size is significantly higher than in the two previous waves because there more attention was given to workers in metropolitan areas (GSMA and SEQ).

[49] The latent variable life satisfaction was also included in the commuting alternatives by different modes, but it was not statistically significant.

Table 5. Sample profile – mean (standard deviation)

Description	**Wave 3**	**Wave 4**	**Wave 5**
Age (years)	40.11 (13.39)	42.03 (14.36)	40.29 (13.32)
Female (1,0)	64%	55%	61%
Personal income ('000 AUD$)	78.63 (51.78)	82.36 (54.60)	88.56 (58.47)
Distance from home to work (kms)	19.58 (32.06)	19.11 (21.30)	20.13 (22.84)
Number of individuals per household	2.78 (1.32)	3.20 (1.38)	3.36 (1.46)
Occupation white collar (1,0)	84%	84%	88%
Located in GSMA (1,0)	63%	56%	56%
Number of days working from home in a normal week	1.63 (2.11)	1.15 (1.83)	1.02 (1.64)
Number of days working from anywhere in a normal week	4.56 (1.29)	4.25 (1.46)	4.36 (1.30)
Number of days working from home pre COVID-19	0.87 (1.61)	1.06 (1.89)	0.71 (1.58)
Number of days working from anywhere pre COVID-19	4.59 (1.06)	5.02 (1.47)	5.28 (1.40)
Travel time to go to work - active modes	33.31 (27.63)	41.00 (34.71)	23.47 (18.58)
Travel time to go to work - public transport	32.86 (23.97)	39.67 (27.74)	36.02 (25.71)
Travel time to go to work - rideshare/taxi	25.08 (22.23)	25.39 (15.39)	28.93 (19.37)
Travel time to go to work - private motorised vehicles	28.60 (30.90)	27.76 (19.05)	30.11 (21.29)
Fare trip to go to work - public transport	6.83 (8.91)	6.81 (6.15)	9.11 (11.84)
Fare trip to go to work - rideshare/taxi	38.93 (56.21)	32.98 (33.45)	34.98 (29.02)
Fuel + toll + park to go to work - private motorised vehicles	6.19 (15.32)	5.52 (9.07)	5.99 (7.62)
Number of respondents	652	755	2009

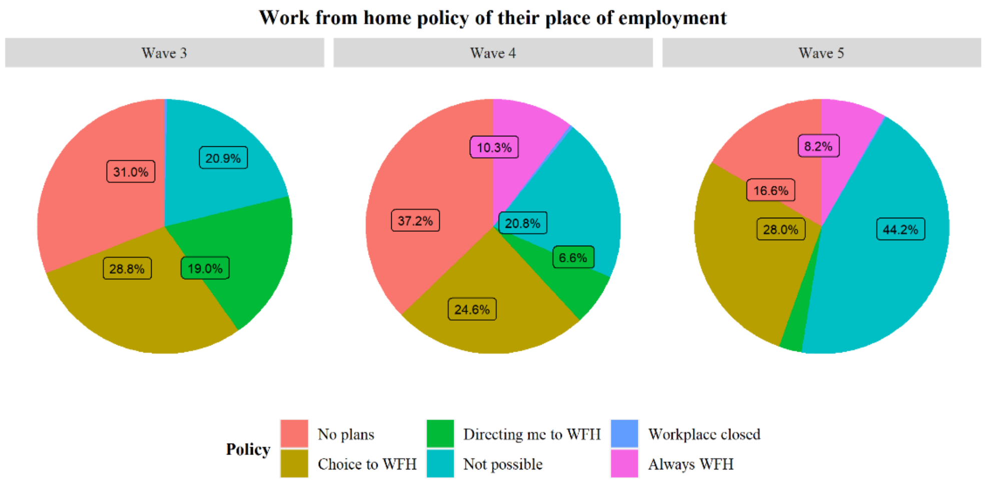

Figure 3. Work from home policy of place of employment

Note: Wave 3 did not include the option "always WFH"

There are important differences in the work from home policy of respondents' place of employment across waves, which is presented in Figure 3. In Wave 5, there was a significant decrease in respondents that said their place of employment had no plans in allowing them to work from home, and a significant increase in respondents that said it was not possible for them to work from home as they had to be onsite. This might be partly explained by a shift in the view towards policies that restrict WFH; in Waves 3 and 4 more respondents considered that their place of employment had no plans to allow them to WFH and, in Wave 5, which represents a "COVID-normal" situation, more respondents consider that their work cannot be done from home. Regardless, together they represent participants that are not working from home – either because they are not allowed or their occupation does not allow for it - which in Wave 3 was around 52%, in Wave 4 58% and in Wave 5 61%. This is very much aligned with what we expected as we move out of the most restrictive pandemic scenarios and into what is hopefully the "end stage" of the pandemic, where more businesses are requiring for their employees to come back to the office. Moreover, businesses, however, seem to be moving away from directing their employees to work from home – which was much more common at the start of the pandemic; but those that allowed employees to decide where to work from seem to have kept their work from home policies across waves – even in Wave 5 COVID-normal scenario.

Figure 4 presents the work choice made for each day of week across waves. In Wave 3, around 30% of respondents worked from home only during weekdays, while this percentage significantly decreased to around 22% in Wave 4, and even further to around 19% in Wave 5. However, in Wave 3 and 4 the preferred day to WFH was apparently Monday, and in Wave 5 it was Friday followed closely by Monday. The modal shares are presented in Figure 5, which shows a significant increase in the use of car to commute in Wave 4 – which was right before the start of the longest lockdown in Australia where COVID-19 cases were increasing relatively fast. In Wave 5, the use of car went down compared to previous waves and the use of public transport increased, while the use of active modes remained relatively stable across waves.

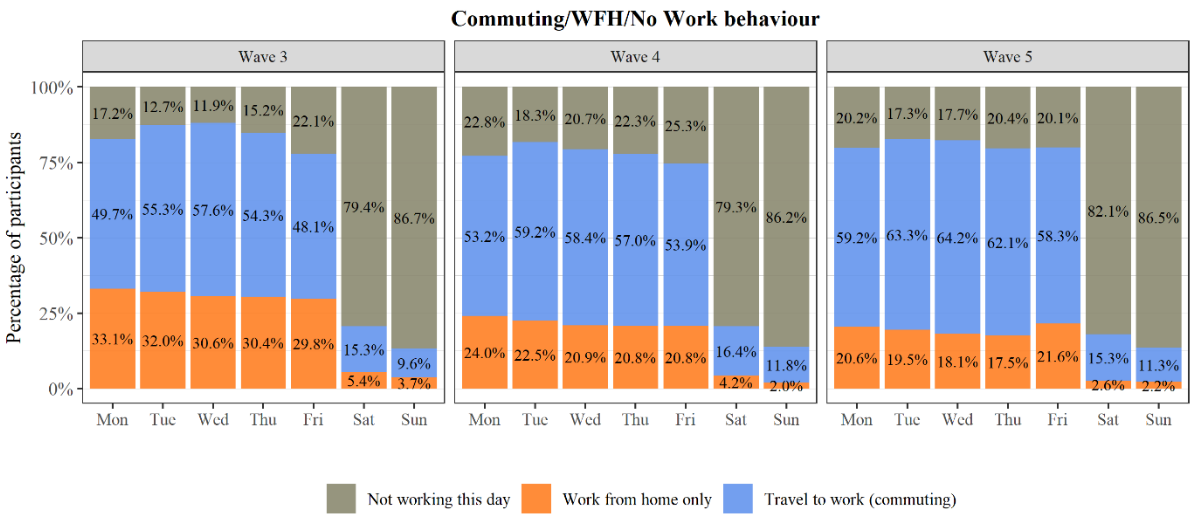

Figure 4. Commuting, work from home and no work behaviour

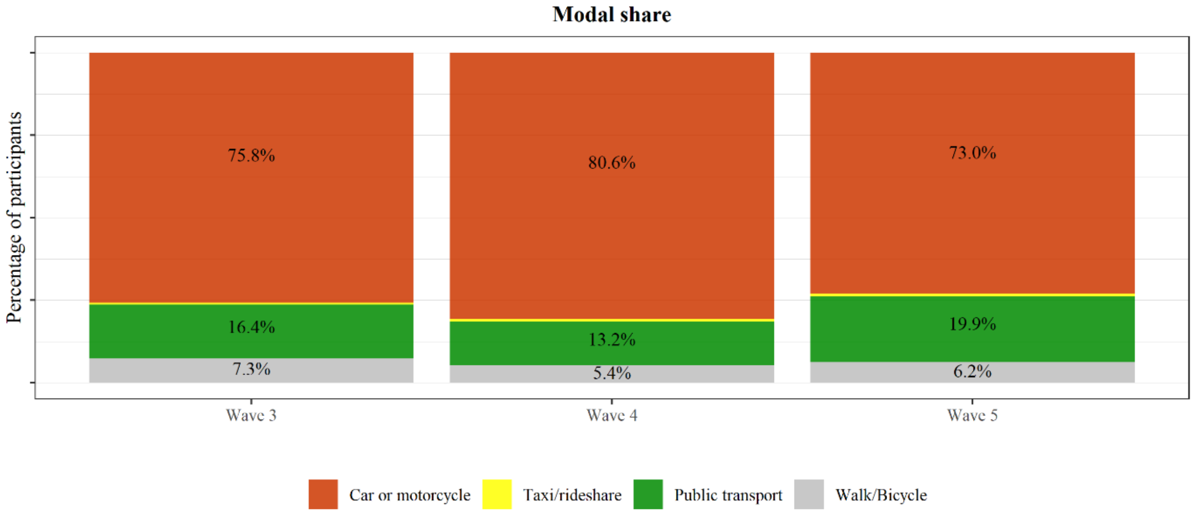

Figure 5. Modal share

The average response for the attitudinal questions used in obtaining the estimates of each latent variable are presented in Figure 6. It can be seen that the while life satisfaction and social-meeting lover attitudes have increased since Wave 3, the concern towards public transport use has decreased significantly. The underlying attitudes in Wave 4 and Wave 5 have remained relatively similar, suggesting that the initial pandemic concerns towards meeting friends, sharing closed spaces with strangers in public transport seem to have lasted until the end of 2021 when these levels improved significantly (Wave 4).

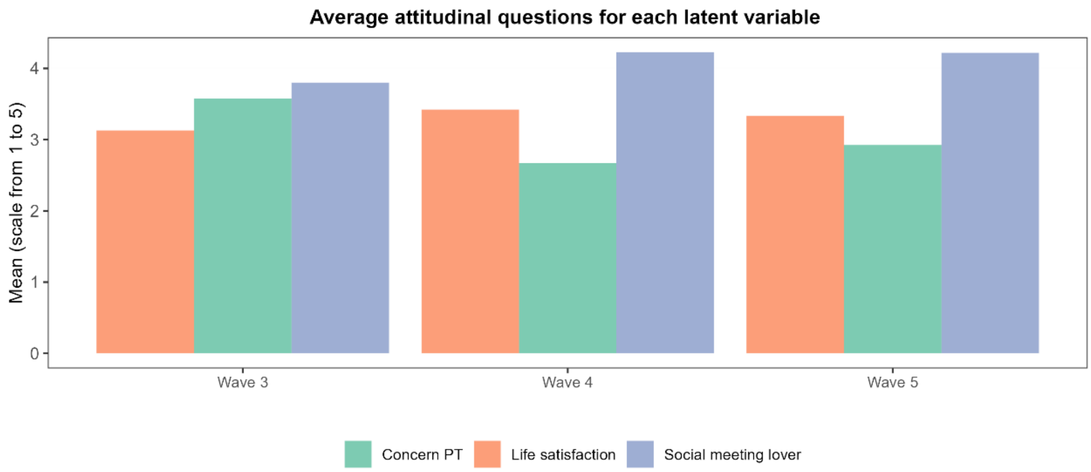

Figure 6. Average attitudinal questions included in each latent variable

5 Results

The structural equations parameter estimates for the latent variables are presented in Table 6. All parameter estimates are statistically significant with a 95% confidence level except for age in the social-meeting latent variable and workplace allowing workers to decide where to work from in life satisfaction latent variable, which are significant at the 85% confidence level. Results show that respondents with white collar occupations are more likely to be concerned about public transport use, as well as respondents located in the GSMA and that used car to go to work prior to COVID-19. It seems that concern towards PT use has decreased in Waves

4 and 5 – collected late 2021 and mid 2022 - relative to Wave 3, which was collected in early 2021.

Table 6. Latent variables' structural equations model results

Description	Mean (t-value)
Latent variable concern about public transport use	
Intercept	-0.05 (0.52)
Occupation white collar (1,0)	0.18 (2.48)
Workplace located in GSMA (1,0)	0.43 (8.62)
Wave 4 (1,0)	-0.93 (12.25)
Wave 5 (1,0)	-0.82 (12.34)
Prior to COVID-19 used car to go to work (1,0)	0.50 (9.46)
Latent variable life satisfaction	
Intercept	3.43 (7.36)
Age (years)	0.005 (2.02)
Personal income ('000$AUD)	0.01 (6.70)
Workplace does not have any plans to allow me to WFH (1,0)	-0.87 (2.78)
Workplace has given me the choice to WFH if I want (1,0)	-0.69 (1.91)
Workplace is directing me to WFH (1,0)	-1.10 (2.48)
My work cannot be done from home (1,0)	-1.19 (2.81)
Wave 4 (1,0)	1.19 (4.95)
Wave 5 (1,0)	0.71 (3.57)
Latent variable social-meeting lover	
Intercept	0.69 (7.66)
Age (years)	0.005 (1.44)
Located in GSMA (1,0)	-0.26 (5.17)
Wave 4 (1,0)	0.72 (9.37)
Wave 5 (1,0)	0.69 (10.59)

The latent variable life satisfaction seems to increase as respondents get older and have a higher income, this latter could have been expected. Results show that the workplace policy towards WFH has a significant impact on their life satisfaction. The base level is represented by respondents that always work from home, and results show that they are the most satisfied with their life. In part, this could be explained by the fact that they chose a job that requires them to always work from home (even before COVID-19), so they represent a percentage of people that will always prefer to WFH and that it suits their lifestyle well (10% of sample in Wave 4 and 8% in Wave 5). Results suggest that respondents that are given the choice to work from home are the second most satisfied with their life, followed by those whose workplace does not plan to allow them to WFH, followed by directing them to WFH and finally those whose work cannot be done from home. This is aligned with earlier findings from this study (Balbontin et al., 2021), which showed that respondents seem to prefer a balance to work from home and the office, and do not want to be directed to work from home or from their workplace every day. The waves dummy variable show that respondents seem to be more satisfied with their life in Wave 4, followed by Wave 5, relative to Wave 3. The latent variable social-meeting lover seems to be positively influenced by age. Respondents that live in SEQ seem to be more positive towards social meetings that those that live in GSMA. Results show that respondents in Waves 4 and 5 have a higher social-meeting loving attitude that those in Wave 3. The parameter estimates for the measurement equations are presented in Table in the Appendix A.

The choice model results, which are estimated simultaneously with the latent variables' structural and measurement equations, are presented in Table 7. The results show that respondents seem to be working more in Wave 5, followed by Wave 4 relative to Wave 3 and as expected, they work less during weekends. The variables included in the WFH alternative show that female respondents are less likely to WFH, same as respondents with higher income, or with more people living in their household. If they have more cars available per person, they tend to work more from home. Respondents seem to work from home more during Mondays, followed by Fridays and Tuesdays. The baseline preference for working from home in the GSMA is lower than those in SEQ (whereas the opposite is true in the MML). Given that WFH rates are consistently higher in the GSMA than SEQ, this negative coefficient highlights the important role of the latent constructs and the dynamic way these factors interact with choices; much of the WFH behaviour in the GSMA is not due to some general underlying preference to WFH and rather a more complex interplay of attitudes and characteristics. Respondents located in the GSMA also WFH less in Wave 4 followed by Wave 5, relative to Wave 3. In terms of WFH policy, as could have been expected, respondents that are given the choice or are directed to WFH, tend to WFH more. The results of the latent variables show that respondents which higher levels of life satisfaction also tend to WFH more, and this relationship has increased in Waves 4 and 5. Earlier studies have suggested that the relationship between life satisfaction and WFH might be in both directions, so future research could focus on understanding the role that they play on each other (Hensher & Beck, 2022b). Respondents with a positive attitude towards social meetings are less likely to WFH, relative to those that are less positive. These results are showing that the choice to WFH is highly influenced by respondents' underlying attitudes and the main conclusions are that respondents that love social meetings prefer to go to the office relative to those that are less positive towards social meetings; and people that are more satisfied with their life tend to WFH more.

The results for the commuting alternatives show that, as expected, travel time and cost have a negative influence on the probability of choosing each mode of transport. Respondents located in GSMA are less likely to use car or motorcycle relative to other modes of transport, and people in SEQ are more likely to use active modes. The distance from home to work has a significant influence in the probability to choose car as driver to go to work. Results show that in Wave 5 respondents were less likely to choose car/motorcycle, followed by Wave 4, relative to Wave 3. Respondents that have more people in their household are less likely to choose active modes to go to work, which could be explained by the fact that they share their trip with family members. The latent variables show that people that love social meetings tend to be less likely choose motorised private transport and active modes – which might be explained by them wanting to meet their friends right after work, which might be in busy areas with limited parking spaces, or by them wanting more flexibility (for example, to enjoy a couple of drinks before heading back home). Respondents that are concerned about the use of public transport are less likely to use light rail, followed by train and bus – in Wave 5 participants concern about public transport are even less likely to choose the bus relative to previous waves.

Table 7. Choice model results

Description	Alternative	Mean (t-value) MML	Mean (t-value) Hybrid
Alternative specific constant no work (base)	No work	-	-
Alternative specific constant WFH	WFH	-0.76 (5.01)	-7.52 (3.32)
Alternative specific constant commute by car driver	Car driver	1.69 (16.75)	1.93 (19.01)
Alternative specific constant commute by car pax	Car pax	-0.69 (6.54)	-0.52 (4.94)

Description	Alternative	Mean (t-value) MML	Hybrid
Alternative specific constant commute by taxi/rideshare	Taxi/Rideshare	-1.55 (9.14)	-1.76 (10.68)
Alternative specific constant commute by train	Train	-0.67 (4.41)	-0.60 (4.29)
Alternative specific constant commute by bus	Bus	-1.19 (7.54)	-1.20 (8.19)
Alternative specific constant commute by light rail	Light rail	-1.18 (5.02)	-1.16 (5.10)
Alternative specific constant commute by ferry	Ferry	-1.40 (4.64)	-1.21 (3.63)
Alternative specific constant commute walking	Walking	1.17 (6.00)	1.44 (6.63)
Alternative specific constant commute by bicycle	Bicycle	0.92 (4.58)	1.11 (4.91)
Alternative specific constant commute by motorcycle	Motorcycle	1.20 (7.99)	1.36 (8.81)
Saturday or Sunday (1,0)	No work	3.85 (73.25)	3.61 (69.35)
Wave 4 (1,0)	No work	-0.61 (3.89)	-0.48 (3.16)
Wave 5 (1,0)	No work	-1.22 (9.53)	-1.02 (8.41)
Female (1,0)	WFH	-0.24 (4.47)	-0.23 (3.09)
Personal income ('000$AUD)	WFH	0.003 (4.76)	-0.03 (2.38)
Number of individuals per household	WFH	-0.08 (3.82)	-0.06 (2.43)
Number of cars per person in household	WFH	0.29 (4.20)	0.23 (3.35)
Monday (1,0)	WFH	0.76 (7.40)	1.16 (10.64)
Tuesday (1,0)	WFH	0.64 (6.26)	1.02 (9.33)
Wednesday (1,0)	WFH	0.50 (4.87)	0.85 (7.75)
Thursday (1,0)	WFH	0.46 (4.43)	0.79 (7.27)
Friday (1,0)	WFH	0.69 (6.70)	1.07 (9.84)
Located in GSMA (1,0)	WFH	0.16 (2.30)	-0.84 (2.20)
Workplace is directing me to WFH (1,0)	WFH	3.07 (32.16)	4.49 (4.65)
Workplace has given me the choice to WFH if I want (1,0)	WFH	1.91 (32.96)	1.87 (3.10)
Wave 4 (1,0)	WFH	-0.92 (6.27)	-3.07 (2.90)
Wave 5 (1,0)	WFH	-1.81 (14.75)	-2.10 (3.00)
In-vehicle travel time (mins)	All modes	-0.01 (8.45)	-0.01 (6.79)
Travel time active modes (mins)	Walking and bicycle	-0.03 (9.32)	-0.03 (8.78)
Cost (AUD$)	All modes except active modes	-0.03 (12.01)	-0.03 (10.91)
Located in GSMA (1,0)	Motorised private transport	-0.06 (0.98)	-0.21 (3.52)
Distance from home to work (kms)	Car driver	0.01 (7.36)	0.01 (5.90)
Wave 4 (1,0)	Motorised private transport	-0.74 (5.18)	-0.33 (2.21)
Wave 5 (1,0)	Motorised private transport	-0.88 (7.59)	-0.42 (3.49)
Number of people in household	Active modes	-0.10 (2.41)	-0.08 (2.07)
Located in GSMA (1,0)	Active modes	-0.43 (3.61)	-0.64 (5.07)
Latent variable satisfied with life	WFH	-	3.25 (2.61)
Latent variable satisfied with life Wave 4	WFH	-	0.15 (1.98)
Latent variable satisfied with life Wave 5	WFH	-	0.17 (2.51)
Latent variable social-meeting lover	WFH	-	-3.90 (3.13)
Latent variable social-meeting lover	Motorised private transport	-	-0.50 (22.46)
Latent variable social-meeting lover	Active modes	-	-0.30 (4.66)
Latent variable PT concern	Train	-	-0.65 (10.88)
Latent variable PT concern	Light rail	-	-0.94 (4.81)
Latent variable PT concern	Bus	-	-0.55 (5.78)
Latent variable PT concern Wave 5	Bus	-	-0.25 (2.14)
Standard deviation of error component	No work	1.28 (41.10)	0.73 (16.28)
Standard deviation of error component	Public transport modes	2.42 (24.64)	1.86 (19.72)
Choice model only			
Number of parameters		*39*	*47*
Log-likelihood at convergence		*-19355.16*	*-18,418.46*
Log-likelihood equal shares LL(0)		*-31750.86*	*-31,750.86*
AIC/n		*1.625*	*1.547*
McFadden's Pseudo-R^2		*0.390*	*0.420*
Hybrid model (full)			
Number of parameters		-	*99*
Log-likelihood		-	*-60,541.88*
Log-likelihood equal shares LL(0)		-	*-86,397.72*

Description	Alternative	Mean (t-value)	
		MML	Hybrid
AIC/n		-	*5.081*
McFadden's Pseudo-R^2		-	*0.299*

Table 7 also presents a simple mixed logit model (MML), which includes the same parameters as the mode choice model in the hybrid model. This model is used to compare the mode choice model part of the hybrid choice model. Results show that there is a significant improvement in the goodness of fit of the hybrid choice model compared to the MML. There are some important differences in the parameter estimates when not including the latent variables. For instance, the parameter estimate for income in the WFH alternative is positive in the MML, suggesting that respondents that have a higher income tend to work from home more often. However, in the hybrid choice model, income has a positive influence on the latent variable life satisfaction, and this latent variable has a positive influence on the probability to WFH, while income has a direct negative influence on the probability to WFH. That is, the hybrid choice model suggests that if we compare two people that are equally satisfied with life, the person that has a higher income tends to WFH less than a person with a lower income. Something similar occurs with people that live in GSMA area: where the MML suggests that they tend to WFH more often, but the hybrid choice model suggests that they tend to be less positive towards social meetings - which negatively influences the probability to WFH – but the dummy for GSMA location negatively influences the probability to WFH. That is, the hybrid choice models results suggest that if we compare two people that have the same attitude towards social meetings, the one that lives in GSMA is less likely to WFH – although people in NSW tend to be less positive towards social meetings which increases their probability to WFH. These are important distinctions when we are trying to understand what drives respondents to decide to WFH or to commute by different modes of transport. Our hybrid choice model results are clearly showing that the impact that underlying attitudes towards the use of public transport, social-meetings and life satisfaction have a significant influence on daily decision to not work, WFH, or to commute by different modes of transport. The value of in-vehicle travel time savings is of $20.69 and are presented in Table 8. This is aligned with what has been found in previous studies in Australia (Hensher et al., 2021) and statistically equivalent to what is found with a simple MML. Therefore, our hybrid choice model provides a statistically equivalent value of travel time savings to simpler models but allows us to gain a better understanding on what influences the decision to commute or to stay WFH and how different variables play a role in influencing underlying attitudes which have a significant influence in preferences.

Table 8. Value of in-vehicle travel time savings

Value of in-vehicle travel time savings	Mean - AUD$/hour	Standard error - AUD$/hour
Simple MML	$23.87	$8.29
Hybrid choice model	$20.69	$7.38

Figure 8 presents the direct mean elasticities calculated for the alternative WFH, commute by car as driver, bus, train, walking or cycling – which are the alternatives of interest, and they are ordered in terms of the average elasticity across waves. Direct elasticities are calculated as a function of the probability to choose an alternative. For instance, to calculate the direct elasticity of an attribute *j* of mode *m* for individual *q,* it is calculated as follows:

$$E_{X_{mjq}}^{P_{mq}} = \frac{\partial P_{mq}}{\partial X_{mjq}} \cdot \frac{X_{mjq}}{P_{mq}} = \beta_{mj} \cdot X_{mjq} \cdot \left(1 - P_{mq}\right) \quad (12)$$

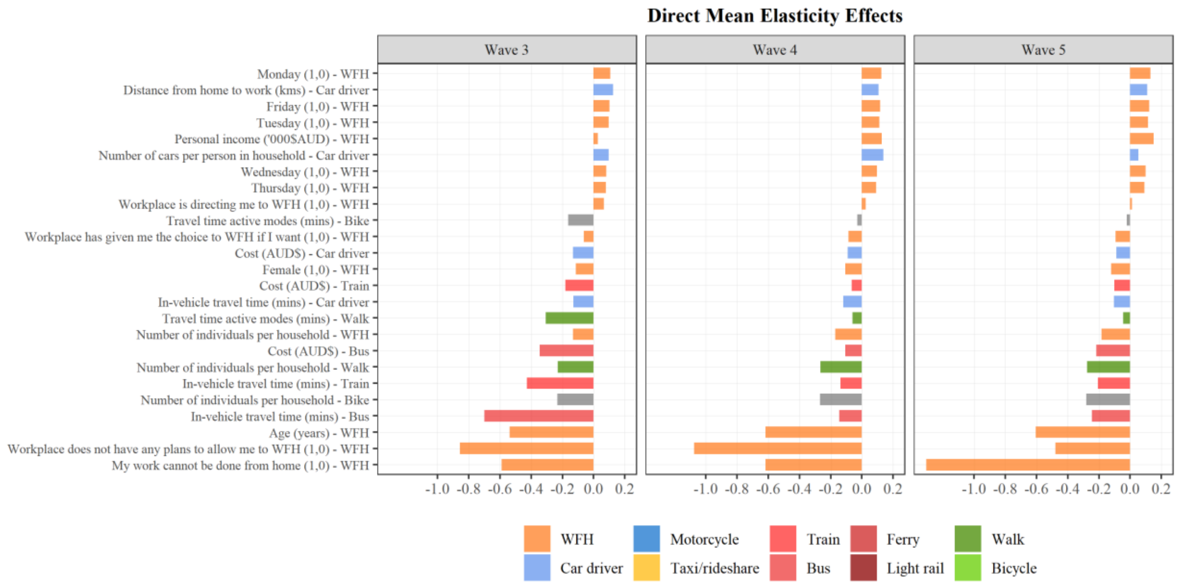

Figure 7. Direct mean elasticity effects

It is interesting to see how the direct mean elasticities of the different explanatory variables have changed over time. The elasticity of the distance from home to work in the probability to use car as driver to go to work has decreased over time, with 0.125 in Wave 3 and below 0.11 in Waves 4 and 5. These numbers are saying, *ceteris paribus*, that if a person lived 10% more kilometres further from where they worked, their probability to choose car as driver was 1.25 higher in Wave 3, and 1.06 higher in Wave 4 and 1.09 higher in Wave 5. The influence on personal income on the probability to choose WFH has increased over time, suggesting that people with higher incomes are more likely to work from home now than they did in late 2020. It is important to consider that the direct elasticities for dummy variables should be considered relative to their base level. This is particularly relevant for the WFH policy of their workplace, since respondents that are given the choice to WFH if they want, have a lower probability to WFH than those that said they always WFH (base level), and that is why they have a negative elasticity. The WFH policy will be looked at in more detail in the next section using simulated scenarios which represent the overall influence.

The elasticity of travel time has decreased over time for all modes, suggesting far less sensitivity to travel time, but this decrease has been much more significant for active modes and especially public transport. This is saying that in Wave 3, people were less likely to choose public transport or active modes for longer trips than in Waves 4 and 5, *ceteris paribus*. This is in part also associated with public transport users being more concerned about using public transport in general due to higher levels of bio-security concerns in the earlier days of COVID-19 before most were vaccinated, exacerbated when spending more time of public transport. The influence of the number of individuals in a household towards choosing to cycle to work has remained relatively similar across waves, same as the age in the probability to WFH.

6 Simulated scenarios

Simulated scenarios were estimated to assess how the probability to WFH, commute by PT and commute by active modes change when different explanatory variables change. The objective of this research is to understand the role that underlying attitudes play in respondents' decision to work from home and to commute by different modes of transport. Therefore, direct changes in the latent variables were simulated to see how they would influence the probability to WFH, to commute by car, public transport (PT), or active modes (Act). The simulated scenarios are particularly useful to understand the influence of the latent variables or dummy variables such as WFH policy of workplace. To calculate the percentage changes in the use of public transport for each scenario, we aggregated the probability to use bus, train, light rail and ferry, when available; and similarly for car we added the probability to use car passenger and car driver, when available. Six different scenarios were simulated which are described in Table 8, and the percentage changes are presented in Figure 8. Appendix B presents the base probabilities to work from home, commute by public transport, car and by active modes. The first scenario assume that every respondent had the option to WFH, which represents an increase of almost 16% in the probability to WFH in Wave 5, almost 9% in Wave 4 and 4% in Wave 3. The majority of this trips are by car, so this scenario would represent a decrease in commuting by car of 2.5% in Wave 3, 5.8% in Wave 4 and 9% in Wave 5, while it would represent a 0.1% decrease in the use of public transport in Wave 3, 0.5% in Wave 4, and 2.1% in Wave 5, and 0.3% decrease in the use of active modes for Wave 3, 0.4% for Wave 4, and 0.7% for Wave 5.

The second scenario represents one where none of the workplaces had any plans to allow their workers to WFH. This obviously decreases the probability to WFH by 26% in Wave 3, 18% in Wave 4, and 15% in Wave 5. In terms of the chosen modes to make these trips to the workplace, almost 13% are done by car, 2.5% by public transport and 1.4% by active modes in Wave 3; more than 7% by car, 1.5% by public transport and 0.7% by active modes in Wave 4; and almost 4% by car, 2% by public transport and 0.4% by active modes in Wave 5. These results suggest that WFH is mainly replacing or being replaced by car trips, and not trips usually undertaken by public transport or active modes.

The third scenario represents a 30-minute city, where the maximum distance from home to work is 10 kilometres and the maximum travel time in all modes is 30 minutes. There are only slight changes in the probability to choose to WFH, or commute by different modes across all waves. This suggests that travel time and distance are not a major determinant in the decision to WFH or to choose their mode of transport, relative to the other explanatory variables that have been included in this model.

Scenario 4 represents the latent variable ‘life satisfaction’. It is interesting to see that if all respondents were 20% more satisfied with their life, 19%, 36% and 30% for Wave 3, 4, 5, respectively would choose to WFH, while 12%, 22% and 15% of them would stop using their car to go to work. when levels are less than 4.2% across all waves, we see a cessation of using public transport, and less than 1.5% active modes. These findings support policy initiatives focused on incentivising the use of public transport and active modes as more sustainable modes of transport, while also encouraging more flexible work options, such as WFH. These results suggest that individuals who are more satisfied with their life usually choose these more sustainable options or directly choose to WFH if their work allows for it.

Table 9. Simulated scenarios description

Simulated scenario	Description
S1: Option to WFH	Everyone has the option to work from home
S2: No plans to WFH	No workplaces have plans to allow them to work from home
S3: 30-minute city	Maximum distance from home to work is 10 kms, and maximum travel time in all modes is 30 minutes
S4: 20% more life satisfaction	Respondents are 20% more satisfied with their life
S5: 50% less concern about PT	Respondents are 50% less concern about the use of public transport

S6: 50% more social meetings	Respondents are 50% more positive towards social meetings

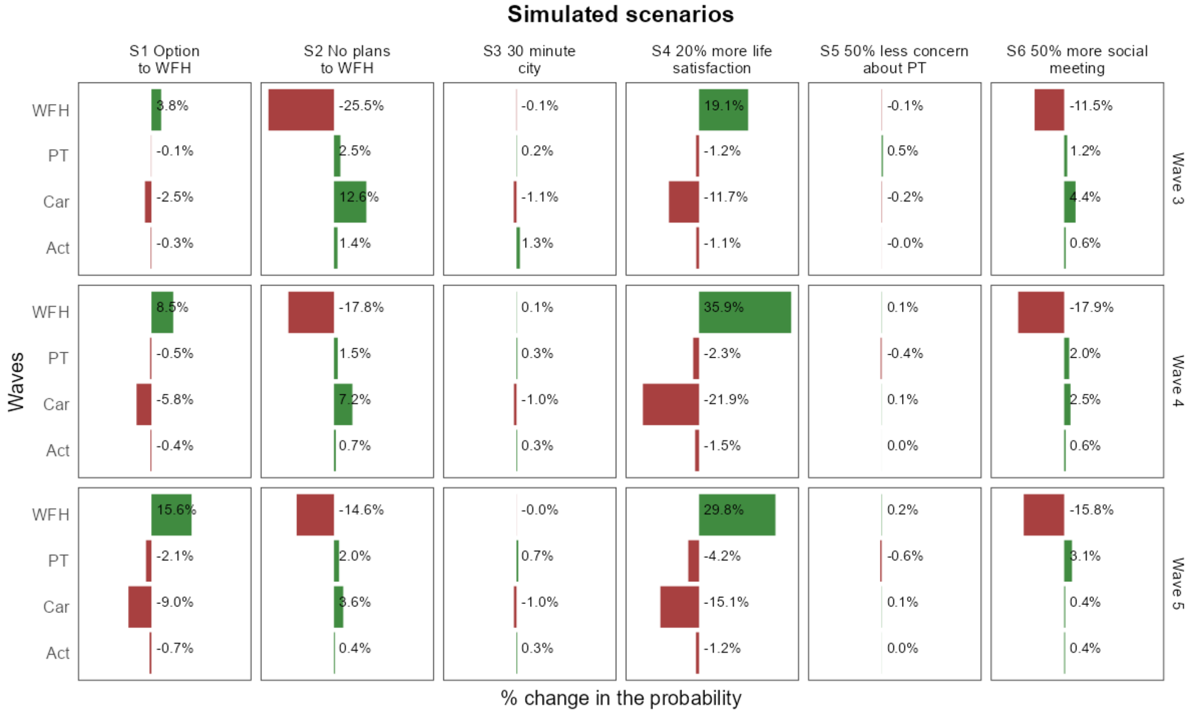

Figure 8. Simulated scenarios results

The fifth scenario represents a 50% decrease in the concern about the use of public transport. These results show that people who are concerned about public transport are not necessarily using it less than people that are less concerned. This is an interesting finding, suggesting that although bio-security concerns have remained throughout the period of the three waves, they have not resulted in any change in the use of public transport across individuals with differing levels of perceived concern about using public transport in the GSMA and SEQ. Other factors have driven any possible differences.

