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Commuting mode choice and work from home in the later stages of COVID-19: Consolidating a future focussed prediction tool to inform transport and land use planning.

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TITLE: Commuting mode choice and work from home in the later stages of COVID-19: Consolidating a future focussed prediction tool to inform transport and land use planning.

ABSTRACT: As COVID-19 slowly dissipated after 30 months since March 2020, working from home (WFH) continues to be popular, with support from notable numbers of employees and employers. With growing evidence that we have either reached, or appear to be close to, a level of WFH to some extent that might be described as an equilibrium outcome going forward, we need to update any travel behaviour response models that have been developed during the passage of the pandemic. This paper sets out a commuter model for each day of the week for the Greater Sydney Metropolitan Area as of September 2022 where the alternative responses are to not work, WFH, or commute by one of ten modes available. Given the probability of WFH obtained from a mixed logit model, we construct a mapping equation to establish the sources of statistical variance by origin and destination location that influence the incidence of WFH. The evidence is used as the basis of commenting on what this means for longer-term structural changes on network performance, the likely move to a greater focus on living locally, and the need or otherwise for employers to retain office space. A significant return to the office has recently been promoted by some employers, and we comment on this as to what it might mean for the future of a hybrid working location model.

KEY WORDS: ***Working from home, hybrid work location, commuting activity, COVID-19, mode choice model, survey data.***

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Introduction

Three years on from the spread of the outbreak of COVID-19 throughout the world, we have taken a journey that has redefined where to undertake work that is best described as cataclysmic. Working from home (WFH) or more broadly remote working (including working near home (WNH)) and now referred to as 'working anytime and anywhere', has been etched into the fabric of western society as a refreshing and productive way of conducting work while delivering greater well-being to balance of work, leisure, and family. The forced real-world 'experiment' has demonstrated that WFH, to some extent, as part of a hybrid work location model for individuals whose work does not always require face-to-face interaction, has many benefits, and has garnered notable support from both employees and employers (Hensher et al. 2022a). We have described this as a positive unintended consequence of the pandemic and has offered up possibly the greatest transport policy lever we have had for many years. To be able to change the composition of daily activities including travel in a non-marginal way by simply working from home to some extent has had a profound impact on the amount of commuting activity and a spillover to non-commuting activity, noting that much of the 'saving' in commuting time is translated into in-house activities with approximately 20% to out-of-home activities (Hensher et al. 2022b, 2023).

Since the beginning of the pandemic, we have been monitoring the changing incidence of WFH and its relationship to key performance metrics such as changes in productivity, happiness of workers including their mental health and anxiety levels, movement in modal use for commuting (notably a drop in public transport trips and an increase in car trips), support from employees and employers for WFH to some extent, plans for returning to the office in due course, and how the WFH story varies by occupation. The journey has been reported in many papers and synthesised in Hensher et al. (2023a).

In September 2022, 30 months after the beginning of the pandemic, we undertook a final survey in a series to establish the level of WFH that we anticipated would be close to what we might observe in the transition to a 'new normal'. While we will not know, without further monitoring, whether we have arrived at a rate of WFH appropriate to embed in a revised commuting model, the evidence in Figure 1 suggests that we need to revise our travel response models to accommodate the legitimate choice of WFH compared to choosing a mode for the commuting activity on each day of the working week[1].

Figure 1 shows the average number of days WFH (over a 7-day week) since the beginning of COVID-19 (March 2020) for the Greater Sydney Metropolitan Area (GSMA), a major metropolitan area in Australia. On average, the number of weekly days WFH has continued to decline, and hence there has been a growth in the return to the office. While it is not clear, however, whether we are at a point yet where we could conclude that it has stabilised as the 'new normal' hybrid model, and further surveys for a few more years might be desirable, a recent survey undertaken in March 2023 by the Institute of Transport and Logistics Studies (ITLS) as part of its Transport Opinion Survey (TOPS)[2] concluded that the March 2023 average for Australia was almost identical to the September 2022 evidence, leading us to conclude that we may have reached or are close to the levels of WFH which we can refer to as the 'next normal' and which will enable transport planners to work with in structuring future

[1] Although the focus of this paper is on the Greater Sydney Metropolitan Area (GSMA)[1], the evidence in Figure 1 is available from several locations in Australia to remind us that the incidence of WFH will vary by location and that location-specific models need to be estimated to capture this heterogeneity. See Hensher et al. (2023a)

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

infrastructure and service plans. The often-suggested metric of 1 to 2 days a week on average working from home, seems to be reinforced by almost all studies in many Western economies.

Changing incidence of the average number of days working from home between March 2020 and September 2022 (Hensher et al. 2023a).

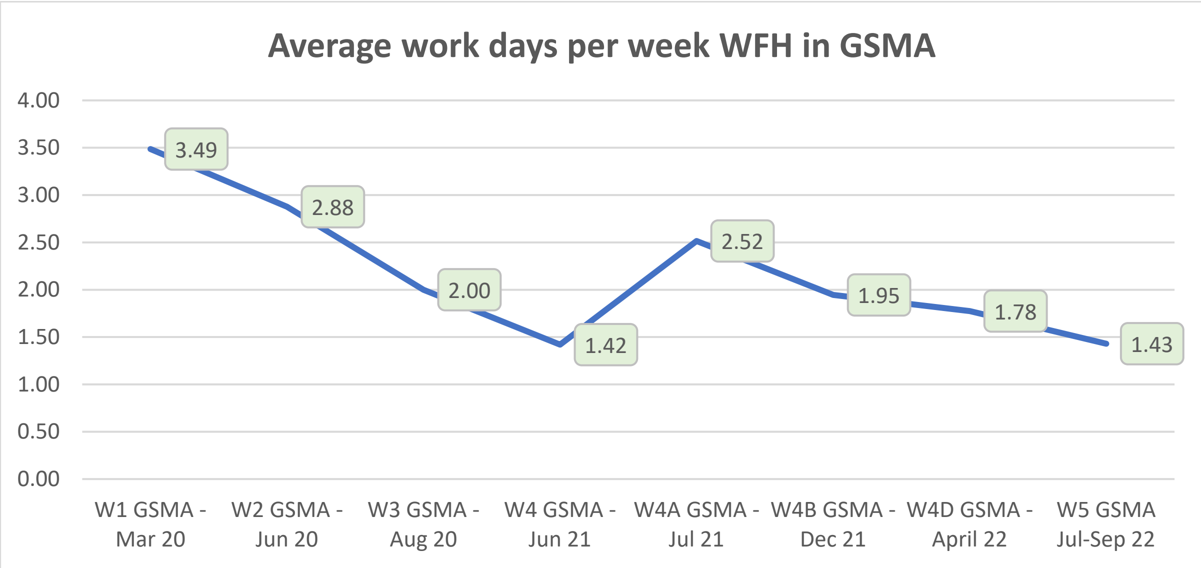


Figure 1. Changing incidence of the average number of days working from home between March 2020 and September 2022 (Hensher et al. 2023a).

The paper is structured as follows. We begin with a synthesised literature review, followed by a descriptive profile of the data collected from the September 2022 survey, and then outline the modelling approach which was informed by the need to create a tractable model form which could be intuitively, rapidly, and robustly implemented in the existing strategic transport models of the research sponsors[3]. We explain the approach undertaken to link WFH with commuting mode choice by day of week, where the alternative responses are to not work, WFH, or commute by one of 10 modes. Given the probability of WFH obtained from a mixed logit model, we construct a mapping equation to establish the sources of statistical variance by origin and destination location that influence the incidence of WFH. We interpret the evidence and conclude with what it might mean for longer-term structural change in the location of activities, but with a qualified assessment of what a growing pressure by some employers for a return to the office at least four, if not five, days a week might mean for undoing all the positive benefits of WFH under a hybrid model.

[3] We worked with industry to create reliable and robust results that could be quickly implemented in existing STM systems to help guide transport policy over the course of the pandemic. It is a very unique project where the data we collected, models we estimated, the impact they had on government forecasts, and thus ultimately policy which was guided by this analysis, was all conducted over very short time frames (especially once data was collected), and is multidimensional in that it needed to provide insight for many different kinds of policy that governments were grappling with in real time. It was an example of a project using choice models that was, REAL, timely, rapid, and very impactful.

An Overview of Key Literature

There is an extensive literature on the extent and impact of WFH since the advent of the COVID-19 pandemic. We do not plan to repeat what has been extensively documented in many papers such as OECD (2021), Beck and Hensher (2022), and Barrero et al. (2021), but it is useful to synthesise some of the evidence promoted in the broader literature.

The literature has extensively explored the impact that WFH has on workers. Mas and Pallais (2020), for example, 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 a 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 WFH (Baruch et al. 2000).

There is noticeable heterogeneity within the WFH experience, particularly during the pandemic. Having children at home and having to share workspaces has resulted in lower family satisfaction (Möhring et al., 2020), although this has changed out of lockdown (Hensher and Beck 2023). 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 was also found that during the pandemic, the 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 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 during 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.

During the pandemic, DeFilippis et al. (2020) investigate impacts on worker productivity, and examine data from thousands of companies, and conclude that WFH comprises more (but shorter) meetings per day, more emails, and longer workdays. From a productivity perspective, Emanuel and Harrington (2021) report that WFH raises productivity by 8%, and Choudhury et al. (2021) show a rise in productivity of 4% as a result of a work anywhere-anytime 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 socioeconomic status, industry, and occupation (Etheridge et al. 2020).

Despite the mix of experiences, it seems that increased rates of working from home will last beyond the impact of the pandemic, given the support from employers and employees. Other authors in Australia have found that WFH frequency may double, with the 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 WFH is here to stay (Baert et al. 2020). Barrero et al. (2021) find, from a survey of more than 30,000 workers in the US, that 20% of full workdays (i.e., 1-2 days per week) 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.

A Descriptive Profile

In this section, we have identified a number of important responses associated with WFH that are observed in September 2022 for the GSMA. A full set of results are given in Hensher (2023a). The data was collected in September 2022 through an online survey as part of a larger study in Australia to understand the influence of working from home on the transport network business performance. We have 1,285 observations (after data cleaning) for each day of the week.

