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The Future of Working Away from Work and Daily Travel: A Research Synthesis

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16. Abstract

This research synthesizes literature on the relationship between working from home and travel. This relationship is a pertinent one because transportation planners and policymakers have long hoped that increased remote work, sometimes called telecommuting or telework, will reduce driving, traffic congestion, and vehicle emissions. This question is especially pertinent today because working from home increased dramatically early in the COVID-19 pandemic and has remained at substantially elevated levels since then. To examine this issue, we review nearly 100 research articles, reports, and some popular accounts of telecommuting and travel prior to and during the pandemic. In conducting this review, we arrive at five principal findings. First, remote work increased dramatically with the onset of the pandemic and appears likely to remain elevated for many years to come. Second, while not everyone can work remotely, for those who have the option to do so, at least part-time, this hybrid option is extremely popular with most workers. Third, employers tend to be skeptical of the benefits of remote work, but the research does not support fears of declining productivity in the near term, and the tight post-pandemic labor market has given workers leverage to insist on remote work options. Fourth, telecommuting has long been touted as a potential solution to chronic transportation problems like traffic congestion and vehicle emissions, but the research has consistently found that it is more likely to increase, rather than decrease, overall driving among remote workers. This extra driving is due both to hybrid workers living farther from work, on average, than non-remote workers and to all remote workers making more household-serving and personal trips when they work from home. And fifth, public transit systems, in contrast to street and highway systems, have been dramatically affected by the pandemic, likely due substantially to the rise in remote work it has engendered. The future of many public transit systems, which draw an outsized share of their riders from commuters to downtowns and other major job centers, will depend on whether and to what extent those job centers re-densify with workers in the months and years ahead.

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Disclaimer

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List of Acronyms and Definitions

ACS	American Community Survey
ATUS	American Time-Use Survey
CBD	Central business district
GHG	Greenhouse gas
ICT	Information Communication Technologies
NHTS	National Household Travel Survey
PMT	Person miles traveled
VMT	Vehicle miles traveled
WFH	Work from home

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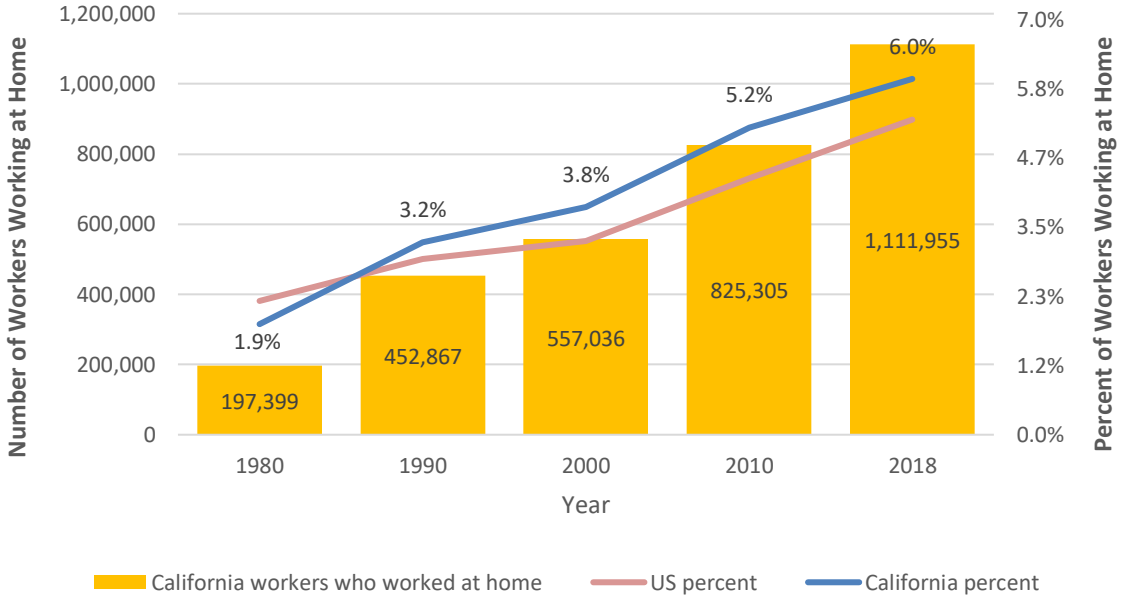
Introduction