The last scenario presents one where individuals would have a 50% more social-meeting lover attitude. These results suggest that across all waves, between 11-18% of respondents would not work from home, where they miss out on social interaction, especially at the office. Interestingly, in Wave 3 4.4% of these respondents that would not WFH would be using their car to go to work, while 1.2% would be using public transport and only 0.6% active modes. However, in the latest Wave (5) collected in the second semester of 2022, 3.1% of respondents that would not WFH would be commuting by public transport, 0.4% by car and active modes. This is suggesting that as we have moved to a new COVID-'normal' scenario, people seem to be moving away from the car and back to public transport in particular, which we suspect has a lot to do with the high levels of fully vaccinated (at least two doses) individuals.

7 Conclusions

The main objective of this paper was to understand changes in mobility patterns since the start of COVID-19, identifying the role of work from home and underlying attitudes influencing individuals' preferences. A hybrid choice model is estimated where the alternatives in the choice model are the decision to not work, to WFH, or to commute by different modes of transport. The model includes three latent variables: concern about the use of public transport, life satisfaction, and social-meeting loving attitude. The dataset includes three waves of data collected in two metropolitan areas in Australia during years 2020, 2021 and 2022. The dataset used in this study includes workers only as the interest is on commuting choices (to and from workplace) and WFH.

The hybrid choice model was compared to a simple mixed multinomial logit model. Results show a significant improvement in the goodness of fit when incorporating these latent variables. Moreover, it revealed a more detailed interpretation of some explanatory variables that had an influence on the alternatives through the latent variables. The results of the modelling show that life satisfaction is positively influenced by age and income, and by having an employer with a more flexible WFH policy rather than being directed to WFH or to go to their workplace every day. Results also show that life satisfaction has gone up since 2020 for all individuals. The latent variable that represents a positive attitude towards social meetings is positively influenced by age, and it has also increased relevance since 2020. The results for the latent variable that represents concern about public transport use suggest that respondents with white collar occupations seem more concerned than those in blue collar occupations, and also people that used car to go to work prior to COVID-19. Results show that the concern towards the use of public transport has decreased since 2020 for all the sample.

Elasticities were estimated using the choice model to quantify the influence of the explanatory variables on the probability of choosing each alternative. The results suggest that the negative influence of travel time decreased since 2020, particularly for active modes and public transport. The distance from home to work was statistically significant, showing that if a person lives 10% further from where they work, their probability to choose car as driver increased by 1.25% in Wave 3, and by 1.10% in Waves 4 and 5. Seven different scenarios were simulated to show how changes in the explanatory variables could influence the probability to WFH, or to commute by car, public transport or active modes. The results are encouraging and suggest that since the start of the pandemic, people are slowly moving away from using their car – particularly people that are more satisfied with their life, seem to be working from home more often and, when having to commute, they tend to use public transport or active modes as opposed to private cars.

Results suggest that work from home as an alternative to going to the workplace has settled as a valid and efficient alternative even in this last wave of data collected in 2022, given it is generally accepted as being non-stigmatised as employers increasingly support this flexible hybrid working model, given evidence of increased perceived productivity (Beck & Hensher, 2021b). Moreover, results show that the majority of these “saved” commuting trips were previously by car, and not by more sustainable options such as public transport and active modes. If respondents do not have the option to WFH and have to attend the workplace, the increase in commuting trips tends to be by car, despite evidence of some amount of return to public transport. One limitation of this study is that we focus only on commuting trips, however changed rates of WFH are also likely to change the nature of non-commuting trips, in particular those which are made whilst working from home. Ongoing research is seeking to understand in greater detail the geospatial and temporal nature of these changes in travel patterns.

Finally, we recognise that the unintended positive consequences of COVID-19 have cushioned the severity of the pandemic to some degree, and this should be recognised as an immediate benefit. More importantly, however, is the potential for longer term gain in well-being and lifestyle that may not have been offered up if life had continued along the journey associated with the pre-COVID-19 state of travel, commuting and associated pressures on work-home balance. Given that it is likely that working from home and/or working near home will continue to feature as a greater proportion of where work is completed, it is crucial to develop and implement best practices for WFH and WNH to maintain a good level of productivity, achieve the right level of work and life balance, and maintain a good level for physical and mental health. The models and results presented in this paper re-affirm the value of this ‘emerging new normal’.

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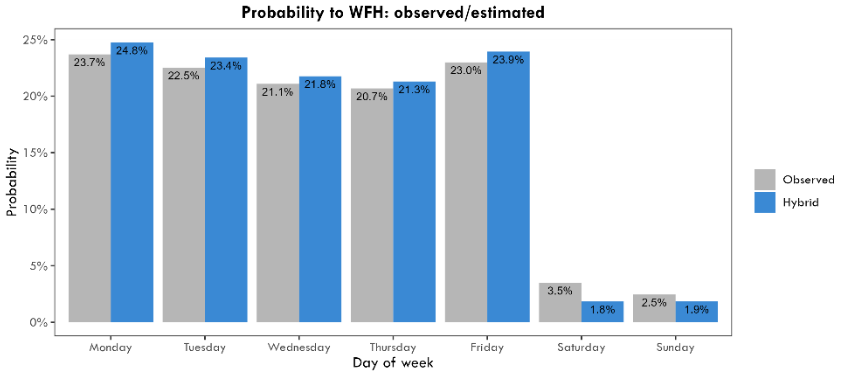
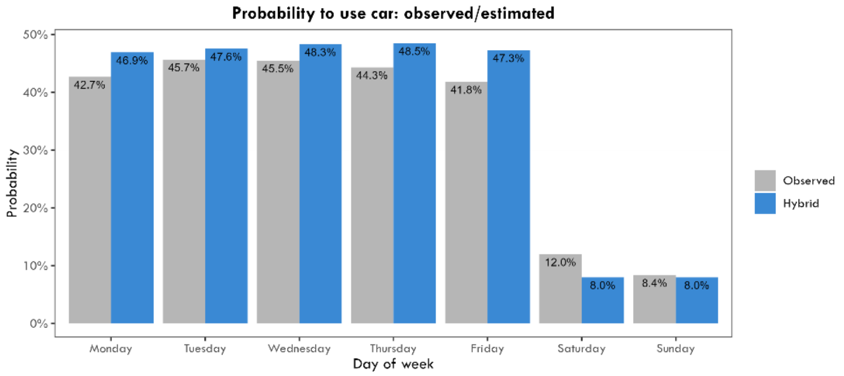
Appendix Paper A. Measurement equations hybrid model

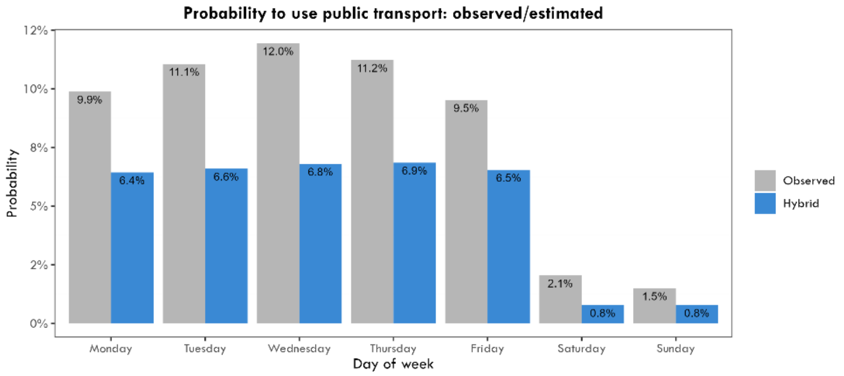
Table 10: Latent variables' measurement equations model results

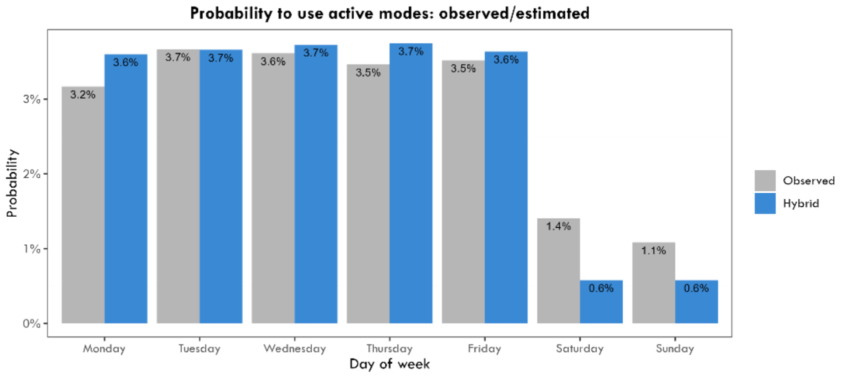
Description	Mean (t-value)
Latent variable concern about public transport use	
Alpha parameter ACvConc	1.73 (20.67)
Delta parameter 1 ACvConc	0.79 (20.49)
Delta parameter 2 ACvConc	2.05 (23.18)
Alpha parameter ACvCoNUs	1.92 (18.03)
Delta parameter 1 ACvCoNUs	0.84 (18.00)
Delta parameter 2 ACvCoNUs	2.13 (19.83)
Alpha parameter WkEnvCnc	0.54 (30.00)
Delta parameter 1 WkEnvCnc	0.34 (29.54)
Delta parameter 2 WkEnvCnc	0.91 (44.70)
Latent variable life satisfaction	
Alpha parameter SatLife	0.15 (13.47)
Delta parameter 1 SatLife	0.41 (32.57)
Delta parameter 2 SatLife	1.16 (50.40)
Alpha parameter SatWorth	0.18 (13.84)
Delta parameter 1 SatWorth	0.42 (31.33)
Delta parameter 2 SatWorth	1.07 (48.19)
Alpha parameter SatHappy	0.14 (13.43)
Delta parameter 1 SatHappy	0.38 (31.41)
Delta parameter 2 SatHappy	0.98 (47.80)
Latent variable social-meeting lover	
Alpha parameter ComFrnd	1.42 (31.64)
Delta parameter 1 ComFrnd	0.33 (17.93)
Delta parameter 2 ComFrnd	1.17 (30.96)
Alpha parameter ComRest	1.61 (28.94)
Delta parameter 1 ComRest	0.36 (17.50)
Delta parameter 2 ComRest	1.48 (30.88)
Alpha parameter ComShop	1.65 (28.08)
Delta parameter 1 ComShop	0.40 (18.14)
Delta parameter 2 ComShop	1.57 (29.63)
Alpha parameter ComDoc	0.72 (35.41)
Delta parameter 1 ComDoc	0.24 (20.77)
Delta parameter 2 ComDoc	0.85 (39.02)

Appendix Paper B. Base scenarios simulations, observed versus estimated









Appendix AA. Paper #23: COVID-19 and public transport response and challenges

Matthew J. Beck
John D. Nelson
David A. Hensher

Abstract

The COVID-19 pandemic has had a significant impact on the propensity to use public transport and although use is recovering to 60-70% of pre-COVID-19 levels in many locations there is a view that it could take many years to fully recover, if at all. In this chapter we bring together the literature on the impacts that the pandemic has had and continues to have on public transport patronage worldwide and draw together the main features of the varying responses as a way of gaining a better understanding of the role that the various initiatives have played in protecting the community of travelers. The chapter begins with a consideration of the short-term response of the public transport sector to the COVID-19 pandemic. Attention is given to the variety of measures introduced and the outcomes that followed. The on-going importance of the biosecurity context is acknowledged. The chapter also addresses the question of how public transport will be impacted in the long term which is relevant both in the context of an extended pandemic (which now seems likely) and also in a "post-pandemic" context. The question of long-term implications seems less addressed in the literature. We conclude that the need for a strong low carbon public transport sector remains pressing (as it was pre-pandemic), while the emerging trends such as reductions in patronage, changes in working practices and the impact of reduced revenue and other sources of financial support are likely to influence public transport for many years to come.

Keywords: Public transport. COVID-19. Short-term effects. Long-term effects. Travel behavior. Policies.

1 Introduction

The COVID-19 pandemic has had a significant impact on the propensity to use public transport, with many countries seeing a decline in patronage to as low as 20% of the pre-pandemic levels. Although public transport use is recovering with 60-70% of pre-COVID-19 levels being a common statistic, there is a view that it could take many years to fully recover, if at all[50]. In this chapter we bring together insights from the literature on the impacts that the pandemic has had and continues to have throughout many countries on the public transport sector and draw together the main features of the varying responses as a way of gaining a better understanding of the role that the various initiatives have played in protecting the community of travelers and laying the foundation for the future of the sector. While there is evidence that catching COVID on public transport remains a minimal risk; nevertheless, a significant number of people have stopped using public transport. So why did this happen? Why is the pace of returning to use of public transport slow, if at all? Ultimately, to paraphrase Jenelius and Cebecauer (2020), it seems increasingly likely that the return to public transport ridership will most likely be influenced by both restrictions imposed by authorities and travelers' own choices. This implies the need to be responsive to the concerns of travelers. Furthermore, there have been significant changes in people's travel behavior and lifestyle since the outbreak of COVID-19. Physical mobility is being progressively replaced by virtual mobility, for example, through teleconferences, working from home (WFH), and online shopping. These changes are expected to continue as the pandemic proceeds through its various phases (Xi et al., 2022). Transurban (2022) in their study of urban mobility trends in Australia and North America report that the average number of days people expect to WFH once the risk from COVID-19 has passed has remained consistent throughout 2022 (the Australian average being 1.7, the average for Greater Washington is 2).

Importantly, if people are indeed reluctant to return to public transport there are systematic effects that need consideration. Firstly, hybrid work models mean that workers will commute to their office location so what might happen to congestion, economic productivity and pollution, if the private vehicle becomes further entrenched as the norm? 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 (Hensher et al., 2022). 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. Secondly, if public transport passenger numbers remain low and providers seek to scale back operations as a result, what impact does that have on captive public transport users in terms of their mobility options, particularly those from lower income segments who need to travel for essential purposes (De Vos, 2020), and the wellbeing impacts of social inclusion?

The decline in public transport patronage is especially critical to operators since it has meant a loss in farebox revenue which has traditionally posed a threat to the financial sustainability of service provision. In many cases operators have had to rely on emergency funding to support existing services which has provided a breathing space for authorities and operators to develop new financially sustainable networks. This funding is coming to an end during 2022 as governments change their focus to one of "living with COVID-19". As if this was not sufficiently challenging, car use has returned to pre-pandemic levels in many countries, increasing the risk of a 'car-led recovery' (Institution of Civil Engineers, 2022). In such a context

[50] For example, at the time of writing a statement from the Queensland Government (22/08/22) indicates that public transport patronage in South East Queensland for the week ending 14 August 2022 is at 73% of pre-pandemic travel. https://statements.qld.gov.au/statements/96002

it is no exaggeration to say that we may have reached a crossroads in terms of the future of public transport. A more positive outlook is offered by Lyons (2021) who suggests that having had to cope with the early diagnosis that public transport is not safe and that travelers should avoid public transport one can be more optimistic that the public transport sector is now better equipped to also address how it can innovate to not only “survive but thrive” in the future. Crucially, though the longer-term perspective is inevitably influenced by the fact that the pandemic has been more persistent than most authorities foresaw at its beginning (Jenelius, 2022), with resulting impacts for transport and society that cannot yet be fully appreciated. This chapter will seek to weigh up the evidence.

The chapter also addresses the question of how public transport will be impacted in the long term which is relevant both in the context of an extended pandemic (which now seems likely) but also in a “post-pandemic” context, but even what lessons can be learnt from this experience given that future pandemics seem likely (Dobson et al. 2020). There is a strong imperative to consider the longer-term perspective since there is an on-going need to address the transport decarbonization debate as well as combatting a public health crisis (Nguyen and, 2021). The question of long-term implications seems less investigated (with some exceptions such as Jenelius, 2022), however as van Wee and Witlox (2021) observe lasting effects on travel behavior can be expected and peak demand among both car and public transport users may be lower than if the pandemic had never happened. Therefore, as a result of the significant drop in public transport rideshare, there is a concern that the pandemic could have a substantial negative impact on social equity, decarbonization, and the financial position of transport providers around the world (Xi, et al., 2022).

1.1 A note on the literature context

A considerable literature has been generated about COVID-19 and transport. In their systematic review of COVID-19 transport policies and mitigation strategies Peralvo et al (2022) identify 442 articles published from 2020 to April 2022. When classified by mode they find that public transport predominates (51.97 %) which they attribute to the perceived higher risk associated with public transport vehicles and infrastructure. Peralvo et al (2022) also characterize the literature by the main actor involved in a given strategy which reveals a clear predominance of the government actor (64.47 %), followed by the operator (28%). Together, both actors are responsible for the formulation and implementation of policies to combat the virus. These actor-oriented strategies are discussed in the next section.

Kim et al (2021) provide a classification of the COVID-19 and public transport literature noting the following: (i) Studies which have conducted surveys about the travel-related behavioral changes induced by the pandemic and which have verified the presence of changes in travel demand and mode choice to avoid infection (e.g. Beck and Hensher, 2020a, 2020b, 2021a, 2021b), Beck et al., 2021 and 2022); (ii) studies which have focused on changes in public transport patronage using actual volume data (e.g. Jenelius and Cebecauer, 2020); (iii) studies which have tested the involvement of neighborhood attributes in the impacts of COVID-19 on public transport (e.g. Brough et al., 2020; Chang et al., 2021; Xi et al., 2022); and (iv) studies analyzing other pandemics which have also considered changes in public transport ridership (e.g. Howland et al., 2020).

The chapter is structured as follows. We begin with a consideration of the short-term response of the public transport sector to the COVID-19 pandemic. Attention is given to the variety of measures introduced and the outcomes that followed. The on-going importance of the biosecurity context is acknowledged. We then turn to discuss the more speculative long-term impacts on public transport before drawing conclusions.

2 The public transport sector response (short-term)

It is fair to say that 2020 became a hallmark year for the world because of the COVID-19 pandemic and its tremendous impact on the operation of city transport systems (McKinsey & Company, 2021). Lyons (2021) suggests that we may look back in wonder at this shock in global society's history. Given that Coronavirus is transmitted by close contact with infected individuals, public transport usage around the world experienced a dramatic decrease after the initial lockdowns in early 2020 with declines in patronage to as low as 20% of the pre-pandemic levels.

Public transport is vital to communities and its preservation in a post-pandemic world is essential (Nguyen and, 2021). Notwithstanding the dramatic reductions in patronage experienced the low income, ethnic and other vulnerable groups continued to use public transport and face higher health risks while trying to access and maintain front-line jobs (Tran et al., 2022). Reductions in service frequencies, while implemented in response to falling demand, had a disproportionate impact on those who need to travel for essential purposes (De Vos, 2020). Whilst this was to be expected (at least with hindsight) at the peak of the pandemic, outside of lockdowns government should endeavor to provide reliable and safe public transport services, given that this is an important means to ensure citizens mobility and livelihood amid pandemics (Kim et al., 2021). There has also been a significant decline in demand for taxis and ride-share services such as carpooling and ride-hailing due to reduced service operations and users' concerns about being exposed to the virus[51]. Daus (2021) notes that as with mainstream public transport, the taxi and TNC sector worldwide has been severely affected by the COVID-19 pandemic. In New York City, for example, taxi ridership plummeted by 94% from early March to early May 2020.

Two and half years later a study by Transurban (2022) reports that public transport patronage is still well below pre-pandemic levels in Australian cities, whereas indicators of private vehicle travel show a return towards pre-pandemic levels. In Sydney public transport patronage was down 33% on pre-pandemic levels in Greater Sydney (June 2022), with a corresponding figure of 41.7% in South East Queensland (May 2022) and 35% in Melbourne (July 2022). In the USA rail patronage was down 55.8% and bus 21.7% in the Greater Washington Area (July 2022).

In the case of London Transport for London (TfL) has provided indicative estimates for changes in modal share in spring and summer 2020 compared to 2018 and 2019 baselines (Table 1). This illustrates the commonly observed trend of public transport ceding mode share to private transport and active modes. If public transport and active modes are combined their share has fallen from 63% in the 2018 baseline to 54.5% in the second quarter of 2020.

Table 1: Estimated quarterly mode shares for 2020 Q1 and Q2, compared to established benchmarks for 2018 and 2019 (UK).

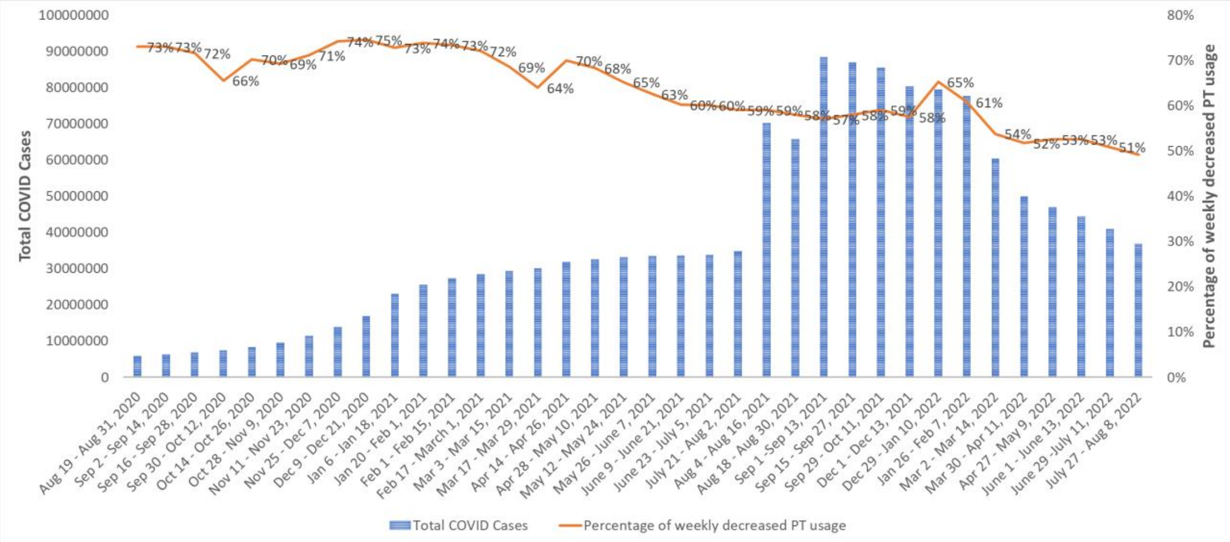
	Public transport (%)	**Private transport (%)**	**Walk and cycle (%)**
2018 baseline	35.5	37	27.5
2019	35.6	36.8	27.5
2020 Q1	33.7	38	28.3

[51] The discussion of the impact of the pandemic on the taxi and ride-share sector is not included within this chapter. The interested reader is referred to Daus (2021) for a comprehensive review.

2020 Q2	8.1	45.5	46.3

Source: Modified from TfL[52]

Figure 1 shows the relationship between COVID-19 cases and public transport patronage for the USA over the two year period from August 2020 in terms of reported fewer trips taken using bus, rail, or ride-sharing services in the last 7 days because of coronavirus pandemic by those who didn't use public transport before the pandemic. The challenge of building back public transport patronage is clear.



Source: data from U.S. Census Bureau Household Pulse Survey.

Figure 1: COVID-19 Cases and Public Transport Patronage (US).

2.1 Measures that were introduced

The responses of public transport operators and authorities to the COVID-19 pandemic have been extensively documented (see for example, Beck et al. 2021; McKinsey & Company, 2021). Examples include a proliferation of COVID-19 travel advice web pages and Apps and Journey planners with indications of safe passenger capacities on board; "on the ground" measures to support distancing measures, e.g., orderly queuing in stations and concourses and at station and in-vehicle signage such as "No dot, no spot" (as introduced in Sydney), as well as QR codes at stops, stations and in-vehicle, a hastened move towards contactless payment and a greater focus on providing information via contactless and touchless media. A strong visual presence of cleaning crews at stations and interchanges (with extra hours measured in hundreds of thousands) has been shown to be important (Beck et al., 2022). Operationally, there have been frequency changes in service levels. In some cities service levels were reduced: the New York subway service was cut by a quarter early in the first wave. In London the Waterloo and City Underground line which primarily caters for commuters was closed from March 2020 to June 2021 (TfL, 2021). As with public transport, the taxi/TNC sector introduced measures such as enhanced cleaning methods, personal protective equipment for staff and prevention mechanisms, such as partitions to guard against virus transmission, which have become priority items for rideshare and taxi fleets (Daus, 2021).

A comprehensive review by Peralvo et al (2022) classified the transport and COVID-19 literature by main actor and their response as they relate to public transport (Table 2).

[52] https://www.london.gov.uk/questions/2020/3302#a-188504

Table 2*:* Actor-oriented strategies to combat COVID-19 in the public transport sector

Actor	**Response**
Government	Analysis of service reduction to decrease the number of infections
	Strategies regarding public transport operations (e.g. crowding management focus on planning and informing the user about the operation of the public transport system).
	Silent policies in the public transport system (e.g. use of contactless door sensors and clear screens between seats.
	Social distancing (at stations and in-vehicle, manage seating in public use vehicles)
	Mask wearing regulations
	Regaining social support for public transport (e.g. effective communication and public fear mitigation; fare-free policies; proposing subsidies for the most vulnerable groups of the population).
Operator	Ventilation within vehicles
	Safety measures for passengers and drivers (e.g. social distancing, disinfection, driver safety).
	Door opening/closing at stops, as a ventilation mechanism.
	Social distancing through management and control of seat restrictions.
	Vehicle disinfection (the most commonly applied biosecurity measure for public transport).
User and industry	Social distancing to reduce time spent at stations and interchanges.
	Crowding management, (e.g. via app-based and web-based services such as capacity reservation with advance booking, online ticket purchase, and e-ticketing, occupancy indicators).
	Regaining social support for public transport through communication and fear mitigation campaigns.

Source: compiled from Peralvo et al (2022).

Commenting on the measures introduced Mashrur et al (2022) suggest that they are likely to be maintained for an extended period as a precaution after the pandemic. They make the point that because of this some individuals may delay their return to public transport while these measures are in place, meaning that patronage may be adversely affected by the very measures put in place to make public transport safe.

The pandemic has demonstrated the importance of supporting all forms of public transport with clear messaging from Government (Beck et al, 2021). A basic premise is that clear "messaging" (or communication) is essential in building confidence amongst public transport users and that safe travel is a question of both putting in place good practice with clear messages while also understanding how to improve safety perception. Negative messages can spread quickly and damage the brand, especially if managed poorly. But at the same time, quick and effective responses from management can turn negative situations into positive ones (Nelson, 2021). In the early days of the pandemic, travelers were faced with the counterintuitive message that they should avoid public transport because it was unsafe. Authorities seemed unaware of the long-term danger that this might create a self-fulfilling prophecy that makes the decline in public transport use seen in lockdowns become much more permanent. This is especially true given the stereotypically negative view of public transport cleanliness, amplified in the context of the pandemic.

It is well established that users of public transport require (and increasingly expect) clear, accurate and timely service information that is readily available and easy to understand. The provision of good quality passenger information has long been associated with promoting safety by making sure that appropriate messaging is used to help passengers use the transport network with ease and confidence (Halpern, 2021).

In his commentary on the role of service information during the pandemic Halpern (2021) argues that the need for interactive and personalized approaches to information provision has been reinforced. Messages need to be adapted to the “current” situation which is likely to be a dynamic one and can be expected to vary at different stages of the pandemic. Specific information is needed on changes to the service and any health measures that must be followed. These are additional requirements on top of the day-to-day operational requirements.

One area where the message has been conflicting however has been whether masks are mandatory for public transport users or “strongly recommended” and this is varied in the same location at different stages of the pandemic. Greater clarification would be helpful for commuters particularly as concerns around transmission of the virus continue. Dzisi and Dei (2020) note there is evidence from an operator perspective that policy on using masks in public transport has been more difficult to enforce (a contrast with the policy on physical distancing). This is interesting since as Peralvo et al (2022) point out physical distancing as a policy is not easily transferable to the public transport context, and less so with other forms of shared mobility, given the constraint of space. However, Daus (2021) suggests that while passengers in small, shared vehicles are not physically distanced due to the proximity to the driver, they are possibly more physically isolated than in conventional public transport.

It is also relevant to note that during the pandemic there have been other interventions introduced which have a direct relevance to public transport. Nelson et al (2022) identify four sets of COVID-19 transport policies, namely: change in operation of public transport services; contestation of road space; support for other shared transport / TNCs; and working from home. Examples of each are given in Table 3.

Table 3: COVID-19 transport policies and their implications for public transport.

Policy	**Impact**	
	Health	**Sustainability**
1. Change in operation of public transport services		
Frequency changes of Public Transport	N/A	no
Physical distancing in Public Transport	yes	N/A
Mask wearing in Public Transport	yes	N/A
2. Contestation of road space.		
Pop-up Cycle lanes	yes	yes
Parking policies	N/A	no
3. Support for shared transport / TNCs.		
Co-modality of Community Transport (CT)	N/A	yes
Support for Taxis / TNCs	yes	yes
4. Working from Home (WFH)		
WFH	N/A	yes

Source: Adapted from Nelson et al (2022).

They note that these policies can either benefit or hinder public transport, while support for other forms of transport (if not handled carefully) abstracts patronage from public transport patronage as can working from home.

2.2 The biosecurity context

A prolonged period of uncertainty inevitably impacts public transport patronage. In seeking to understand the role of choices made by travelers several studies have specifically focused on the relationship between level of concern with public transport (primarily focused on biosecurity) and actual and intended public transport use during the pandemic and in the “next normal” and beyond.

Mashrur et al (2022) note that COVID-19 has generated an unprecedented level of fear of infection among trip makers, with public transport suffering the most from this perception.

Dong et al (2020) from a cross-sectional study in China conducted early in the pandemic, but at a time when the virus was felt to be under control (March 2020), confirmed that passengers’ feelings of safety enhanced their overall satisfaction with regard to public transport; in other words, perceived safety had a positive effect on overall satisfaction. They noted that an individual’s subjective experiences and opinions on the pandemic were directly related to confidence in using public transport, thus emphasizing the crucial role of operators and authorities in providing reassurance that public transport is safe to use.

For the case of Australia, Beck et al. (2021), drawing on the findings of an ongoing country-wide study, report that concerns over biosecurity issues around public transport are enduring and that even as COVID-19 restrictions are eased, both concern about crowds onboard and hygiene have a significant and negative correlation with public transport use (see Figure 2).

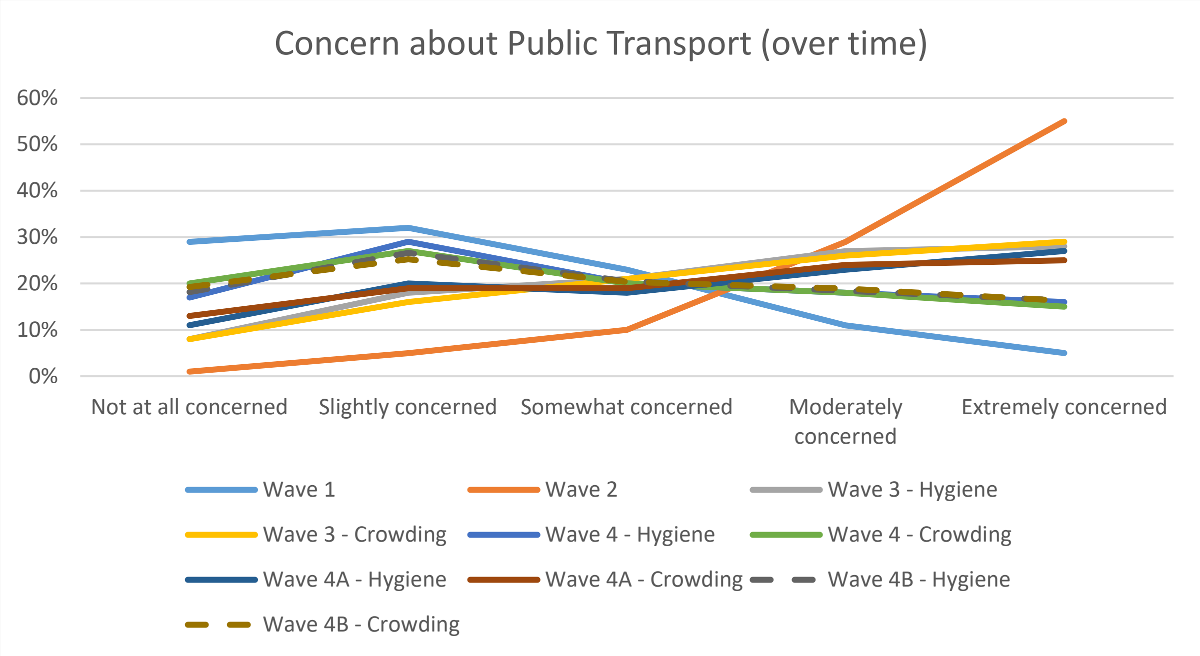


Figure 2: Level of hygiene (all waves) and crowding (Wave 3 only) concern about public transport.

Figure 2 shows data drawn from six waves of data collection in 2020[53].. An attitude to risk is incorporated via passenger concerns about the hygiene of public transport modes in two ways. In Wave 1, 2 and 3 a proxy measure relating to the fear of infection is used ("What would be your level of concern about hygiene on public transport today?"). In Waves 3 and 4 the volume of people currently using public transport is used also as a proxy for the difficulty of maintaining physical distance.