Although the average number of days WFH shown in Figure 1 is informative, the incidence of WFH by day of the week is equally important since transport planners need to know if there is likely to be a spike or flatness throughout the week. Figure 2 shows the percentage of participants who WFH on each of the weekdays, with the five weekdays showing a higher WFH incidence on Monday and Friday with a lower relatively flat level on Tuesday through to Wednesday. The differences do impact on the amount of traffic on the roads and even in public transport. Most notable, however, is the significantly higher incidence of WFH for employees whose office is in the central business district (CBD) of Sydney (Figure 3). Again, Monday and Friday are much more pronounced (45.3%) in contrast to the other weekdays (32.2% to 40.9%). The higher incidence of WFH, when the main office is in the CBD, is linked to occupation and the greater ability for some occupations to WFH. White-collar professional and administrative jobs dominate the CBD.

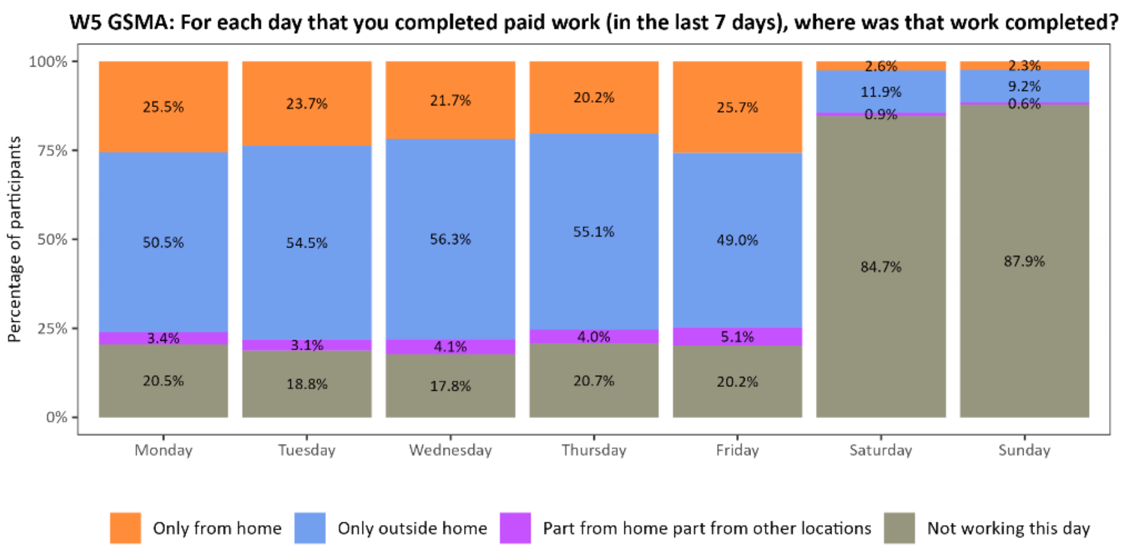


Figure 2. Percentage of participants who WFH for each of the seven weekdays for the entire GSMA

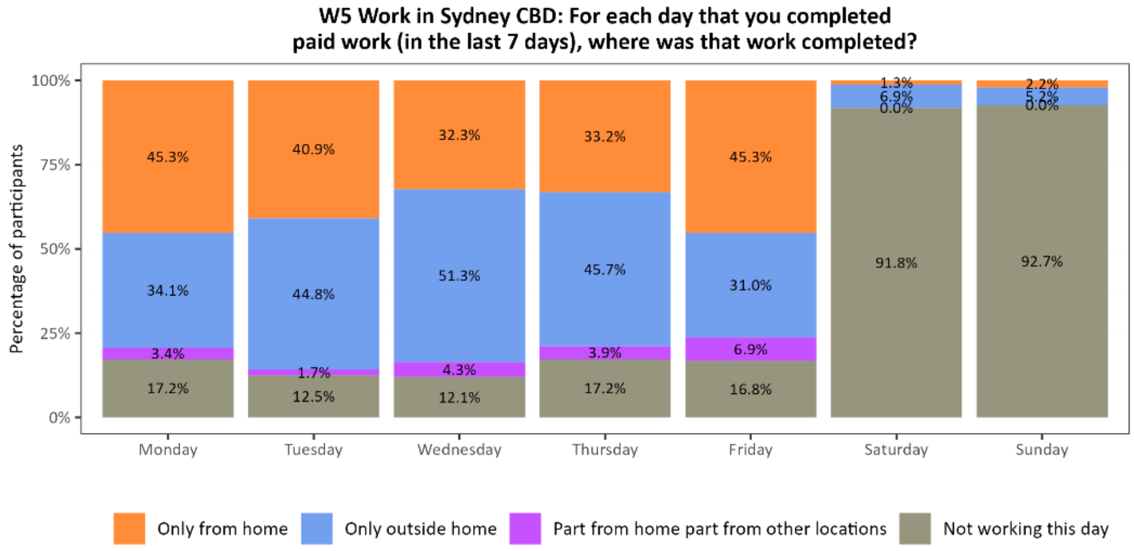
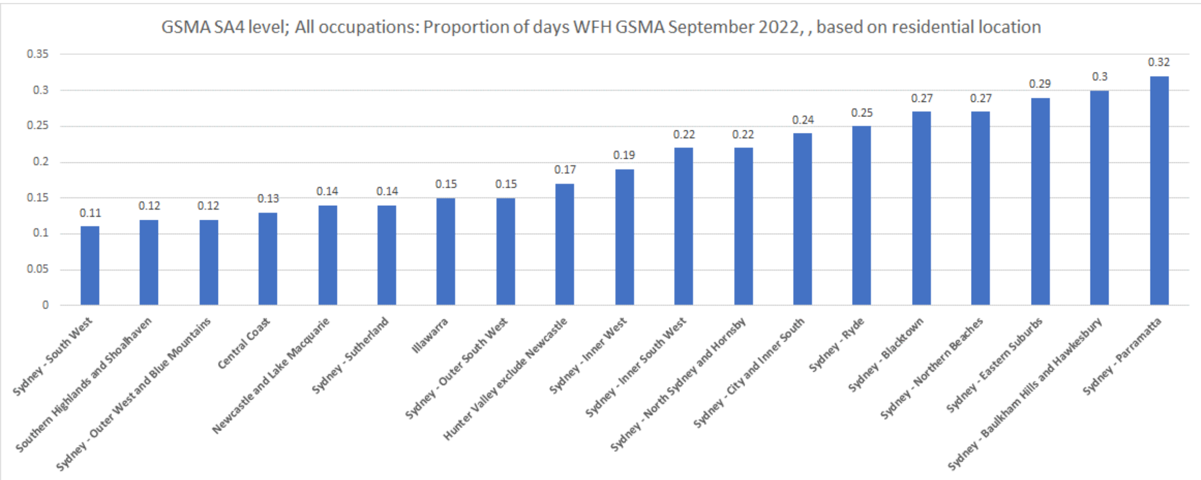


Figure 3. Percentage of participants who WFH for each of the seven weekdays for the Sydney Central Business District

The incidence of WFH by occupation based on where employees live, is summarised in Figures 4 and 5. While all occupations have some amount of WFH on average, the dominant quantum relates to managers, professional, admin, and clerical staff as well as sales personnel. The spatial differences are quite marked, varying on average at an SA4 level[4] from 0.11 to 0.32 proportion of days per week WFH and an average of 0.727 to 2.091 days per week, suggesting that it is necessary to recognise this in the modelling of the incidence of WFH. Given knowledge of these locations, the differences appear to be linked to socioeconomic, occupation and distance to work influences, all of which will be tested as candidate explanatory variables in the mixed logit model.



[4] SA4s are the largest sub-state regions in the Main Structure of the ASGS and are designed for the output of a variety of regional data, including data from the 2021 Census of Population and Housing. https://www.abs.gov.au/statistics/standards/australian-statistical-geography-standard-asgs-edition-3/jul2021-jun2026/main-structure-and-greater-capital-city-statistical-areas/statistical-area-level-4

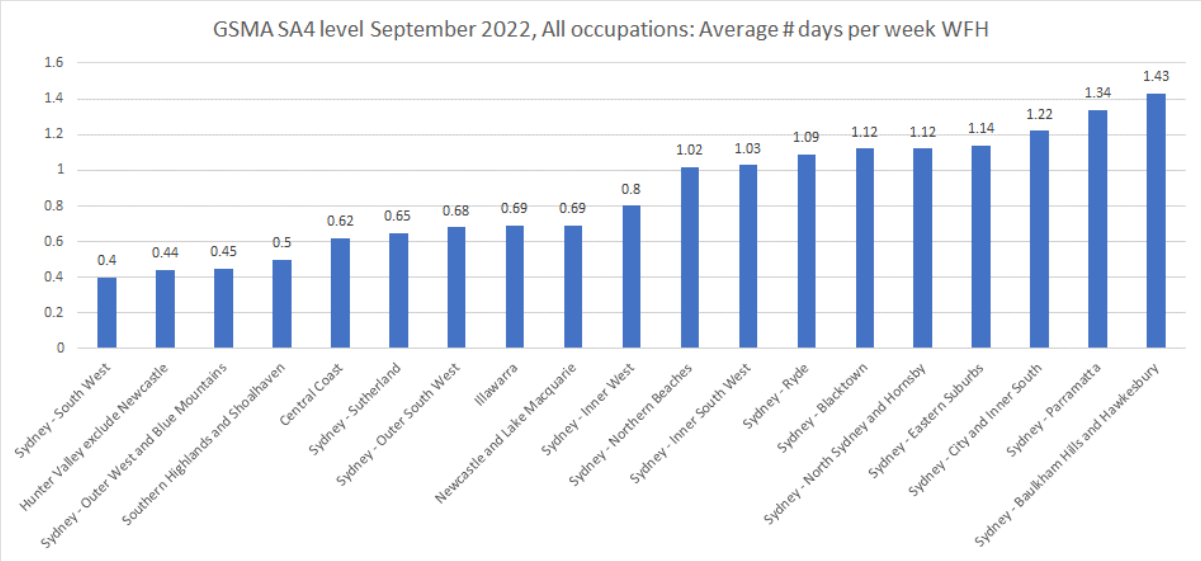


Figure 4. The incidence of WFH for all occupations by spatial residential location (a) proportion (b) average number of days