The COVID-19 pandemic turned American work life outside-in. Prior to the pandemic nearly all American workers worked outside of the home most or all of the time. Suddenly, over only a few weeks in March 2020, the Brookings Institution estimated that at least half of all American workers were working at home as a result of SARS-CoV-2 prompted closures (Guyot & Sawhill, 2020). Although many jobs could not shift to remote work, many workers who once worked from offices and cubicles took to kitchen tables, couches, and home offices, while meetings shifted from conference rooms to virtual webcam "rooms."

Telecommuting—also known as telework, remote work, and working from home— generally refers to any work that takes place in the home instead of in a traditional multi-worker non-home office setting. Despite a relatively large body of research on the topic dating back a half-century, shares of U.S. and California workers who primarily work at home grew slowly in the four decades leading up to the outbreak of COVID-19. From 1980 to 2018, the share of Californians who worked primarily at home rose from just under two percent of the state's workforce to six percent, shown in Figure 1 as the blue line (U.S. Census Bureau, 1980). This trend largely mirrors, though is somewhat higher than, the trajectory of national work at home growth, which is delineated by the red line in Figure 1: the national share of work-from-home grew from 2.3 percent in 1980 to 5.3 percent in 2018. Prior to the pandemic, only 1.1 million Californians and 18.5 million Americans worked primarily at home (US Census Bureau, 2018).

Figure 1. Work-at-home trends in California and the United States, 1980–2018

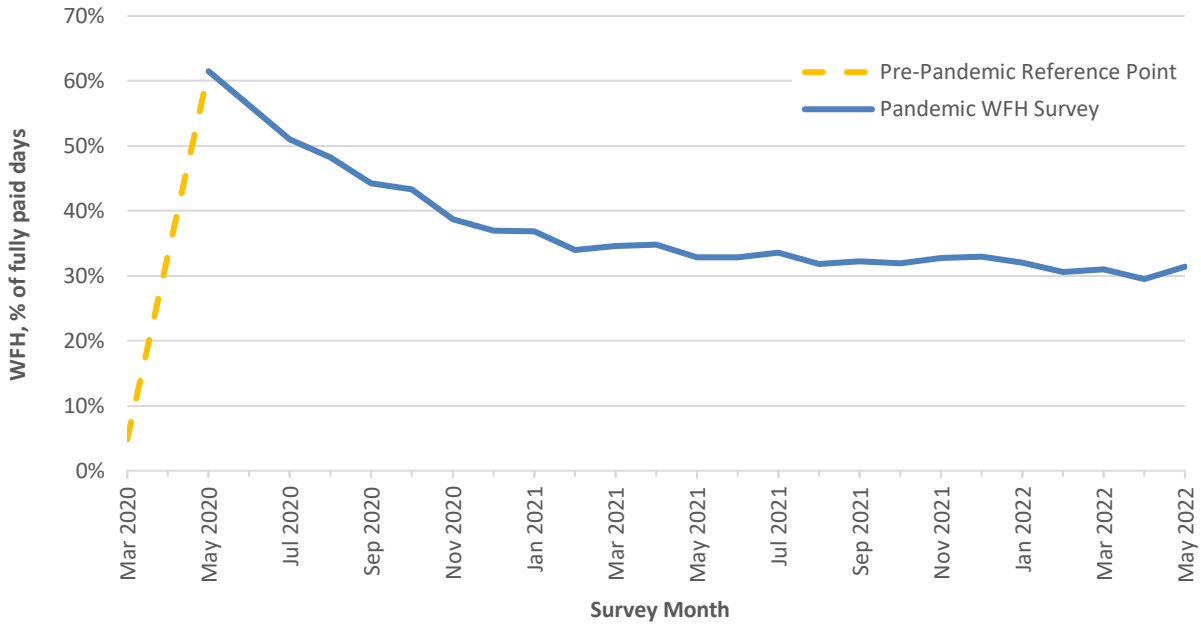


Source: US Census (1980–2000) and American Community Survey (2010, 2018).