Figure 2 illustrates the dramatic difference in the concern about hygiene on public transport before COVID-19 and immediately after the first outbreak at Wave 1. Although concern in Wave 2 had diminished (consistent with an easing of conditions) more than half the number of respondents still reported moderate to extreme concern. While concern decreased between the two survey waves levels of concern remained largely unchanged from Wave 2 to Wave 3 remaining at an average level appreciably higher than that prior to COVID-19. Interestingly, in Wave 4 concern (while still higher than prior to COVID-19) was reduced again – with key population centres in Sydney and Brisbane having experienced an almost 6-month run of close to zero new COVID-19 cases in the community. In Wave 4A that concern spiked again as outbreaks of the Delta variant occurred in these two metropolitans areas; although not as high as the levels of concern when the COVID-19 pandemic first began. Once again, by the end of the "Delta lockdown" in Sydney as captured by Wave 4B, concern about public transport had diminished – a confluence of case numbers being back under some degree of control and the widespread uptake of the COVID-19 vaccine (Sydney came out of lockdown once 80% of the eligible population had been vaccinated). It might be expected over time that results could be influenced by the availability of better information (as discussed above) and better knowledge about how to combat infection (e.g. a greater appreciation of the importance of mask wearing and improved ventilation) which adds impetus to the need to get the message right when it

[53] Wave 1 (March 2020); Wave 2 (June 2020); and Wave 3 (September 2020), Wave 4 (March 2021), Wave 4A (July 2021 as Sydney and QLD entered lockdowns), and Wave 4B (November 2021 as Sydney emerged from an extended lockdown).

comes to rebuilding traveler confidence. Clearly, there is a persistent issue of confidence amongst travelers that public transport is safe to use. In a later phase of the same study (conducted during lockdown in July 2021) in the metropolitan areas of Greater Sydney and South East Queensland, Beck et al (2022) found that ongoing cleanliness, limits on people using public transport and/or physical distancing measures combined with ongoing use of masks were the most commonly stated measures that would increase confidence in using public transport.

Further evidence of the ongoing concern over biosecurity is shown in a study by the authors of travel choices amongst staff and students at the University Sydney. Figure 3 shows reported perception in May 2022 from a survey of 642 staff and students. Whilst this survey might be considered to have taken place during a prolonged period of COVID "new-normal" with minimal restrictions in place, a mask mandate on public transport has continued throughout 2022 (although compliance has steadily dropped, partly associated with a lack of enforcement, and Omicron cases were around 10,000 / day in May 2022.

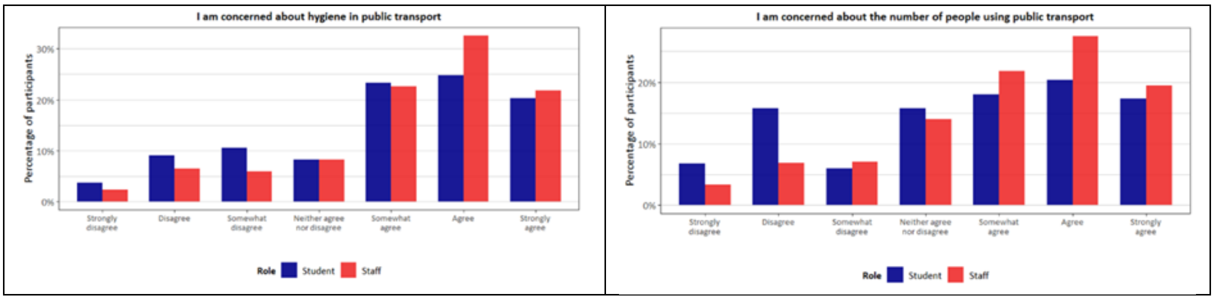


Figure 3: Concern about hygiene and crowding on public transport amongst University of Sydney staff and students (May 2022).

Figure 3 shows that students and staff are almost uniformly concerned about hygiene on public transport and this mirrors other studies (Beck and Hensher, 2020a and b). Taking the number of people using public transport as a proxy for the difficulty of maintaining physical distance, responses largely mirror that of concern over hygiene on public transport. The same study also found that both students and staff have increased their use of cars to travel to campus (either as driver or passenger) compared to before COVID-19; this is more marked for staff. Not surprisingly, and in line with findings elsewhere, this has been at the expense of public transport. There is an indication from both cohorts that their public transport use will increase in future but will not return to pre-pandemic levels. Active modes are expected to continue to grow in popularity.

These findings relating to biosecurity imply that there is a need to conduct further studies around the factors that are likely to restore greater confidence in the use of public transport. Beck et al. (2022) derive segments of public transport users by level of concern. Drawing on findings from a study conducted during lockdown in July 2021 in the metropolitan areas of Greater Sydney and South East Queensland, they conclude that for a large percentage of people distancing and observable cleaning will be needed. This would seem to be where the focus of awareness campaigns to promote public transport as safe should continue to be, even in conditions of the "new normal" when restrictions have been largely relaxed.

2.3 The short-term outcomes

Basu and Ferreira (2021), from their survey of 2,200 respondents in metropolitan Boston, report that one in five of zero-car households agreed that COVID-19 had enhanced their intention to purchase a car. They conducted follow-up interviews with ten previously zero-car owning households that had purchased a car subsequently and found that the major reasons for their decisions were primarily threefold. These can be summarized as uncertainty around public transport service frequency; lack of trust in safety measures introduced by the transport authority; and fear of other passengers not adhering to the safety guidelines. This underscores the ongoing concern that many of those lost to public transport because of the virus will never return.

A study from Poland (Przybylowski et al, 2021) which surveyed 302 public transport users in Gdansk in May and June 2020, found that 25% of respondents did not plan to return to public transport as they doubted that the services will ever be safe. According to a survey in the Hanover Region, local bus and light rail services have been replaced by bicycle, car, and working from home (WFH), whereas train use has been significantly replaced by bicycle; females, in particular, have a higher fear of infection than males, which deters them from using public transport (Schaefer et al., 2021).

A study in the Netherlands by De Haas et al. (2020) found that, attitudes towards travelling by public transport have become more negative during the pandemic, and those surrounding car use have become more positive. It was not clear to De Haas et al. (2020) if such changes in attitudes will last if infection risks disappear after the pandemic. The same study found that that many of those who were able to work from home during the pandemic are expected to work even more from home in the future.

Drawing on data from a study of residents in Toronto to capture the COVID impact on public transport use during the summer of 2020, Mashrur et al (2022) found more optimistic evidence about ridership recovery. Encouragingly, 56.3% of the 933 respondents disagreed that they would never use public transport again, as opposed to 13.4% who firmly agreed to this statement. Also, 48.8% of the respondents disagreed that they would be using public transport less frequently after the pandemic. The same study found that respondents exhibited a willingness to return to public transport once mass vaccination is attained; 71.3% of respondents firmly agreed that they would return to public transport. Another important policy outcome was that notifying riders about vehicle and station cleanliness by any visible means possible, could help to gain trust in the measures introduced to enhance the safe use of public transport (see also Beck et al. 2022). This is something that should be continued even after the immediate threat of COVID-19 has waned so as to not lose patronage from those willing to return.

Tran et al (2022) conducted a novel studying using sentiment analysis to investigate travel experience of vulnerable citizens that continue to rely on public transport during the pandemic and their concerns over risk and safety. They apply sentiment analysis based on machine learning on a Twitter data set (517,000 tweets) representing the experiences of nearly 120,000 public transport passengers collected before and during COVID-19 in Metropolitan Vancouver. Findings showed noticeable upward trends in fear, disgust and anger among different age groups while using public transport, with positive sentiments remaining comparatively flat. Results showed that all age groups exhibited sharp increases in negative sentiments by the second wave of COVID-19 (October 2020). By the second wave of the pandemic, there were distinct increases in negative sentiments for men and women including fear, sadness and anger.

The646 implications of the pandemic on travel behavior for different segments of the population are also investigated in a study using US data by Xi et al (2022) who argue that future planning should recognize that while individuals in the high-income or high-employment density (ED) segment have greater discretion in their work trips and flexibility in choosing to WFH, people in the low-income and low-ED segments do not have as much discretion over how many work trips they can take. Thus, more attention should be focused on achieving equity in terms of access to public transport by allocating subsidies for the most vulnerable groups of the population who continue to rely on public transport in times of crisis.

There are examples where the impact of the pandemic appears to have been less dramatic. Nguyen and Pojani (2021) conducted a study in Hanoi where the pandemic had not decimated bus ridership. This is attributed to the mandated use of face masks and the provision of hand sanitizer onboard vehicles; physical distancing onboard was not introduced. From a survey conducted in September 2020 at the end of the third wave 100% of passengers wore face masks, 28% used the hand sanitizer provided and 38% of passengers carried their own bottles of hand sanitizer. It should be noted that at the time of the survey Vietnam was experiencing lower infection rates and deaths than many other countries.

Kim et al (2021) describe a study which compared patterns of changes in car and bus usage resulting from the pandemic in Daejeon Metropolitan City, South Korea. They were particularly interested in the roles of land attributes such as land use and land price in influencing behavioral changes.

They found that reduction of car trips was greater in areas with a high density of commercial facilities and offices while reduction in the number bus trips was similar in all areas. Also, people living in wealthier neighborhoods reduced their trips more, especially trips by bus. Similar to the findings from Xi et al (2022) who used data from across the US, Kim et al (2021) argue that their findings from the social equity aspect, imply the need for maintaining public transport services to support the mobility requirements of the lower socio-economic groups both during and post-pandemic.

Emphasizing the influence of physical distancing policies on everyday movements, De Vos (2020) notes that the very act of distancing might negatively affect subjective well-being with calls on public transport operators to focus on creating ways to make use of public transport safe, since people avoid using public transport when it is viewed as unsafe. In the longer-term, which is discussed further in the next section, the public transport sector will need to consider ways of futureproofing against virus-driven stresses. Florida et al. (2020) suggest pandemic-proof infrastructure and transport management will likely include the continuation or further development of current measures such as touchless solutions, capacity monitoring and floor markings.

There have also been far reaching effects in terms of ownership and control in the public transport sector. For example, in a railways context in May 2021, the UK Government announced that the infrastructure provider Network Rail would be replaced by a new state-owned body to be known as Great British Railways (GBR) which will also contract passenger services. The emergence of GBR can in part be attributed to COVID-19 since the Government had suspended passenger rail franchises for much of 2020 following the dramatic fall in passenger numbers.

In terms of operational responses for bus services the case for introducing a flexible public transport system is made by Kim et al (2021) who suggest that Demand Responsive Transport (DRT) may be used to reduce operating deficits caused by reduced demands during pandemics and to ensure much safer environments by providing passenger-customized services.

During periods of lockdown, DRT (like other forms of public transport), was characterized as an essential service and this was beneficial for certain groups of travelers such as carers for example. With DRT the ability to book ahead ensures that physical distancing is maintained and the booking and confirmation of pick-up and set down ensures contact tracing where required (Nelson and Caulfield, 2022). Kaufman (2021) from an analysis of DRT patronage in New South Wales found that locational context can fundamentally impact on-demand service uptake with rural and regional services recovering to 7% above pre-pandemic levels by September 2020 while urban services were only 60% of pre-pandemic levels (but still building back more quickly than fixed route services). Perhaps these recovery trends are not so surprising given that DRT offer is traditionally predicated as a personalized transport service.

Nelson and Wright (2021) suggest that it will be necessary to consider the effect that COVID-19 will have on market demands and operator supply and whether this will lead to more or less interest or indeed need for DRT solutions. For example, it may be that passengers spread in small groups across smaller vehicles are better than larger numbers of passenger physically distanced on fewer large vehicles (conventional buses) – at greater cost of provision but with greater flexibility of operation.

Nelson and Caulfield (2022) observe that it is striking to note that amongst the growing literature of the reported impact of COVID-19 on travel behavior there is relatively little documented experience of how rural travel behavior has been impacted. Nelson and Caulfield (2021) consider how travel behavior has changed and some of the responses that public transport operators and shared transport providers have implemented. It is encouraging to note the role that DRT and community transport (CT) has played a strategic role in sustaining rural communities.

If, during the initial phases of the pandemic, it was felt that there was not the time to learn from the experience of other jurisdictions now there is the chance to reflect on what happened in different places and what can be learnt, including through strengthened international collaboration (Nelson et al., 2022).

3 Longer-term implications

Thus far, this chapter has focused on the short-term response of the public transport sector. In this section we consider the longer-term implications. Jenelius (2022) captures the situation succinctly with his observation that the question currently on many operators', planners' and politicians' mind is whether, and how, the trends emerging from the pandemic will change the long-term future for public transport. Answering this question is made more difficult without knowledge of what successive “next new 648normal” will be.

Speculating on the likely long-term effects of COVID-19 on travel and activity behavior, van Wee and Witlox (2021) suggest that the continuing shift from onsite to online settings will result in lower congestion levels on roads as well as less crowding in public transport. Hensher at al (2022) observe that we should also reflect on long distance domestic travel. Specifically, we are likely to see a significant reduction in domestic business air travel, replacing for example, the Sydney to Melbourne return flights (typically 4 hours out of the day) to attend a one-hour meeting with an online meeting. This may translate into a growth in local non-commuting activity with time freed up.

In the longer-term, mobility in our cities must change. Policies need to be tailored to different age segments with land use planning addressing the demand for housing choice and different land uses. Areas with mixed land use – offering housing, retail, leisure and jobs – provide the opportunity of jobs closer to home and mitigates against the centralization of specialized hubs.

If a lower pressure on peak hours is maintained investments in capacity extensions of existing links (such as parts of the motorway network or railway stations and lines) to reduce congestion (roads) and crowding (public transport) might become less attractive, assuming that attractiveness is based on the difference between societal benefits and costs (van Wee and Witlox, 2021).

Neilsen (2021) provides a useful perspective with his observations on the implications of the pandemic for public transport. First, the pandemic has been a reminder of how important public transport is as a crucial part of society's basic infrastructure and an influencer of travel behavior. This is a good reason for using public money to finance the system. Second, the need to maintain physical distancing can perhaps induce a revision of what is considered an acceptable capacity in public transport vehicles (especially when linked with lingering biosecurity concerns, discussed above, which have the potential to persist for years to come). Third, in most large cities working from home and staggered hours is flattening the traffic peaks and saving resources that might be used to strengthen the basic, off-peak transport services (Beck et al., 2021). Differential pricing of both public transport and private car traffic would support this development. Finally, the pandemic has also induced more walking, cycling, and e-biking as a replacement for short-distance travel in crowded public transport. Improved conditions for the active modes may have the potential to enhance the attractiveness of public transport by supporting network design recommendations for greater distances between stops, faster and more direct and frequent services along high-quality routes.

Some contributions to the literature have identified opportunities for the development of a greener, more resilient mobility in the light of the impacts of COVID on the environment. Budd and Ison (2020) advocate for a new concept of "Responsible Transport" to help inform and shape transport policy responses to COVID-19. Tardivo et al. (2021) highlight the positive impact of significantly reduced mobility on the environment in the early stages of the pandemic (with the massive improvement in air quality in Delhi often cited) and suggest that rail services can provide support for policies necessary to encourage a shift away from the intensive use of carbon fossil fuels for transport. Gutiérrez et al. (2020) call for momentum to maintain the promotion of active modes as part of a combined offer with public transport to make cities healthier and more sustainable; this could include a renewed focus on first / last mile connectivity for public transport, although it is not clear that this is a likely outcome. Such measures, argue Tardivo et al. (2021), are essential to avoid a "return to normality" in a GHG context. Beck et al (2022) note that since public transport use lags significantly behind the rebound in private vehicle use in many jurisdictions, authorities should do everything within their power to avoid the further entrenchment of the motor vehicle as the dominant mode of transport, as this would be the fastest way to erode any gains in sustainability.

Nelson et al (2022) identify several policy considerations for public transport which should be developed while transitioning to recovery. The move to "living with COVID-19 should be aligned with a policy of sustainability and a commitment to reducing the carbon footprint from mobility, built on a strong public transport system which will need to be adequately financed. There is an opportunity to never return to the peak phenomenon where we have excessive road congestion and public transport crowding. Ensuring this will need to include a commitment to supporting public transport services, paying more attention to road space reallocation in favor of active modes and giving serious consideration to the introduction of road user charging. Finally, in terms of future preparedness for further virus driven stresses in coming years it will be important to change the mindset of key decision makers and operators from 'if' to 'when'. We have the opportunity now to make lasting changes, but it will require co-operation between multiple government departments and public and private sector.

4 Conclusions

This chapter has explored the impacts of the COVID-19 pandemic on the public transport sector drawing a distinction between the observable short-term impacts and the more speculative long-term impacts. Looking to the future there is the opportunity, notwithstanding the impacts of the pandemic, to develop strategies to both maintain the traditional ingredients of successful public transport (which we might summarize as good service design, awareness of and responsiveness to customer needs, deployment of technology as an enabler etc), and address the implications of external factors that are shaping the future of the sector such as the interface with new mobility modes and the anticipated impacts of greater automation (Nelson and Wright, 2019). As Preston (2020), writing in a pre-pandemic context, notes public transport is continually evolving with bus and rail services needing to respond to the impact of disruptive technologies.

In the longer term, it should also be noted that actual recorded cases of COVID-19 transmission on public transport are difficult to find, and though some transmission is likely to have happened, there has been no known instance of public transport being a “super-spreader” event. This has important implications for how the safety of public transport is messaged; specifically, despite the concerns, it remains a viable and safe transport option, particularly if sensible precautions are taken by the individual. There is also the long-term benefit of increased cleaning and sanitation brought about by the pandemic, which can also be used to assuage perceptions about the cleanliness of the mode more broadly. In some respects, it will be interesting to see if any ongoing concerns about public transport are related specifically to the mode itself or are more nuanced in that (potential) users are in fact more concerned about other public transport users than the mode itself. Finally, should public transport patronage remain low, there will need to be a sharper focus on the public good aspect of public transport, rather than farebox revenue as the main indication of value.

Government actions and economic incentives post-COVID-19 will likely influence the CO2 emission path for decades through a ‘new normal’ but the decrease in emission levels experienced early in the pandemic will only be temporary (Logan et al., 2022). The need for a strong low carbon public transport sector remains pressing and for more innovative solutions such as Mobility as a Service (MaaS) to be built around public transport, whilst recognizing the to rethink monthly subscription plans to allow for variable travel patterns (Hensher, 2020). Furthermore, as Jenelius (2022) observes, the trends that existed pre-pandemic such as digitalization and automation, and the demand for increasingly personalized services remain, while the emerging trends which have been highlighted in this chapter such as reductions in patronage, changes in working practices and the impact of reduced revenue and other sources of financial support are likely to influence public transport for many years to come.

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Appendix BB. Paper #24: The influence of working from home on the number of commuting and non-commuting trips by workers during 2020 and 2021 pre- and post-lockdown in Australia

Camila Balbontin
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Matthew J. Beck

Abstract

Since the start of 2020, we have seen major changes in the way communities operate. Mobility behaviour has been drastically impacted by work from home (WFH) and by lockdowns and restrictions in different jurisdictions. This study investigates the influence of WFH and different lockdown patterns on commuting and non-commuting trips in Australia by workers between early 2020 and late 2021. The data includes three waves of data collection to represent different lockdown periods. A multiple discrete-continuous extreme value (MDCEV) model is estimated to represent the number of one-way trips undertaken weekly with different purposes (commuting, work-related, education, shopping, personal business/social recreation), and by different modes (car, public transport, active modes). Explanatory variables include socioeconomic characteristics, location, the time period during the pandemic (i.e., waves), and latent variables. The results suggest that across all waves and jurisdictions, respondents that WFH more often are more likely to undertake relatively more shopping trips and personal business/social recreation trips, perhaps substituting these trips in replacement of their lesser commuting trips. Interestingly, all other influence held constant, individuals who are more concerned about the use of public transport are more likely to undertake commuting trips by all modes, more likely to do shopping trips, and less likely to undertake personal business/social recreation trips – suggesting they are prioritising essential trips rather than social/personal trips.

Keywords: COVID-19; working from home; Australian experience; commuting trips; non-commuting trips; productivity; public transport implications

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1 Introduction

The COVID-19 pandemic has reshaped the way we live and travel, possibly for many years to come. The 'New Normal' seems to be one that is best associated with living with COVID-19 rather that 'after COVID-19'. After more than two years since the pandemic spread throughout the world, we have amassed a significant amount of evidence on what this is likely to mean for patterns of commuting activity in a setting where working for home (WFH) is becoming a more popular and legitimate alternative to choosing to commute. With WFH continuing to some extent as a non-stigmatised alternative to going to the regular office, non-commuting travel is also likely to change as workers and their families have greater flexibility in how they schedule that other travel activity. Moreover, in Australia the pandemic has also seen a significant model shift from public transport to the car, followed by active modes to a lesser extent.

In this paper we develop a series of trip making models for workers in New South Wales and Queensland in a metropolitan setting, using three waves of data: the first one was collected between September-October 2020 when there were relatively minor restrictions in Australia; between March-May 2021, a period at the start of what would be the longest sustained period of lockdown in New South Wales (with relative freedoms still existing in Queensland throughout the same time period); and November-December 2021, the period at the end of this prolonged lockdown in New South Wales. Given the mix of lockdown conditions and COVID case numbers in the two jurisdictions of these time periods, multiple comparisons can be made under different government enforced restrictions.

A multiple discrete-continuous extreme value (MDCEV) model is estimated to represent how respondents assign their mobility patterns in fifteen different alternatives representing five purpose types and three modes of transport. The trip purposes are commuting, work-related, education, shopping and personal business/social recreation trips; while the modes are car, public transport and active modes. This model allows us to understand both the discrete choice of making certain type of one-way trips by different modes, and the continuous choice of how much of those trips to do weekly. The differing patterns of travel activity are explained by different socioeconomic, geographic, and attitudinal variables to gain a better understanding on what is driving the levels of trip-purpose-mode-specific travel during the pandemic, before and after lockdown periods. The attitudinal variables include concern towards the use of public transport due to hygiene and the number of people using it, life satisfaction, attitudes towards authorities/government and community response to the pandemic, and attitudes towards social or massive meetings. Different scenarios are simulated to analyse the influence of the different explanatory variables on the average number of one-way trips for each purpose and mode.

The paper is organised as follows. The next section presents a brief literature review of the number of trips models using MDCEV models and the influence of COVID-19 and working from home. Section 3 describes the data used in this study. The fourth section presents the methodology to estimate the MDCEV models and to obtain the latent variables using factor analysis. Section 5 presents the model results, while section 6 presents the simulated scenarios. The final section discusses the main findings of this research.

2 Literature review

Since the start of COVID-19, a significant amount of literature has focused on understanding the influence that it has had on mobility patterns in different context around the world (Beck et al., 2020; Beck & Hensher, 2020; Hensher et al., 2021a; Balbontin et al., 2021; Barbieri et al., 2021; Zhang et al., 2021; Vallejo-Borda et al., 2022). This section will briefly review studies that have specifically focused on the link between commuting and non-commuting trips.

Astroza et al. (2020) compare the number of trips by purpose and mode between a normal week and during the first week of COVID-19 restrictions in Santiago, Chile during March 2020. They used jointly estimated binary probit (BP) and linear regression models. The dependent variable of the BP model is to WFH or not, and the dependent variable for the regression model is the number of trips other than work or study (i.e., shopping, errands, medical, leisure). Their results suggest that individuals with higher incomes and a higher education level are more likely to WFH, and people that WFH more are less likely to do non-commuting trips. Fatmi (2020) studies the daily travel activities during COVID-19 travel restrictions in the Kelowna region of British Columbia, Canada during March to May 2020. Their results show that participation in activities outside of home was reduced by more than 50%, and the most frequent trips were due to routine shopping, followed by work-related trips. In terms of recreational and social activities, the number of trips seemed to increase for a higher share of older adults, while it decreased for a higher share of younger adults. Jiao & Azimian (2021) study the changes in travel behaviour in the second phase of the COVID-19 pandemic in the United States. They estimate two binary logit models using as dependent variables dummy variables equal to 1 if they travelled less to stores and by public transport during the second phase of the pandemic than pre-pandemic. Their results show that older respondents less likely to travel to stores during the second phase of the pandemic, and less likely to use public transport for these trips. Individuals without a graduate degree were less likely to reduce their trips to a store and by public transport. Individuals in larger households were more likely to travel to stores and by public transport. Politis et al. (2021) use data collected in two waves in Thessaloniki, Greece: one year before and during the COVID-19 lockdown of April 2020. They used regression models and cox proportional hazards duration models to analyse travel behaviour. Results showed that the average daily trips per person decreased by 50% during lockdown, which was much higher for non-commuting trips. In terms of modes of transport used, the share of walking trips increased, private car was also increased mostly for commuting trips, and the use of public transport decreased significantly.

Bhat et al. (2016) propose a method for a finite discrete mixture of normal version of the multiple discrete-continuous probit model using travel survey data in New Zealand. Their framework and results allow for a better understanding on the influences of individual preferences for tourism destinations. These types of models have been used widely in time allocation by activity type studies (Pinjari et al., 2009; Pinjari & Bhat, 2010a; Calastri et al., 2017; Jokubauskaitė et al., 2019; Palma et al., 2021). Bhaduri et al. (2020) use an MDCEV model to explain the mode choice and frequency of use for weekly trips including work from home across various cities in India during March-April 2020. The trips included commuting trips by mode and other discretionary activities, where each alternative represented work from home or a mode of transport. Their results show that inertia has a higher influence on commuting trip rather than on discretionary trips; and inertia is higher for car and motorbike of longer trips. Results show that modes with lower levels of social distancing, such as public transport, have a lower inertia; and those middle-aged adults are more likely to use car than other respondents.

This section briefly described studies that have focused on the number of trips or used MDCEV models. The contribution of our article is to use an MDCEV model to understand the effect of COVID-19 in commuting and non-commuting travel behaviour by mode using mode-purpose-specific alternatives and using data from different periods during the pandemic.

3 Data description

The data used in this study was collected as part of a larger study in Australia to understand the influence of work from home in the transport network (Beck et al., 2020; Beck & Hensher, 2020; Hensher et al., 2021; Balbontin et al., 2022). In this paper we develop a series of trip making models for workers in The Greater Sydney Metropolitan area (GSMA) in New South Wales (henceforth referred to as GSMA) and South East Queensland (henceforth referred to as SEQ), using three waves of data: Wave A, B and C. Wave A was collected during August-September 2020, when there were relatively minor restrictions in Australia; Wave B was collected on April-May 2021, a period at the start of what would be the longest sustained period of lockdown in NSW (with relative freedoms still existing in QLD throughout the same time period); and Wave C was collected during December 2021, the period at the end of this prolonged lockdown in NSW. Given the mix of lockdown conditions and COVID case numbers in the two jurisdictions of these time periods, multiple comparisons can be made under different government enforced restrictions. The three waves of data were collected using an online survey that contained different questions regarding respondents' work, travel behaviour, attitudes towards the pandemic and socioeconomics. Wave A data contains 661 workers, Wave B and Wave C each contain 645 workers.

Figure 1 represents the number of one-way weekly trips by mode and purpose for each wave and jurisdiction. Wave A is relatively similar between GSMA and SEQ, although respondents in GSMA usually make slightly more work-related one-way trips and in SEQ do more education trips. In Wave B, where GSMA was starting its longest lockdown period and SEQ had more freedoms, respondents in SEQ make significantly more commuting trips, particularly by car, while respondents in GSMA seem to undertake more shopping trips. In Wave C, at the end of this lockdown, respondents in GSMA and SEQ both did fewer commuting trips by car than in Wave B, but more trips in public transport; and shopping trips by car increased in SEQ while they decreased in GSMA.

The survey included attitudinal questions to understand respondents' attitudes towards the government and authorities' response to the pandemic, their level of comfort associated with undertaking different types of activities, their level of satisfaction with life in general, and their concern towards the use of public transport due to the pandemic. These questions were used to construct the latent variables, which will be detailed in section 1.2, but the average score (between 1 and 5) for these questions is presented in Figure 2. Results show that during the first year of the pandemic, in Wave A, respondents in GSMA and SEQ were significantly more concerned about using public transport, which decreased and remained around three points in Waves B and C – although respondents in SEQ seem a bit less concerned than in GSMA. In terms of satisfaction with life and support towards authorities/government and community response, the level has remained relatively the same across all Waves, although satisfaction with life in general has increased slightly in Wave C while support for the government and community response has decreased. In terms of level of comfort associated with undertaking different activities, in both states, respondents seem much more comfortable in participating in small social group-based meetings (friends and family) as compared to large gatherings of people (e.g., concerts, watching professional sports live, live entertainment), and respondents feel more comfortable in the last two Waves relative to the Wave A.

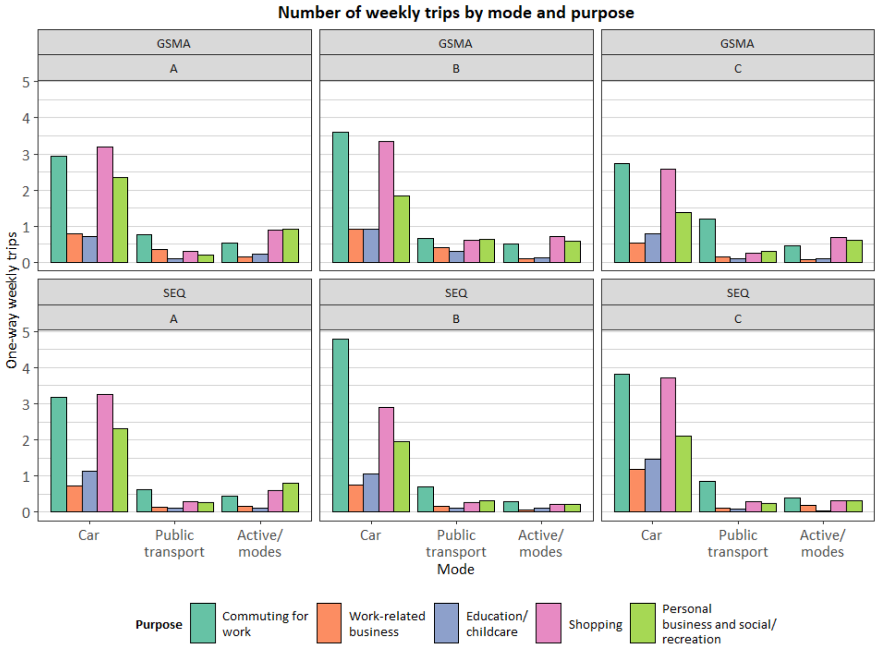

Figure 1. Number of weekly one-way trips by mode and purpose

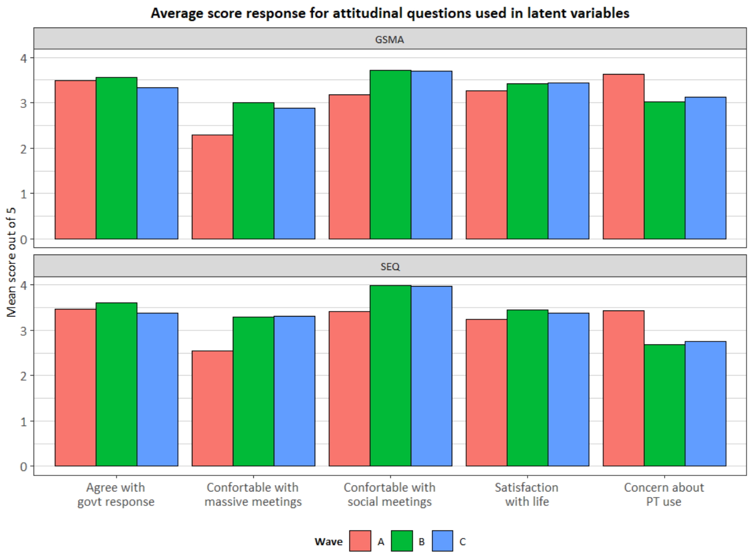

Figure 2. Average score response for attitudinal questions used in defining the latent variables

General descriptives of respondents are presented in Table 1. The average levels are relatively stable across waves and states, although average personal income is slightly lower in SEQ than in GSMA (a disparity that is also reflected in Census data). In terms of days working from home (WFH), during the first year of the pandemic, the average days WFH are close to two days a week, while in Wave B it decreased significantly to 1.33 for GSMA and 0.85 for SEQ. This is expected as GSMA was at the beginning of a lockdown phase. In Wave C, the averages increased again reaching 1.66 in GSMA and 1.28 in SEQ.

Table 1. General descriptives - mean (standard deviation)

	Wave A		Wave B		Wave C	
	GSMA	SEQ	GSMA	SEQ	GSMA	SEQ
Age (years old)	40.48 (13.48)	40.45 (13.74)	41.23 (14.59)	41.88 (13.33)	44.87 (14.77)	40.97 (13.83)
Gender: male (1,0)	41%	31%	48%	41%	46%	35%
Income ('00AUD$) personal	81.65 (55.83)	73.40 (45.68)	83.87 (52.32)	77.97 (54.33)	84.67 (61.66)	83.86 (59.90)
Occupation manager (1,0)	16%	13%	18%	11%	20%	18%
Occupation professional (1,0)	31%	32%	30%	28%	29%	29%
Occupation blue collar (1,0)	13%	15%	14%	18%	17%	13%
Distance from home to work (kms)	19.11 (25.70)	21.39 (65.92)	17.50 (20.83)	18.25 (18.15)	17.36 (17.10)	14.75 (14.31)
Number of days WFH last week	2.09 (2.28)	2.00 (2.33)	1.33 (1.90)	0.85 (1.57)	1.66 (2.07)	1.28 (1.90)
Number of days worked last week	4.61 (1.36)	4.67 (1.29)	4.25 (1.48)	4.29 (1.40)	4.10 (1.54)	4.42 (1.51)
Number of respondents	373	288	351	294	297	348

Table 2 presents the percentage of respondents that do at least one trip for each purpose-mode, and the average number of trips that these respondents undertake. The average number of commuting trips has not changed significantly across waves – with the exception of Wave B public transport trips – but the percentage of respondents that commute reached a maximum in Wave B where 90% of respondents commuted at least once. In Wave B, the percentage of respondents using car to commute was the highest at 71%, while in Waves A and B it is around 68%.