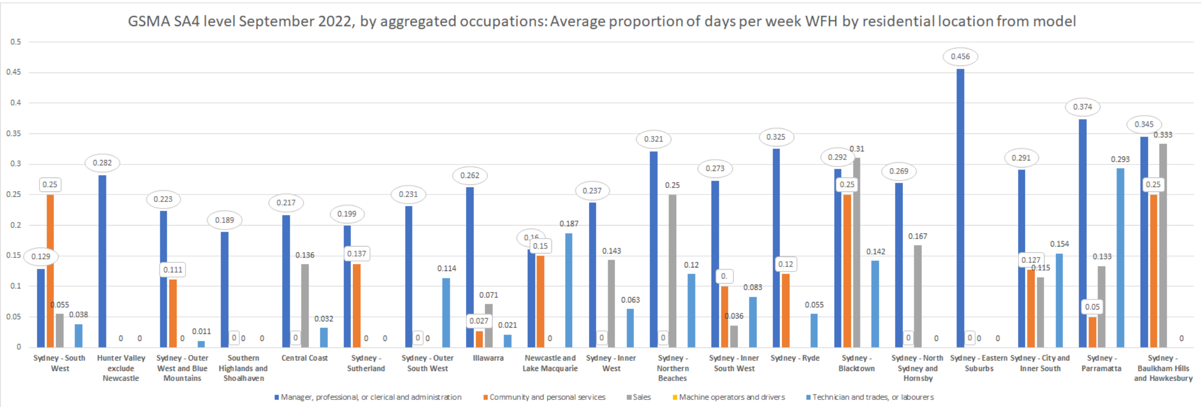


Figure 5. The incidence of WFH by occupation class for each spatial residential location

One, if not the most, important feature of WFH that impacts on the support from employers is productivity and the risk of reduced productivity if someone is not in the office. We have found that, like many other studies (e.g., Barrero et al. 2021, Ramani et al. 2021) productivity as perceived by both the employee and the employer[5] has remained unchanged and may even have increased on balance, whether perceived or economic (Barrero et al. 2021, Beck and Hensher 2022a). Figure 6 supports the position that the great majority of employees have either delivered productivity at about the same level or greater while WFH compared to the pre-COVID-19 WFH practice. This perceived level is agreed to by both employees and employers and was seen throughout the pandemic.

The Productivity Commission in Australia states that "workers may be more productive at home because they have better control over their time and enjoy better work–life balance. Firms will be able to tap into a larger pool of (more productive) labour. While not strictly a productivity impact, workers

[5] The relevant question is: In general, how productive do you think **your staff** have been in the last week whilst working from home compared their work in their pre-COVID-19 location?

have been shown to work longer hours when working from home during the pandemic"[6]. Barrero et al. (2021) for the USA conclude that employer plans and the relative productivity of WFH imply a five percent productivity boost in the post-pandemic economy due to re-optimised working arrangements. 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.

As hybrid working becomes more structured, and technologies and work patterns better support the mix between WFH and work "on-site", we can expect productivity gains to be enforced as workers and workplaces gain the benefits of better flexibility, but also better face-to-face contact. As long as productivity is seen as a positive outcome of working from home, especially by employers, who also recognise the lifestyle and well-being benefits to their employees (something that will inevitably be built into an increasing number of employment contracts going forward), and that a preference of workers to continue to work from home remains given the many benefits on life-balance that have been recognised, the 'next normal' will almost certainly be linked to the delivery of structural change centred around a hybrid working model.

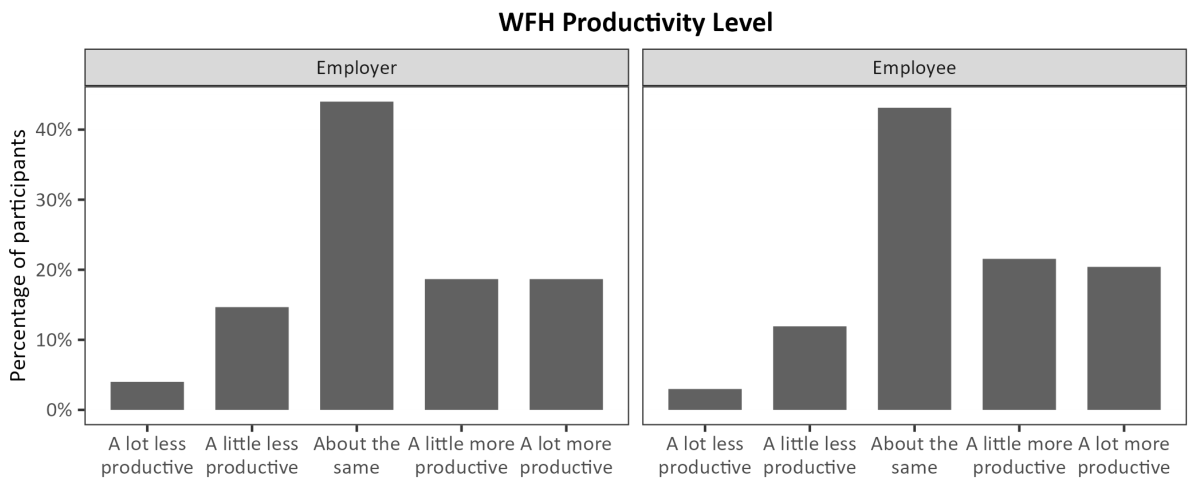


Figure 6. Employer and employee views on productivity gains from WFH

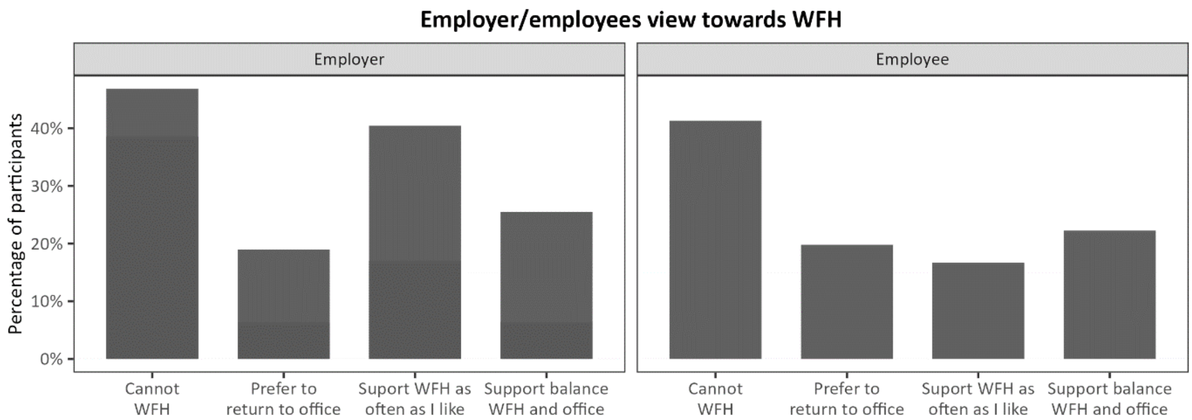


Figure 7. Employer and employee views on WFH

One source of improved productivity as a result of WFH is time saved from not commuting, and of particular interest is what happens to any travel time reallocated away from commuting to other

[6] https://www.pc.gov.au/research/completed/working-from-home

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 (Jara-Diaz 2000) 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, distinguishing between in-home and out-of-home activities. The results for the total daily and weekly 'saved' time by not commuting in September 2022 suggest that GSMA respondents saved an average of 74 daily minutes and 9.4 hours in the last week by not commuting. These 'savings' are relative to the amount of commuting time that is continuing under the hybrid model (Figure 8), and which varies by residential SA2 location.

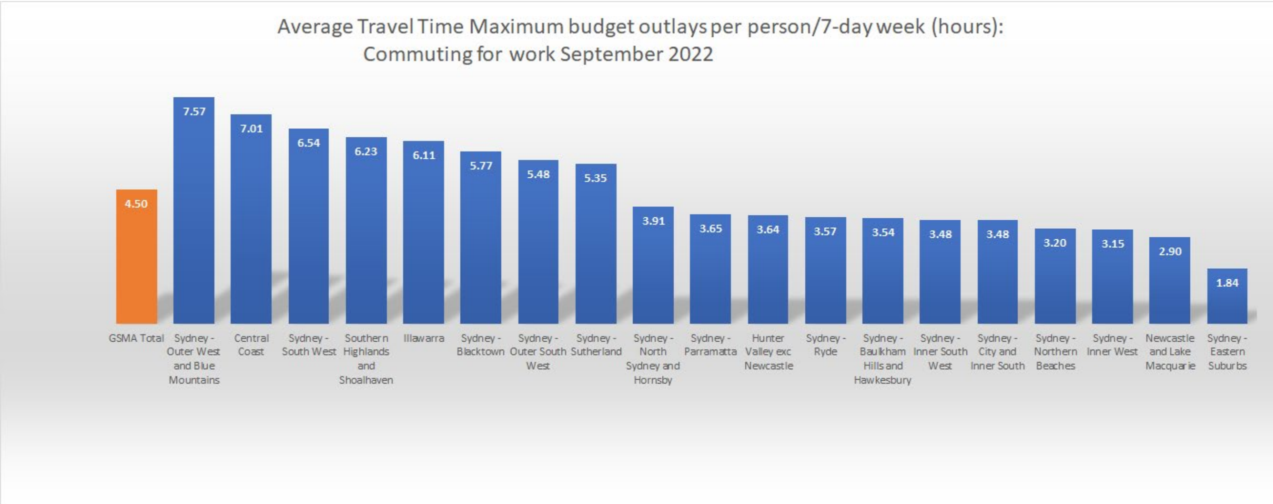


Figure 8. The average commuting time per week outlaid by SA4 residential location in September 2022

Figure 9 summarises the allocation of this 'saved' time to activities associated with nine activity categories. The dominant allocation involves extra time spent on work associated with the current employer, close to 30%, signalling a potential productivity benefit. Next are household tasks (close to 25%), and leisure at home (19%). The balance of 26% of time reallocation is primarily out-of-home leisure and work activities which has important implications on a change in non-commuting travel consequent of reduced commuting travel. 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.