For those who telecommuted only part-time prior to the pandemic, working from home was widely viewed by employers and employees alike as when they "had an easy day" (The Economist, 2020). Despite remarkable advances in information and communication technologies (ICT) in the years since 1980, many office-based firms remained slow and/or reluctant to adopt working-from-home at any scale. Well prior to the pandemic, one researcher called telecommuting "more myth than modern work form" after finding in a survey of all but two of the top-100 Australian companies that few employees worked from home (Lindorff, 2000, p. 2). One theory is that this may have been a result of "sticky work cultures," with firms reluctant to adopt the management practices needed for virtual work (Guyot & Sawhill, 2020).

But in the time since California Governor Gavin Newsom first issued a statewide shelter in place order on March 19, 2020, the landscape of remote work has changed dramatically. As data from Barrero et al. (2021a) displayed in Figure 2 show, the nationwide percent of all paid workdays carried out remotely skyrocketed in the first two months of the pandemic, peaking at 62 percent in May 2020. By the end of 2020, however, that rate had settled at around 37 percent. Two years later, the share saw only modest declines, averaging 31 percent of all paid workdays being worked from home in 2022 with only minimal fluctuations. On the one hand, this may seem to pale in comparison to May 2020, and indeed it does; on the other hand, 31 percent working from home is roughly *six times* what it was before COVID-19 struck.

Figure 2. U.S. work-at-home trends during the COVID-19 pandemic



Source: Barrero et al. (2021a), with updated data in 2022.

Of course, this dramatic shift in workplace location from office to home has profound implications for transportation, as well as for the size, configuration, and location of both homes and offices. Telecommuting by its very nature implies the absence of a physical commute, and as such, its increased prevalence has the potential to drastically change demand for our transportation systems—many of which are designed to accommodate morning and evening peak period commutes into and out of downtowns and other office centers. Indeed, vehicle traffic volumes plummeted in the early months of the COVID-19 pandemic, only to quickly, if unevenly, rebound to pre-pandemic levels; U.S. vehicle travel in 2022 was about the same (99.3%) as just prior to the pandemic (Alternative Fuels Data Center, 2022). In contrast, public transit ridership during the second year of the pandemic was less than half (48.7%) of pre-pandemic levels (Federal Transit Administration, 2022), with most systems in 2022 mired at about a quarter to three-quarters of pre-pandemic levels (depending on the agency); systems predominantly serving major downtowns, like Bay Area Rapid Transit (BART) in the San Francisco Bay Area, have been hit especially hard. Taken together, these trends beg the question: To what degree are elevated levels of remote work here to stay, and what does this shift in work location portend for our transportation systems?

The by-now substantial body of pre-pandemic research on working from home offers insights into the behaviors of telecommuters, but the pandemic-fueled wave of remote work is very different in both scope and scale from what came before. Accordingly, this report examines both pre-pandemic and in-pandemic research on working-from-home and travel, and considers its near-, mid-, and longer-term implications for travel behavior and transportation systems. We specifically examine the effects of telecommuting on both work-related and overall personal travel, with a focus on the persistence of working from home, changes in commuting and residential patterns, personal vehicle travel, traffic congestion, and environmental consequences. We conclude by discussing gaps in the existing research, prospects for post-pandemic travel recovery, and future research needs.