Table 2: Percentage of respondents that do at least one trip for each purpose-mode and the number of one-way trips

	Wave A		Wave B		Wave C	
	%	N Trips	%	N Trips	%	N Trips
Commute by car	50%	6.08 (3.88)	64%	6.44 (4.13)	53%	6.28 (3.80)
Commute by public transport	13%	5.53 (4.06)	16%	4.33 (2.92)	17%	5.86 (3.54)
Commute by active modes	11%	4.57 (3.89)	10%	3.91 (3.16)	8%	5.09 (3.34)
Work-related trips by car	20%	3.74 (5.16)	20%	4.09 (5.79)	20%	4.44 (5.88)
Work-related trips by public transport	5%	4.89 (9.56)	8%	3.67 (2.61)	4%	3.04 (2.28)
Work-related trips by active modes	5%	3.39 (3.55)	6%	1.51 (1.02)	3%	4.70 (5.82)
Education trips by car	18%	5.02 (3.45)	21%	4.59 (3.74)	21%	5.46 (3.89)
Education trips by public transport	3%	2.87 (1.94)	6%	3.26 (2.23)	4%	2.50 (1.64)
Education trips by active modes	4%	4.00 (3.64)	6%	1.90 (2.00)	2%	3.23 (2.35)
Shopping trips by car	74%	4.37 (4.41)	77%	4.10 (3.50)	71%	4.50 (3.24)
Shopping trips by public transport	8%	3.93 (2.89)	9%	4.85 (2.69)	7%	3.67 (2.94)
Shopping trips by active modes	20%	3.88 (3.24)	14%	3.50 (3.59)	12%	3.93 (2.87)
Social recreation/personal business trips by car	58%	4.01 (3.90)	55%	3.39 (2.78)	48%	3.70 (2.88)
Social recreation/personal business trips by public transport	9%	2.73 (2.03)	10%	4.82 (3.20)	9%	3.14 (2.47)
Social recreation/personal business trips by active modes	17%	4.98 (4.72)	13%	3.33 (2.39)	10%	4.37 (3.53)

The second most frequent trip refers to shopping trips, which are in their majority made by car. The data shows significant differences across waves and jurisdictions in terms of commuting and non-commuting travel behaviour, which will be analysed with more detail in the next sections. A similar table but separated by region is presented in Table 10 in the Appendix. The main difference across jurisdictions can be found in commuting trips by car, which is significantly higher in SEQ than in GSMA in Wave B (70% versus 60%) and in Wave C (59% versus 45%). The use of car for shopping trips is significantly higher in SEQ than in the GSMA for Wave C (79% versus 61%), and significantly lower for shopping trips in active modes (8% versus 17%).

4 Methodology

4.1 Modelling framework

The overall modelling framework is presented in Figure 3. The proposed framework focuses on the decision to choose to undertake a one-way trip by purpose and mode. The respondent characteristics z_q, such as their age, gender, occupation, location (state), as well as their latent attitudes LV_q (e.g., level of comfort going out to social meetings, level of concern towards the use of public transport, level of life satisfaction, among others), and the lockdown conditions defined by the waves of data D_W, determine the propensity to undertake on-way trips for each purpose by each mode. Error terms are associated with trip purpose type η_p, mode η_m, and the relative utility of each alternative, U_{pm}. The combination of the purposes and modes generates a total of fifteen alternatives, which are presented in Figure 4.

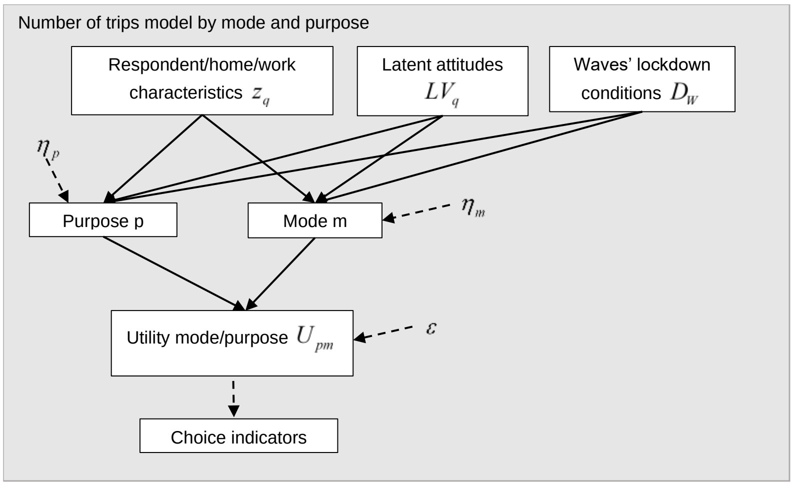

Figure 3. Mode and purpose number of one-way trips model structure

Each alternative is represented by two subindexes: one associated with the mode of transport used *m* ($m = 1,...,M$); and the other with the travel purpose *p* ($p = 1,...,P$). The multiple discrete-continuous extreme value (MDCEV) model used in this study was originally proposed by Bhat (2005) and later extended in Bhat (2008) where the utility function is defined as the sum over all purposes and modes, as follows:

$$U(x) = \sum_{p=1}^{P}\sum_{m=1}^{M}\frac{\gamma_{pm}}{\alpha_{pm}}\psi_{pm}\left\{\left(\frac{x_{pm}}{\gamma_{pm}}+1\right)^{\alpha_{pm}}-1\right\} \quad (1)$$

subject to the budget constraint:

$$\sum_{p=1}^{P}\sum_{m=1}^{M}x_{pm}p_{pm} = B \quad (2)$$

where $\psi_{pm} = \exp(V_{pm} + \varepsilon_{pm})$ (3)

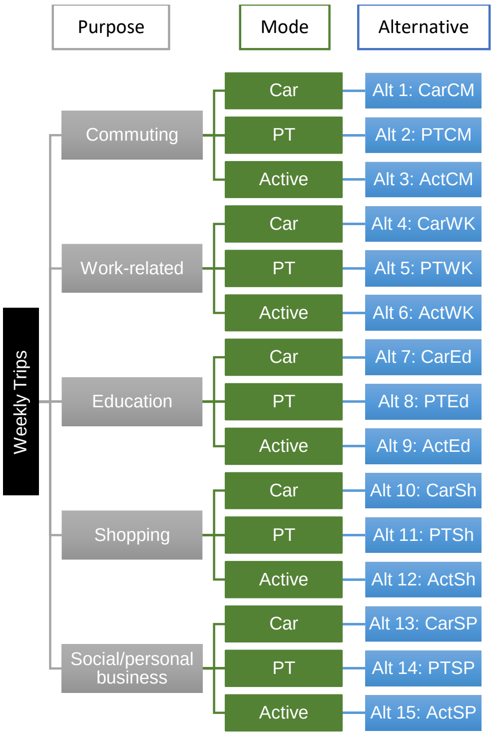

Figure 4. Alternatives definition

The budget B is represented by the total number of one-way trips made by an individual last week. That is, it is assumed that individuals have a mobility pattern that is relatively stable, and they can choose how to distribute the total budget (i.e., how many trips by each purpose and mode to do weekly). P represents the number of purposes and M the number of modes, so the combined *pm* represents the different alternatives; x_{pm} is the number of weekly one-way trips by purpose *p* and mode *m*; p_{pm} is the unit cost of alternative *pm,* which is assumed equal to 1 since all alternatives have the same influence on the mobility budget; ψ_{pm} refers to the baseline utility parameters which represent the marginal utility of one unit of consumption of alternative *pm* at the point of zero consumption for that alternative; V_{pm} determines the alternatives' deterministic base utility and ε_{pm} is an independent and identically distributed random term with a Gumbel distribution with mean zero and a unit variance. α_{pm} and γ_{pm} are parameters that determine control satiation of each alternative, which shows the added benefit to the baseline utility of one additional trip, and γ_{pm} enables corner solutions. These satiation parameters operate differently theoretically, but empirically it is difficult to disentangle the two effects, as discussed in Bhat (2008), and with this in mind we estimate a generic $\alpha_{pm} = \alpha, \forall p, m$ and alternative-specific γ_{pm}. Equations (1) and (2) are revised as follows:

$$U(x) = \sum_{p=1}^{P}\sum_{m=1}^{M} \frac{\gamma_{pm}}{\alpha} \psi_{pm} \left\{ \left(\frac{x_{pm}}{\gamma_{pm}} + 1 \right)^{\alpha} - 1 \right\} \tag{4}$$

subject to the budget constraint:

$$\sum_{p=1}^{P}\sum_{m=1}^{M} x_{pm} = B \tag{5}$$

As $\alpha \to 0$ equation (4) collapses to a linear expenditure system as follows (Bhat, 2008):

$$U(x) = \sum_{p=1}^{P} \sum_{m=1}^{M} \gamma_{pm} \psi_{pm} \ln\left(\frac{x_{pm}}{\gamma_{pm}} + 1 \right) \quad (6)$$

The deterministic baseline utility function V_{pm} for each alternative *pm* (purpose and mode) and individual *q* is defined as:

$$V_{pm} = ASC_{pm} + \sum_{j} \left(\beta_{mj} z_{qj} + \beta_{pj} z_{qj} \right) + \sum_{i} \left(\beta_{mi} LV_{qi} + \beta_{pi} LV_{qi} \right) + \beta_{WB} \cdot D_{WB} + \beta_{WA} \cdot D_{WA} + \eta_p + \eta_m \quad 7)$$

ASC is the alternative specific constant; z_{qj} represent different variables related to the individual characteristics, such as income, age, gender, occupation, proportion of days that they work from home (WFH), among others; LV_{qi} represent latent variables included in the model, as will be explained in the following subsection; β_{mj} and β_{pj} represent the parameter estimates associated with the individual characteristics z_{qj} or latent factors LV_{qi} which are common for mode *m*, and purpose *p*, respectively; D_{WB} and D_{WA} represent dummy variables equal to 1 if the respondent belongs to data wave A or B, respectively, and β are its associated parameter estimates; η_p and η_m represent the error components associated to mode *m* and purpose *p*, respectively.

4.2 Latent variables estimated using factor analysis

Respondents were asked to answer several attitudinal questions that referred to their concern about using public transport (PT), their attitude towards social or massive meetings (WFH), concern about health due to COVID-19, among others. We used the Kaiser-Meyer-Olkim (KMO) test to measure sampling adequacy (Kaiser & Rice, 1974) and Bartlett's Test of Sphericity (Bartlett, 1951) – which showed that factor analysis might be useful with our data. All the attitudinal questions were analysed using parallel analysis to identify the number of latent variables (Horn, 1965). This analysis suggested five latent variables should be used to represent respondents' attitudes. The method of extraction is maximum log-likelihood with oblique rotation given that there might be some correlation between these attitudes. The five latent variables extracted are represented as follows[54]:

7. Authorities and community's response supporters: respondents that believe the authorities and community response towards the pandemic has been appropriate.
8. Massive meeting lovers: respondents that feel comfortable having any type of meeting, including music events, watching live entertainment, among others.
9. Social meeting lovers: respondents that feel comfortable having social meetings with friends, visiting restaurants and pubs, gyms and exercise groups, among others.
10. High level of life satisfactions: respondents that said to be satisfied and happy with their life.
11. Concerned about public transport: people that are concerned about hygiene and the number of people in public transport due to COVID-19.

The attitudinal questions defining each latent variable and their weights are shown in Table 3 to Table 7. The higher weights in the second latent variable, related to support towards the

[54] These factors were extracted using all the Waves together. However, the same latent factors emerge within each Wave of data, which shows their robustness.

authorities and community's response to the crisis, refer to the response of other people to COVID-19 (if they have been appropriately self-distancing, self-isolating, etc.), and if the response of the wider community and government has been appropriate.

Table 3. Survey questions associated latent variable authorities and community's response supporters

Survey question	Weight
The Federal government response to Covid-19 has been appropriate	0.72
The State government response to Covid-19 has been appropriate	0.70
The response of business to Covid-19 has been appropriate	0.74
The response of the wider community to Covid-19 has been appropriate	0.73
People have been appropriately social distancing as a measure to combat Covid-19	0.66
People have been appropriately self-isolating as a measure to combat Covid-19	0.67
I trust governments to respond to Covid-19 in the future	0.80
I trust business to respond to Covid-19 in the future	0.79
I trust other people to respond to Covid-19 in the future	0.72

Scale: Strongly disagree (1), Disagree (2), Somewhat disagree (3), Neither agree nor disagree (4), Somewhat agree (5), Agree (6), Strongly agree (7)

The second and third latent variables refer to how comfortable respondents feel with different types of meetings. These latent variables might seem similar, but the parallel analysis suggested that they should be considered separately: i.e., respondents that feel comfortable in smaller social meetings do not necessarily feel comfortable in massive events, and vice versa.

Table 4. Survey questions associated with the latent variable massive meeting lovers

Survey question	Weight
If someone asked you to each of the following, how comfortable would you feel about undertaking these day-to-day activities at the moment?	
Watching professional sport	0.78
Music events	0.93
Watching live entertainment	0.92
Playing organised sport	0.61

Scale: Very uncomfortable (1), Uncomfortable (2), Somewhat uncomfortable (3), Neither (4), Somewhat comfortable (5), Comfortable (6), Very comfortable (7)

Table 5. Survey questions associated with latent variable social meeting lovers

Survey question	Weight
If someone asked you to each of the following, how comfortable would you feel about undertaking these day-to-day activities at the moment?	
Meeting with friends	0.82
Visiting restaurants	0.77
Going to the shops	0.75

Scale: Very uncomfortable (1), Uncomfortable (2), Somewhat uncomfortable (3), Neither (4), Somewhat comfortable (5), Comfortable (6), Very comfortable (7)

The fourth latent variable represents respondents that seem to be satisfied and happy with their life nowadays. The fifth latent variable refers to health concern and is defined by how a person thinks about COVID-19 as a serious public health concern which requires drastic measures to be taken. The last factor relates to a concern about the use of public transport (PT), defined by the concern about hygiene and the number of people using PT.

Table 6. Survey questions associated with latent variable high level of life satisfaction

Survey question	Weight
How satisfied are you with your life nowadays?	0.88
How worthwhile do you think the things that you do in life are?	0.84
How happy did you feel yesterday?	0.86

**Scale from 0 (not at all satisfied) to 10 (completely satisfied)

Table 7: Survey questions associated with latent variable concerned about PT

Survey question	Weight
Imagine you had to catch public transport tomorrow, what would be your level of concern about hygiene be?	0.94
Imagine you had to catch public transport tomorrow, what would be your level of concern about the number of people using public transport?	0.96

Scale: Not at all concerned (1), Slightly concerned (2), Somewhat concerned (3), Moderately concerned (4), Extremely concerned (5)

5 Model results

The model results for the deterministic part of the utility function V_{pm} are presented in Table 8. Candidate sociodemographic characteristics (presented in Table 1), wave dummy variables, and latent variables were included in each alternative. Other potential influences that are not presented were not statistically different from zero (e.g., income, location dummy variables), and are excluded from the final model. Similarly, four error components were identified as statistically significant, associated with the car for all trip purposes, and specific trip purposes for all modes, namely commuting work-related or education trip purposes. This suggests that there is a correlation between the car trips, regardless of the trip purpose; between the commuting, work-related and education trips, regardless of the mode used to make them. The results show that male respondents are more likely to undertake work-related trips, and individuals that work as managers or in blue collar occupations (i.e., technicians and trades workers, machinery operators and drivers, and labourers) are also more likely to undertake work-related trips. Age is negatively correlated with the number of education trips made weekly. The distance from home to work has a positive influence on all trips made by car, which suggests that individuals that live further away from home are more likely to use their car for all trips than other modes. The proportion of days working from home (WFH) has a negative influence on all trips made by car and as expected, a negative influence on the number of commuting trips by all modes.

The latent variable results suggest that:

- Individuals who support the authorities/government and community response to the pandemic are less likely to undertake commuting and shopping trips (government health messaging asked people to reduce travel activity wherever possible; for a long period of time only shopping for necessities and essential commuting was permitted, so it is logical that those who expressed positive support for the government action would also similarity attempt to reduce activity in line with what was recommended by authorities).
- Respondents that feel comfortable attending massive meetings are more likely to use public transport for all their trips (not surprising as if they are comfortable in large crowds, they would have less qualms about using public transport) and are less likely to undertake commuting and shopping trips.

- Those that feel comfortable going to social meetings are more likely to use the car on all such trips (likely as these small group social meetings are in local areas and not readily served by public transport, additionally these smaller meetings are typically with family and friends and not strangers that one may encounter on public transport) and are less likely to do all but social recreation/personal business trips.
- Respondents that said they are satisfied with their life nowadays are less likely to undertake commuting, work-related and shopping trips (likely a function of still being able to complete meaningful work from home and are more able to accommodate the reduced amount of travel activity and social contact – perhaps finding the latter to be less important to their overall mental wellbeing than others).
- Finally, respondents that said they are concerned about using public transport are more likely to undertake trips for all purposes except social recreation/personal business (likely respondents concerned about the use of public transport will avoid leaving their houses if they do not believe it is necessary, which is usually associated to social or personal trips).

The wave dummy variables suggest that participants in Wave A were less likely to undertake all but social recreation/personal business trips relative to Wave C – which suggests that, even when restrictions were not as strict during the first wave, people were working from home more frequently and avoiding work-related or shopping trips, prioritising their social and personal business trips. Results show that in Wave B respondents were less likely to undertake commuting or shopping trips and more likely to use public transport relative to Wave C, likely related to the fact that Wave B was collected at the start of the longest lockdown in NSW and QLD had relative freedoms, where WFH had increased given authorities' indications, and people were probably avoiding shopping and public transport where they had contact with strangers. In separate work focusing on public transport usage through the pandemic, we have shown that those who need to use public transport for trip making (essential workers, those on lower incomes) are among those who are most concerned about the biosecurity of public transport (Beck at al. 2022).

Table 8. Model results MCDEV deterministic utility function – mean (t-value)

Description	Mode	Purpose	Mean	T-value
ASC	Car	Commuting	1.08	13.73
ASC	PT	Commuting	0.77	6.00
ASC	Active modes	Commuting	-0.20	-1.63
ASC	Car	Work-related	-2.14	-17.22
ASC	PT	Work-related	-2.60	-13.96
ASC	Active modes	Work-related	-2.93	-15.68
ASC	Car	Education	-0.95	-5.29
ASC	PT	Education	-1.60	-7.31
ASC	Active modes	Education	-1.75	-7.93
ASC	Car	Shopping	1.34	16.37
ASC	PT	Shopping	-1.15	-8.95
ASC	Active modes	Shopping	-0.40	-3.44
ASC	PT	Social/personal business	-1.23	-10.45
ASC	Active modes	Social/personal business	-0.82	-7.62
Male (1,0)	All	Work-related	0.54	4.87
Profession manager (1,0)	All	Work-related	0.55	4.10
Profession blue collar (1,0)	All	Work-related	0.49	3.38
Age (years)	All	Education	-0.02	-4.32
Distance from home to work (kms)	Car	All	0.002	2.03
Proportion of WFH	Car	All	-0.43	-3.79
Proportion of WFH	All	Commuting	-2.97	-26.11
Latent variable support government/authorities' response	All	Commuting	-0.09	-2.46

Description	Mode	Purpose	Mean	T-value
Latent variable support government/authorities' response	All	Shopping	-0.07	-2.03
Latent variable massive meetings lover	PT	All	0.12	3.14
Latent variable massive meetings lover	All	Commuting	-0.20	-5.32
Latent variable massive meetings lover	All	Shopping	-0.15	-4.69
Latent variable social meetings lover	Car	All	0.18	4.44
Latent variable social meetings lover	All	Commuting	-0.30	-7.04
Latent variable social meetings lover	All	Work-related	-0.38	-7.45
Latent variable social meetings lover	All	Education	-0.32	-6.55
Latent variable social meetings lover	All	Shopping	-0.19	-5.16
Latent variable high level of life satisfaction	All	Commuting	-0.18	-4.54
Latent variable high level of life satisfaction	All	Work-related	-0.15	-2.77
Latent variable high level of life satisfaction	All	Shopping	-0.14	-4.03
Latent variable concern towards PT	All	Commuting	0.17	4.24
Latent variable concern towards PT	All	Work-related	0.28	5.46
Latent variable concern towards PT	All	Education	0.27	5.31
Latent variable concern towards PT	All	Shopping	0.15	4.38
Wave B (1,0)	Car	All	-0.27	-2.50
Wave B (1,0)	PT	All	0.25	2.11
Wave B (1,0)	All	Shopping	-0.15	-2.04
Wave A (1,0)	All	Commuting	-0.51	-5.70
Wave A (1,0)	All	Work-related	-0.37	-3.09
Wave A (1,0)	All	Education	-0.60	-5.06
Wave A (1,0)	All	Shopping	-0.42	-4.91
Error component	Car	All	-0.49	-7.52
Error component	All	Commuting	-0.49	-7.25
Error component	All	Work-related	-0.88	-6.87
Error component	All	Education	-0.79	-6.61
Sample size	1951			
Number of parameters estimated	65			
Log-likelihood	-16,808.8			
AIC/n	17.298			

The satiation parameter estimates are presented in Table . Note that the satiation parameters account for the diminishing marginal utility associated with increased consumption of a good (that is to say that someone will eventually complete a number of trips for each purpose and/or mode that satisfies them). The generic α parameter was estimated as a function of α_{base} to ensure it lies between 0 and 1, as follows:

$$\alpha = \frac{1}{1+\exp^{-\alpha_{base}}} \quad (8)$$

The results for α_{base} show that $\alpha \rightarrow 0$, the utility function collapses to a linear expenditure system as presented in equation (662). The satiation effects of the γ parameters for each alternative (purpose *p* and mode *m*) are presented in Figure . These were simulated calculating the alternatives' deterministic utility value, V_{pm}, for each respondent in the sample (considering availability) and simulating the utility expression for different alternatives' number of trips values. Even though the location dummy variables for GSMA or SEQ were not significant themselves, there were differences across the statistically significant explanatory variables between them. Therefore, we can still analyse GSMA and SEQ separately as their baseline utilities and the average number of trips for each purpose-mode are different across waves given the model's explanatory variables.

Table 9. Model results MCDEV satiation parameters – mean (t-value)

Description	Mode	Purpose	Mean	T-value
α_{base}	All	All	-15.98	-0.21
γ	Car	Commuting	1.89	13.61
γ	PT	Commuting	2.09	8.33
γ	Active modes	Commuting	2.82	7.61
γ	Car	Work-related	2.10	10.10
γ	PT	Work-related	1.68	6.14
γ	Active modes	Work-related	1.31	5.72
γ	Car	Education	3.73	9.71
γ	PT	Education	1.62	5.70
γ	Active modes	Education	1.52	5.48
γ	Car	Shopping	0.70	15.12
γ	PT	Shopping	2.69	7.42
γ	Active modes	Shopping	1.87	9.88
γ	Car	Social/personal business	1.39	17.51
γ	PT	Social/personal business	2.11	8.03
γ	Active modes	Social/personal business	2.14	9.38

The results show that the satiation effect for commuting by car is the lowest, followed by shopping trips by car, by commuting by public transport, and then by personal business or social/recreation trips by car. That is, the benefit in the utility caused by one additional commuting or shopping trip by car is higher than for all other purpose-mode trips. For example, if a person is currently doing six one-way trips and decides to increase them by three, its accrued utility for commuting by car will increase by 0.95, it will increase by 0.72 for shopping by car, while it increases in approximately 1 point, and only 0.24 for shopping by public transport (dotted line). The highest satiation effects seem to be for education trips and work-related in active modes, followed by education and work-related trips in public transport, and then by work-related and education trips by car. These results show the importance of including purpose-specific satiation effects, which seem to be lowest for commuting and shopping trips, and highest for education and work-related trips; and mode-specific satiation effects, which are lowest for trips by car. The relationship between alternatives is equivalent between SEQ and GSMA, with the highest difference in commuting by car trips which has a significantly lower satiation effect in SEQ – suggesting that respondents in that area have a higher utility for doing one additional commuting trip by car.

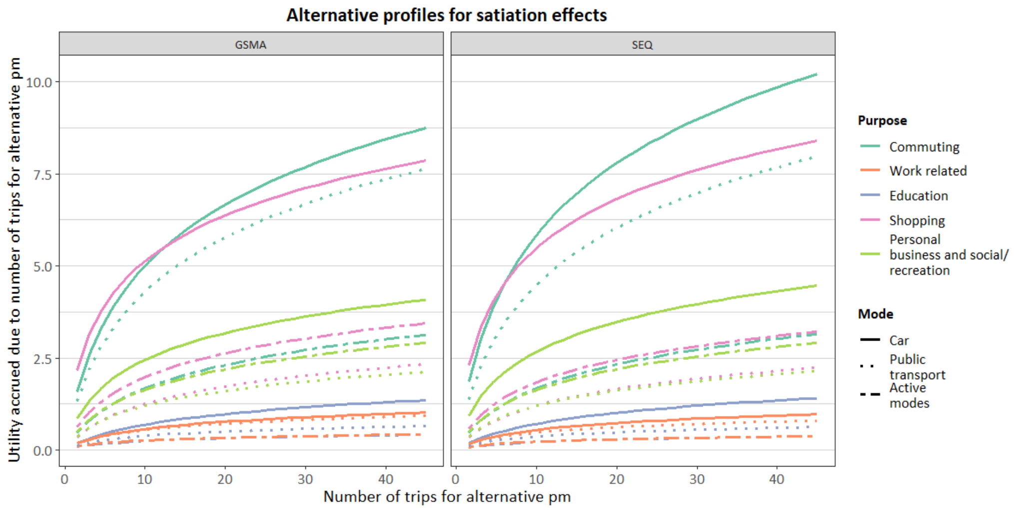

Figure 5. Alternative profiles' results for satiation effects

6 Simulated Scenarios

The simulation method for models was originally proposed by Pinjari & Bhat (2010). In this section, we calculate the optimal consumption for each alternative as follows (when $\alpha \rightarrow 0$):

$$x_{pm} = \left(\frac{\psi_{pm}}{\lambda} - 1 \right) \gamma_{pm} \tag{9}$$

where $\lambda = \dfrac{\sum_{p=1}^{P} \sum_{m=1}^{M} \gamma_{pm} \psi_{pm}}{B + \sum_{p=1}^{P} \sum_{m=1}^{M} \gamma_{pm}}$ (10)

Scenarios were simulated by changing one of the explanatory variables and analysing the optimal consumption of number of one-way trips for each alternative. The first simulated scenario refers to the number of one-way trips by the proportion of days working from home, with the results presented in Figure 6. The results suggest that across all waves and jurisdictions, respondents that WFH more often are more likely to undertake shopping trips and personal business/social recreation trips, and less likely to make commuting trips. It is interesting to note that in SEQ in Wave C, the increment in shopping trips seems to be higher as the frequency of WFH increases compared to other waves.

The second simulated scenario represents the changes in the number of one-way trips given by the distance from home to work, which are presented in Figure 7. This explanatory variable does not have the same significant influence as the proportion of days WFH. However, it shows a slight increase in commuting trips by car (continuous dark green line) and a decrease in the number of commuting trips by public transport (dotted dark green line) – with a similar relationship in the case of the shopping and work-related trips.

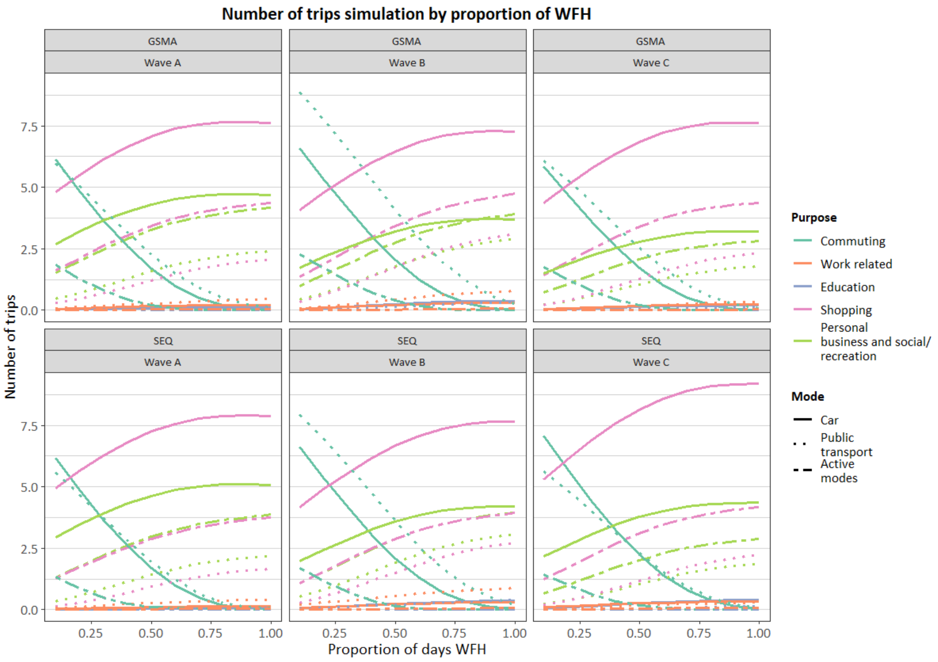

Figure 6: Simulated number of one-way trips by proportion of WFH

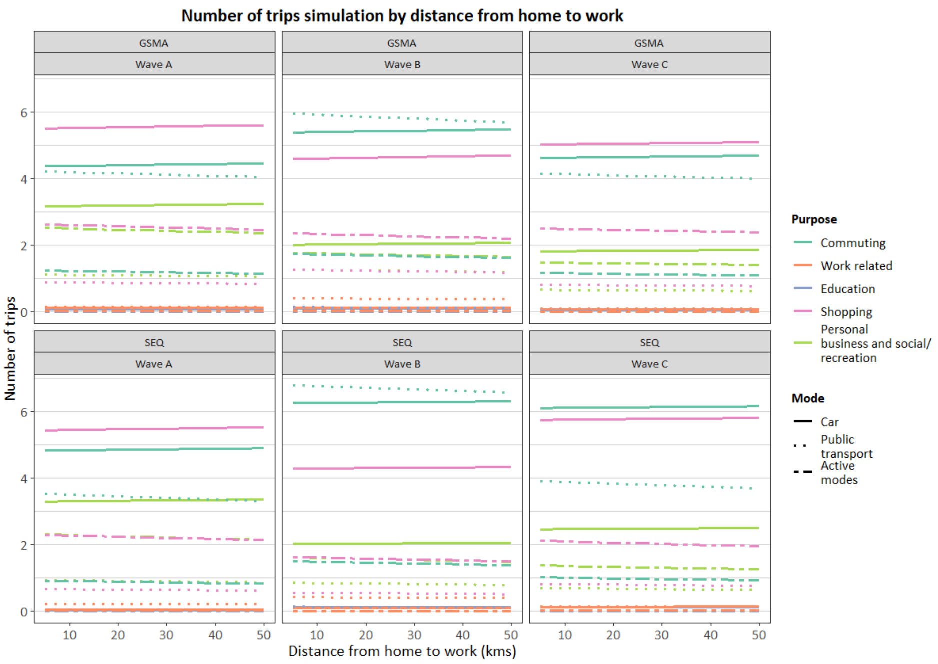

Figure 7: Simulated number of one-way trips by distance from home to work

We also simulated scenarios for the latent variables. It is important to note, however, that the value of the latent variable does not have a direct value as they are calculated using factor analysis. The average of the latent variables across the sample are close to zero, and the value for each respondent shows how likely they are to belong to each category. For example, a respondent that has the highest value for life satisfaction represents a participant that was on the higher end of life satisfaction relative to the other participants. The results for life satisfaction latent variable are presented in Figure 8. These results show that participants that feel more satisfied with their life in general today undertake less commuting and shopping trips and seem to be undertaking more personal business/social recreation trips. In Wave A, the positive influence on personal business/social recreation trips was higher than in Wave B and C; but in SEQ it seemed to increase in Wave C relative to B. The simulated scenario for the latent variable that represents the level of comfort going to social meetings is presented in Figure 9. Respondents that are more comfortable attending social meetings are less likely to undertake commuting trips, with the negative influence higher for commuting trips by public transport than other modes. Similarly, the level of comfort associated with attending social meetings has a positive influence on shopping trips made by car but a negative influence on shopping trips by public transport. As expected, it has a positive influence on the number of personal business/social recreation trips, and its influence is higher for trips made by car than other modes.

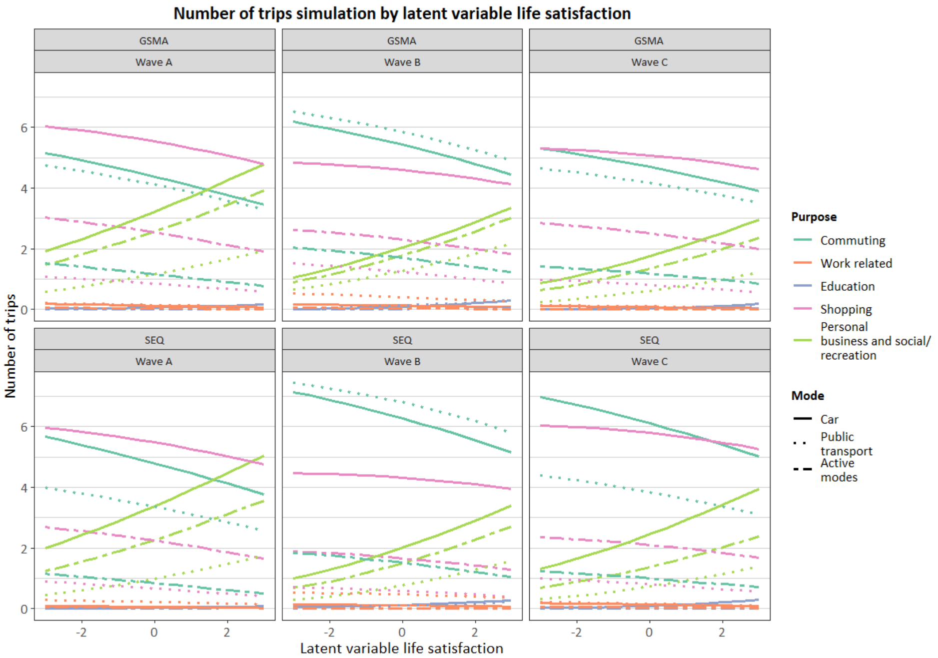

Figure 8: Simulated number of one-way trips by the latent variable for life satisfaction

The simulated scenarios for the latent variable representing concern about the use of public transport is summarised in Figure 10. Interestingly, the results show that respondents that are more concerned about the use of public transport seem to have a similar view on the number of trips made by car and public transport (i.e., slopes for each purpose type are similar). The results suggest that individuals who are more concerned about the use of public transport are more likely to undertake commuting trips by all modes, are more likely to undertake shopping trips, and less likely to make personal business/social recreation trips. As mentioned above, respondents that are more concerned about contact with other individuals through the use of public transport, will probably avoid doing non-essential trips and only focus on going to work and food shopping.