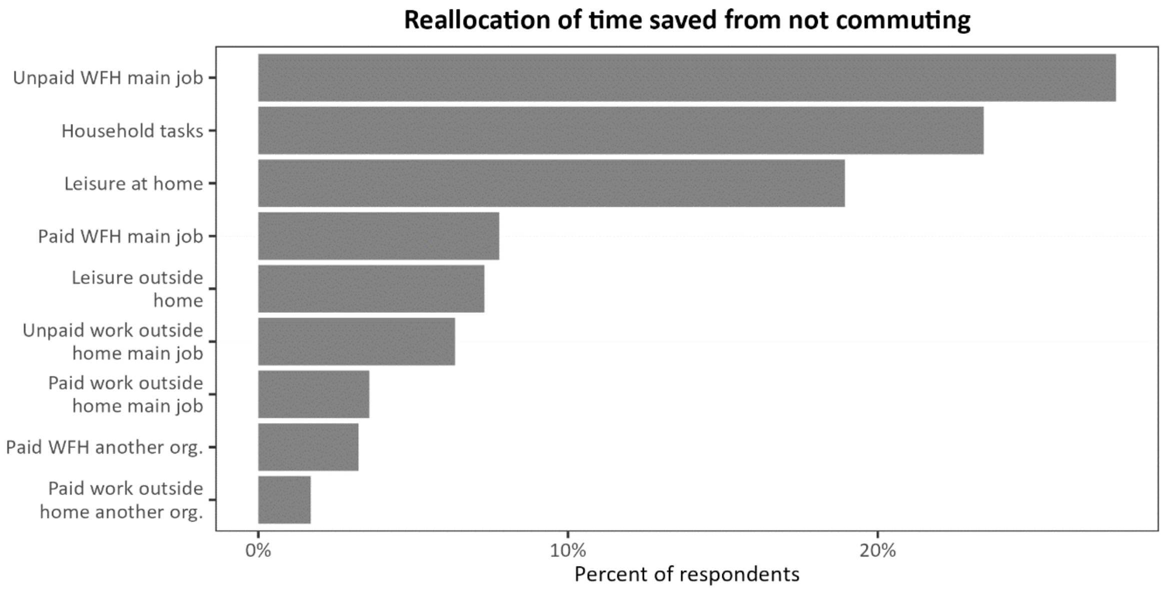


Figure 9. Commuting time saved and reallocated to various activity types.

The Data Source

The profile of respondents' characteristics included in the models, as well as the descriptive profile of the alternative's attribute levels us in modelling and application, are presented in Table 1. We have 1,285 observations (after data cleaning) for each day of the week (DoW), which for the commuter mode choice model is a total of 7,714 observations that represent the different available alternatives for each DoW. In Table 1, it can also be seen that the City of Sydney local government area (LGA), which contains the central business district for the GSMA, is clearly the most employment intensive LGA in Sydney. This is a feature replicated by many cities worldwide, with work being particularly concentrated in a CBD area; with the majority of work in this area being amenable to WFH or existing to support office workers who could WFH more often now than previously.

The levels of service and costs associated with all modes align well with expected levels, as do the socioeconomic characteristics, given the 2021 Census. Of special interest are the variables representing the workplaces in the GSMA that are defined by Transport for NSW (TfNSW) as strategic employment centres. We have included them in the modelling activity in response to TfNSWs interest in being able to account for the influence that these centres have on the probability of WFH. In addition, we needed to recognise, through an additional dummy variable in the model, the non-strategic employment centres to allow a future policy application when a new location is deemed a strategic centre. The current strategic centres represent 36% of all postcodes in the GSMA. In the mapping equation that relates the probability of WFH to a large number of influences, we have included a representation of strategic centre location that was found to be best defined as the number of jobs per square kilometre associated with each strategic centre and the balance of all other locations.

Table 1. Descriptive statistics of all data items in the modelling system

Variable	Mean (std deviation)
Travel time (mins)	34.53 (25.65)
Distance from home to work (kms)	23.52 (22.92)
Fuel cost ($)	4.79 (4.51)
Parking cost ($)	0.41 (4.11)
Tolls cost ($)	0.17 (1.70)

Variable	Mean (std deviation)
Access time (mins)	14.11 (13.39)
Egress time (mins)	10.47 (8.65)
Waiting time (mins)	8.87 (7.51)
Standing time (mins)	17.02 (15.57)
Number of transfers	0.50 (0.70)
Personal annual income (AUD$000)	90.69 (60.89)
Age (years)	40.53 (13.23)
Number of cars in household	1.00 (0.74)
Number of people living in household	3.38 (1.46)
Number of children living in household	0.77 (1.03)
Number of adults living in household	2.61 (1.07)
Cars per adult in household	0.42 (0.32)
Proportion of sample who work in a Strategic Centre	0.36 (0.48)
Total jobs per square km/1000 at postcode level	22.94 (38.55)
Number of jobs per sq km in work postcode (employment density)	2.16 (7.94)
Number of jobs in work postcode	103,280.10 (159,895.80)
Workplace located in Bondi Junction (1,0)	0.27%
Workplace located in Campbelltown-Macarthur Metropolitan Cluster (1,0)	0.82%
Workplace located in Chatswood (1,0)	0.73%
Workplace located in Greater Parramatta Metropolitan Centre (1,0)	4.20%
Workplace located in Greater Penrith (1,0)	0.91%
Workplace located in City/CBD (1,0)	19.98%
Workplace located in North Sydney (1,0)	1.09%
Workplace located in Hornsby (1,0)	0.91%
Workplace located in Kogarah (1,0)	0.37%
Workplace located in Liverpool (1,0)	1.09%
Workplace located in Macquarie Park (1,0)	1.92%
Workplace located in Norwest (1,0)	1.92%
Workplace located in St Leonards (1,0)	1.19%
Workplace located in Olympic Park (1,0)	0.73%
Jobs per square km in Bondi Junction	0.03
Jobs per square km in Campbelltown-Macarthur Metropolitan Cluster	0.00
Jobs per square km in Chatswood	0.05
Jobs per square km in Greater Parramatta Metropolitan Centre	0.34
Jobs per square km in Greater Penrith	0.01
Jobs per square km in City of Sydney	19.78
Jobs per square km in North Sydney	0.29
Jobs per square km in Hornsby	0.01
Jobs per square km in Kogarah	0.01
Jobs per square km in Liverpool	0.01
Jobs per square km in Macquarie Park	0.11
Jobs per square km in Norwest	0.03
Jobs per square km in St Leonards	0.09
Jobs per square km in Olympic Park	0.02
Estimated WFH probability	0.19 (0.11)
Days worked prior to COVID-19	5.31 (1.40)
Days worked last week	4.30 (1.33)

The Commuter Mode vs WFH Model

The model structure used in this study is presented in Figure 10. Respondents were asked, for each day of the week, where they worked from and, if they went outside the home to work, 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 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 (Table 2) by ten modes of transport: car driver, car passenger, taxi/rideshare, train, bus, light rail, ferry, walk, bicycle, and motorcycle, not all of which are available to each worker. The 12 alternatives relate to each day of the week (combining Saturday and Sunday), and to recognise this panel format representing the weekly travel behaviour for each individual, we estimated the mixed logit model accordingly.

This model structure includes alternatives that are presented in Table 2 for each day of the week. The alternative of no work (alternative 1) is described by the alternative specific constant ASC_{NoWork} and by respondents' socioeconomics z_n. The working from home alternative (alternative 2) is described by its alternative specific constant; respondents' socioeconomics; and by dummy variables that represent each different day *d* of the week day_d.

The utility functions are defined as follows:

$$U_{NoWork} = ASC_{NoWork} + \sum_n \beta_{NoWork,n} \cdot z_n \tag{1}$$
$$U_{WFH} = ASC_{WFH} + \sum_n \beta_{WFH,n} \cdot z_n + \sum_n \beta_{WFH,d} \cdot day_d$$

where β represents the estimated parameters associated with the different attributes or characteristics. The utility functions for the modal alternatives (alternatives 3 to 12) are described by alternative specific constants for each mode together with attributes for levels of service and costs. 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 (2). Note that the parameter estimate β for access, egress and waiting times is generic[7].

$$\begin{aligned} U^{PT}_{Mode_m} &= ASC_{Mode_m} + \beta_{Mode_m,TT} \cdot TT_{Mode_m} + \beta_{Mode_m,Cost} \cdot Fare_{Mode_m} \\ &\quad + \beta_{Mode_m,AEWT} \cdot \left(AcT_{Mode_m} + EgT_{Mode_m} + WT_{Mode_m} \right) \end{aligned} \tag{2}$$

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[8], as presented in equation (4), and by the distance from their home to their office $Dist_{Home-work}$. Note that the parameter estimate β for fuel, toll and parking was estimated in the preferred model as generic[9].

[7] They were estimated as specific first and the results suggested that they were not statistically different.

[8] The respondents' socioeconomics were tested in different modes of transport, but they were statistically significant only in the car driver mode, except for age.

[9] They were estimated as specific first and the results suggested that they were not statistically different.

$$U_{Mode_m}^{Car/moto} = ASC_{Mode_m} + \beta_{Mode_m,TT} \cdot TT_{Mode_m}$$
$$+\beta_{Mode_m,Cost} \cdot \left(Fuel_{Mode_m} + Park_{Mode_m} + Toll_{Mode_m}\right) + \sum_n \beta_{Mode_m,n} \cdot z_n + \beta_{WFH,Dist} \cdot Dist_{Home-work} \quad (3)$$

The active modes and car passenger[10] alternatives are described only by the travel time, as presented in equation (5).

$$U_{Mode_m}^{Active} = ASC_{Mode_m} + \beta_{Mode_m,TT} \cdot TT_{Mode_m} \quad (4)$$

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, 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 (Hensher et al. 2021).

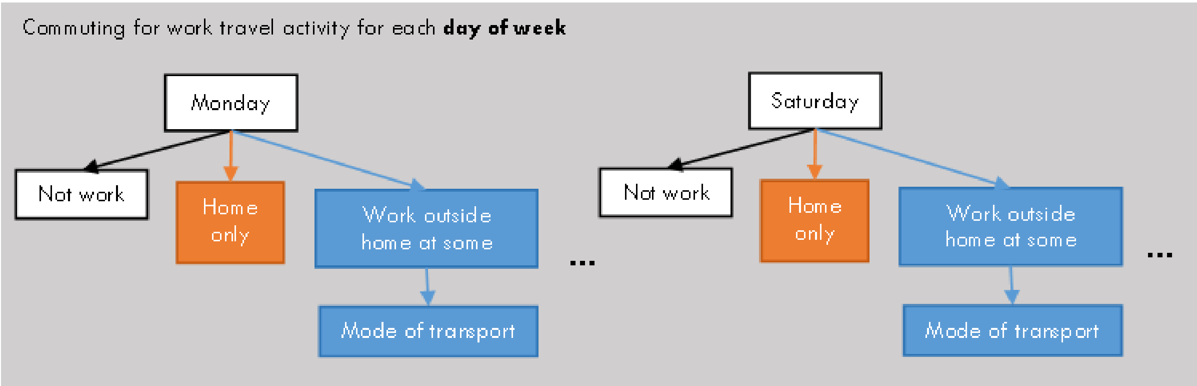


Figure 10. The Mixed logit commuter mode and WFH choice model

Table 2. Alternatives in mixed logit model for each day of week

Alternative	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

[10] We tested the option of including the costs associated with a car trip, but they were always not statistically significant, suggesting that car passengers do not usually pay for these costs and, therefore, are not part of their decision.