Definitions and Data

Research on telecommuting is substantial and has grown even larger as the pandemic has worn on. One reason that so much ink has been spilt on the topic is that the results are so varied. This variance is due to a lack of agreed-upon definition for telecommuting (and its synonyms), to the many different data sources employed by researchers, and to the many outcome variables examined, including work performance and job satisfaction, travel behavior, residential location choices, and health outcomes. The large body of research is the product of two other factors as well. First, interest in remote work among managers, government officials, and researchers substantially exceeded the actual incidence of pre-pandemic remote work. Second, that script flipped in the pandemic when more than half of all workers suddenly started telecommuting, and research on this newly big topic quickly ramped up. Thus, while the body of research on working from home is substantial, it consists of a collection of independent studies that vary widely in subject, data, methodology, and analysis.

Defining Telework

So just what is telecommuting? Mokhtarian (1991) examined this question in an early overview of telecommuting research. More recently, Allen et al. (2015, p. 43) offered an operational definition of telecommuting:

> *Telecommuting is a work practice that involves members of an organization substituting a portion of their typical work hours (ranging from a few hours per week to nearly full-time) to work away from a central workplace—typically principally from home—using technology to interact with others as needed to conduct work tasks.*

However, even this definition—which is born out of a thorough research of definitions in more than a dozen studies on the topic—is not a consensus definition. Rather, it is unlikely that any definition will be fully agreed upon, as telecommuting has a "complex, multifaceted nature…as a social phenomenon" (Mokhtarian et al., 2005, p. 2).

Further, while most studies use these terms to mean the same phenomenon, they are not all truly interchangeable. While telecommuting, teleworking, virtual working, and remote working all generally imply that a worker is substituting office work for work somewhere else (often at home), working at/from home can be a much broader term. For example, self-employed workers may run small businesses out of their home and thus have no workplace from which to stay home. Further, Ameer et al. (2021) highlight the differences in working from home in highly agricultural U.S. states as compared with the country overall; they find that while the share of home-workers in these agricultural states diminished by half from 1970 to 2010 (from 11% to 5%), the five percent share was still higher in 2010 than in the rest of the country. This is likely the result of farming from home, and not virtual work.

Another embedded reason for confusion is the inconsistency across workers studied with regard to how often they telecommute. Some pre-pandemic telecommuters did so only occasionally or once per week, while others did so full-time. Many data sources frequently used in analyzing telecommuting—including the U.S. Census, American Community Survey (ACS), and the American Time Use Survey (ATUS)—do not provide respondents with an option to report part-time telecommuting. For the census and ACS, responses are based on workers' behaviors in the week prior to completing the survey and on where the respondent worked for the *majority* of the time. For the ATUS, responses are based on the days in which respondents were surveyed, meaning that while a worker may only telecommute once per week, if their response day was on that day, they would be characterized as a full-time telecommuter. With the substantial rise in the number of workers who split their work time between a worksite and home during the pandemic, such all-or-nothing definitions of remote work are increasingly problematic.

Geography, Subjects, and Samples

We reviewed studies of telecommuting in Australia, Belgium, Canada, China, Italy, the Netherlands, Norway, the Philippines, Romania, South Korea, Sweden, Singapore, the United Kingdom, the United States, and Vietnam. These countries vary substantially in economic structure, working norms and cultures, and policies; what may be commonplace in the United States may be rare or drastically different in the Netherlands or China. This extends to business practices and travel behaviors as well.

Similarly, many studies examine narrow slices of home workers to analyze specific aspects of the phenomenon, so the results are often relevant to a specific subset of workers or topics. For example, conclusions drawn from a study of municipal employees in San Diego (Mokhtarian et al., 1998) are difficult to directly compare with a study of private-sector financial firm employees in New Jersey (Henke et al., 2016).