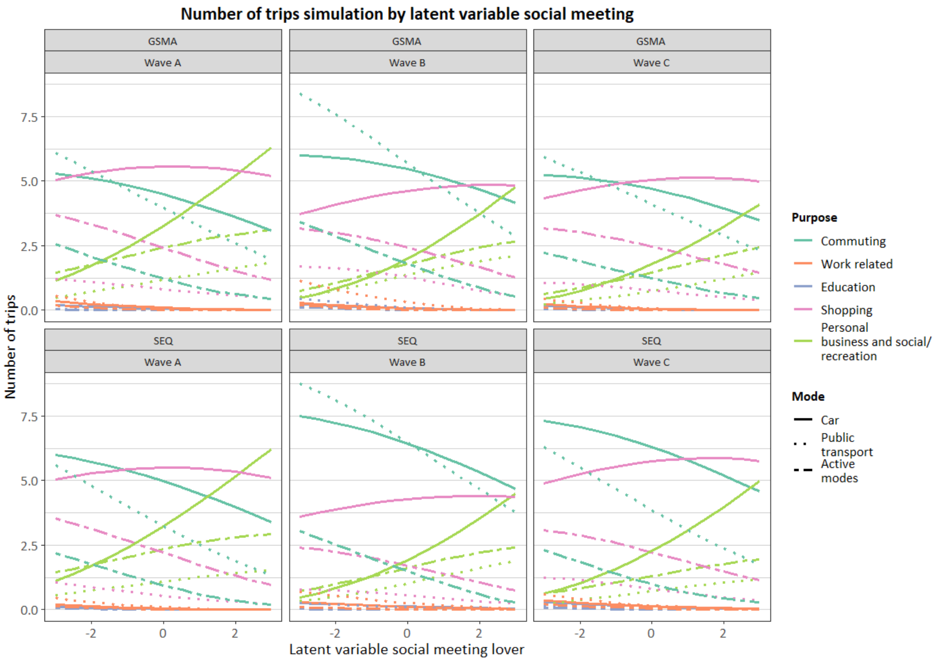

Figure 9: Simulated number of one-way trips by the latent factor for social meeting lover

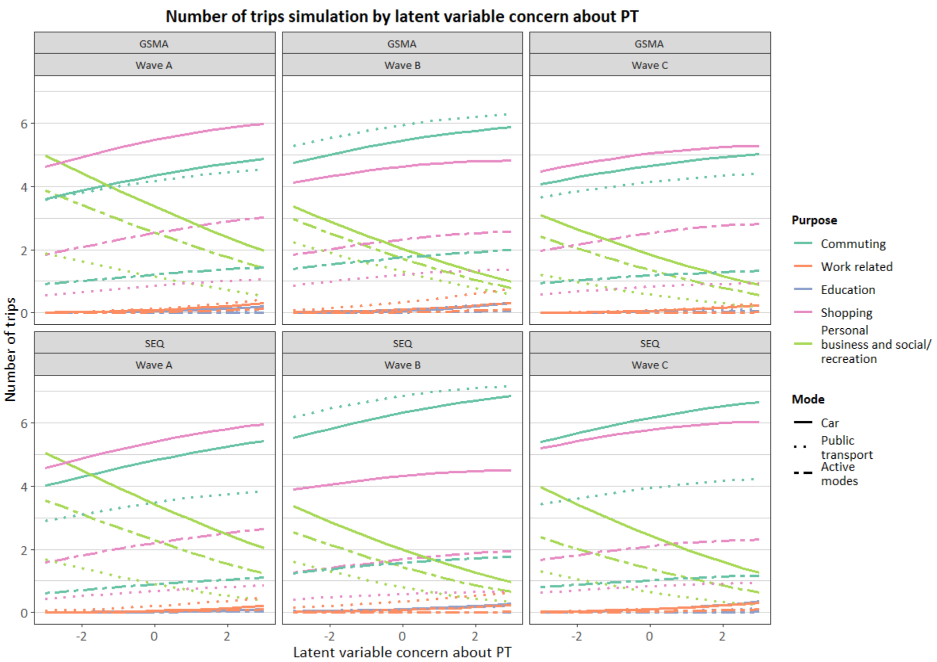

Figure 10: Simulated number of one-way trips by the latent variable for public transport use concern

7 Conclusions

This paper investigated the influence of working from home and other explanatory variables on the number of weekly one-way trips made by workers in two metropolitan regions in GSMA and SEQ. A multiple discrete-continuous extreme value (MDCEV) model was estimated to provide a behavioural understanding of the number of one-way trips undertaken by different purposes and modes at three points in time during the pandemic. Fifteen alternatives were considered in total, each representing a combination of five purposes (i.e., commuting, work-related, education, shopping, personal business/social recreation trips) and three modes of transport (i.e., car, public transport and active modes). The results showed a correlation between the alternatives that represented trips made by car, alternatives representing commuting, work-related and education trips by any mode. The estimated parameters that refer to satiation effects show statistically significant differences between purposes and modes, being the lowest for commuting and shopping trips, and highest for education and work-related trips; and for mode-specific satiation effects, they are lowest for trips by car. The wave dummy variables suggest that participants in Wave A were less likely to do all but social recreation/personal business trips relative to Wave C; and in Wave B respondents less likely to undertake commuting or shopping trips and more likely to use public transport relative to Wave C. These findings suggest that during the first year of the pandemic respondents were working from home more often and avoided any trips that were not related to their social life or personal business – which are associated to trips with no or little contact with strangers. Right before one of the longest lockdowns in Australia – where COVID-19 cases had significantly increased in the country, respondents chose to WFH when possible, and avoided trips in which they will probably have contact with different people, such as shopping or public transport trips.

Scenarios were simulated to obtain an understanding of how the model estimates can be used to establish the behavioural implications of changing levels of relevant explanatory variables on the changes in one-way trips by purpose and mode. Given a specific interest in the role of increased WFH, the simulation results suggest across all waves and jurisdictions, that individuals who WFH more often are more likely to undertake increased shopping trips and personal business/social recreation trips, and less likely to undertake commuting trips, the latter expected. The latent variable for life satisfaction suggests that respondents who are more satisfied with their life nowadays are less likely to undertake commuting and shopping trip, but more likely to undertake more personal business/social recreation trips. In Wave A, the positive influences on personal business/social recreation trips were greater than in Waves B and C; however in SEQ this seemed to increase in Wave C relative to B. Interestingly, the latent variable for concern towards the use of public transport has a similar influence on the number of one-way trips made by car and public transport, with individuals more likely to undertake commuting trips by all modes, more likely to make more shopping trips, and less likely to undertake personal business/social recreation trips.

While there has been a significant amount of research on how the COVID-19 pandemic has impacted on the incidence of commuting activity, especially by mode, in large measure due to increased working from home, the translation of this impact to all trip purposes and modes has been somewhat neglected. Given a finite amount of weekly time available, it is useful to know the extent to which increased WFH and consequent reduced commuting trips has resulted in changes in the incidence of travel by other trip purposes and associated modes. Prior to the pandemic there has been limited attempt to examine the relationship between WFH and other trip making behaviour; some literature finding it to be a complement for non-commuting trips (Mokhtarian et al., 1995, 2004; Choo et al., 2005) and others finding reduced commuting trips being substituted for non-commuting trips (Zhu, 2012; Kim et al., 2015). In this study, we find that those who WFH at a higher rate also have relatively more non-commuting trip activity. This is likely to have spatial implications as this non-commuting activity is likely to be occurring in more local suburban areas in and around the homes where those WFH live. Although not detailed specifically in this paper, we are seeing strong signs that this 'next normal' is almost certainly resulting in a longer-term growth in local trips for all trip purposes with modal substitution occurring between car, public transport and active modes (the latter growing fast in terms of walking, bicycles and e-scooters).

We consistently find the satiation parameter for cars to be lower than that for other modes across all time periods, meaning that car use will likely grow more quickly and to higher levels than other modes. This is borne out both in the GSMA and SEQ where vehicle use has rebounded very strongly in both areas, often exceeding levels observed prior to the start of the pandemic. This suggests that the dominance of the private vehicle as the preferred mode for trip making has been strengthened by the pandemic and if use of the car is to be reduced, there will likely need to be an external policy measure to dampen “consumption”. Finally, we also observe strong rebounds in social activity when confidence returns about meeting safely with family and friends, particularly in small group and/or lower risk social contexts. Beck et al. (2022) flagged a potential for pandemic fatigue becoming a significant concern when mixed with a growing desire to engaging in day-to-day activities where comfort in completing those activities was returning, arguing that authorities would need to communicate the need for caution and observance of COVID-19 health protocols, or else the potential for contagion would be high. Unfortunately, in Sydney as an example, as social trip making and connections rebounded heavily, rates of transmission grew exponentially, ultimately forcing the city into an extended lockdown. Moving forward, potentially into other pandemic situations should they arise, it will again be the strong rebound in social activity that will likely cause contagion – as social activity is a key part of the human condition. Lastly, we find a strong link between rates of WFH and measures of wellbeing (Hensher & Beck, 2022). Admittedly, if you are able to WFH well, you are likely to be more positive about your life compared to those who have been unable to do so, but similarly in ongoing work we find that the ability to WFH provides those who can the opportunity to use time more flexibly such that not only do their employers benefit, but their work-life balance is improved. Such balance between WFH and work in the office should be a key component of work moving forward given the win-win for business and society.

By identifying some of the key influences on patterns of change in mobility, we anticipate gaining an improved behavioural understanding on the switching patterns of travel. An appropriate behavioural modelling framework to achieve this is one that can account for the choice of mode (a discrete decision) and the frequency of one-way trips (a continuous choice) by trip purpose, recognising the presence of budget constraints and satiation effects. The MCDEV model framework enables us to assess the changes in mobility patterns in a behavioural appealing way. The evidence found in the analysis of trip making changes between three periods during the ongoing pandemic suggests that increased WFH and reduced commuting is associated with varying rates of change in one-way non-commuting trip making behaviour which varies by trip purpose and mode. Failure to recognise this behavioural response across all trip-making activity, if the focus is only on commuting changes, will result in misinformed advice on how the pandemic has changed the overall amount of travel activity. Figure 6 in particular shows how WFH impacts on the incidence of one-way trips by trip purpose and mode, which are, on average, significant changes.

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Appendix Paper

Table 10: Percentage of respondents that do at least one trip for each purpose-mode and the number of trips they do by state and wave

	Wave A				Wave B				Wave C			
	GSMA		SEQ		GSMA		SEQ		GSMA		SEQ	
	%	N Trips	%	N Trips	%	N Trips	%	N Trips	%	N Trips	%	N Trips
Commute by car	49%	5.97 (4.22)	51%	6.21 (3.42)	60%	6.01 (3.49)	70%	6.89 (4.68)	45%	5.99 (3.94)	59%	6.47 (3.69)
Commute by public transport	13%	5.73 (4.31)	12%	5.24 (3.71)	16%	3.98 (2.72)	15%	4.80 (3.15)	20%	5.94 (3.91)	15%	5.76 (3.08)
Commute by active modes	11%	4.71 (4.42)	10%	4.38 (3.05)	13%	3.76 (2.98)	7%	4.29 (3.59)	8%	5.22 (3.54)	8%	4.97 (3.20)
Work-related trips by car	20%	3.99 (6.34)	21%	3.45 (3.25)	23%	4.01 (6.75)	18%	4.22 (3.96)	15%	3.45 (2.89)	23%	5.01 (7.01)
Work-related trips by public transport	6%	5.60 (11.65)	4%	3.54 (2.67)	11%	3.50 (2.68)	4%	4.25 (2.34)	5%	3.27 (2.15)	4%	2.77 (2.49)
Work-related trips by active modes	5%	3.10 (2.94)	4%	3.85 (4.43)	8%	1.39 (0.69)	4%	1.82 (1.60)	3%	2.44 (1.01)	3%	6.55 (7.43)
Education trips by car	16%	4.34 (3.14)	19%	5.76 (3.65)	23%	4.04 (3.12)	19%	5.37 (4.40)	18%	4.40 (3.05)	24%	6.16 (4.23)
Education trips by public transport	3%	2.92 (2.07)	3%	2.82 (1.89)	8%	3.48 (2.50)	4%	2.67 (1.15)	4%	2.15 (1.72)	3%	2.91 (1.51)
Education trips by active modes	5%	4.60 (4.04)	4%	3.00 (2.70)	8%	1.57 (1.29)	4%	2.67 (3.03)	2%	4.14 (2.85)	2%	2.17 (0.98)
Shopping trips by car	70%	4.55 (4.80)	79%	4.15 (3.92)	77%	4.33 (3.49)	76%	3.81 (3.50)	61%	4.19 (2.86)	79%	4.70 (3.47)
Shopping trips by public transport	7%	4.32 (3.19)	8%	3.52 (2.53)	12%	4.84 (2.83)	5%	4.88 (2.36)	9%	2.73 (2.60)	6%	5.00 (2.93)
Shopping trips by active modes	22%	4.03 (3.28)	17%	3.62 (3.18)	19%	3.68 (3.85)	8%	2.96 (2.64)	17%	4.07 (2.91)	8%	3.67 (2.83)
Social recreation/personal business trips by car	56%	4.17 (4.77)	60%	3.82 (2.51)	56%	3.26 (2.28)	55%	3.54 (3.30)	41%	3.31 (2.42)	53%	3.96 (3.14)
Social recreation/personal business trips by public transport	8%	2.61 (1.98)	9%	2.87 (2.10)	13%	4.77 (3.17)	6%	4.95 (3.36)	11%	2.72 (2.33)	6%	3.82 (2.59)
Social recreation/personal business trips by active modes	18%	5.00 (4.83)	16%	4.94 (4.61)	17%	3.36 (2.57)	7%	3.24 (1.79)	13%	4.53 (3.81)	8%	4.11 (3.10)

Appendix CC. Paper #25: Working from home 22 months on from the beginning of COVID-19: What have we learned for the future provision of transport services?

David A. Hensher
Matthew J. Beck
Camila Balbontin

Abstract

COVID-19 has delivered an unintended positive consequence through working from home (WFH). While it may be some time until we are able to indicate, with some confidence, the impact that WFH will have on traffic congestion and crowding on public transport, there is a sense already that it is a game changer, and indeed is one of the most effective policy levers that the transport sector has had for many years in 'managing' the performance of the transport network. This paper draws on multiple ways of survey data that have been collected since March 2020 when the pandemic first resulted in severe restrictions in Australia. We present the evidence up to December 2021 on the incidence of WFH and how it has been received by employees and employers from the height of restrictions up to a period when restrictions were relaxed, followed by further lockdowns throughout Australia. We show what this might mean for work productivity, lifestyle, and the changing preferences for passenger modes. With a growing preference, within some occupation classes, to WFH 1 to 2 days a week, and a good spread through the weekdays, we discuss what this means for the way we analyse the impact of transport initiatives on the performance of the transport network with a particular emphasis on the growth in suburbanisation of transport improvements, less costly service and infrastructure improvements, and the changing role of public transport.

Keywords: COVID-19; working from home; Australian experience; productivity; strategic models; public transport implications; strategic impacts

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1 Introduction

COVID-19 has resulted in a seismic change in the way we all work and travel. A notable change has been remote working away from the main office with much of this occurring from home. Recognising that not all jobs can support working from home (WFH), the ability to do so to some extent is now seen as a legitimate alternative to commuting to the traditional workplace for many workers, with much of the prior stigma evaporating as a result of the relatively productive experience. Since March 2020 when the pandemic took hold and Australia went into lockdown, initially for an unknown period, we recognised a need to start tracking the changes that were expected to unfold as many individuals and households entered an unexplored option to WFH. As a forced measure, it gave us a real-world experiment of the impacts of an extreme event on the way we go about our business and live our lives.

The ongoing journey to track changes in WFH and all of the consequent positive and negative impacts began with a first survey in March/April 2020 and has continued to this day with six surveys undertaken and at least two more planned (see Figure 1). During this 22-month period we have witnessed strict lockdowns, easing of restrictions and the removal of most restrictions. A timeline of events is summarised in the Appendix A of this report, noting that there have been significant differences between each State in Australia. The most significant differences relate to a total border closure in Western Australia for most of the time (opening up in March 2022), significant periods of lockdown in Victoria throughout the entire period (Melbourne totalling 263 days, more than any other city globally), and a notable 106-day lockdown in Sydney and the Region of NSW from July to October 2021. These variations have provided a rich opportunity to gain an understanding of the impact of restrictions with different degrees of severity on the propensity to WFH and a range of ancillary impacts such as unexpected positive support from employers to WFH, significant reductions in the use of modes that involve sharing, notably public transport and ride sharing services, with a return to the use of the private car where travel had to take place.

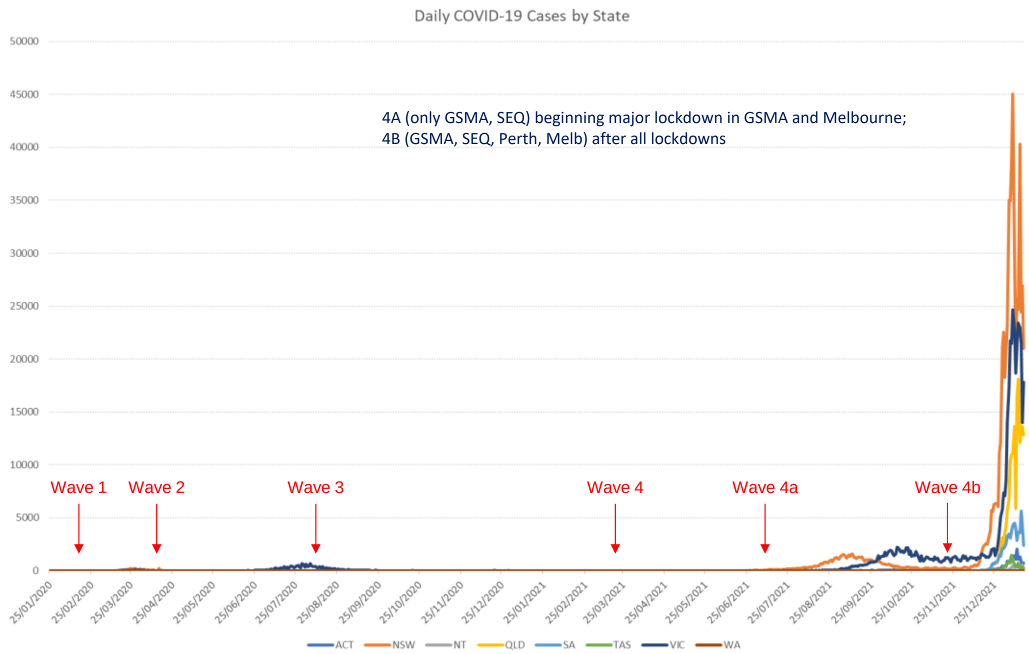


Figure 1. The timeline of surveys to date

With reduced commuting in all jurisdictions accompanied by increased WFH, our interest focussed on what this might mean for future use of all the passenger modes, including active modes of walking and cycling, and whether the accumulating evidence over 22 months signals a ‘new normal’ as we learn to live with COVID-19 under an increasingly vaccinated population. Our research thus far focusses on three streams: a descriptive overview of what changes are occurring as a result of WFH; a consideration of how the spatial incidence of WFH can be embedded in a new suite of travel choice models to account for changes in commuting modal activity and the spill-over to non-commuting travel with greater flexibility in where and when individuals work, opening up new temporal and spatial opportunities for travel; and what all of this might mean for a broader structural change agenda linked to transport investment in the future, growing levels of car use and congestion with continued nervousness in using public transport and other modes associated with sustainability goals, the suburbanisation of activity (linked to a 15 minute city), a rethink of the value proposition of the Central Business District (renamed as a Downtown Activity Precinct), and implications for wellbeing and social exclusion.

The paper is structured as follows. We begin with an overview of the surveys undertaken over the first 22 months of the pandemic, followed by a descriptive synthesis of some of the most interesting findings in terms of the changing incidence of WFH and the accompanying views on employee productivity as perceived by employees and employers, the ways in which travel time ‘savings’ from reduced commuting is reallocated to other work and leisure activities, and what this means for wellbeing and general satisfaction with life. The final section offers a high level strategic and policy-focussed view on what all the findings mean for future transport and land use planning and investment. A large number of papers have been published by the authors on the Australian WFH project, and hence we avoid duplicating the detail of these papers, using the current paper to synthesise this research and outline some of the key insights as societies slowly gain an understanding of what the ‘next normal’ may indeed deliver.

2 A Journey through the last 22 months

The sample size, date, location and key socioeconomic characteristics are summarised in Table 1. All surveys were conducted online using the Pure Profile customer panel. The data was appropriate cleaned using widely accepted methods (extreme outliers, speed of completion, non-sensical responses) and the resulting sampling lines up well with the Australian Bureaus of Statistics (ABS) census in 2016, the latest release year (the 2021 census is yet unreleased).

Table 1. Overview of Survey Samples

	Wave 1	Wave 2	Wave 3	Wave 4	ABS*
Total Sample	1074	1457	1500	2019	n/a
Survey period	30 March – 15 April 2020	23 May-15 June 2020	4 August-10 October 2020	April-May 2021	2016
Number of workers	714	916	742	1149	
Female	52%	58%	58%	59%	51%
Age	46.3 (σ = 17.5)	48.2 (σ = 16.2)	48.2 (σ = 16.2)	48.3 (σ = 17.6)	48.2
Median Income[55]	Household = $92,826 (σ = $58,896)	Household = $92,891 (σ = $59,320)	Personal = $62,551 (σ =$46,964)	Personal= $61,410 (σ =$47,500)	Personal = $60,320 H'hold = $74,776

[55] ABS reported income is for all individuals 15 years or older, whereas we sample 18 years or older, this may explain some of the discrepancy in personal income.

Have children[56]	32%	35%	35%	32%	25%
Number of children	1.8 (σ = 0.8)	1.7 (σ = 0.9)	1.8 (σ = 0.8)	1.79 (σ = 1.0)	1.8
Occupation for those working:					
Manager	1%	2%	14%	16%	13%
Professional	38%	35%	28%	27%	22%
Technician & Trade	5%	6%	6%	5%	13%
Community & Personal Services	8%	10%	10%	10%	11%
Clerical and Administration	17%	17%	22%	20%	14%
Sales	23%	22%	11%	10%	9%
Machine Operators / Drivers	2%	2%	4%	5%	6%
Labourers	5%	5%	7%	6%	10%
State					
New South Wales	22%	32%	31%	44%	32%
Aust. Capital Territory	2%	2%	1%	1%	2%
Victoria	28%	24%	24%	2%	26%
Queensland	22%	18%	22%	43%	20%
South Australia	11%	11%	9%	4%	7%
Western Australia	11%	10%	10%	4%	10%
Northern Territory	1%	1%	1%	0%	2%
Tasmania	2%	3%	1%	1%	1%

*https://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/6302.0Main+Features1May%202016?OpenDocument=#:~:text=of%20Explanatory%20Notes.,TREND%20ESTIMATES,the%20same%20time%20last%20year.

The primary focus of our research has been on the States of New South Wales (NSW) and Queensland since the funding support came primarily from transport authorities in these two States. In this paper we will focus on the metropolitan areas of NSW and Queensland, referred to as the Greater Sydney Metropolitan Area (GSMA) and South East Queensland (SEQ), respectively. The GSMA includes Newcastle in the north through to Sydney and Nowra/Illawarra in the South; SEQ stretches from the Sunshine Coast in the north through Brisbane to the Gold Coast in the south. Although some preliminary modelling of commuter mode choice and the probability of WFH was undertaken using Waves 1 (Beck et al. 2020) and Wave 2 (Hensher et al. 2021), the main development of a mode choice model incorporating WFH that can be integrated into strategic transport models for the GSMA and SEQ occurred in Wave 3 (Hensher et al. 2020a) and Wave 4 (with Wave 4 reported in a later section). We ensured we had enough workers in Waves 3 and 4 to be able to estimate discrete choice models of the mixed logit form.

In addition to the first four waves, we recognised a need to get into the field during the significant lockdown (in Sydney in particular) from July 2021 to October 2021, and to also get back into the field soon after the main lockdowns were eased or totally relaxed. This results in Waves 4A and 4B where the focus was on the suite of questions related not to the requirements of a re-estimated modal choice model (reserved for Wave 5 in April 2022), but to capture the WFH responses and other associated impacts that were also identified through Waves 1 to 4. Wave 4A focussed only on the GSMA (418 individuals) and SEQ (363 individuals) and Wave 4B had 2,189 observations spread throughout four locations (GSMA=678, SEQ=850, Melbourne=437, and Perth=224).

[56] Our survey reports whether a household has children or not, whereas the ABS only provides a definition of a family and includes households without children in that composition.

2.1 How has the incidence of WFH changed?

Figure 2 summarises the proportion of days working that are WFH over the six periods. Waves 1 and 2 are during the initial lockdown period (see Appendix A timeline) when the Federal and State governments mandated working from home unless a person's job was defined as essential and required being out of the home. We see the highest incidence of WFH at 0.697 for the GSMA in the first month of the pandemic, significantly higher than Australia as a whole (0.598) and SEQ (0.542). In part this is explained by the occupation mix of residents (Beck and Hensher 2020a). At this time the nature of the COVID-19 virus was still unknown and no vaccine existed.

As the first lockdown period progressed into its third month (June 2020), we started to see a reduction in the incidence of WFH, but still well above 0.5 for the GSMA but just below 0.5 for SEQ (Beck and Hensher 2020b). As lockdown was eased and generally relaxed except for a few conditions such as social distancing in public venues and mask wearing on public transport and other close contact venues outside the home, the proportion of days WFH reduced to an average of 0.502 for the GSMA and 0.4 for SEQ (Wave 3, Beck and Hensher 2021a, 2021b). These are still relatively high suggesting an average of 2 to 3 days a week WFH across the working population, which translates into higher averages for occupations such as professional, manager and clerical workers.

Wave 4 began a period of significant easing of most restrictions but maintaining social distancing and mask wearing on public transport. The vaccine rollout had begun, though less than 1 in 5 people in Australia were vaccinated. We now see a considerable drop in the incidence of WFH at an average of 0.280 for SEQ and 0.284 for the GSMA, closer to an average of 1 day per week. The question at the time was whether this is going to be indicative of what the 'next normal' might look like. This was soon dispelled with a major lockdown when the Delta strain took hold and Australia's view on minimising the number with the disease (in contrast to the hospitalisation rate) resulted in a lockdown similar to the earlier period at the beginning of 2020. The proportion of working days WFH sky-rocketed (Wave 4A) to 0.524 for SEQ and 0.503 for the GSMA, back to the levels in mid-2020 but not to the levels in the first months of the pandemic. As the Delta virus became contained to what was described as acceptable levels, with the 80% vaccination rate achieved for two jabs, by Mid-October the GSMA opened up with SEQ already opened up early August (but with border closures since the 80% full vaccination rate was not yet achieved as a condition for border to be re-opened). Again, we saw a significant drop in the incidence of WFH (Wave 4B) down to 0.246 for SEQ and 0.389 for the GSMA. The SEQ figure is interesting in that it is a return to the Wave 4 estimate before the lockdowns in SEQ although the GSMA average remains relatively high suggesting greater reticence to get out and about. This can in part be explained by the explosion of Omicron that had begun in mid-December 2021 and grew at an exponential rate in NSW in particular (Figure 1). Although residents were not restricted during the Omicron outbreak, there was significant nervousness about interacting with other people, which we have described as voluntary lockdown (officially referred to as shadow lockdown by State government).

At the end of 2021 and the beginning of 2022, we are not able to suggest that we have arrived at a level of WFH that could be referred to as the forward planning estimate, but we did seek out the views of the Wave 4B sample on what they believe will be their WFH activity in the near future. This could be seen as a reliable indicator given the accumulated experience with WFH over 22 months, and Figure 2 shows the main evidence, where the dotted line is the average among all workers who indicated they want to WFH at least one day a week. If this is reinforced in planned surveys in 2022, we may be in a position after two to three years to suggest that 1 to 2 days WFH a week will become the 'next normal' average[57]. It is interesting that both Sydney and Melbourne workers who can WFH, and who have spent long periods in lockdown (especially Melbourne), are still quite positive about WFH and want it to be a high proportion of their working mix. Importantly though for transport planning in particular, we would need to obtain estimates by location (notably origin-destination pairs) with the GSMA and SEQ. We present such findings for Waves 3 and 4 in a later section.

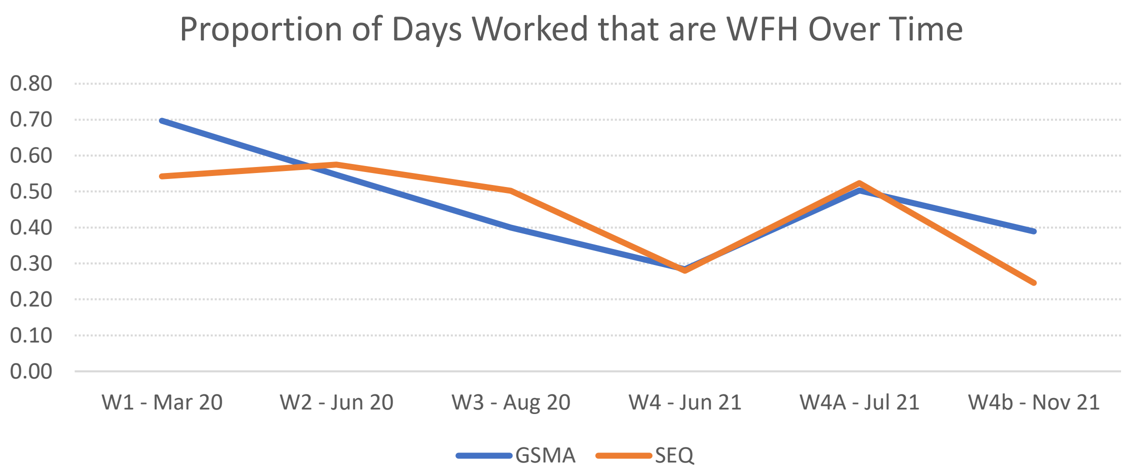


Figure 2. The proportion of working days that are working from home

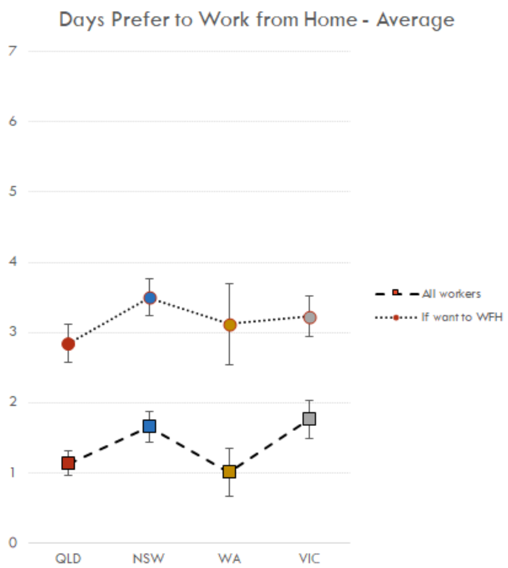


Figure 3. Number of working days that individuals prefer to work from home.

[57] This is the average among ALL workers, which effectively means that ~20% of commuting volume over the week could be reduced by WFH. Of interest, as discussed in next sections, is what do they use the 'saved' time when they do not commute?

A key influence on the ability to WFH is an individual's occupation. We see in Figure 4 that employees in the categories of manager, professional and clerical/administration are more likely to be able to WFH, which aligns well with the nature of work and the ability to work from any location, in contrast to many workers in other categories such as technician and trades who cannot do their job unless they are on-site. In a number of papers such as Hensher et al. (2022a), we have developed a mapping equation to obtain variations in the probability of WFH depending on occupation in particular, and locational attributes as well as the commuting travel time. The probability obtained from the mixed logit model of the commuter choice between no work, WFH and, if commuting, mode of transport by time of day and day of the week over seven days. The mapping equation is used to obtain a spatial representation of the probability of WFH as shown for the GSMA in Figure 5.

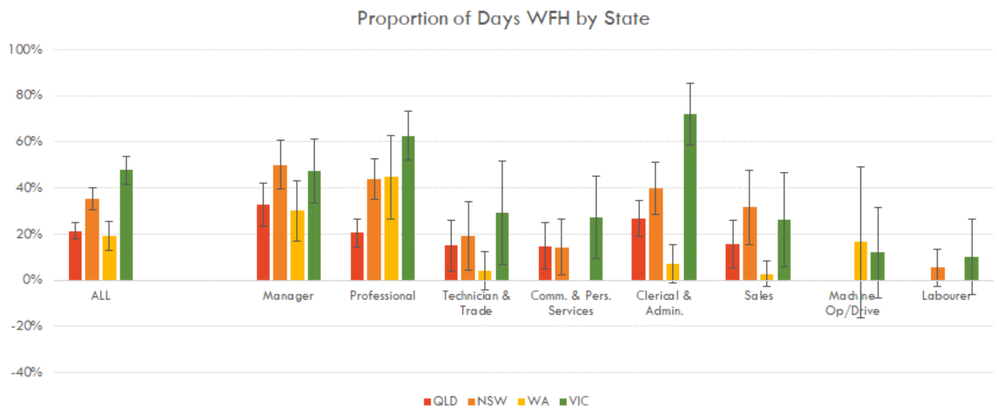


Figure 4. Percentage of working days that individuals work from home by occupation.

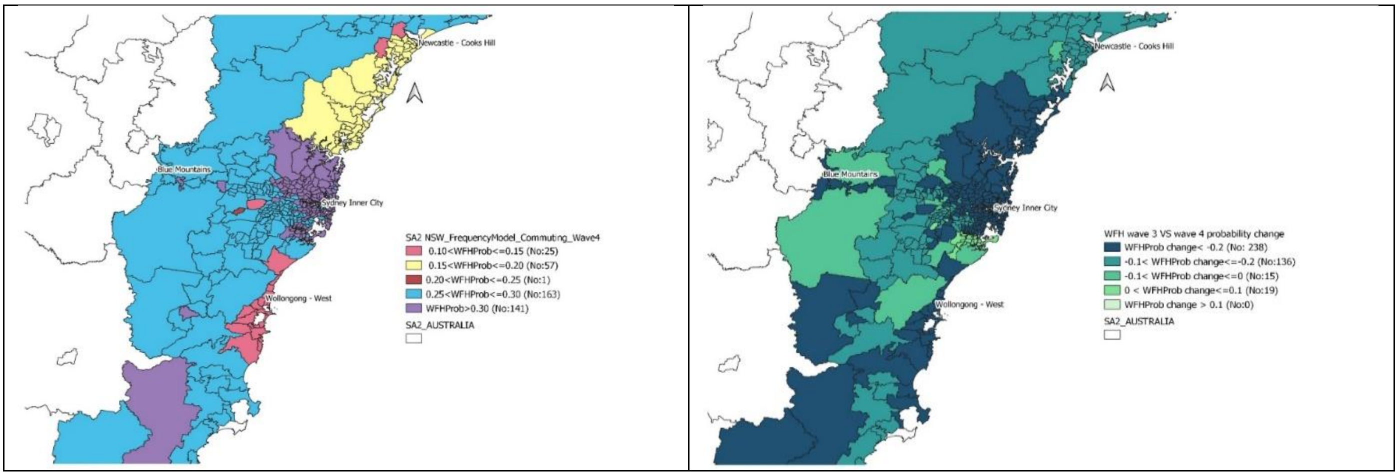


Figure 5: Probability of WFH by SA2 GSMA, Top is Wave 4; Bottom is difference with Wave 3

2.2 What do commuters do with the time saved from reduced commuting?

A particular interest is what happens to any travel time reallocated away from commuting to other activity classes as a result of increased working from home. This is a test of the extent to which the theoretical trade-offs between travel and work, and travel and leisure, and work and leisure occur under the new era of a greater incidence of working from home. Our research offers new evidence on the way in which 'saved' commuting time over a period (i.e., a week) is allocated to three main activity classes, namely paid work, unpaid work and leisure, and furthermore what are some of the statistically significant influences on this re-allocation. Details are provided in Hensher et al. (2022c). Table 2 shows that on average for those who save time from commuting, 60 mins per day is saved, with this saving being allocated on average as 45.9% to leisure, 32.1% to paid work and 22% to unpaid work. The findings are important in obtaining estimated time benefits from reduced commuting activity with such travel time being traded against work and against leisure, and what this might mean for the future travel, activity location, and lifestyle landscape.