The final mixed logit model is reported in Table 3. Account is taken in estimation for observations associated with the same respondents (i.e., the data on each of the seven days of the week). The overall fit of the models is impressive with a significant improvement in the log-likelihood. Most of the parameter estimates are significant at a 90% confidence level or better, except for the number of cars in the household and personal income, both of which are in the car driver utility expression and we have retained them to recognise that we anticipated their statistical significance but suspect that the presence of the WFH alternative has resulted in the reduced relevance of these two potential influences under a mode choice only specification. Figure 11 shows the distribution of the probability of WFH in September 2022 as estimated through the mixed logit model. The mean estimate of the probability of WFH is 0.160 which translates as 1.18 days WFH per week.

Three parameters in each model were estimated as random to test and account for preference heterogeneity: travel time and cost for all modes except the active modes, and distance in kilometres to work from home for car driver. Different parameter distributions were tested (e.g., normal, lognormal, triangular). 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. All three random parameters follow a constrained normal distribution, with a standard deviation equal to the mean. We used 100 Halton intelligent draws, noting that we increased this to 1000 and the results were almost identical. The mean value of time (VoT) across all modes is $21.22/person hour, which aligns well with the findings in previous waves of the study. For example, in Wave 3 (August 2020) the mean VoT is $26.02/person hour and in Wave 4 (July 2021) it is $26.10/person hour. Pre-COVID-19, we suggest an estimate of $22.69/person hour; hence, there has been a noticeable increase during the worst period of the pandemic, possibly suggesting the desire to spend less time travelling in any form during the uncertainty of the pandemic expressed itself in high VTTS. There are signs, however, suggesting that after 30 months, as society moves out of the worst of COVID-19, we are returning to a VoT estimate, similar to the pre-COVID estimate in 2019.

A series of parameters for day of the week dummy variables were estimated, with Wednesday and the weekend excluded. *Ceteris paribus*, we see that the probability of WFH on Monday and Friday compared to the other days of the week is higher, which is what the descriptive data is also telling us. Respondent age and occupation (the latter a dummy variable for blue-collar workers) are statistically significant and suggest that *ceteris paribus*, older workers tend to have a higher probability of not working on a particular day, and that blue-collar workers have a lower probability of WFH compared to other occupations. We drill down further on the occupation heterogeneity regarding WFH in the mapping equation (Table 4). Participants who drove their car prior to COVID-19 have a higher probability of continuing to drive compared to commuters that did not drive prior to COVID-19.

Table 3. The mixed logit model results

Variable	Alternative	Mean (t-value)
Alternative specific constant	Car driver	0.536 (4.14)
Alternative specific constant	Car passenger	-0.761 (5.89)
Alternative specific constant	Taxi/rideshare	-1.221 (4.57)
Alternative specific constant	Public transport	1.239 (8.81)
Alternative specific constant	Active modes	1.114 (6.77)
Age (years)	Non-work alternative	0.025 (22.70)
Blue collar workers (1,0)	WFH	-1.201 (8.55)
Monday (1,0)	WFH	0.900 (10.45)
Tuesday (1,0)	WFH	0.774 (8.81)
Thursday (1,0)	WFH	0.545 (5.98)
Friday (1,0)	WFH	0.903 (10.51)

Travel time (mins) - *mean*	All commuting modes except active travel modes	-0.009 (2.55)
- *standard deviation*	All commuting modes except active travel modes	0.009 (2.55)
Fuel + parking + toll or public transport fare (AUD$) - *mean*	All commuting modes except active travel modes	-0.027 (4.84)
- *standard deviation*	All commuting modes except active travel modes	0.027 (4.84)
Distance from home to work (kms) - *mean*	Car driver	0.010 (2.76)
- *standard deviation*	Car driver	0.010 (2.76)
Personal annual income (AUD$000)	Car driver	0.0004 (0.64)
Number of cars in household	Car driver	0.004 (0.08)
Used car prior to COVID-19 (1,0)	Car driver	1.467 (16.41)
Access, egress and waiting time (mins)	Public transport	-0.011 (4.51)
Travel time (mins)	Walk	-0.0082 (1.61)
Travel time (mins)	Bicycle	-0.032 (3.52)
Restricted log-likelihood		*-19,168.57*
Log-likelihood at convergence		*-8,324.05*
Sample size		*7,714*
Number of parameters estimated		*20*
AIC/n		*2.163*

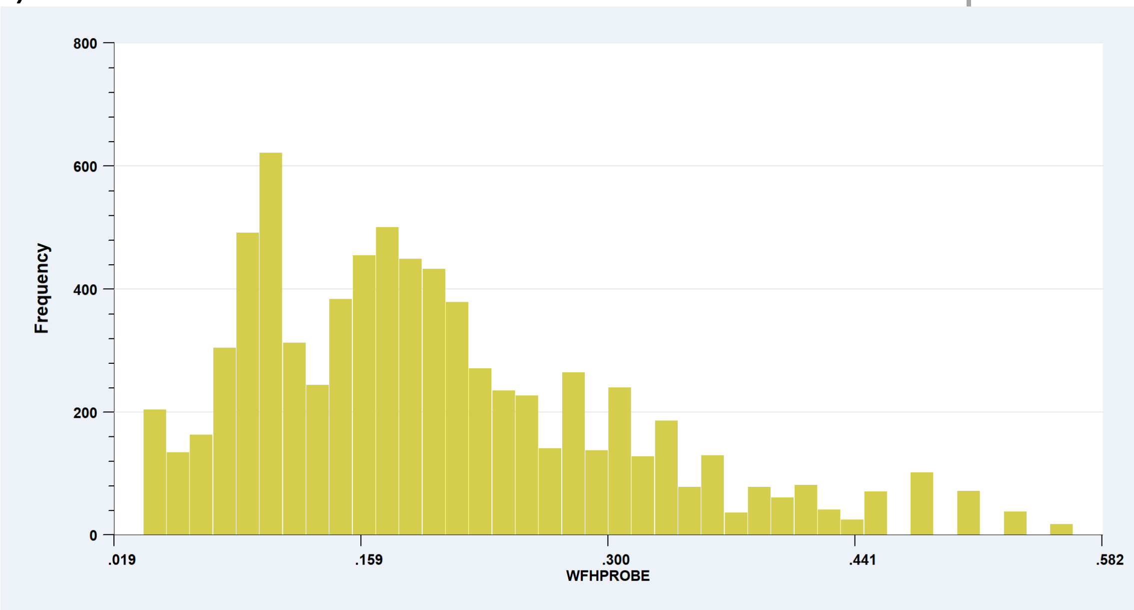


Figure 11. Distribution of probability of WFH compared to commuting, obtained from the mixed logit model.

WFH probability mapping GSMA model results

The mixed logit model provides the estimate, for each respondent and day of the week, of the probability of WFH compared with commuting, after removing the probability of not working. A censored regression model was estimated with the probability of WFH as the dependent variable and several socio-economic and contextual influences as explanatory variables, including indicators for strategic employment centres. To ensure that the probability of working from home satisfies the 0-1 bound, we imposed a non-linear constraint to satisfy this condition using a censored regression form, also known as a Tobit model with left- and right-censoring in the dependent variable. The results of the regression model are presented in Table 4.

The overall explanatory power of the Tobit model for the disaggregated data is 0.438 using the decomposition formula to mimic the R-squared fit in a regression model (noting that the unconstrained regression model fit is 0.762) which is an impressive capture of sources of systematic variation in the probability of WFH (or conversely of commuting). What is most noticeable is that the parameter estimates of the tobit and regression model are almost identical, giving comnfidence in an unconstrained model if that is used in practice. This is primarily due to having all probabilities of WFH well above 0.0 and below 1.0. Such a mapping model is useful in an application and strategic policy setting 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 on a rich array of socio-economic 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 4 for a given origin-destination pair, they can then obtain an estimate of the spatial probability of WFH, and hence adjust the incidence of commuting on particular days of the week and weekend. We have undertaken this calculation for each sampled worker and aggregated up to the SA2 level to obtain, in Figure 14, a mean probability of WFH estimate for each residential location. Probability estimates have also been obtained for each OD pair but are not reported herein.

Table 4. Mapping equation between the probability of WFH vs commuting and statistical influences. Constrained (0,1) Tobit Model: probability WFH.