Stated vs. Revealed Preferences and Individuals vs. Firms

Many studies in the telecommuting literature, especially those conducted during the pandemic, rely on self-reported survey data. Survey researchers might ask respondents if they feel they are more productive working from home or if they would like to continue working from home when COVID-19 shifts to being endemic. While informative in many respects, there are two important factors that these types of surveys can miss. First, what a worker says they will do and what behaviors they ultimately choose can vary, sometimes substantially. This may be because respondents do not want to reveal their true motivations or intentions, or it may simply be because people don't know what they will actually do in an uncertain future. Second, even for workers who would stay true to their stated preferences once decision time arrives, their firms' work location policies may diverge from that preference. For example, a worker might indicate on a survey that they would like to continue working from home, but they may later find that, once their colleagues return to the office, they too may wish to return, even if only on a part-time basis; alternatively, a worker may remain steadfast in the desire to continue working

remotely, but their firm's policies or their supervisor may insist on office work, either full-time or in a hybrid schedule.

While many studies refer to the mass migration of work from office to home during 2020 and into 2021 as a natural experiment, it was one for many workers that involved little in the way of choice, transitioning from "you must come to work" to "you must work from home to avoid infection." So, research on working from home during the pandemic, particularly in that first year between the first safer-at-home orders and the widespread availability of vaccines, should be viewed with some caution, as we are most interested in what the world of work and travel will be like after the pandemic, rather than early in it.

Who Works from Home

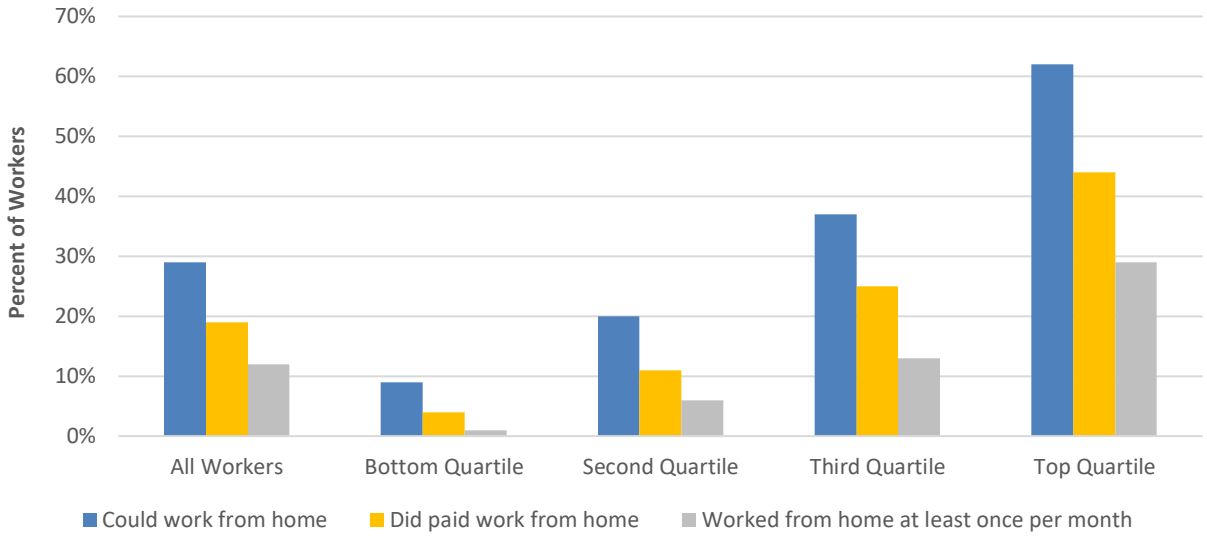
Prior to March 2020, nearly all individuals who worked from home *chose* to do so. The choice to work from home — and who is offered that choice — is important to understanding the phenomenon at large, but the absence of that choice is also important. From March 2020 forward, many of those who worked from home did so because of the pandemic, and many of those workers would not have taken that choice had it not been forced on them (Palumbo, 2020).