Table 2. Descriptive Profile of the Incidence of Commuting Time Re-allocation throughout a week

	GSMA	SEQ
Commuting time saved (mins per day)	63.2 (116.8)	58.5 (101.1)
Time spent doing additional work that I receive pay for (%)	32.1 (33.4)	23.9 (31.2)
Time spent doing additional work for which I receive no extra pay (%)	22.0 (25.4)	23.3 (30.6)
Time spent on leisure or family (%)	45.9 (33.9)	52.8 (38.3)
Days per week WFH only	2.8 (1.8)	2.4 (1.8)
Days per week WFH at some point	3.2 (1.6)	2.8 (1.6)
Days per week Work (from any location)	4.3 (1.6)	4.2 (1.5)

Hensher et al. (2020c) undertook a simulation of the relationship between the probability of allocating saved commuting time to each activity class as age and commuting time varies. We found that as the amount of time saved from reduced commuting increases, *ceteris paribus*, the probability of allocating a higher quantum of time to leisure and unpaid work increases and decreases for paid work. The rate of change is similar for leisure and unpaid work as the amount of commuting time saved increases, although the latter has a lower probability, suggesting that the main substitution is between paid work and both unpaid work and leisure. The simulation results in our sample suggest that, *ceteris paribus*, if a respondent saves less than 100 minutes as a result of less commuting, then they will allocate more of this time to paid work relative to unpaid; but this will be opposite for a respondent saving more than 100 minutes as a result of less commuting. In the case of an individual's age, as age increases, *ceteris paribus*, the probability of allocating a higher quantum of time to leisure increases significantly, while it decreases for both paid and unpaid work at a similar rate, suggesting approximately equal substitution between all work and leisure activities. The results show that, *ceteris paribus*, a respondent who is 50 years old tends to allocate half of their saved time from not commuting to leisure, around 30% to paid work and 20% to unpaid work.

The Wave 4 finding does not provide enough evidence on the extent to which the reallocation of commuting time to leisure, paid and unpaid work is associated with specific activities that occur inside or outside of the home. This is important to know since any outside activity is associated with increased travel which can add to the quantum on non-commuting travel on the road network or elsewhere depending on whether active modes or public transport is used. In subsequent waves (beginning with 4B) we explore this issue more and Figure 6 summarises the allocation time to activities associated with leisure and paid/unpaid work. For the GSMA, 23% of all time saved is associated with leisure activities undertaken in the home, 18% being household tasks (i.e., chores), and 9% is associated to leisure outside of the home, i.e., a total of 50% of the saved time is allocated to leisure activities plus household tasks. The equivalent percentages for SEQ are 17.5% for leisure activities in home, 19% for household tasks, and 11% for leisure activities outside home, i.e., 47.5% of all saved time is allocated to leisure plus household tasks in SEQ.

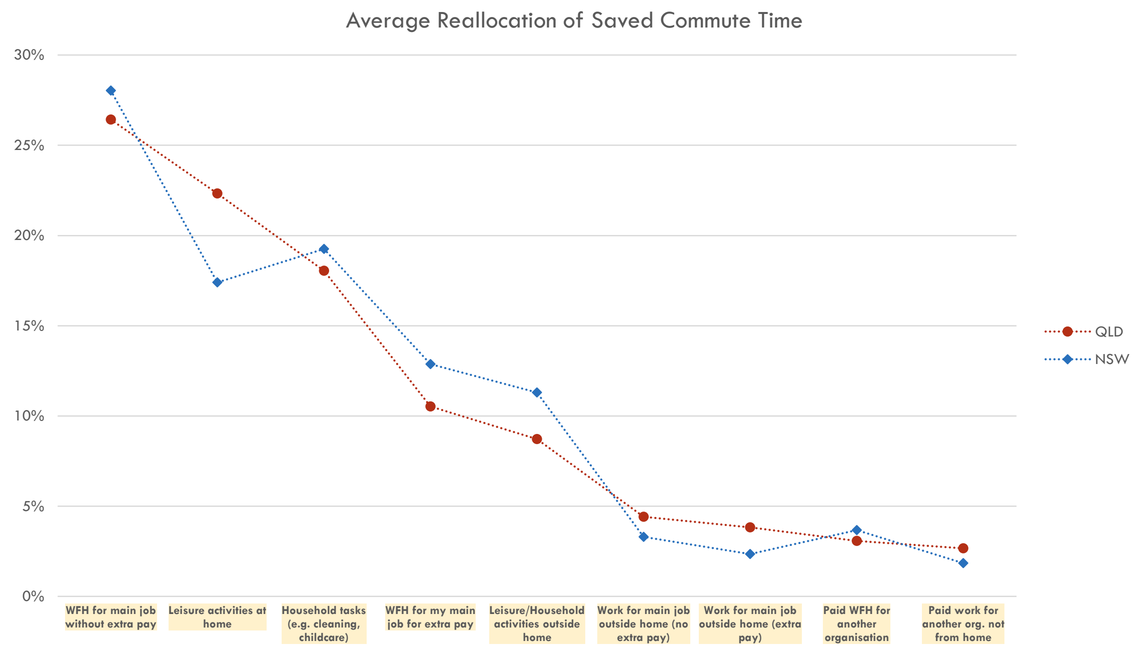


Figure 6. The breakdown of the allocation of saved commuting time within leisure and work (Wave 4B)

2.3 Does WFH and reduced commuting have a positive benefit on Wellbeing?

While we would have preferred that the virus had not taken hold, we must look forward to use this 'extreme event experience' to obtain positive benefits to individuals, households and society more broadly. This position must recognise that mental health and well-being, including social exclusion has not gone away (see Stanley et al. 2021) and that it remains a high priority for governments as well as for business more generally.

Included in Waves 3 and 4 were a series of well-being questions identical to those used in the UK Office of National Statistics Annual Population Survey (ONS 2021), as part of their quarterly estimates of life satisfaction. The four questions used asked respondents to indicate: (i) how satisfied they are with life nowadays, (ii) how worthwhile they think things done in life are, (iii) how happy they felt yesterday, and (iv) how anxious they felt yesterday. The four well-being questions are reported on a scale from 0 representing 'not at all' to 10 representing 'completely'. Given concerns often raised about the mental health risks associated with extensive periods of WFH, we wanted to investigate the extent to which experiences with working from home, and associated impacts such as reduced stressful commuting has resulted in improved well-being or not.

We look at 'how worthwhile are the things you do in life' which is highly correlated with all except the anxiety scale. In the distribution presented in Figure 7, we see a right-skewed distribution with rating scores of 7 and 8 dominating. This already hints at evidence that satisfaction with life, in particular as people moved away from the initial peak of COVID-19 infections, was returning to some greater degree of positive 'normality', and was robust for those people who were still working during this period.

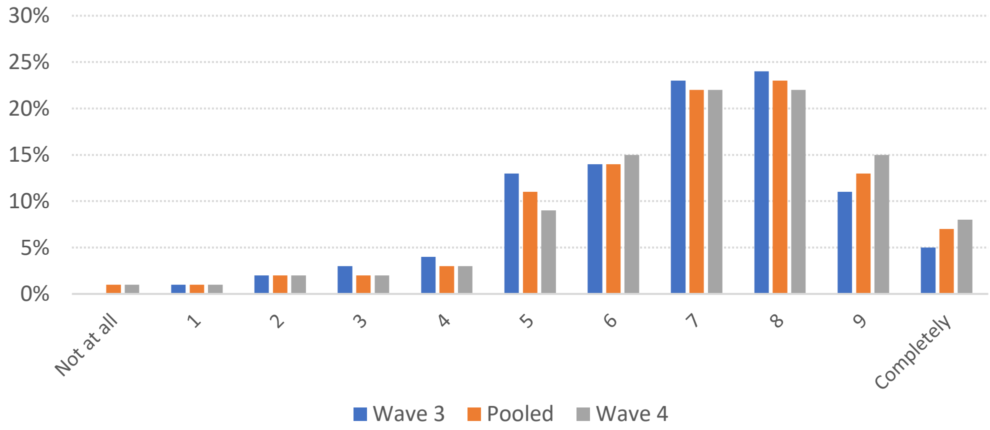


Figure 7. Distribution of the "how worthwhile are the things you do in life" statement

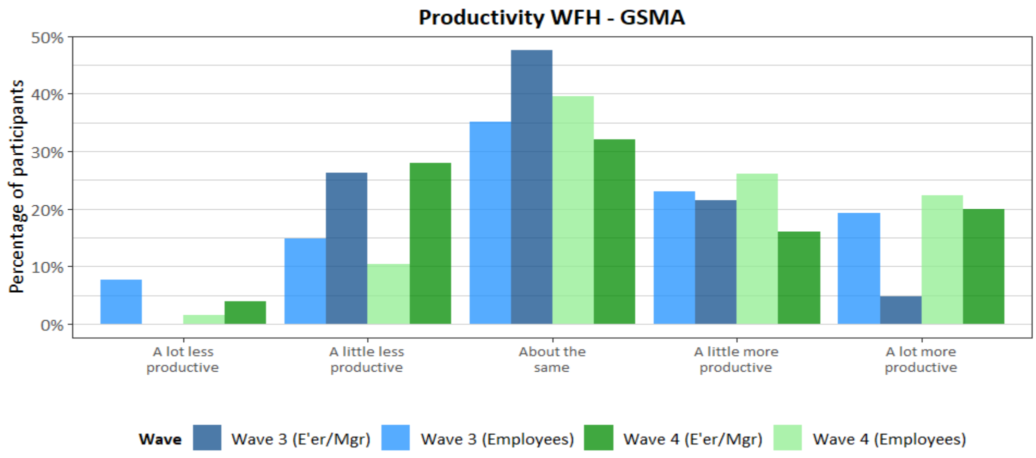
The detailed analysis is set out in Hensher et al. (2022d) using Waves 3 and 4 data and herein we provide a summary of the main findings as to whether there is a systematic behavioural link between well-being, with working from home, reduced commuting linked to distance to work, balancing work with non-work activities, and various socio-economic characteristics. We implement an ordered logit choice model on the 11-point scale to investigate the presence or otherwise of such a relationship. The evidence suggests that the opportunity to have reduced commuting activity linked to working from home, increased work-related productivity and an improved balance between time spent on work and time spent not working, have all contributed in a positive way to improving the worth status of life, offsetting some of the negative consequences of the pandemic. Thus, the empirical evidence suggests that some good has come out of the pandemic and the policy implication is very clear; namely, to continue to ensure that people feel trusted and supported to work from home successfully, and know they are making a contribution while doing so. Meaningful work provides meaning to life.

2.4 What is the evidence on Productivity implications of WFH?

"The five-day office week is dead, long live the hybrid model", says Productivity Commission's chair, Michael Brennan (July 12, 2021, SMH)

One of the risk factors in WFH was whether it would have a negative impact on the productivity of employees. We have found that, like many other studies, productivity as perceived by both the employee and the employer has remained unchanged, and may even have increased on balance. Encouragingly, employers have been surprised, with the ability of employees to remain productive and even often increase their productivity, which has links to reduced stress associated commuting, increased flexibility in when to work, and the general improvement in lifestyle. Some of the productivity gains may also be attributable to people working more (see allocation data in Section 2.2) either because they feel they have to, or because they have nothing else to do in lockdown. The implication being that it should not be the expectation that people work longer (particularly unpaid) while WFH, otherwise that could potentially degrade the experience.

Clearly the support from employees and employers for WFH is not uniform as shown in Figure 8 (top graph), with a higher percentage of employees and employers perceiving a little more and a lot more productivity in Wave 4 compared to Wave 3, possibly partly linked to being better organised and began to see a continuing employer support for WFH. This translates in the lower graph of Figure 8 into a sizeable percentage of employees having the choice to WFH with a balanced plan (or hybrid model) of office and home. In general, we conclude that perceptions of productivity while WFH have remained constant throughout the pandemic, and even at the end of the most recent lockdown (Wave 4B, Figure 9), workers feel they are just as productive as in their regular workplace before COVID-19.



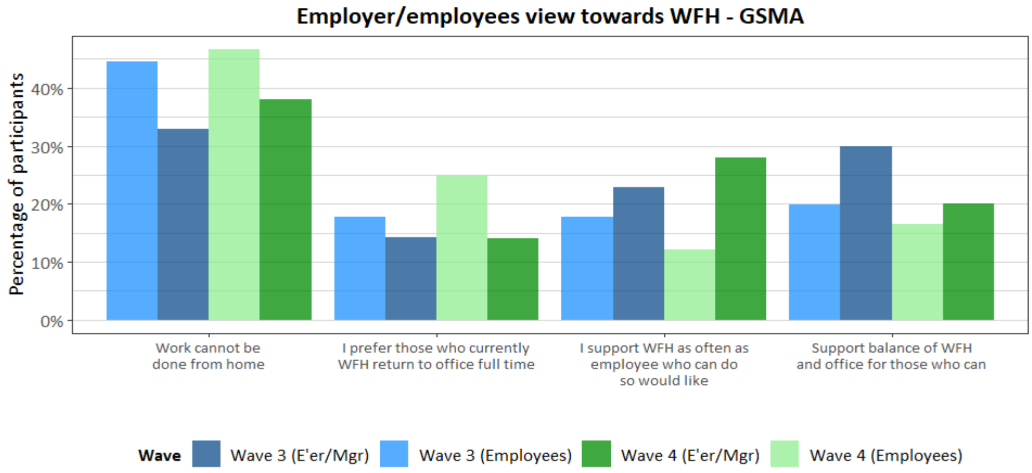


Figure 8. Perceived productivity impact of WFH by employees and employers: Waves 3 and4

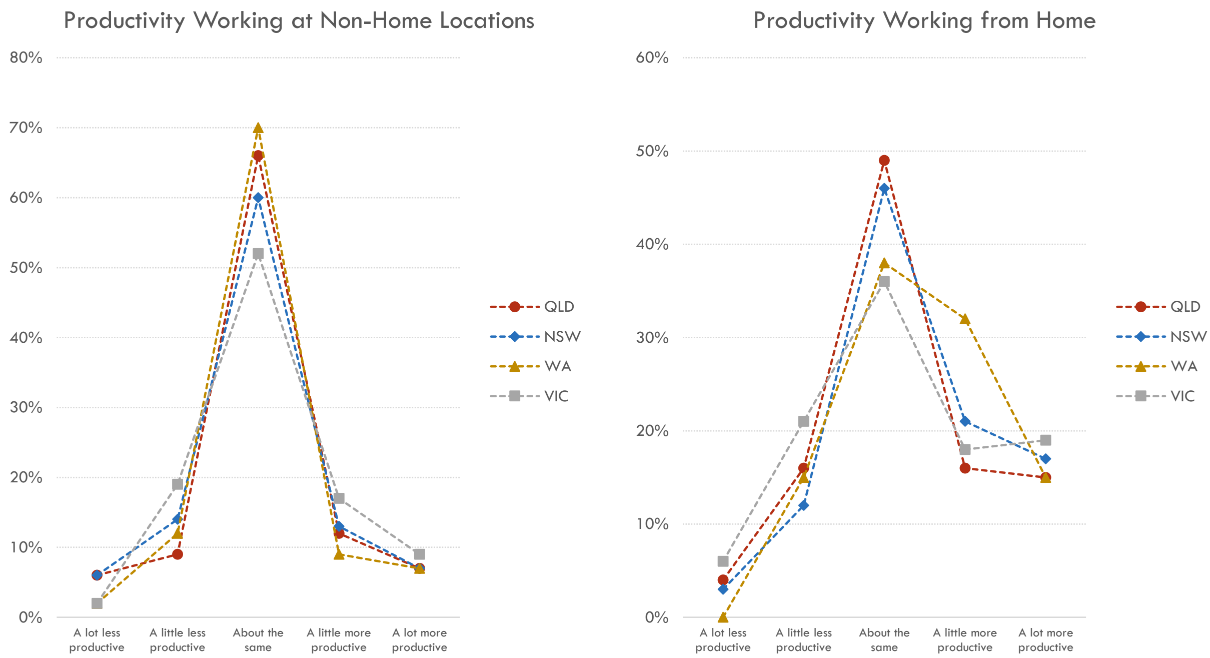


Figure 9. Perceived productivity impact of WFH by employees: Wave 4B

2.5 How might WFH impact on the Days of the Week Commuting?

Knowing the incidence of WFH is important; however also identifying what days of the week WFH occurs is important for transport planning since capacity needs are typically determined by the peak periods. Figure 10 summarises the percentage of workers who WFH on each of the 7 days of the week. In general, for each metropolitan area and wave of data, the distribution is remarkably flat across the weekdays, with a range in the latest period of Wave 4B being 26% to 30% for the GSMA and 15% to 19% for SEQ. What this suggests is that the WFH impact has spread evenly through the weekdays, which is a very encouraging sign for peak period planning; however, it is necessary to look at the evidence at an origin-destination level in order to see the extent to which this flatness is spatially widespread or not.

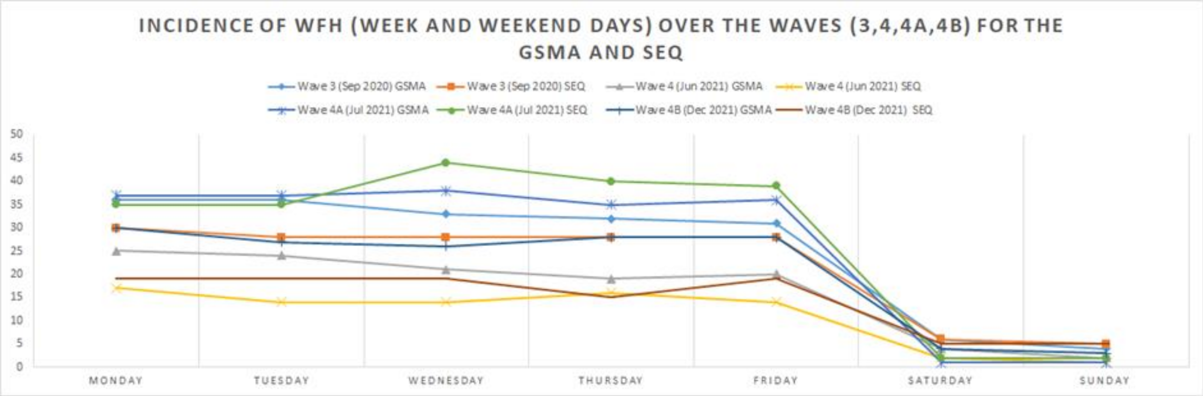


Figure 10. The incidence of WFH by day of the week across the waves for the GSMA and SEQ

2.6 The Impact of the Pandemic on Public Transport Use by Commuters: Waves 4A and 4B

Public transport patronage has taken a deep dive during the pandemic and remains at levels significantly lower than those before COVID-19. In Australian capital cities, levels have struggled to go beyond 70% of the pre-COVID-levels with patronage being as low as 45% during some periods of lockdown. Beck et al. (2021a) have looked into the barriers to public transport use and actions required to restore confidence. In this section we provide an overview of the main findings.

Commuters were asked to indicate what their main barriers were to using public transport at the present moment. The evidence for the GSMA and SEQ is provided in Figure 11. For those that are concerned, there were 14 themes emerging. The inability to social distance, and the number of other public transport users not doing so, was a concern, as was the cleanliness and hygiene status of public transport. With regards to cleanliness, reference was commonly made to the lack of overt sanitising services on-board and the large number of touch points that are required while using public transport (notwithstanding contactless ticketing). While the lack of enforcement of COVID regulations was explicitly mentioned by a small number of respondents, implicit concerns about social distancing and mask wearing are concerns about others not following the rules or being made to follow them. Concerns about the behaviour of other passengers mainly comprised of not being sure of where other people are from or where they have been, general distrust of the hygiene status of other people, and a very clear theme that many feel that people still use public transport when they should otherwise stay home because they are sick (coughing and sneezing, general germs and/or illness not just specific to COVID-19). This category could be described as a distrust of other people and generally thinking of other public transport users as inconsiderate of others.

Respondents were then asked what measures would need to be taken in order to make them feel more confident about using public transport. The most important measure is ongoing cleanliness. Many respondents stated that they had to be able to see that it was being done (either having continuing cleaning being conducted, scented cleaning materials, even an information sheet in the vestibule that informed passengers of when the carriage or bus was last cleaned). Limits on people using public transport and/or social distancing measures combined with ongoing use of masks were also a commonly stated measures that would increase confidence. Several respondents stated that more services were required to allow for distancing to occur. A smaller number of respondents explicitly stated they wanted more enforcement of regulations. Vaccination and/or low to no case numbers would be needed for some to return to using public transport. In responses, some suggested that vaccination be mandatory for travel on public transport, and others suggested that there be vaccinated-only carriages made available. Respondents in SEQ state that having sanitiser stations or antibacterial wipes available for passengers would make them feel more confident, many stating they would be happy to wipe down their own seat if they had wipes.

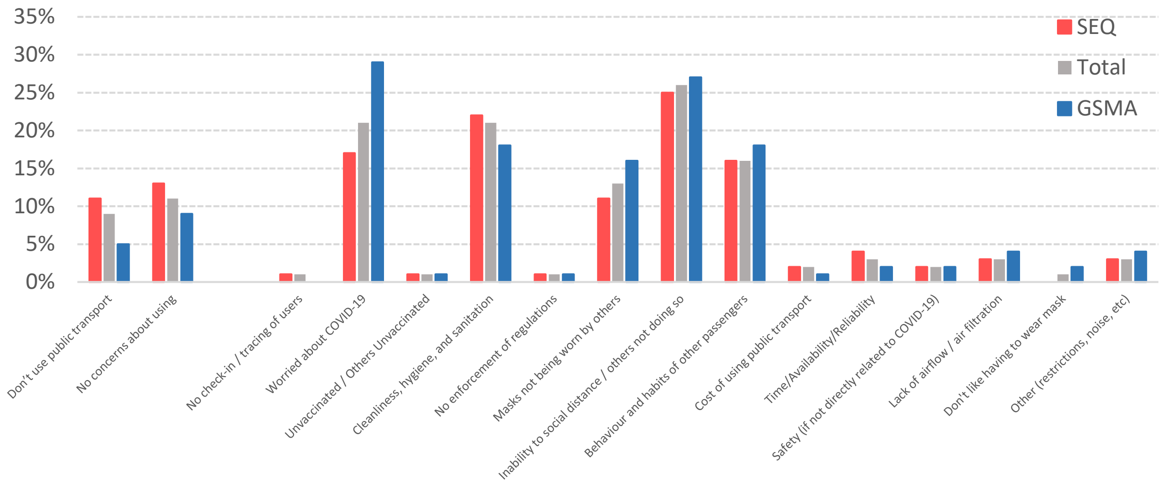


Figure 11: Commonly Stated Barriers to Public Transport Use. Wave 4A

In the December 2021 survey (Wave 4B), we asked all of the sample (commuters and non-commuters) when they felt that public transport will be safe to use. As summarised in Figure 12, 15%-55% felt it was safe now with the lower percentage being in Melbourne and the highest in Perth, this not being surprising given the duration and degree of exposure to COVID-19. Also, we see around 10% believing it will take 12 months, with 12%-20% suggesting that they are not confident about returning to public transport. These estimates align amazingly close to what many pundits are suggesting will be the longer term (10 year) return to public transport of around 80%.

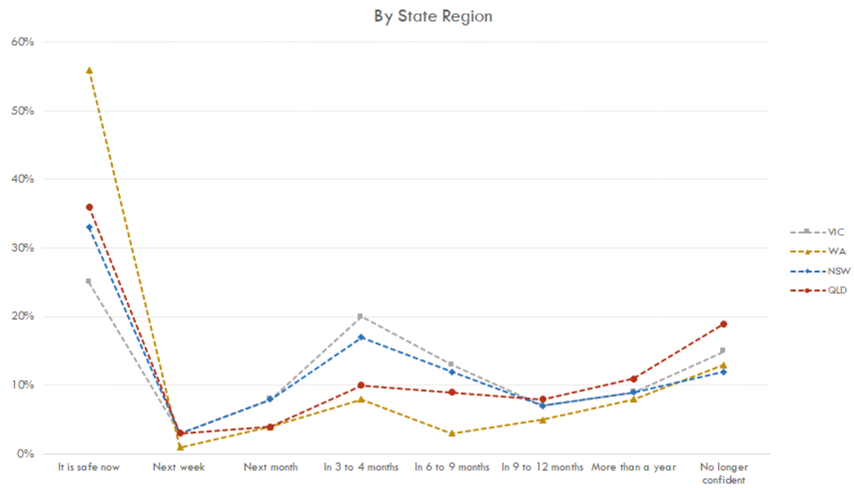


Figure 12. When will Public Transport be Safe to Use? Wave 4B

3 The Policy Message and Structural Change: Has COVID-19 helped or hindered?

'Flexibility is here to stay' and 'employers who offer a balance of WFH and in office will attract more high-quality employees' (The Future of Office Space Summit, 17 Feb 2021)

If "done right", WFH/Remote working is possibly the greatest transport policy lever we have had for many years. A defining outcome will be that more people will WFH to some extent, likely averaging 1 to 2 days a week in what has been broadly termed a hybrid work model (with fluctuations around this in the next few years) and using the reduction in commuting time to engage in increased leisure and work activity. Flexibility and convenience and reluctance to go back to pre-pandemic working norms will be key drivers of this outcome with norms around WFH being redefined. While there are advantages and disadvantages to working from home, in a non-lockdown circumstance where children are at school and businesses are open, but biosecurity conditions are front and centre, the positives seemingly outweigh the negatives. Wider literature outlines the bigger impact that WFH has had on women in families with children (particularly during periods of lockdown where schools have been closed) while prolonged working from home during lockdown periods may result in more women leaving the workforce. Conversely, it may also be possible that woman could return to the workforce if they could work from home given the flexibility such work offers. While a recurring finding is that women carry the bulk of the domestic responsibilities while working flexibly, government and business should view more flexible working arrangements through a less gendered lens, giving families more choice in how they make work and care decisions, with the ultimate potential being a higher workforce participation of women.

“More than half 54% of employees surveyed around the world said they would consider leaving their jobs if they are not given some form of flexibility regarding where and when they work.” (Smarten Spaces). Many employees will want this option in their employment contracts - it will become part of negotiation and crucial to retention. Organisational resilience will need redefining or recrafting. New workers to the labour market will benefit more from face-to-face interaction to build networks (but no need to do it 5 days a week). Indeed, WFH has also become a key factor in the value proposition of different places of employment. Surveys conducted by the BBC (2021) in the United Kingdom show that 60% of workers want to work from home at least some of the time, along with a large increase in the number of job adverts referencing flexible working arrangements. A report by McKinsey finds similar results in the US, further noting a potential talent drain for companies that return to fully onsite work (Alexander et al. 2021). Organisational resilience will thus need redefining or recrafting, opening up continuing paid and unpaid work from home plus some additionally released leisure time with reduced commuting activity.

With hybrid work settings, many high-density office hubs will have a reduced number of workers at any one time, typically 80% of pre-COVID levels (Beck and Hensher 2020b). We expect greater opportunities to provide satellite/third party office space under “office space as a service” (OSaaS), including new apartment blocks with a designated office floor (‘commute to work by lift’). Density then becomes increasingly a bio-security risk linked to continuing nervousness in using public transport, especially if crowding returns, and indeed the associated higher density nodes in central metropolitan areas. Marginal residential relocation away from capital cities (exception maybe the second home) is likely to increase, noting that in Australia in the 12 months to the end of March 2021, 22,651 Melburnians moved to regional Victoria while 24,500 Sydneysiders moved to regional NSW; although a large amount was occurring regardless of COVID and WFH due to the regular cycle of residential mobility.

The enticement to relocate to outside of metropolitan areas will be driven strictly by better access and jobs in the regions. Residential choices are likely to be selected with more flexibility relative to work locations, and work locations will be chosen more flexibly relative to residential locations. There is, however, a growing view that with a day or two working from home and three to four days in the office, big cities will not wither away[58]; however remote work is likely to move the city's borders to the edge of the metropolitan area, a reflection of expanding regional labour markets. Rather than drastically changing cities, WFH has subtly reimagined city life by giving more workers more flexibility. The Brookings analysis of the USPS migration data[59] concluded that remote work will settle into a new level, higher than pre-pandemic but lower than the present. The hybrid-work environment is pushing people to live within travelling distance near work, but not quite as close as they used to. Local amenity and the built environment will likely play a large role and require a more localised focus on what constitutes areas that are accessible for active travel, which has spiked during the pandemic.

We can anticipate greater use of cars for all trip purposes and increased local (suburban) trip congestion (linked also with higher rates of passenger car registrations) in large measure due to the bio-security concerns in using public transport: Google Mobility data has consistently shown car usage to rise to above pre-pandemic levels in many countries. Staggered working hours are hypothesised to contribute to changing levels of road traffic as a result of more single–occupant car use; spreading demand better over the day, with the level of traffic in the peak hours associated with commuting lowering as offices reduce capacity at any one time. However non-commuting traffic is also changing and some of this is moving to peak periods as a result of greater flexibility in when work is done, while also adding to traffic throughout the day, in both the traditional peak and off-peak periods. Finally, cost constraints on using the car to commute may also be reduced as a person travels to work fewer times during a given week. Additionally, it has been shown that, for a variety of reasons, telecommunications and travel are complementary (Choo and Mokhtarian 2007), which could further lead to increased localised travel in particular by car.

How this change in car usage may impact on congestion is unknown at this stage and needs careful monitoring by transport authorities. Ideally, increased working from home would help reduce congestion and crowding due to a lower aggregate number of commuting trips. However, should barriers to car use be reduced (in particular cost) and to public transport be increased (due to bio-security concerns), we could see that when commuting is done the car becomes an even more dominant alternative. If this is the case, then transport authorities should work closely with businesses to ensure peak spreading is encouraged, and ultimately it may indeed strengthen the need for a more efficient form of road pricing than currently exists.

The quality of the living environment will become more important including larger units, an office at home, and enhanced digital connectivity. Linked to WFH, increased online activity by workers reinforces the possibility of a 15-30 minute city, a residential urban concept in which most daily necessities can be accomplished by either walking or cycling from residents' homes, which in the past has been especially hampered given it is mainly related to closer commuting locations with satellite offices.

58 https://www.businessinsider.com.au/remote-work-made-cities-bigger-nyc-san-francisco-metro-areas-2021-9

59 https://www.brookings.edu/blog/the-avenue/2021/06/24/remote-work-wont-save-the-heartland/

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Appendix DD. Paper #29: Exploring the Impact of Different Lockdown Experiences on Work from Home Behaviours and Attitudes

Matthew J. Beck
David A. Hensher

Abstract

In the first 22 months of the COVID-19 pandemic, from March 2020 to December 2021, we witnessed a seismic change in the way in which work was undertaken, especially in the move from the regular office to working from home (WFH). Through periods of lockdown, easing of restrictions and reinstatement of restrictions, individuals gained a new appreciation of WFH, and with the stigma of WFH virtually gone, preferences evolved for increased WFH to some extent, with a partial return to the office (be in the location prior to COVID-19) or a local satellite office. This paper explores surveys that were undertaken in late June 2021 and mid-November 2021 to capture changes that were occurring just at the beginning of another lockdown and after easing of restriction yet again. We focus on three metropolitan locations – the Greater Sydney Metropolitan Area, South East Queensland and Melbourne, each of which went through very different durations and associated experiences of lockdown. The most important finding over the two time points is that irrespective of the degree of severity of the lockdown and the duration thereof, employee preferences for working from home remained equally high, attitudes towards working from home remained strongly positive, productivity remained unchanged and skewed in favour of greater productivity, and the desire to continue to work from home did not differ because of lockdowns. The incidence of WFH will remain at around 1-2 days a week for many occupations and this has the support of employers. This is a significant structural change defining the 'next normal'.

***Keywords**:* COVID-19, lockdowns, working from home, factor analysis, cluster analysis, attitudes, behaviour

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1 Introduction

Throughout the COVID-19 pandemic, restrictions and lockdowns have been used to restrict the movement of people and thus limit the spread of the virus. This has bought about a significant change in where work is completed. As discussed in Beck and Hensher (2022a, 2022b), the working from home experience in Australia has been sustained and positive overall. With the exclusion of Melbourne that had battled several outbreaks since the start of the pandemic, towards the middle of 2021 the rest of Australia had experienced a sustained run of almost zero community COVID-19 transmission: with cases almost exclusively isolated to the returning international traveller hotel quarantine system.

However, in the latter half of June 2021 the Delta variant was found to have escaped hotel quarantine and rapidly spread through Sydney to the point that the Greater Sydney Metropolitan Area (GSMA) was placed into lockdown on July 1, 2021 (for what was initially meant to be a week). At the same time, Delta had moved from Sydney to parts of South East Queensland who acted relatively quickly, locking down the region (from the Sunshine Coast through to Brisbane and the Gold Coast – SEQ) for a three-day period based on a small number of Delta cases circulating in a small number of schools. In the Victorian capital city of Melbourne (MELB), residents were only just regaining freedoms coming out of their most recent lockdown, but cases of the Delta variant were also detected in the community, and by late July 2021 the city had returned to lockdown conditions as Delta case numbers increased. At this point in time across Australia, the vaccine rollout had only just begun.

While the lockdowns in each three jurisdictions were designed to be short circuit-breakers, each jurisdiction implemented them at different points in the case number growth. GSMA was locked down when cases numbers were averaging above 20 per day, SEQ was placed in to lockdown with case numbers averaging 5 per day, and MELB was locked down when case numbers hit 20 per day. Perhaps as a function of the differing speed of implementing restrictions on the movement of people, each jurisdiction had a significantly different trajectory to the other with respect to COVID-19 cases and the duration of the lockdown periods.