Variable	**Mean (t-value)**
Constant	0.093 (27.65)
Age (years)	-0.002 (46.41)
Cars per adult in household	-0.033 (10.98)
Number of people living in household	-0.002 (4.06)
Occupation manager (1,0)	0.113 (49.72)
Occupation professional (1,0)	0.117 (55.09)
Occupation clerical and administration (1,0)	0.111 (50.34)
Occupation sales (1,0)	0.124 (48.19)
Occupation community and personal services (1,0)	0.119 (43.90)
Occupation labourer (1,0)	0.010 (3.46)
Chose PT for commute (1,0)	0.012 (10.03)
Distance from home to work (kms)	0.001 (19.08)
Located in Newcastle (1,0)	-0.022 (11.39)
Located in Illawarra (1,0)	-0.015 (6.77)
Located in Central Coast (1,0)	-0.028 (14.14)
Monday (1,0)	0.118 (64.85)
Tuesday (1,0)	0.097 (57.67)
Thursday (1,0)	0.063 (42.48)
Friday (1,0)	0.118 (65.08)
Total jobs per square km/1000 at non-strategic centres (=0 in a strategic centre)	0.0002 (2.04)
Total jobs per square km/1000 in Bondi Junction	-0.001 (1.81)
Total jobs per square km/1000 in Campbelltown-Macarthur Metropolitan Cluster	-0.046 (0.98)
Total jobs per square km/1000 in Chatswood	0.006 (5.20)
Total jobs per square km/1000 in Greater Parramatta Metropolitan Centre	0.003 (8.39)
Total jobs per square km/1000 in Greater Penrith	-0.037 (8.22)
Total jobs per square km/1000 in City	0.0002 (13.18)
Total jobs per square km/1000 in North Sydney	0.0004 (2.41)
Total jobs per square km/1000 in Hornsby	0.003 (0.72)
Total jobs per square km/1000 in Kogarah	0.008 (4.02)
Total jobs per square km/1000 in Liverpool	-0.008 (1.96)
Total jobs per square km/1000 in Macquarie Park	0.001 (1.35)
Total jobs per square km/1000 in Norwest	-0.004 (1.60)
Total jobs per square km/1000 in St Leonards	0.001 (1.02)
Total jobs per square km/1000 in Olympic Park	-0.002 (1.10)
Commuting travel time by car to main office location (mins)	-0.001 (13.34)
Disturbance standard deviation: Sigma	***0.0423 (113)***
Sample size	***6,419***
Number of estimated parameters	***36***
Log-likelihood	***11185.4***
Adjusted R-squared (OLS)	***0.762***
R-squared (decomposition)[11]	***0.438***

[11] Veall, M. and Zimmermann, K. (1992) propose a surrogate R-squared for a Tobit model. The measure, referred to a the decomposed R-squared and reproduced below Table 4, takes the variance of the conditional mean function around the overall mean of the data in the numerator. The denominator contains the sum of the numerator and a residual variance, the true value minus the conditional mean function.

$$R^2_{DECOMPOSITION} = \frac{\frac{1}{n}\sum_{i=1}^{n}\left(\hat{y}_i - \bar{y}\right)^2}{\frac{1}{n}\sum_{i=1}^{n}\left(\hat{y}_i - \bar{y}\right)^2 + \frac{1}{n}\sum_{i=1}^{n}\left(y_i - \hat{y}_i\right)^2}$$

$$= \frac{\text{Variation of predicted mean}}{\text{Variation of predicted mean} + \text{Residual variation}}$$

Occupation is clearly a significant driver of the ability to WFH, and all six occupation dummy variables #have positive and statistically significant parameter estimates. Figure 12 shows the variation from a high of 0.181 (or 1.32 days per week) for sales employees to a low of 0.073 (equal to 0.51 days per week WFH) for labourers. The larger household size tends to reduce the probability of WFH, which may in part be due to the working environment at home, being disturbed too much by other household members, especially if there is no separate room/study/home office in which to work[12]. Interestingly, although the number of cars per adult in a household was not statistically significant in influencing the probability of commuting by car as a driver when someone commutes to an office, it is statistically very significant with a negative parameter in the mapping equation, suggesting that households with more cars have a lower probability to WFH. This appears consistent with the increased use of the car and reduced public transport use when commuting to the office during COVID-19.

Distance from home to the main office has a positive parameter, which supports the widespread view that, *ceteris paribus*, workers who live further away (in kilometres) from their main office are more likely to have a higher incidence of WFH. The GSMA is described by the Sydney Metropolitan Area (SMA) and a number of outer metro locations such as Newcastle, the Illawarra (including Wollongong) and the Central Coast[13]. This results in a higher incidence of WFH, after controlling for occupation and distance to work, in particular. Many residents of the Central Coast and the Illawarrra tend to work in the SMA (especially close to the CBD) and use public transport prior to the pandemic, and this in part explains the increase in WFH as concerns about using public transport (and indeed other sharing modes) snowballed.

[12] A constraint that appears, anecdotally, to be the case for households with many children.

[13] The Newcastle area is typically a good 90-minute drive from many locations in Sydney with the Central Cost at least 1 hour. The Illawarra is also around 1 hour or longer south of the SMA.

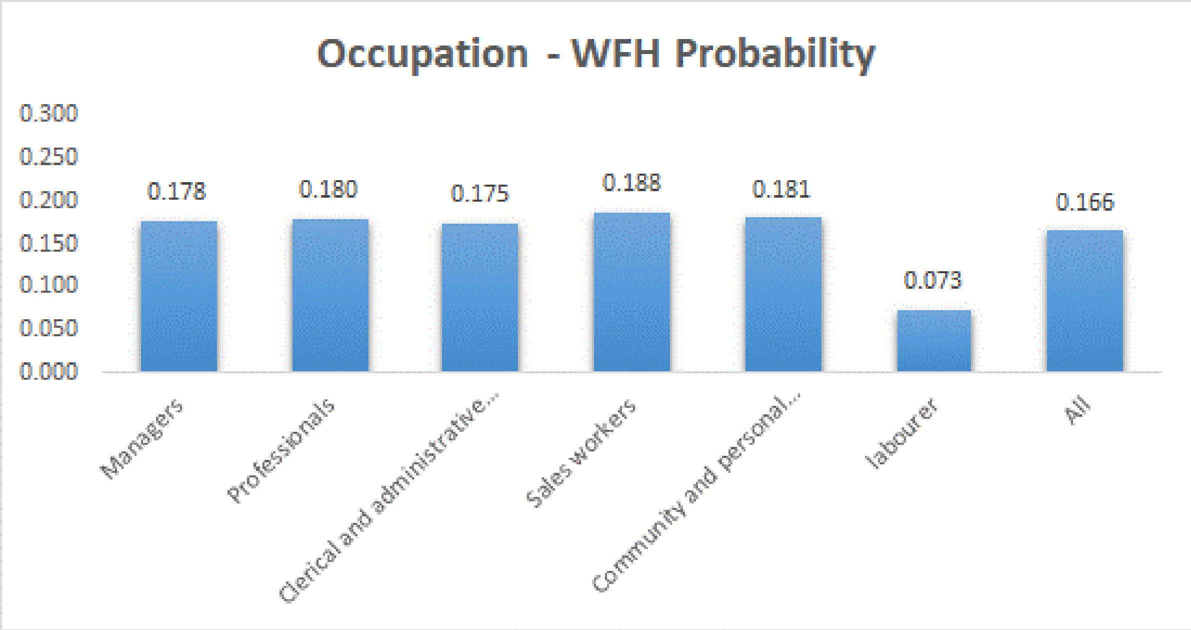


Figure 12. Variation in the mean estimate of the WFH probability by occupation.

Looking more closely at the 15 strategic centres (as well as the non-strategic centres), we see in Figure 13 a distribution of the mean estimate of the probability of WFH varying from a low of 0.129 (0.903 days per week WFH) to a high of 0.2 (0r 1.4 days per week WFH) with an average of 0.166.

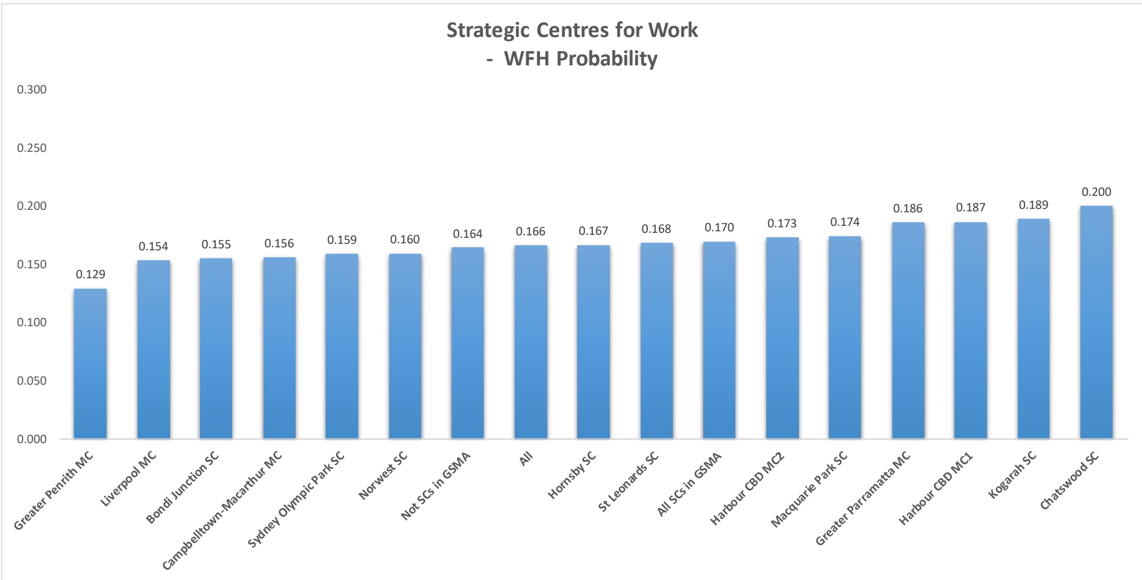


Figure 13. The average estimate of the probability of WFH when working in a strategic centre.