Who Chose to Work from Home Before COVID-19

Pre-pandemic telecommuters chose to do so for a variety of reasons and were largely confined to a specific group of industries. Vanderstrukken et al. (2022) identify three overarching types of telecommuters through a latent class analysis using 2016 to 2018 survey data: 1) those for whom working from home is a job requirement, 2) those who see working remotely as more efficient and better for managing work pressures, and 3) those who seek work-life balance and view working remotely as a way to achieve that. Logically, regardless of reason, not all jobs can be done remotely, and among those who can there is a range of advantages and disadvantages of remote work. For example, remote work was less likely to occur in consumer-facing industries that rely on personal interactions, including arts, entertainment, recreation, restaurant and accommodations services, and administrative support services (Gaduena & Alcantara, 2021).

Those who could work from home and who did so prior to the pandemic were overwhelmingly in the top income quartile. In fact, as Figure 3 shows, the opportunity and choice to work from home rises with income, which is consistent with prior findings (Singh et al., 2013). This stands to reason on two fronts: first, a larger share of lower-wage jobs cannot be performed remotely, and second, higher-wage workers tend to have more bargaining power over salary and working conditions, and may be more likely to bargain for flexible work location opportunities as a relatively low-cost benefit.

Figure 3. Pre-Pandemic Work from Home Option and Frequency by Income Quartile



Source: Bureau of Labor Statistics, 2019; adapted from Brookings Institution (Guyot and Sawhill, 2020).

Beyond income, there are important differences between the option to, the choice to, and the frequency with which someone works from home. Middle-aged workers (ages 35 to 50) were the most likely age group pre-pandemic to have the option for telecommuting, yet they were also the least likely to telecommute frequently (Singh et al., 2013). Additionally, men were more likely to be telecommuters than women (Drucker & Khattak, 2000), but women were more likely to choose to work from home than men if an employer offered them the option (Singh et al., 2013). In a study of city employees in San Diego, Mokhtarian et al. (1998) found that women tended to rate the advantages of telecommuting more highly than men, and were more likely than men to list family, personal benefits, and stress reduction as motivations for telecommuting. However, the authors also found that women were more likely than men to encounter supervisors unwilling to allow telecommuting, and that women were also more likely to be concerned with lack of visibility to management.

Telecommuting can play an important role in work-life balance, but such balance does not always entail working from home. While the relationship between flexible work schedules in general and reported work-life balance is positive (Feeney & Stritch, 2019), the relationship between telecommuting and work-life balance appears to be positive as long as the choice to telecommute is provided, regardless of whether the worker actually opts into it. In fact, workers who are offered the option of telecommuting but instead choose to work in the office report the highest average levels of work-life balance. Those who telecommute rank second; those who cannot telecommute due to the nature of their job (e.g., assembly-line workers) rank third; and those whose job would typically allow them to telecommute but whose employer denies them the option rank last (Koh et al., 2013).

Who Worked from Home During the Pandemic

Through the first year of the pandemic, much of the employed U.S. population that could telecommute did so. Most estimates for the percentage of jobs able to be done remotely hover around 40 percent in developed countries (Dingel & Neiman, 2020; Holgersen et al., 2021). Among jobs with telework potential, roughly 85 percent were remote in May 2020; by December 2020, that share receded to just below 60 percent (Ker et al., 2021). While there were many factors associated with teleworking during the pandemic, exclusive telework was largely a function of company closure policy and pre-pandemic remote work frequency; that is, if a company could continue its work remotely and created policies to do so to prevent the spread of the virus, its workers did so (Nguyen, 2021). Indeed, the share of work done remotely in the first two months of the pandemic exceeded the percentage of jobs previously thought of as able to be done remotely by large margins, as fear of infection led sectors that do not inherently possess remote work capabilities, like public schools, to make do working remotely until the virus was better understood.