Figure 1 highlights the different experiences with case numbers and lockdown duration(s). As can be seen, NSW experienced the highest daily case numbers at any time during the pandemic (till that point in time), and what was meant to be a week of lockdown extended into 107 consecutive days of heavily restricted movement (no travelling outside of the local government area, work from home wherever possible, unless conducting essential work, and masks in most venues including public transport). Likewise in Victoria, despite a very brief respite from the strictest of restrictions for the first week of August, the residents of Melbourne spent 78 days in lockdown, their sixth for the pandemic: on the 4th of October 2021 Melbourne marked 245 days of lockdowns and became the city with the longest cumulative time in lockdown in the world (Boaz 2021).

1.1 Outline of Paper

We have been collecting data since the beginning of the pandemic to understand how measures to combat COVID-19 have impacted on work, travel activities, household spending, and attitudes. Previous research has identified key issues and potential future implications (e.g. Beck and Hensher 2020a,b Beck and Hensher 2022a,b). In this paper however, we seek to examine two unique and unexplored data periods, specifically those that relate directly to “before” and “after” the differential lockdown experiences during the second half of 2021 in the Eastern states of Australia. The purpose of this paper is to understand how these experiences have impacted on WFH behaviour and attitudes.

Two separate waves of data collection are used to do this, which are also shown on Figure 1. The first survey wave, referred to as Wave A (all analysis related to this data is denoted by _*a* in text and on charts), was conducted in the metropolitan areas of two states at the start of the lockdown periods that began in the two regions at the start of July: Greater Sydney Metropolitan Area (GSMA_a); and South East Queensland (SEQ_a). The second survey period referred to as Wave B (and denoted by _*b*) was conducted in November 2021 when lockdowns had eased significantly[60]. In Wave B, respondents from the Melbourne region were also sampled given their uniquely different accumulated lockdown experience. Overall, data collected gives us three different lenses to exam WFH attitudes and behaviours:

- The SEQ lockdown which essentially ended after a week as COVID-19 numbers flatlined, giving a pool of data where life was relatively normal over the 5-month time-period.

- The GSMA that started at the same time SEQ but ultimately lasted almost 4 months, given a pool of data where people entered a lockdown after a sustained period of relatively normality, for what ended up being a sustained period spent in lockdown and WFH.

- The MELB lockdown that was a little shorter than GSMA (90 days versus 107) but added to a much longer in total amount of time spent in lockdown and WFH since the start of the pandemic (the most days in the world).

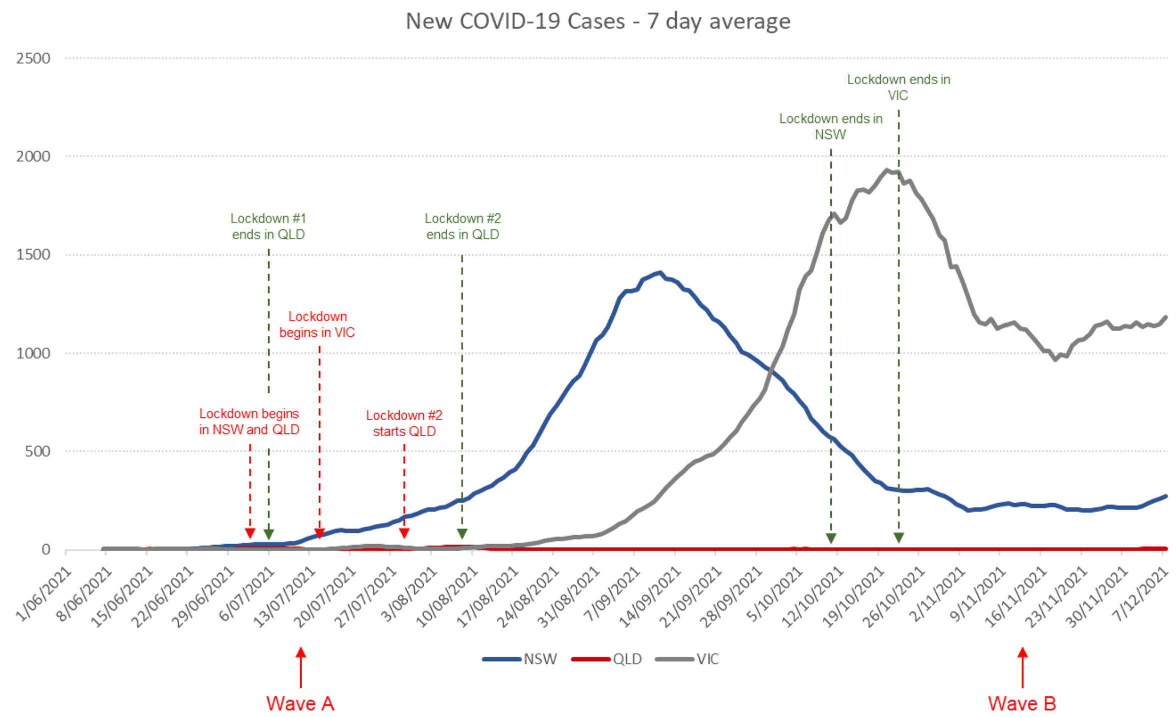


FIGURE 1: Daily COVID-19 Cases, Lockdown Periods and Data Collection

[60] In December 2021 the Omicron variant would see case numbers explode to more than 20,000 daily cases on a regular basis. However, given the widespread levels of vaccination (>90% in GSMA for example) no further lockdowns occurred. However, individuals were instructed to use "personal responsibility" with respect to minimising their risk of contracting COVID-19.

The paper is structured as follows: we briefly review the ligature on working from home and telecommuting; we then provide insight into the sample composition for each of the analysis periods; then offer insights into how the working from home behaviour differs across the regions as a result of the differing lockdown experiences. The next section identifies distinctive segments of workers with respect to how they evaluate the WFH experiences; and then we discuss the overarching implications of the analysis before concluding comments.

2 Literature Review

Working from home, or telecommuting, and the travel behaviour that arises, has been of interest to the transport community for some time (c.f. Nilles et al. 1976, Salomon 1986, Hall 1989, Mokhtarian 1991). However, prior to COVID-19 the uptake of WFH had been limited. As a result of the pandemic however, the role of telecommuting has been thrust into prominence, and questions again arise about the impact it will have on travel activity, such as whether WFH will be a complement or as either a complement or substitute for non-commuting trips (Mokhtarian et al. 1995, Mokhtarian et al. 2004, Zhu 2012, Kim et al. 2015), if considerable time-savings from not commuting can be generated (Lari 2012) and how that contributes to reduced work-life conflict (Hayman 2009), and the potential of telecommuting to be a powerful public policy on reduction vehicle kilometres travelled (Mitomo and Jitsuzumi 1999, Choo et al. 2004).

Outside of transportation, the literature has also explored the impact that WFH has on workers. Mas and Pallais (2020) find that for the typical worker is in a job where almost none of the tasks can be performed from home, work arrangements have been relatively stable over the past 20 years, but that work conditions vary substantially with education, and jobs with schedule or location flexibility are less family friendly on average; thus concluding that women are not more likely to have schedule or location flexibility and seem to largely reduce their working hours to get more family-friendly arrangements. Those with a more suitable office space at home are also more likely to opt into telecommuting (Baruch et al. 2000). Unsurprisingly, socio-demographics alone do not explain WFH intentions, and attitudes are a powerful determinant of the choice to do so (Haddad et al., 2009), and interestingly the social influence of friends, neighbours and colleagues have also been found to contribute significantly to WFH norms (Páez and Scott 2007, Scott et al. 2012, Wilton et al. 2011).

There is of course, heterogeneity within the WFH experience, particularly during the pandemic. Having children at home and having to share work spaces has results in lower family satisfaction (Möhring et al., 2020). In Australia, Craig and Churchill (2021) find that WFH resulted in a rise in domestic work burdens for all, and while females shouldered most of the extra unpaid workload, men’s childcare time increased more in relative terms, so average gender gaps narrowed. Another large Australian study found that females were more likely to adjust work arrangements to care for children, but that the COVID-19 prompted WFH experience has resulted in a greater acceptance of fathers working from home and time with family (AIFS 2020). It has also been found that during the pandemic impact of mandated working at home on pain, stress, and work-family and family-work conflict is gendered and influenced by parental obligations (Graham et al. 2021), thus any future WFH policy will still need to ensure that need to ensure that such practice does not widen gender disparity. Additionally, there are equity considerations for those workers who are not able to work from home, and thus were disproportionately exposed to greater declines in employment during the pandemic (Mongey et al. 2021).

The work environment can also be an important contributor to mental health; people with pre-existing psychological vulnerabilities are more affected by behavioural and psychosocial health risk factors linked with social isolation in the pandemic in part due to WFH (Bouziri et al. 2020). In a longitudinal analysis, Pirzadeh and Lingard (2021) highlight the importance of considering work-life satisfaction and creating opportunities for improved work-family balance when designing teleworking arrangements. Others have also found that it is crucial to develop and implement best practices for working from home to maintain a good level of productivity, achieve the right level of work and life balance and maintain a good level for physical and mental health (Okuyan and Begen 2022). Such policy should consider family-work conflict, social isolation, and distracting work environments as potential obstacles and job autonomy and self-leadership as potential enablers of WFH engagement (Galanti et al. 2021). Finally, there is also a need to better understand the safety factors that are relevant to telecommuting (Belzunegui and Erro-Garcés 2020).

Prior to the pandemic, Mas and Pallais (2017) found that applicants willingly accept an 8% income drop in exchange for the ability to work from home in a full-time job in a field trial with among call-centre job applicants. In a similar experiment in China, Bloom et al. (2015) found that when allowed to select home or office, half of employees selected to WFH which led to the gains from WFH almost doubling to 22%, highlighting the role of learning and selection effects when adopting modern management practices vis-à-vis WFH. Dutcher (2012) found that telecommuting may have a positive effect on employee productivity for creative tasks but a negative impact on dull tasks.

During the pandemic, with respect to the impacts on worker productivity, DeFilippis et al. (2020) examine data from thousands of companies and conclude that WFH comprises more (but shorter) meetings per day, more email, and longer workdays. From a productivity perspective, Emanuel and Harrington (2021) report that WFH raises productivity 8%, and Choudhury et al. (2021) show a rise in productivity of 4% as a result of a work anywhere approach. Work flexibility has also been shown to increase productivity in a large Italian firm (Angelici and Profeta 2020). In the UK it has been shown that WFH productivity is not significantly different from that of workplace productivity but does vary based on socio-economic status, industry, and occupation (Etheridge et al. 2020). On the other hand, Battiston et al. (2021) find that for emergency call centre staff, productivity is higher when teammates are in the same room, and that the effect is stronger for urgent and complex tasks. In Japan it has been found that productivity was lower for employees and firms that started WFH practice only after the spread of the COVID-19 pandemic (Morikawa 2022).

Despite the mix of experiences, it seems that increased rates of working from home will last beyond the impact of the pandemic. Other authors in Australia have found that WFH frequency may double, with intention to do so influenced by subjective norms and perceived behavioural control (Jain et al. 2022). In Belgium it has been found that as a result of increased efficiency and a lower risk of burnout, the majority surveyed (85%) believe that teleworking is here to stay (Baert et al. 2020). Barrero et al. (2021) find that, from a survey of more than 30,000 workers in the US, 20% of full workdays will be supplied from home after the pandemic ends, compared with just 5% before. They argue this increase is a function of better-than-expected WFH experiences, new investments in physical and human capital that enable WFH, greatly diminished stigma associated with WFH, lingering concerns about crowds and contagion risks, and a pandemic-driven surge in technological innovations that support WFH. The increase in WFH practices is also supported by a surge in patent applications for new technologies that better enable WFH (Bloom et al. 2021), and large shifts in regulation in professions previously thought to be not conducive to WFH (Bajowalla et al., 2020 and Webster, 2020). In assessing the impact on productivity, Barrero et al. (2021) find a 5 percent productivity boost in the post-pandemic economy due to re-optimized working arrangements, much of which is masked by savings in commute time.

There is also evidence that cities are starting to change shape as a result of this emerging trend. Using data from the US Postal Service and Zillow, Ramani and Bloom (2021) find that in dense US cities, households, businesses, and real estate demand have moved from central business districts towards lower density suburban areas, labelling the phenomenon the "Donut Effect" reflecting the movement of activity out of city centres to the suburban ring. While many have speculated that WFH might result in people moving out of a city altogether, this US study does not find evidence for large-scale movement of activity from large US cities to smaller regional cities or towns.

3 Sample Description

The data collection was conducted in GSMA_a and SEQ_a in Wave A (the start of the Delta variant lockdown in July 2021) and GSMA_b, SEQ_b and MELB_b in Wave B (in November 2021 after the lockdowns had ended in GSMA and MELB, and where SEQ lived relatively free of restriction for this four-month period). The demographics of each sample are shown in Table 1. The sample characteristics align well with those from the most recently available published Australian Bureau of Statistics census data; where we extracted data for the sample of working age population from which the sample was drawn. Although there is some gender imbalance within each sample, but over all the data the ratio of male to female is as per the population. We also note that the samples are repeated cross-sectional in nature. In analysing the data, the points of comparison over time are limited to the GSMA and SEQ regions, with the MELB data being used in discussion of Wave B results to provide another lens on the WFH experience, given their sustained working from home experience.

TABLE 1: Sample Characteristics

		GSMA_a	SEQ_a	GSMA_b	SEQ_b	MELB_b	ABS (2016)
	Sample Size	*387*	*329*	*340*	*387*	*208*	---
Age	Mean	45.1	44.3	44.6	40.9	40.7	42.9
	Stdev	13.5	14.7	14.7	13.7	13.9	14
Gender	Female	59%	52%	52%	65%	33%	50%
	Male	41%	48%	48%	35%	67%	50%
Income	Ave ($'000)	90.1	89.3	85.6	84.9	91.3	90.8
	Stdev	60.8	56.0	62.3	59.7	65.3	---
Children	Yes	63%	67%	61%	57%	66%	60%
	Ave (if yes)	1.7	1.8	1.5	1.6	1.4	1.8
Vehicle Access	Have a license	90%	88%	86%	89%	88%	90%
	Own a motor vehicle	94%	98%	92%	98%	94%	93%
Occupation	Manager	17%	19%	21%	19%	18%	13%
	Professional	28%	27%	29%	29%	30%	22%
	Technician and trades	4%	7%	6%	7%	6%	14%
	Community and personal services	9%	7%	8%	9%	9%	11%
	Clerical and administration	26%	23%	18%	21%	17%	14%
	Sales	8%	8%	8%	9%	9%	9%
	Machine operators and drivers	3%	3%	3%	3%	5%	6%
	Labourers	4%	5%	7%	3%	6%	10%

4 Descriptive Analysis

4.1 Extent of Working from Home

As expected, in both the GSMA and SEQ, working from home in the week prior to the lockdown was significantly lower than at the start of the lockdown and at the end. The average in both areas was approximately one day per worker per week (3 days per week among those able to WFH). After the first week of the lockdown (_a) the number of days rose significantly in both jurisdictions, to an average of two days per week (just under 4 days per week among those able to WFH). In Wave B, after the lockdown had ended, WFH in SEQ had returned to be the same as prior to the lockdown in terms of the average number days, while in the GSMA rates of WFH were lower than at the start of the lockdown (averaging 1.5 days per week among all workers, 3 days per week among those able to WFH), days WFH were in the GSMA_b were significantly higher on average than SEQ_b. In MELB_b the average of 2 days per week per worker (and 4 days per week among those able to WFH) was significantly higher than both GSMA_b and SEQ_b.

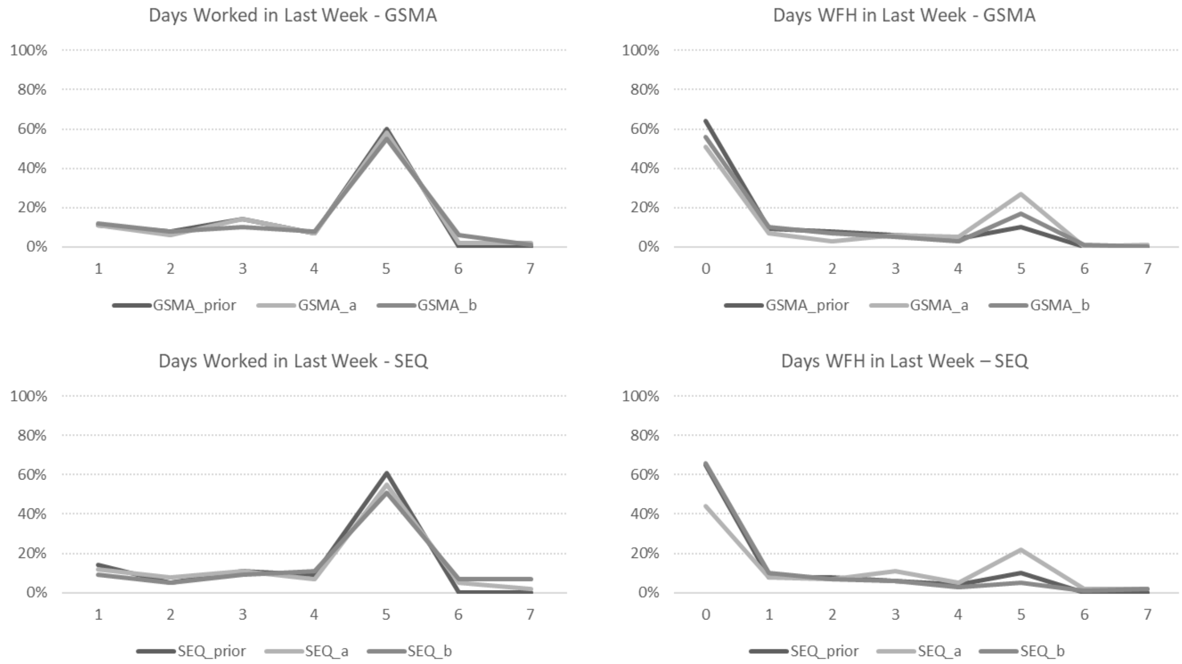


FIGURE 2: The Distribution of Days Working and Working from Home

Figure 3 shows how WFH behaviour was distributed over the days of the week; and as can be seen for all jurisdictions, it is spread evenly from Monday to Friday, and that the rates of WFH were highest in MELB_b, high in GSMA_b, and lowest in SEQ_b (where rates of WFH were identically distributed to what was occurring prior to the lockdowns occurring)[61]. Overall, this evidence supports the logical *a priori* assumption that the extended lockdown created higher sustained rates of WFH in the most affected regions of GSMA and MELB, and the short sharp lockdowns in SEQ only generated short-term impacts on the rates of WFH that disappeared over the data collection period.

[61] Care must be taken in comparing the evidence in Figure 2 with that in Figure 3. Figure 2 is the profile of days WFH in the last week, whereas Figure 3 refers to the incidence of WFH on each day and that an individual may WFH on more than one day over the week.

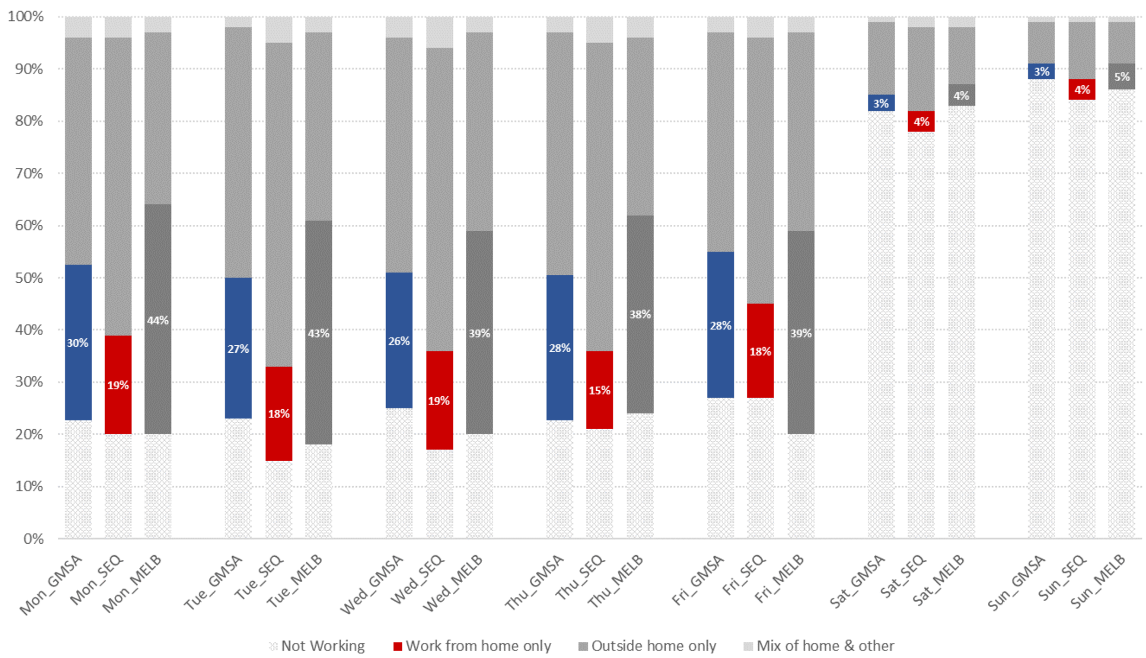


FIGURE 3: Distribution of WFH by Day of Week – Wave B

4.2 Impact on Productivity

Respondents were asked to evaluate their productivity while working from home relative to their "normal" work location in the periods where there are no restrictions or lockdowns on a 1 (a lot less productive) to 5 (a lot more productive) scale. Across these scale items, there was very little difference in the distribution of responses from Wave A to Wave B[62]; the distributions also match those from previous findings that productivity has remained robust among those WFH since the start of the pandemic. This is indeed emphasised when looking at the average responses across these scale items, shown in Figure 4. Except for SEQ_a, all locations report an average that is significantly higher than "about the same" level of productivity, indicating that, in aggregate, employees view themselves as being just as productive (if not more so) while working from home[63]. Indeed, there is no difference in any average reported level of productivity over time and across regions, leading to the conclusion that WFH experiences have been uniformly robust despite the differing lockdown circumstances and durations over which WFH has been completed.

The responses from employees may suggest a view of their own productivity through a biased prism; as such we also collected data in Wave B of the perceptions of employee productivity from individuals who employ or manage staff[64]. Figure 5 shows the average productivity reported by the employer respondents and shows that those in charge of staff view the productivity of those staff, as well as the overall productivity of the business, to be slightly positively improved as a result of increased WFH by those staff who are required to do so[65].

[62] These results can be provided upon request.
[63] This finding has been found in many studies of which a recent summary is given in https://www.apollotechnical.com/working-from-home-productivity-statistics and https://www.hrmonline.com.au/productivity/productive-working-from-home/
[64] Sample size of managers/employers: GSMA_b = 60, SEQ_b = 76, MELB_b = 39.
[65] We also have evidence that suggests that although some organisations may have experienced reduce productivity during this period, it is not to do with the performance of employees but to do with other constraints such as reduced activities of individuals and other organisations that an employer trades with.

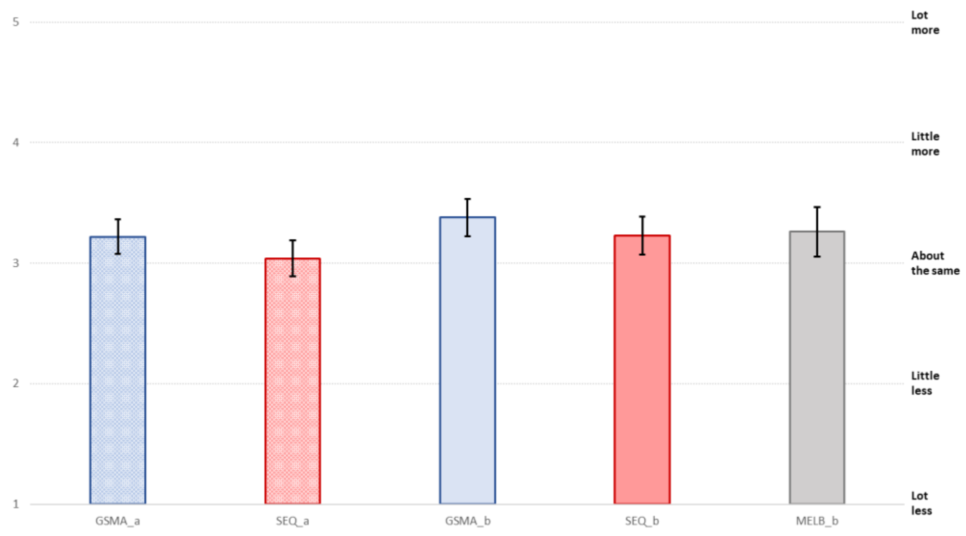


FIGURE 4: Relative WFH Productivity (with 95% Confidence Intervals)

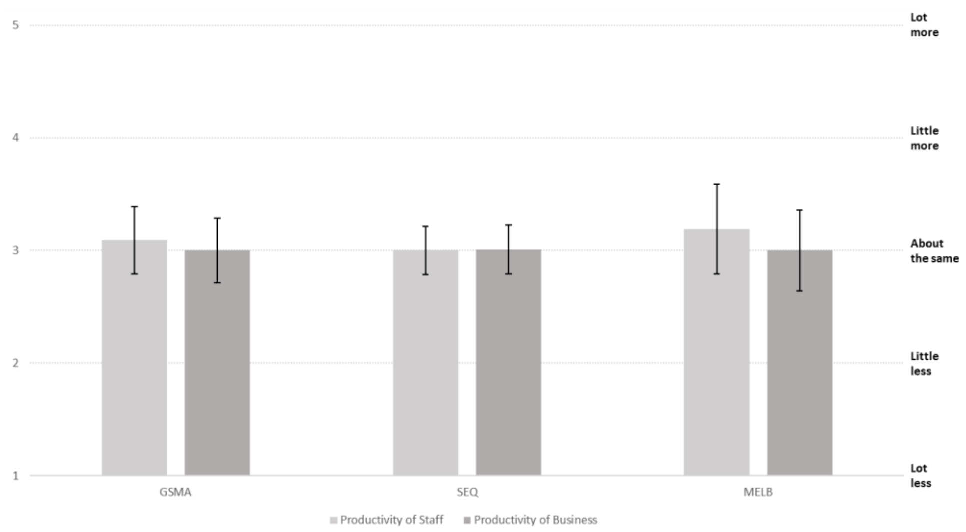


FIGURE 5: Managers/Employers Assessment of Staff and Business Productivity – Wave B Only (with 95% Confidence Intervals)

4.3 Attitudes towards Working from Home

Much like the perspectives on perceived productivity, attitudes towards working from home remained robustly positive in both GSMA and SEQ. Figure 5 shows the average responses for Wave A and Wave B to each of the nine attitudinal statements regarding the WFH experience. In both regions, there are no significant differences in any attitude between the two waves: with all regions displaying average significant levels of agreement with all statements. Figure 6 shows the average scores for the Wave B data. Generally, attitudes in SEQ are more favourable, which makes sense given that after four months of almost no restrictions, those who WFH are likely choosing to do so. Attitudes are generally lower in MELB; logical given the long duration of lockdowns experienced since the start of the pandemic and the potential monotony therein. It is interesting to note that the biggest difference is in the ability to find a balance between paid/unpaid work, and work/not working, suggesting there is some preliminary evidence that longer periods of WFH might disrupt the ability for a person to find that balance. It is important to note that any differences observed are not statistically significant. This, combined with the stability in perceived productivity, suggests that WFH has a robustly positive experience, irrespective of there being no lockdowns versus lockdowns and the duration of thereof.

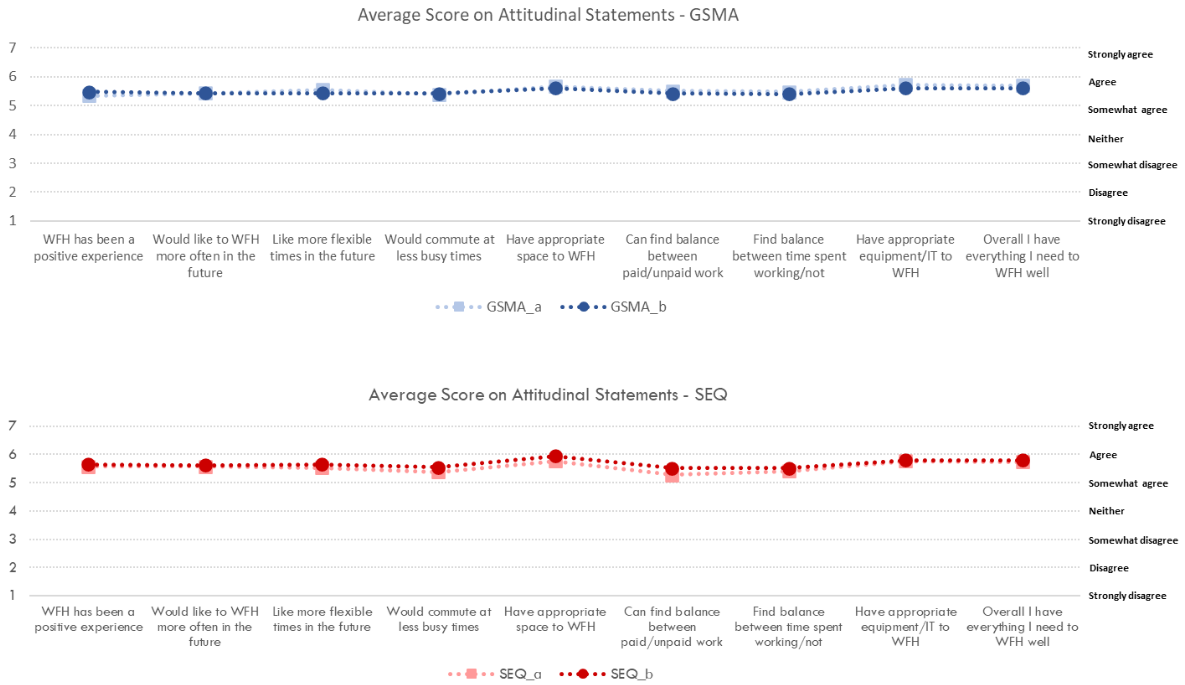


FIGURE 5: Average Agreement with Work from Home Statements by Region and Wave

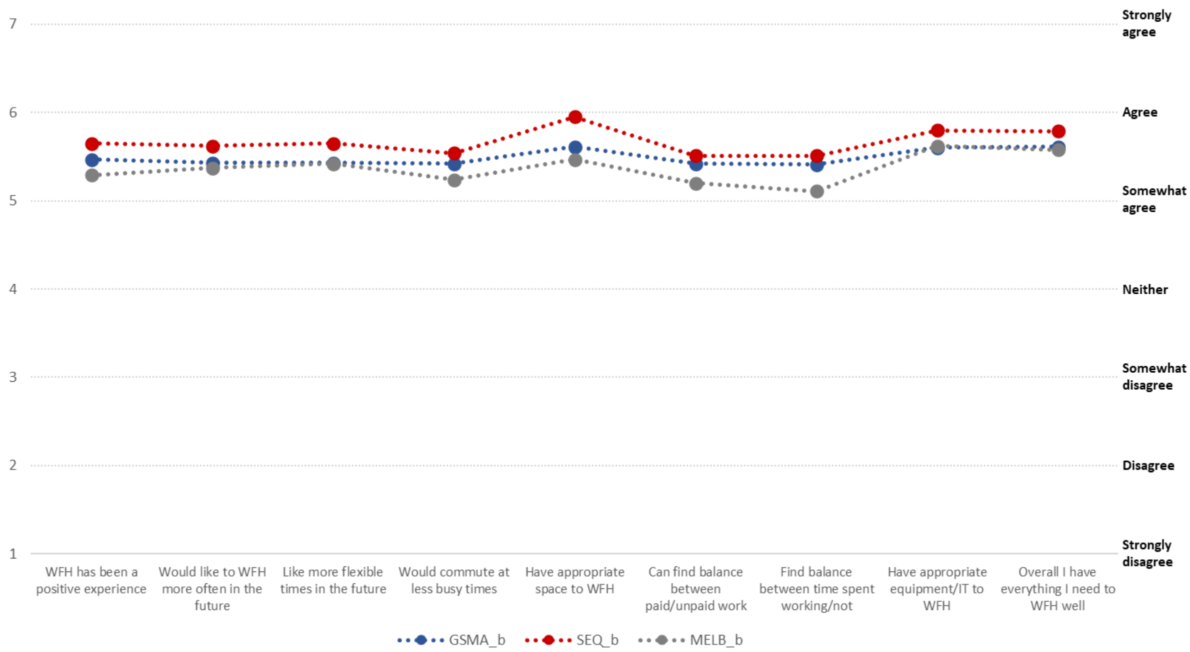
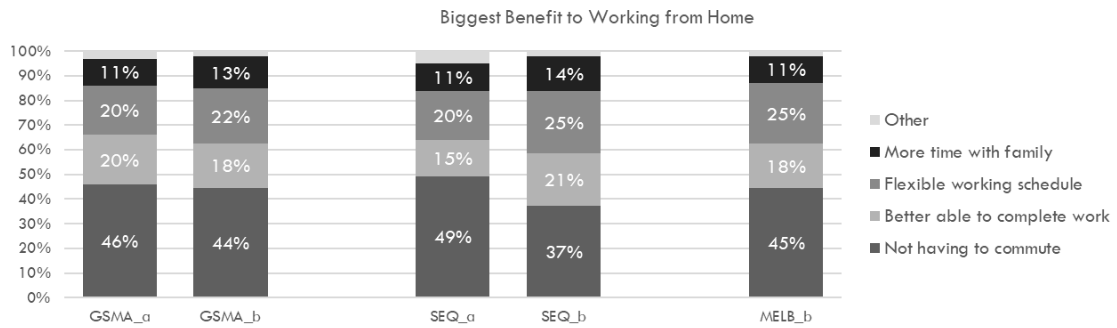


FIGURE 6: Average Agreement with Work from Home Statements – Wave B Only

4.4 Benefits and Challenges of Working from Home

Figure 7 shows the benefits and challenges of working from home by region and wave. With respect to the benefits, not having to commute remains the most important benefit over time and across regions. Interestingly, there is some variation over time in SEQ where after four months of relative freedom, the ability to better complete work and the benefit of a more flexible work become the most important benefits for a greater number of people. Again, this may be linked to the fact that those who WFH in SEQ were doing so by choice, likely because it works best for them. Interestingly in Sydney, after the four-month lockdown ended, there was a big jump in the number of people who felt that the ability to concentrate on work was the biggest challenge associated with WFH; perhaps a function of people in the GSMA having relative freedoms for a long period of time before being placed in a lockdown that ended up being longer than first expected. In other areas, the challenges remain largely consistent. Previous published work has shown that the majority of time saved from not commuting in allocated to family/household activities (the rest to additional work). In Wave B the GSMA allocates an average of 48% to leisure activities plus household tasks; for the SEQ that averages is 49%; and MELB the average is 55%.