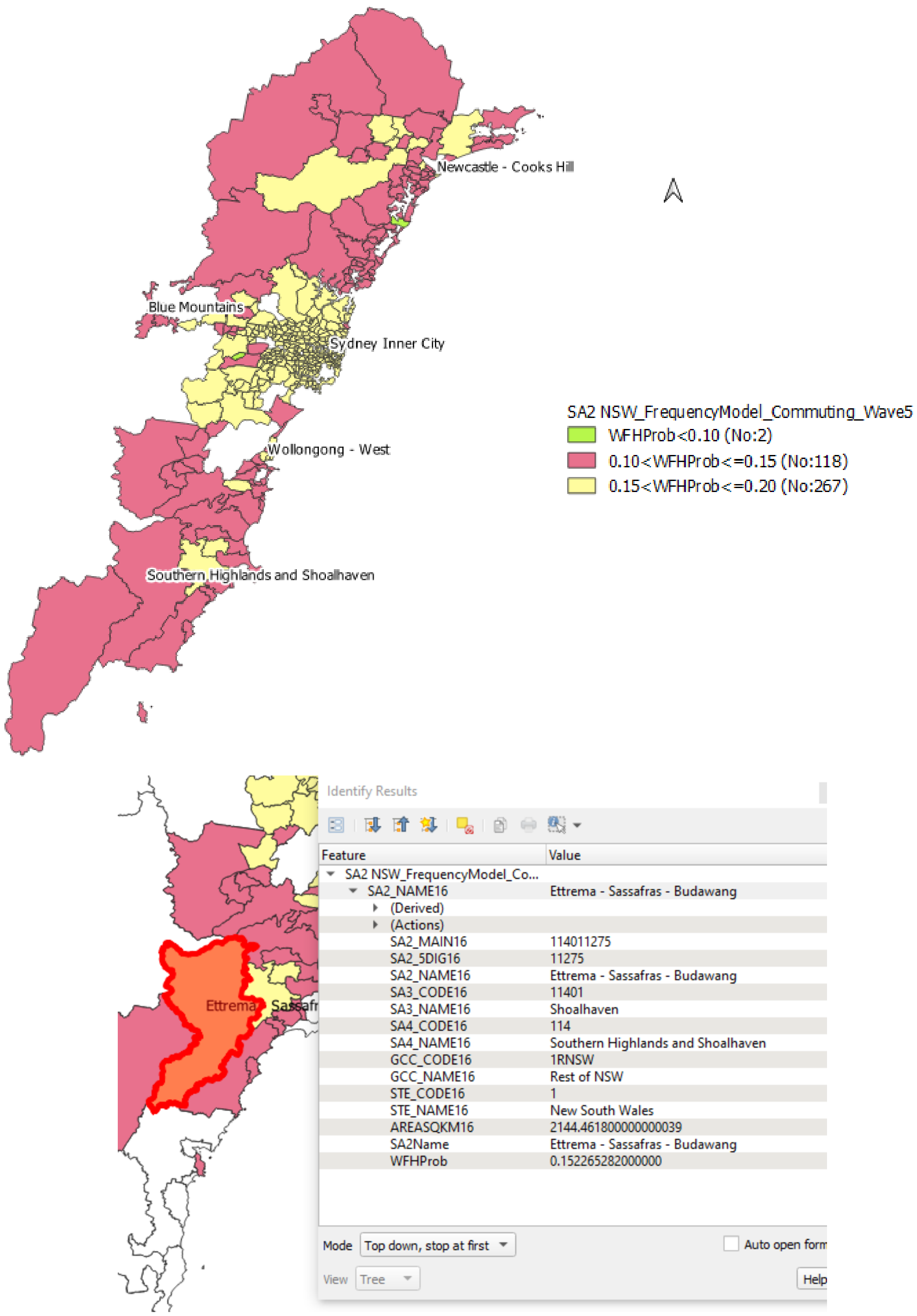


Figure 14[14]. The mean probability of WFH by SA2 residential location, allowing for strategic centre dummy variables interacted with jobs per square km.
Notes: 0.1= 0.7 days per week, 0.15=1.05 days per week, 0.2=1.4 days per week, Southern Highlands has a high WFH incidence in Wave 5.

[14] An interactive version is available: https://interactive.guim.co.uk/embed/iframeable/2019/03/choropleth_map_maker_v6/html/index.html?key=oz-230404-greater-sydney-wfm-probability-survey

Figure 15 provides a schematic overview framework to illustrate how we have taken the model structure in this paper and embedded it into a metropolitan strategic transport model system[15]. The mixed logit model is the CMC model; the mapping equation is the DSS[16] and, although not reported in this paper, a series of models for the number of trips by purpose were also estimated with the elasticity outputs used to adjust trip levels by purpose in the presence of a predicted WFH estimate.

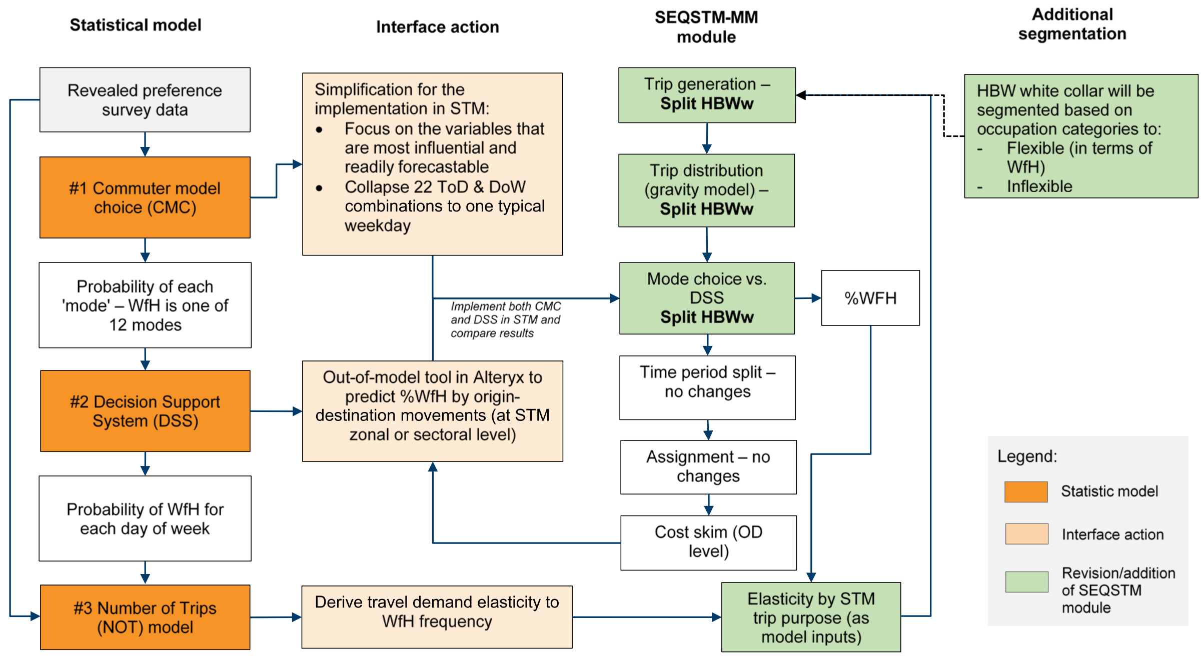


Figure 15. An example of how WFH estimates can be embedded in a revised strategic model system.

In applying the model at a route level, the types of evidence obtained in the presence of OD based WFH probability estimates are shown in Figure 16 for a location in Southeast Queensland[17]. Road traffic decreases by less than 10% on most of the network. The exceptional changes on toll roads such as Legacy Way, Clem 7 and Airport Link are due to sensitive route choice when tolls are involved.

[15] This is a real focus of the paper, illustrating how choice modellers need to think about client requirements, adapt accordingly, but still provide robust outputs for policy development.
[16] The DSS used a conversion to Alteryx to obtain OD level outputs for visualisation.
[17] Although this application is for South East Queensland (SEQ), the modelling approach presented for the GSMA is the same as for the SEQ, except the parameters and some variables change. A similar process was implemented by TfNSW using the WFH estimates provided by ITLS, but we do not have access to the final structure known as Project Phoenix.

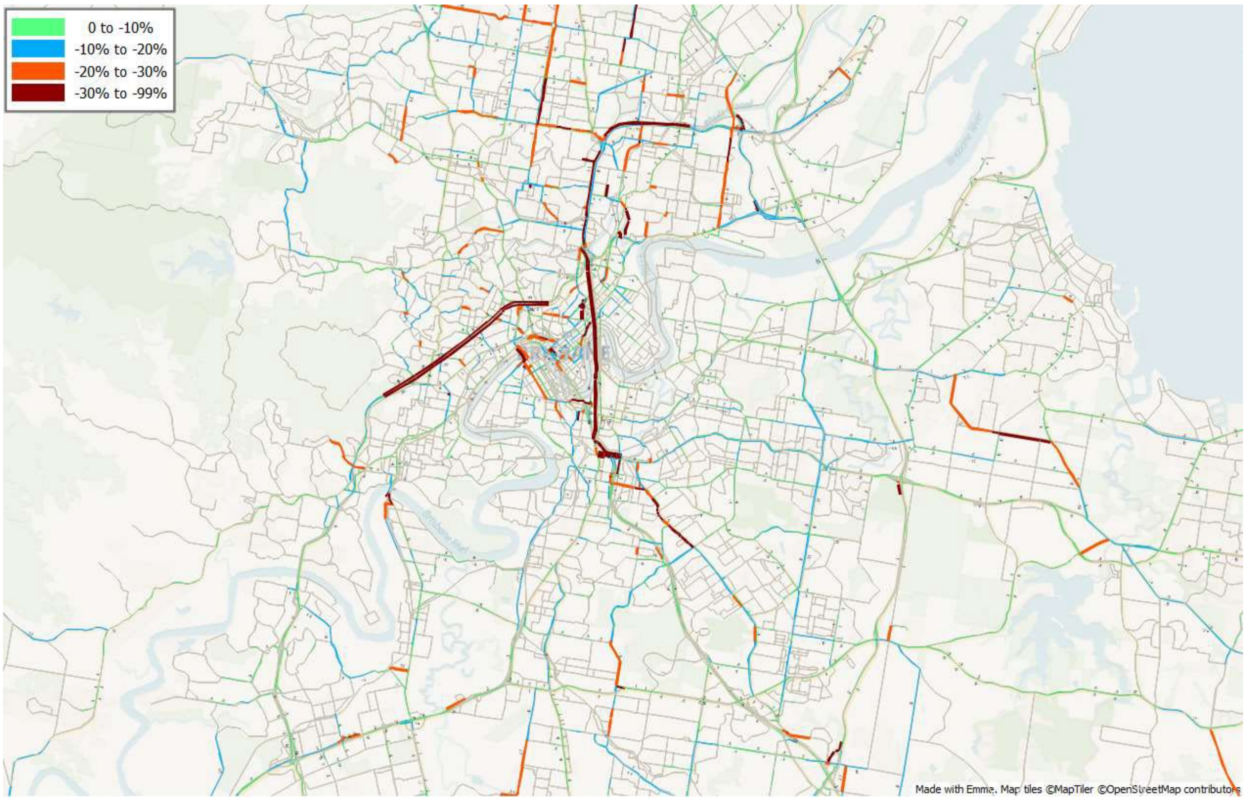


Figure 16. WFH Impact (percentage change) at a route level

Conclusions

Since March 2020 when the COVID-19 concern escalated into a pandemic and a series of lockdowns resulted in forced working from home (WFH), with the exception of essential services requiring face to face contact, the subsequent period up to May 2023 in many countries revealed many unintended positive consequences of WFH to some extent. While there were also downsides, the general sense is that forced WFH highlighted many structural changes moving forward that have gained strong support by a significant number, but not all, of employees and employers. A three-year research project in Australia from March 2020 to April 2023 provided evidence that work-related productivity generally increased or remained the same, with flexibility in when and where to work, delivering healthy outcomes for a work-leisure-family lifestyle balance. As the pandemic subsided and more and more people started returning to the office to some extent, the hybrid working model took on appeal for many employees and indeed employers, as shown in Figures 17 to 18.