Once firms implemented COVID-19 workplace policies, who ultimately worked at home? In short, white collar jobs went remote, while blue collar jobs did not (Matson et al., 2021). As before the pandemic, those who worked remotely from March 2020 forward were generally wealthier. Those in the top half of incomes were more likely to have worked from home and less likely to have stayed home but been unable to work (Guyot & Sawhill, 2020), and those who were economically disadvantaged were less likely to hold jobs that were able to be done remotely (Holgersen et al., 2021). Relatedly, those workers who reported some level of difficulty managing their expenses were also less likely to telecommute (Jiao & Azimian, 2021).

Further specifics vary from study to study, but all generally point to pandemic-motivated telecommuters being more likely young to middle aged with higher levels of education. In addition, Jiao and Azimian (2021) found across three different time periods during the pandemic that married workers, women, those in households with more than two people, and those reporting high anxiety were more likely to work remotely. Barbour et al. (2021) identified COVID-19 telecommuters as likely to possess a graduate degree, work in the information technology or administrative support sectors, and/or have a college degree and children at home. On the other hand, the factors associated with not telecommuting during the pandemic were all over the map, including workers who: were over 49 years old, did not possess a college degree and had children at home, were low-income, worked in the marketing sector, had a graduate degree and lived in a large city, and/or were male with children at home.

Ultimately, the apparently scattershot nature of factors predicting who is working from home amid the pandemic suggests that reliably predicting the effect of increased post-pandemic telecommuting on travel behaviors will take some time to sort out. What we know now is that higher-income workers and white-collar workers are telecommuting more than others, and that those workers tend to have longer commute distances (at least in Southern California) (Blumenberg & Siddiq, 2022). But what that will mean for their travel behaviors and associated travel patterns over the longer term remains uncertain.

Effect on Travel

For full-time telecommuters, the effect on commuting is obvious: it ceases on work-from-home days. However, the journey-to-work accounts for a much smaller share of person miles of travel and, especially, personal trip-making than is commonly believed. For example, according to the 2017 National Household Travel Survey, commuting accounted for 23 percent of person miles of travel, and just 22 percent of all personal trip-making (Federal Highway Administration, 2018). So even if commute travel were not replaced by other forms of travel, the overall effect of increased working from home on vehicle travel, traffic congestion, and emissions may not be as dramatic as many might hope.

In particular, the effect of part-time telecommuters—of which there are many more than full-time telecommuters—is both complex and nuanced. For the transportation system, an increase in telecommuting (both full-time and weekly hybrid) leads to a decrease in the number of commuters. Shifts in the timing and direction of vehicle traffic, and depressed public transit ridership — particularly into and out of downtown office centers — during the pandemic have demonstrated this. But despite these declines and shifts in commuting, several studies make compelling cases that, while telecommuters' peak period trip-making decreases as expected, their overall trip-making and vehicle travel actually *increases*. (Table 2 at the end of this section details a list of studies on this topic. It begins with the last U.S. study to find a moderate decrease in telecommuters' trip-making which used data from 1988–1998; the rest since then have found increases. Studies prior to the late 1990s tended to only examine telecommuting's effect on commuting and work trips, which does not provide a holistic view on the effects working remotely would have on overall travel.)

Telecommuting and Travel during COVID-19

While most telecommuting during the COVID-19 pandemic has taken place at home, not all telecommuters are home workers. Technology enables people to work in a variety of places outside the home, even outdoors but, before vaccines became widely available in Spring 2021, the SARS-CoV-2 virus did not. While shelter-in-place orders were in effect, nearly all alternative workplace and business meeting destinations for office workers remained closed: traditional offices, libraries, coffee shops, restaurants, coworking spaces—even friends' and families' homes were restricted in the first year of the pandemic. And even after vaccines became widely available in Spring 2021, many workers remained wary of social and professional interactions, especially in large group settings. This has likely reduced working in shared offices, traveling for business, and attending other large gatherings, which may also affect how increased telecommuting influences travel behavior.