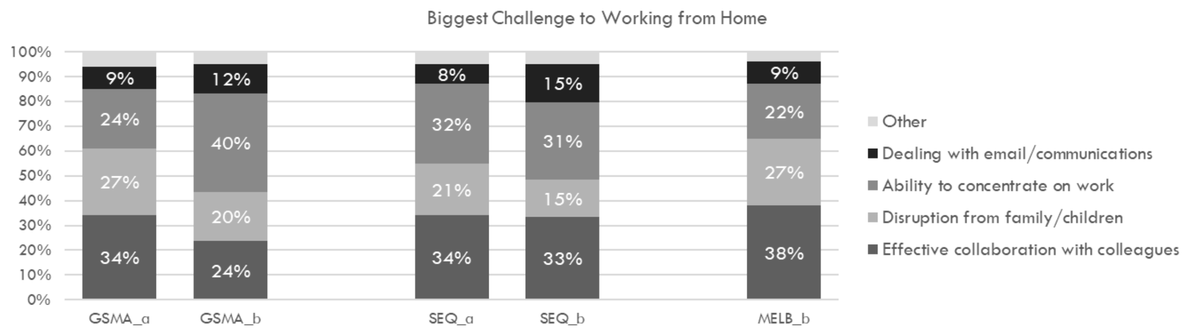


FIGURE 7: Benefits and Challenges of Working from Home

4.5 Risk of COVID-19 in the Workplace

Figure 8 shows the changes in concern about COVID-19 and the workplace. There was no significant change in perceived risk from GSMA_a to GSMA_b, nor from SEQ_a to SEQ_b, but concern in SEQ_b is significantly lower than the other regions at the same point in time. This is a logical finding given the differences in case numbers over the time horizon. It is interesting to note that concern is not high in any region at any point in time, indicating that the desire to WFH is not linked to a concern about COVID in a compelling way.

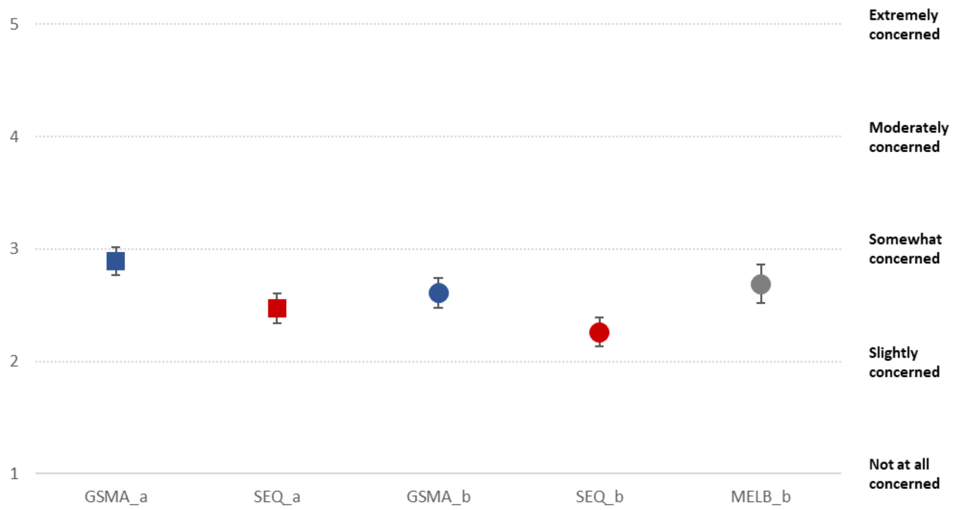


FIGURE 8: Concern about COVID-19 in the non-Home Workplace – Wave B Only

4.6 Future Working from Home Intentions

Given the degree of consistency in WFH measures, despite the varying extent and duration of lockdowns witnessed in the GSMA, SEQ and MELB regions in the second half of 2021, it is interesting looking at differences that may (or may not) exist with regards towards WFH in the future. Figure 10 shows that despite the duration of time spent in lockdown, 56% of MELB respondents would like to continue to have at least one day a week working from home, compared to 47% in the GSMA and 40% in SEQ. It may be that those in MELB have now established new habits that allow them to WFH well, and thus enjoy the benefits more fully. Figure 10 shows how respondents would like to allocate their days spent working from home over the week. The distribution of WFH is stable over the week in each location and matches the current (Wave B) levels, except for Victoria where the Wave B levels of WFH contract to essentially match those observed in GSMA.

Among those workers who want to work from home, the average number of days desired in the GSMA is 3.5 per week (resulting in a desire to complete 66% of their work from home; and an average of 1.7 WFH days among all workers), compared to 3.3 in MELB (61% of their working days completed at home; and an average of 1.8 among all workers surveyed). These two regions exhibited a significantly higher daily average than the 2.9 days that is desired in SEQ (55% of days worked done from home; an average of 1.1 days WFH per week among all workers).

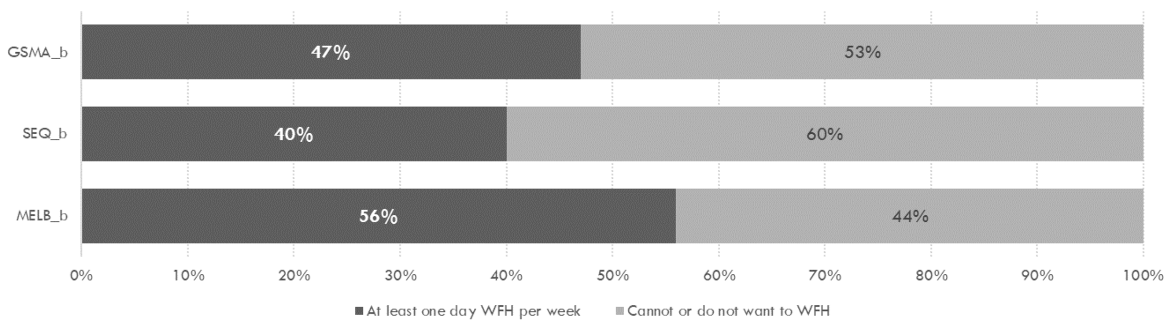


FIGURE 9: Proportion of Workers Who Want to Work from Home in the Future (no restrictions)

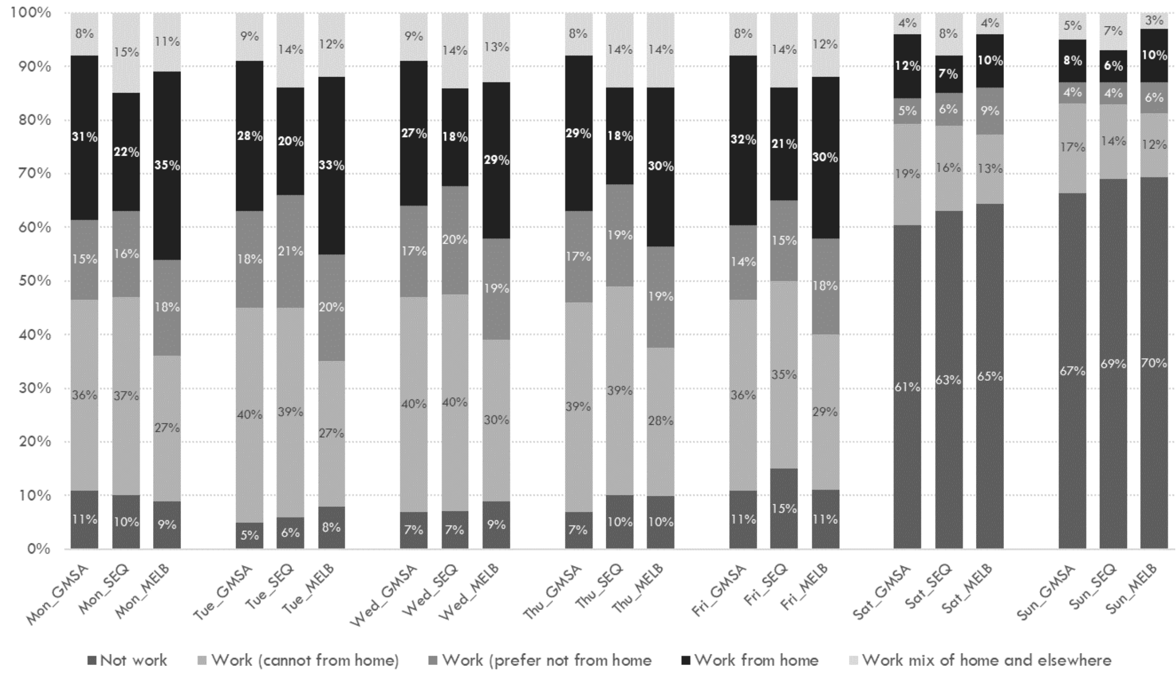


FIGURE 10: Work Location by Day of Week in Future (no restrictions)

In terms of what might motivate workers to return to the regular workplace (Figure 11), collegiate interaction and the work setup seem to be most persuasive. In all jurisdictions, attitudes towards the workplace in being able to create better collaboration, enjoyment of the social environment, and the ability to have face to face discussions, all exhibit average responses that are significantly higher than moderate importance, as does the regular workplace creating an ability to separate home from work, work more effective, and a provide a better working space. While there is some degree of importance placed on these attributes of the workplace, the importance is not high, indicating that these are perhaps nice to have rather than “have to have” in order to complete work successfully. It should also be noted that once again, there are no significant differences in attitudes across the three locations, despite the different lockdown durations. This might suggest that some amount of resilience has been established that is linked to the revised preferences of employees, supported by employers, to WFH to some extent.

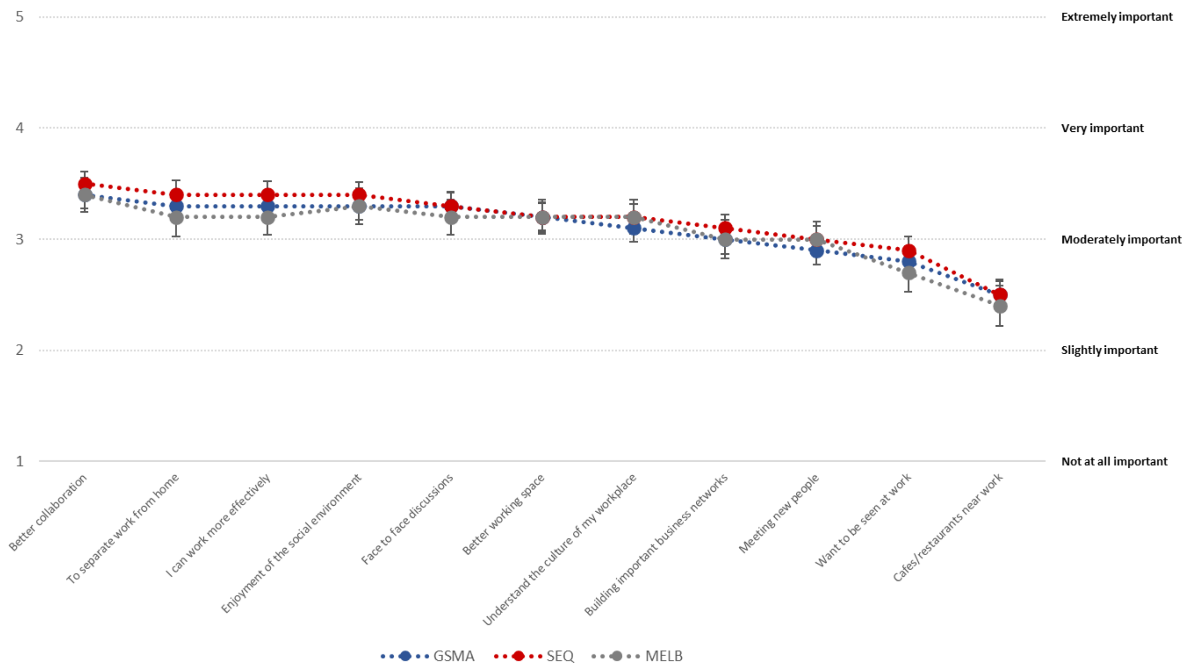


FIGURE 11: Reasons to Return to the Office (no restrictions)

5 Work from Home "User" Segmentation

To better understand the differences that might exist across the three regions and lockdown experiences, we used cluster analysis to identify similarity patterns. Initially we undertook the analysis for each region and each time-period, but as per the results discussed in previous sections, the results were not differentiated from each other, suggesting that while segments of workers with different WFH attitudes existed, they did not differ by state or by the different lockdown conditions experienced therein[66]. As such, the analysis was completed on data where all respondents from Wave B were pooled into a single data set for analysis. This decision is supported by the fact that, in the following analysis, worker segments are not distinguished by geographic location (and thus lockdown experiences).

5.1 Drivers of Work from Home Attitudes

To identify the latent constructs driving attitudes towards the WFH experience, a factor analysis on the attitudinal statements (presented in Figure 5 and 6) was undertaken. The factor loadings presented in Table 2 show a strong link between the responses split across two factors. The Kaiser-Meyer-Olkin measure of sampling adequacy of 0.890 indicates that factor analysis on the data is highly appropriate and the Bartlett's Test of Sphericity ($\chi 2$ = 2892.12, d.f. = 36, sig. = 0.000) shows that the underlying correlation matrix is not an identify matrix. The grouping of attitudinal statements on each factor suggest that the two latent attitudinal constructs exist for WFH evaluated through the perspective of "*Balance and Facilities*" and "*Flexibility and Time Saved*". The overall evaluation of WFH and the desire for more WFH in the future are positively linked to both constructs, though more strongly with "*Balance and Facilities*".

[66] The region and time-period specific analysis can be provided on request.

Table 2: Factor Loadings – Work from Home Attitudes

	Balance and Space	Flexibility and Time Saved
WFH has been a positive experience	**0.636**	0.500
Would like to WFH more often in the future	**0.613**	0.553
Like more flexible times in the future	0.272	**0.853**
Would commute at less busy times	0.166	**0.862**
Have appropriate space to WFH	**0.812**	0.260
Can find balance between paid/unpaid work	**0.821**	0.237
Find balance between time spent working/not	**0.832**	0.124
Have appropriate equipment/IT to WFH	**0.810**	0.293
Overall I have everything I need to WFH well	**0.803**	0.310

5.2 Identifying Working from Home Worker Segments

Factor scores were estimated using the regression method (with the measures of attitudinal strength relative to the mean of the latent construct rather than an absolute measure) and were then used as inputs into K-means clustering to identify different segments/clusters of workers who differed in their attitudes towards working from home. Ultimately a three-cluster solution provided the largest number of clusters while still retaining statistical significance between the average factor scores for each latent construct[67].

Figure 12 shows the average factor score for each of the latent constructs within each cluster. The actor scores themselves have no absolute value, rather they are relative scores (i.e., a negative value does not indicate a negative underlying attitudinal, rather it is lower than respondents in other clusters). The first cluster (16% of workers allocated to this segment), termed "*Great Balance, Less Time*" contains workers who have relatively more positive attitudes towards their ability to find balance while WFH and the facilities they have to undertake WFH, but have the lowest perception of the time they are saving by WFH. The second cluster (accounting for 31% of workers) is termed "*Less Balance, Lower Time*" given they have the lowest relative attitudes towards their ability to find balance and the quality of their WFH space and have lower relative attitudes towards they time they are saving by WFH or having better work flexibility. The last cluster has relatively positive attitudes towards being able to find a balance while WFH and view the time savings from WFH and the greater flexibility very positively; as such this cluster is termed "*Good Balance, More Time*" (and is the largest segment with 53% of workers allocated).

[67] *Balance and Facilities* (F = 310.689, Sig 0.000); *Flexibility and Time Saved* (F = 294.289, sig. = 0.000).

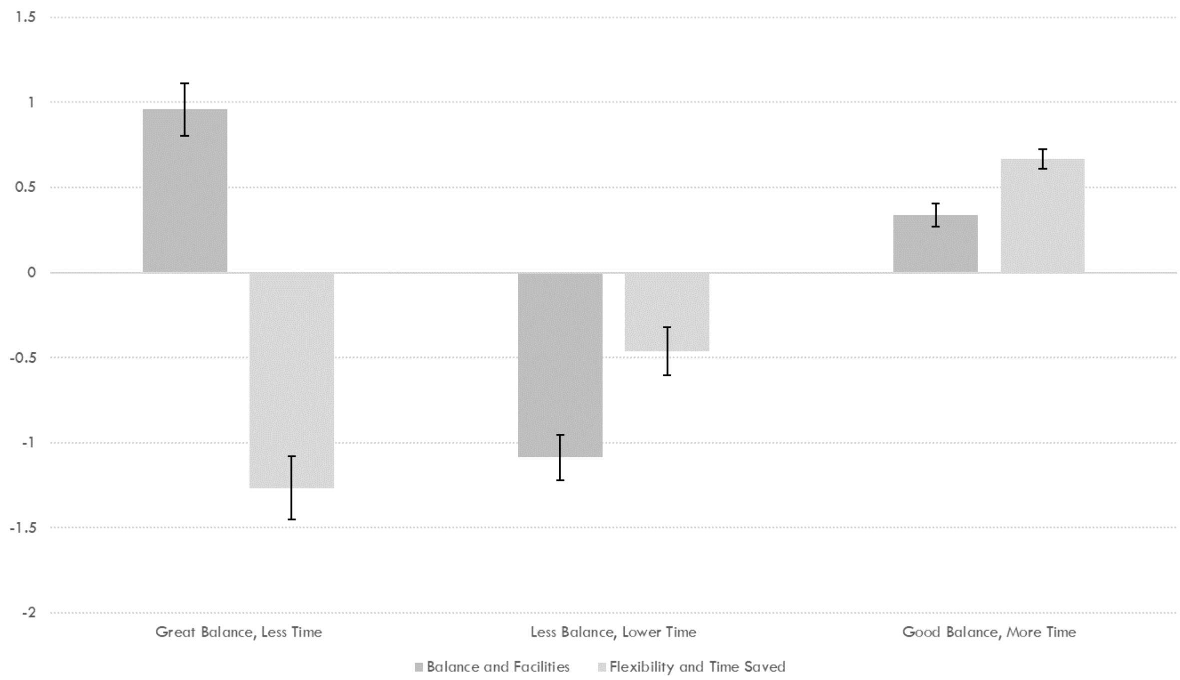


FIGURE 12: Defining Worker Segments by Underlying Work from Home Attitudes

Once the segments were established, the characteristics of the workers allocated to each segment were analysed to further understand what other variables may be driving the differences between the clusters. Table 3 presents the results of this analysis, where sociodemographic, current work from home behaviours, future work from home intentions, and wider attitudes about COVID-19 were examined. For several of the attitudinal variables, exploratory factor analysis was used to reduce the number of variables down to the underlying latent constructs driving the observed responses (thus reduce the number of variables from 48 to 10). The results of the factor analysis for each of the set of attitudinal statements used in defining the clusters are summarised in Table A1 in the appendix.

5.3 Describing the Working from Home Segments

When looking at Table 3 and the variables which differ significantly between clusters it is interesting to see how attitudes are the predominant differentiators, with only a relatively small number of socio-demographics being significant. All segments have similar composition of region, gender, income and largely the mix of occupations are quite similar. In terms of describing the segments:

Great Balance, Less Time: This segment has respondents who are older on average. They spend the most days WFH in the last week, and report their perceived productivity while WFH to be about the same as their "normal" place of work. They reallocate a significantly higher proportion of commuting time saved towards leisure/family activities (perhaps explaining why they can find the most balance between work and life), have relatively less positive attitudes towards returning to the office, want to maintain a high number of days spent working from home when there are no more restrictions (which translates into a large proportion of work being done from home). They exhibit moderate attitudes towards the impact of COVID-19 and the response by wider institutions; and are relatively positive in terms of the local institution response and the trust in governments to respond to COVID-19 moving forward. The relatively more comfortable completing essential day to day activities and report the highest relative subject wellbeing measure.

TABLE 3: Describing the Work from Home Segments

		Great Balance, Less Time	**Less Balance, Lower Time**	**Good Balance, More Time**		
	Sample Size	*75*	*141*	*240*	**Chi / F**	**sig.**
Region	GMSA	13%	37%	50%	6.714	0.152
	SEQ	18%	25%	57%		
	MELB	19%	31%	51%		
Age	Mean	**48.2**	38.5	40.8	**13.731**	**0.000**
	Stdev	15.1	13.8	11.9		
Gender	Female	49%	50%	51%	0.083	0.959
	Male	51%	50%	49%		
Income	Ave ($'000)	98	105.6	100.7	0.371	0.690
	Stdev	70.7	72.9	62.6		
Children	Yes	33%	38%	**48%**	12.388	0.054
Vehicle Access	Have a license	87%	**73%**	92%	5.892	0.053
	Own a motor vehicle	96%	**87%**	96%	**12.718**	**0.002**
Occupation	Manager	27%	**20%**	28%	**26.373**	**0.023**
	Professional	35%	37%	31%		
	Technician and trades	1%	**9%**	4%		
	Community and personal services	4%	4%	6%		
	Clerical and administration	27%	**16%**	23%		
	Sales	5%	9%	7%		
	Machine operators	1%	1%	0%		
	Labourers	0%	5%	0%		
Work from Home	Days of work	4.7	4.2	4.2	2.969	0.052
	Days WFH	**3.4**	2.7	2.9	**3.459**	**0.032**
	Proportion of work that is currently WFH	72%	**63%**	69%	1.506	0.223
	WFH productivity	3.1	**2.7**	**3.7**	**44.496**	**0.000**
	Days wanting to work in the future	5.3	5.3	5.1	1.637	0.196
	Days wanting to WFH in the future	3.0	**2.1**	2.8	**6.834**	**0.001**
	Proportion of work that is WFH in the future	56%	**39%**	55%	**9.123**	**0.000**
	Hours saved per week by not commuting	8.5	8.1	11.2	2.710	0.068
	Prop. of time reallocated to paid extra work	12%	**26%**	17%	5.897	0.003
	Prop. of time reallocated to unpaid extra work	23%	27%	**36%**	4.421	0.013
	Prop. of time reallocated to family/leisure activities	**66%**	47%	47%	6.678	0.001
Attitudes	Concern about public transport hygiene	2.6	2.7	**3.2**	**8.492**	**0.000**
	Concern about public transport crowding	2.8	2.8	**3.2**	**4.469**	**0.012**
	Concern about COVID-19 in the workplace	2.0	2.4	**2.7**	**8.696**	**0.000**
	Reasons to Return to the Office (factor)	**-0.555**	**0.051**	**-0.093**	**9.378**	**0.000**
	COVID-19 Impact & Wider Response (factor)	**-0.042**	**-0.111**	**0.203**	**5.061**	**0.007**
	Local Response & Trust Governments (factor)	**0.156**	**-0.296**	**0.078**	**8.515**	**0.000**
	Leisure Activity Comfort (factor)	-0.052	0.061	0.055	0.385	0.681
	Essential Activity Comfort (factor)	**0.247**	**-0.396**	**0.129**	**18.103**	**0.000**
	COVID-19 Risk Perception (factor)	-0.125	-0.101	0.063	1.863	0.156
	Subjective Wellbeing (factor)	**0.390**	**-0.274**	**0.177**	**15.398**	**0.000**

Less Balance, Lower Time: workers in this segment are less likely to have a license or own a motor vehicle, more likely to be blue collar workers (technician and trades, machine operators, labourers), and to reallocate more of their saved commuting time to extra paid work relative to the other segments. This group has the most positive relative attitudes towards a return to the office, having the lowest relative attitudes towards the impact of COVID-19 and the results of various institutions to the pandemic, are relatively less comfortable completing essential day to day activities, and report the lowest relative subjective wellbeing outcomes. While significantly lower than other segments, they still want to complete a high proportion of their work from home, with 39% of work being completed from the home location. They do, however, have the lowest average rating of their productivity while working from home.

Good Balance, More Time: Interestingly, workers in this segment are more likely to have children than those in other segments but have the highest average rating of their productivity while WFH relative to their normal work location. They want to maintain at least half of their work being doing from home as we move towards an environment with no restrictions. They have the largest average amount of time saved per week by not commuting (at the 10% level), which they are more likely to reallocate towards unpaid extra work compared to those in other segments. They have the highest average levels of concern about COVID-19 in the workplace, the hygiene of public transport, and the crowding levels on public transport. They have relatively moderate attitudes towards the benefits of returning to the office, relatively greater attitude towards the impact of COVID-19 and the response required. They express relatively moderate comfort in completing essential day to day activities and have relatively moderate subjective wellbeing.

6 Discussion

In this paper, using repeated cross-sectional data, we have examined the impact that differing lockdown trajectories across three jurisdictions have had on the working from home experience and attitudes thereof. In the GSMA, we have a region that had experienced sixth months of relatively minimal restrictions before entering a lockdown that was meant to be short, but ended up lasting 107 days. SEQ had also experienced a long period of time with minimal restrictions, and at the same time as the GSMA they entered a lockdown that only lasted for a very short period with the region very quickly returning to “normal”. Lastly, there is MELB which had experienced a preceding 12 months marked by extended lockdowns, and shortly after regaining most of their freedom, they found themselves back in a lockdown that went for another 78 days.

Despite these radically different experiences, the perspectives towards working from home in each jurisdiction are statistically unchanged. Relative productivity in each region remained equally robust, with perspectives of business and staff productivity being about the same as prior to the pandemic (if nore slightly more productive) over both the time period and the locations examined. Attitudes towards the work from home experience also remain statistically the same after the lockdowns as before, and statistically the same across the three locations examined. In Wave B data workers attitudes were equally positive in the GSMA, SEQ and MELB despite their different experiences with the extent of WFH that had occurred over the previous four months. In fact, rather than lockdowns diminishing the desire to work from home, it appears that the most recent lockdown experiences in the GSMA and MELB have only strengthened the desire to spend more time working from home as we move into a world where we live with COVID-19 with minimal restrictions on movement and where work is done. Indeed, in MELB, the region most affected by lockdowns overall, there is a greater propensity to want to work from home than in the other two locations.

In November of 2021 the NSW State Government announced that no further restrictions on movement would apply, given the penetration rate of double vaccinations within the community (> 90% of the eligible population has received two doses at that time). Not long after a new variant of Omicron started circulating; this variant ended up being the most contagious till that point in the pandemic, and very quickly NSW reporting case numbers that exceed 20,000 new cases a day (prior to this the maximum number of cases was just shy of 1,500). The Government urged citizens to assume personal responsibility when it came to protecting themselves from the virus, which resulted in a widespread voluntary (or shadow) lockdown[68]. The fact that workers were quick to return to working from home, and their employers supported such actions, is further evidence that in Australia, WFH has continued to work.

In aggregate, those who currently WFH have found the experience to be overall positive and want to continue to do so to some extent moving into the future, despite differences around the relative positivity of the experience. We identified three distinct segments that differ by their attitude towards the WFH experience. These segments are not strongly defined by their individual characteristics, nor their job, nor the region where they live (and thus the nature of the lockdowns they have experienced). Rather, attitudes are the key differentiators between the segments.

While all segments want to continue to WFH, they differ in the extent to which they wish to do so. The *Less Balance, Lower Time* segment appears to represent workers who value some aspects of working from home, but also like the office environment, and are likely to find the hybrid approach to work to lend itself to better work productivity. The *Great Balance, Less Time* segment exhibit less of a desire to return to the office, are equally productive while working from home, their overall higher subjective wellbeing and their reallocation of time to family/leisure likely makes them happiest. The *Good Balance, More Time* segment have clearly enjoyed the WFH experience. They appear to value the relatively large amount of time saved by not commuting (11 hours per week on average) and use that saving to spend a little more time working, which may explain why they feel they are more productive while they WFH relative to their normal place of work. Despite the extra time spent working, they can still find the balance required to make this a positive experience and would like to continue the WFH arrangement moving forward to a greater extent relative to other segments. Workers in this segment do seem to have a greater acknowledgment of the impact of COVID-19 and the need to respond accordingly and exhibit more concern about COVID-19 as it pertains to public transport and the workplace (but do not view COVID-19 itself to be more of a risk than those in other segments).

What is interesting, however, is that the two segments with the most the most positive towards WFH in the future (*Great Balance, Less Time* and *Good Balance, More Time*) and want to complete a higher proportion of days worked from home, both share the ability to find a relatively better balance and have relatively better facilities to empower working from home. Moving forward, this suggests that equipping staff with appropriate technology is important, with provision of WFH technology infrastructure seen equally important as a potential investment in the transportation network, and workers should be encouraged to develop ways to better separate work from home life while working from home in order to make the experience more rewarding. Interestingly, most workers in the most positive segment of the three, *Good Balance, More Time*, are more likely to have children, emphasising how WFH

[68] https://www.smh.com.au/politics/nsw/treading-water-small-business-welcomes-overdue-support-20220130-p59sbu.html

could be a positive for those with families rather than families being a distraction for those WFH. This has important, and positive, societal implications.

This paper presents clear evidence that as the pandemic continues to disrupt work and activity, the work from home experience remains robustly positive despite extreme lockdowns that many workers have experienced. If anything, the desire to WFH seems to become greater as the WFH experience intensifies. One possible explanation for this is that those working from home can use the extended experience to form habits and norms that are more conducive to WFH and that the benefits of saved commuting time and better flexibility are accumulated in significantly greater quantities. Equally, there may also be some cognitive dissonance in that as WFH intensifies during lockdowns, attitudes shift so that those who WFH, to a large extent, can feel like they enjoy the experience. We acknowledge that the repeated cross-sectional nature of the data does not allow us to answer this question as fully as a time series panel dataset; we encourage future research to explore these types of effects, although since we started collecting data (March 2020 to December 2021), there is a strong sense of what the emerging / next normal might look like.

7 Conclusion

Overall, working from home has worked for many, especially employees in occupations where on-site activity is not essential. There are limited socio-demographic differences that have emerged in our analysis thus far, which highlights just how widespread disruption has been. However, this does not mean that such differences or inequalities will not arise or become embedded in the future. This is something the transport community, and indeed social scientists more broadly, need to be keenly aware of so that income or social exclusion inequalities are not further embedded, or that policies implemented do not rise to new forms of inequality (such as technology accessibility or digital literacy for example) (Stanley et al., 2021). WFH does tend to favour higher income, white collar workers, in particular males.; equally however, outside of lockdowns we are seeing that WFH allows some women (who still shoulder most of the household work) to re-enter the workforce, given that work has the potential to be more flexible. We do note in this paper that WFH attitudes did not differ by gender, but that any future WFH policy should consider equity and balance through many lenses gender included.

This paper builds on previous evidence that working from home will be a bigger part of the commuting mix moving forward. Since the start of the pandemic we have been tracking perspectives of productivity from both the employee and the employer side, and such perceptions have remained robust (Beck and Hensher 2022a,b). Indeed, the Productivity Commission (Federal government agency) has recently declared that working from home in Australia has been so successful that the 5-day in the office working week is no more (PC 2021). We will continue to track this moving forward as embracing WFH will likely be more widespread than other countries such as the US or the UK. Highlighting this, we present new evidence that while one might expect that enthusiasm would dampen because of extreme lockdowns, this *a priori* expectation is far from being confirmed. COVID-19 has been a crippling event in many ways to travel behaviour and the impact it has on urban travel, but WFH has the potential to be an unintended positive consequence of the widespread disruption, and if embedded by business and government into the working week in an intelligent way, can be the biggest transport policy lever the sector has seen for at least since the internal combustion engine and mass manufacturing delivered affordable cars, and through commuting time savings result in higher productivity and better work-life balance.

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Appendix Paper

Table A1: Factor Analysis Results on Attitudinal Questions

Attitudes towards COVID-19 Impact and Response	KMO Statistic	0.88
Bartlett's Test of Sphericity	Approx. Chi-Square	6967.79
	df	78
	Sig.	0.00
	COVID-19 Impact and Wider Response	*Local Response and Trust Governments*
Appropriate self-isolation to combat COVID-19	-0.048	**0.631**
Federal government response has been appropriate	**0.612**	0.342
Appropriate social distancing to combat COVID-19	0.534	0.531
Trust other people to respond in the future	**0.685**	0.394
Wider community response has been appropriate	**0.758**	0.245
Trust governments to respond in the future	0.204	**0.839**
State government response has been appropriate	0.247	**0.834**
Business response has been appropriate	**0.783**	-0.01
Trust business to respond in the future	**0.798**	0.013
Go to work from time to time (social isolation)	**0.711**	0.402
Combatting COVID-19 requires drastic measures	**0.796**	0.22
COVID-19 will continue to affect travel	**0.821**	0.017
COVID-19 is a serious public health concern	**0.452**	0.142
Comfort in Completing Day-to-Day Activities	KMO Statistic	0.95
Bartlett's Test of Sphericity	Approx. Chi-Square	13079.47
	df	78
	Sig.	0.000
	Leisure Activity Comfort	*Essential Activity Comfort*
Meeting with friends	0.188	**0.855**
Visiting restaurants	0.423	**0.814**
Going to the shops	0.382	**0.815**
Going to the movies	**0.635**	0.594
Going to pubs or bars	**0.682**	0.566
Gyms and exercise groups	**0.737**	0.391
Doctor's appointments	0.362	**0.736**
Professional sporting events	**0.864**	0.314
Music events	**0.891**	0.274
Live entertainment	**0.893**	0.292
Schools and/or childcare	**0.633**	0.512
Playing organised sport	**0.785**	0.391
Work functions	**0.623**	0.606

Table A1 (cont.): Factor Analysis Results on Attitudinal Questions

COVID-19 Risk Perceptions	KMO Statistic	0.78
	Approx. Chi-Square	1667.25
Bartlett's Test of Sphericity	df	6
	Sig.	0.000
Risk of COVID-19 to my health	**0.878**	
Risk of COVID-19 to health of someone I know	**0.884**	
Risk of COVID-19 to the health of the general public	**0.880**	
Risk of COVID-19 to the health of the economy	**0.573**	
Subjective Wellbeing	KMO Statistic	0.75
	Approx. Chi-Square	1749.62
Bartlett's Test of Sphericity	df	6
	Sig.	0.000
Satisfaction with life nowadays	**0.913**	
Worthwhile things done in life are	**0.898**	
Happiness felt yesterday	**0.902**	
Anxiousness felt yesterday	**-0.289**	
Reasons to Return to the Office	KMO Statistic	0.95
	Approx. Chi-Square	6660.21
Bartlett's Test of Sphericity	df	55
	Sig.	0.000
Face to face discussions	**0.759**	
Better working space	**0.757**	
Meeting new people	**0.792**	
Building important business networks	**0.789**	
Enjoyment of the social environment	**0.814**	
I can work more effectively	**0.763**	
Understand the culture of my workplace	**0.836**	
Better collaboration	**0.831**	
Want to be seen at work	**0.790**	
Cafes/restaurants near work	**0.656**	
To separate work from home	**0.732**	