Interestingly, and perhaps with an eye to the future, we see in Figure 19 that many employees who can do some or all of their work from home, feel they are much better prepared to do so in the future. In the case of the GSMA, prior to the pandemic, the fringes of the metropolitan region experienced bushfires that burnt out a number of train lines on the greater urban network, and in the later stages of the pandemic, almost the entire state (indeed the eastern seaboard of Australia) experienced several incidences of “generational flooding” in rapid succession, which washed segments of the track away. With ageing infrastructure requiring maintenance, combined with increasingly unpredictable and extreme climate conditions, having some resilience to complete work at a location other than the main office will be important in maintaining productivity and economic resiliency. A unique and ongoing part of this research project is to continue to examine how the choices and experiences during the pandemic, inform/reinforce/change choices made in the future, with respect to work and travel.

This paper reports on evidence from data collected in September 2022 as part of a 3-year research project to identify the incidence of working from home and the key drivers in support of, or against, the probability of working from home. At the time of the survey, the support of employers for employees to WFH to some extent, typically 1-2 days a week and even more in some situations, showed strong signs of a possible continuing quantum of WFH to be used as the basis of short to medium term predictions of what role WFH might play in redefining commuting activity and the associated changes in lifestyle and office capacity utilisation.

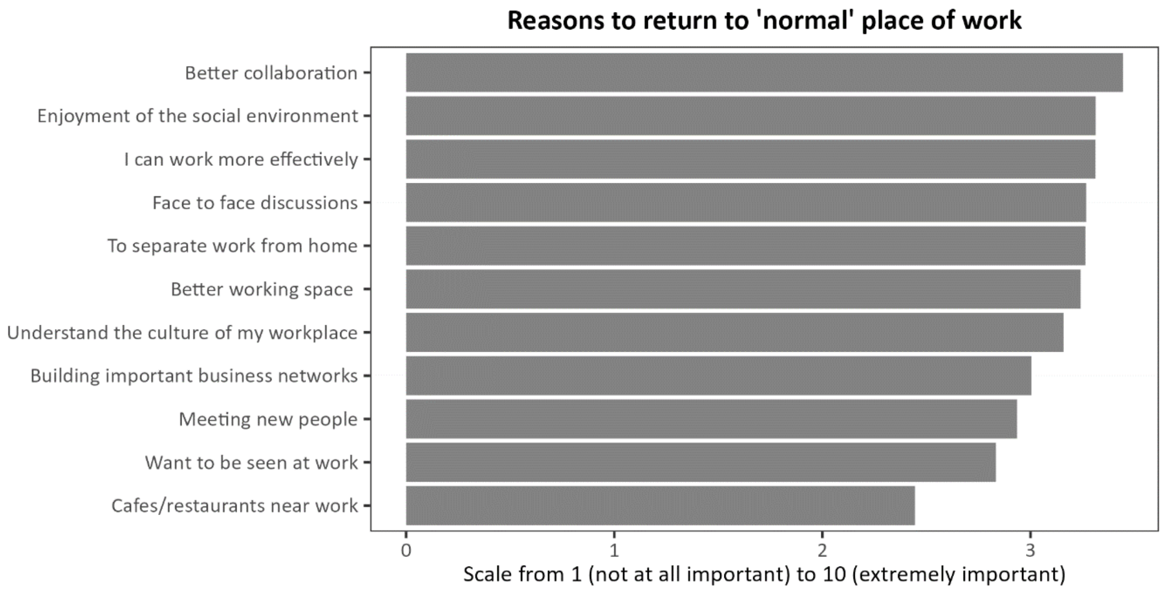


Figure 17. Reasons for returning to the office to some extent.

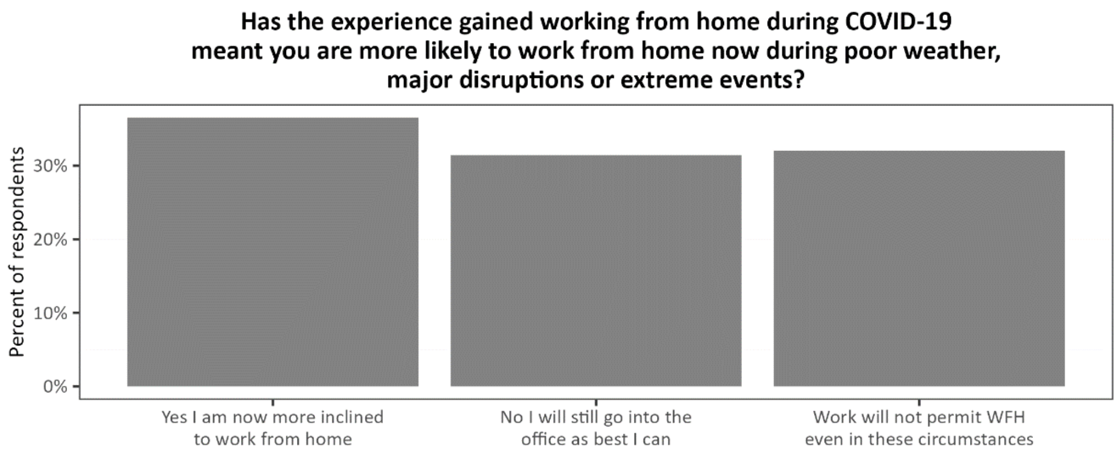


Figure 18. Inclination to work from home when there are disruptions and weather events.

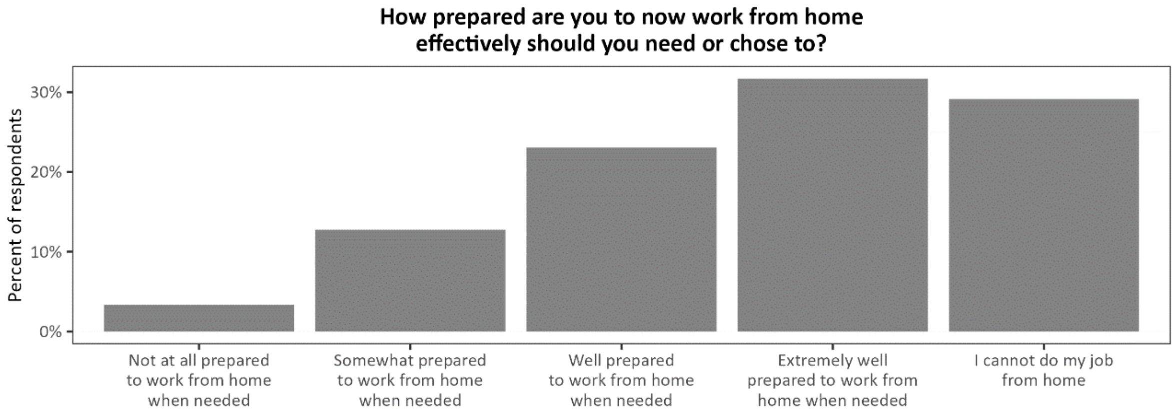


Figure 19. Future preparedness to work for home.

The decision to work from home or to commute during COVID-19 continues to evolve and has a major structural impact on individuals' travel, work, and lifestyle. Flexibility and work-life balance now have new meaning in the sense that it is actionable without stigma. It has non-marginal spin-offs linked to suburbanisation and the 15-minute city. The following quotes are symbolic of a changed future.

> *'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)*
>
> *'Employees demand a different approach to the workplace, one flexible to their needs and better equipped to address work-life balance. Getting them "back to work" entails more than just insisting that it happen as you'd like.'*
> *https://www.smartenspaces.com/blog/struggling-get-employees-back-work*

Despite this, in mid-2023, a handful of businesses and business leaders, have put pressure on employees to return to the office on a permanent basis, ignoring the extensive evidence on the subject. This pushback is being led by a few large organisations (notably banks and legal firms) wanting a 4-to-5-day return to the office. Some of the arguments offered up appear to be linked to a belief that work in the office is more productive, new ideas can result in face-to-face talking, and fairness and justice are required to all employees regardless of whether work can be done remotely to some extent. The return to the office mandates being rolled out for a return to what is effectively a pre-COVID-19 office situation, appear to have ignored the progress made through WFH to some extent in delivering positive outcomes to the organisation while adding less stress and positive benefit to employees.

Substantial evidence from many sources suggests that two or three days in the office is enough to provide the important social interaction, mentoring, sharing of ideas and creativity, all of which are facilitated by face-to-face contact (Hensher et al. 2023). The days spent working from home allow greater concentration, better focus on completion of work, and extra time in the day through not commuting that is often reinvested into additional work (Hensher et al. 2022). Overall, greater flexibility improves work-life balance, and happier employees are more loyal and more productive.

The potentially biased commentary in the media in many countries supporting a return to the office full time fails to recognise that both employers and employees have seen productivity benefits from some amount of working from home, as shown in the evidence above. There are a host of other financial benefits to business, and benefits to society that arise from the intelligent adoption of a more flexible approach to where work is completed. The motivation to force employees to return to the office permanently is unclear, ignorant of ample evidence, and perhaps driven by old style 'command and control' management styles. Work from home or work from the office is not a binary choice, and the discussion should not be so reductive.

Some amount of compromise was subsequently agreed to as a result of a backlash from unions and other parties, agreeing typically to a 50% of time back in the office, which amounts to 2-3 days a week. The structural changes that have arisen through WFH might be at risk with a sledgehammer approach to returning to the office, seriously damaging the relationship between employers and employees. WFH should be regarded as a key force in a broad social landscape instead of being treated as merely an alternative work arrangement.

Time will tell whether this turnaround, after such positive support, will reproduce pre-COVID-19 commuting activity with all of its negative externalities such as increased congestion on the roads, crowding on public transport, and increased stress on one's life, all things that have been reduced significantly as a result of increased WFH. Whatever the outcome, the modelling framework developed in this paper can be updated with new parameter estimates if the changes in magnitude and pattern of WFH behaviour changes in a non-marginal way. As a significant transport policy level, monitoring WFH changes is essential if revised strategic transport models are to maintain their currency.

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