Nonetheless, although overall traffic volumes recovered quickly in the summer and fall of 2020, they were generally below pre-pandemic levels during the first year of the pandemic. During the second year of the pandemic and since then, vehicle travel has generally been just below, at, or

just above pre-pandemic levels as the rest of the economy reopened and then boomed, even though remote work remains substantially elevated compared to pre-2020 levels. What this means for the future of travel is uncertain, but because studies that examine pandemic travel behaviors do not capture a fully open economy, particularly between the springs of 2020 and 2021, we mostly focus here on the pre-pandemic behaviors of telecommuters.

Work Travel Behaviors and Vehicle Travel

When telecommuters do travel to work, their commutes tend to be longer than those who regularly commute, based on studies in the decade prior to the pandemic. As Table 1 shows, telecommuters (in this case defined as any respondent who reported telecommuting at least once per week) had commutes, total work-trips (including commutes), and total non-work trips that were *all* longer in distance than non-telecommuters.

U.S. telecommuters took more frequent trips of all types, including non-commute work-related trips (e.g., sales visits) than non-telecommuters, in spite of not actually commuting to an office (Zhu, 2012). This effect holds true for metropolitan areas of all sizes, although the differences are smaller in large metro areas (Zhu et al., 2018). These higher levels of trip-making hold true for lower-income *and* higher-income workers on days they telecommute (He & Hu, 2015). So, while the commute may cease on days when workers telecommute, telecommuting does not eliminate all work-related trips, nor does it encourage shorter commutes when they do occur.

Table 1. Trip-Making for Telecommuters and Non-Telecommuters in 2009

Type	Measure	Telecommuters*	Non-Telecommuters
Commute (One-Way)	Avg. Distance	21.3 mi.	13.7 mi.
	Avg. Duration	31.5 min.	23.4 min.
Total Work Trips (in trip day)	Avg. Distance	42.7 mi.	29.8 mi.
	Avg. Duration	71.9 min.	54.3 min.
	Avg. No. of Trips	2.4 trips	2.3 trips
Total Non-Work Trips (in trip day)	Avg. Distance	36.1 mi.	31.2 mi.
	Avg. Duration	73.6 min.	64.4 min.
	Avg. No. of Trips	4.2 trips	3.8 trips

**Telecommuters are defined here as any respondent who reported telecommuting ≥1 time per week*

Source: National Household Travel Survey (2009) via Zhu (2012)

Why the longer trips when telecommuters do commute to work? The causal arrow here likely runs in both directions. In other words, those living farther from work are likely more motivated to work remotely, at least part-time; in addition, telecommuting may, over time, allow more workers to choose housing further from their worksite. Indeed, one commonly proffered reason is that workers tradeoff total time spent commuting with housing costs; that is, they may choose

cheaper or more housing in exchange for longer, less frequent commutes. In a unique study using panel data that tracks the same sample of workers over time, de Vos et al. (2018) show that when previous commuters become telecommuters, working from home allows them to accept a five-percent increase in typical travel duration from home to work, on average. Specifically, every additional 8 hours per week of working from home is associated with a 3.5 percent increase in typical travel duration from home to work.[1] (We explore the role of residential location in later sections of this report.)

Telecommuting's role in public transit use is more nuanced. Two studies have found that transit use is more likely among telecommuters in the aggregate. Pre-pandemic telecommuters in the U.S. had 56 percent greater odds of using transit at least once per month (Chakrabarti, 2018) and were disproportionately represented among commuter rail users, as 22 percent of U.S. commuter rail users also reported worked from home at least occasionally (Jin & Wu, 2011). But commuter rail is hardly typical transit: commuter rail accounts for just five percent of all public transit boardings nationally (American Public Transportation Association, 2021) and trips on the mode are typically very long. Further, these outcomes may not indicate *daily* transit use: U.S. telecommuters were 71 percent less likely to use transit on a day they telecommuted (Chakrabarti, 2018). Collectively, these findings suggest that telecommuters are more likely to do exactly what de Vos et al. (2018) describe—live farther from the office because they need to commute less often—while also having a higher propensity to use public transit than otherwise when they do commute in.

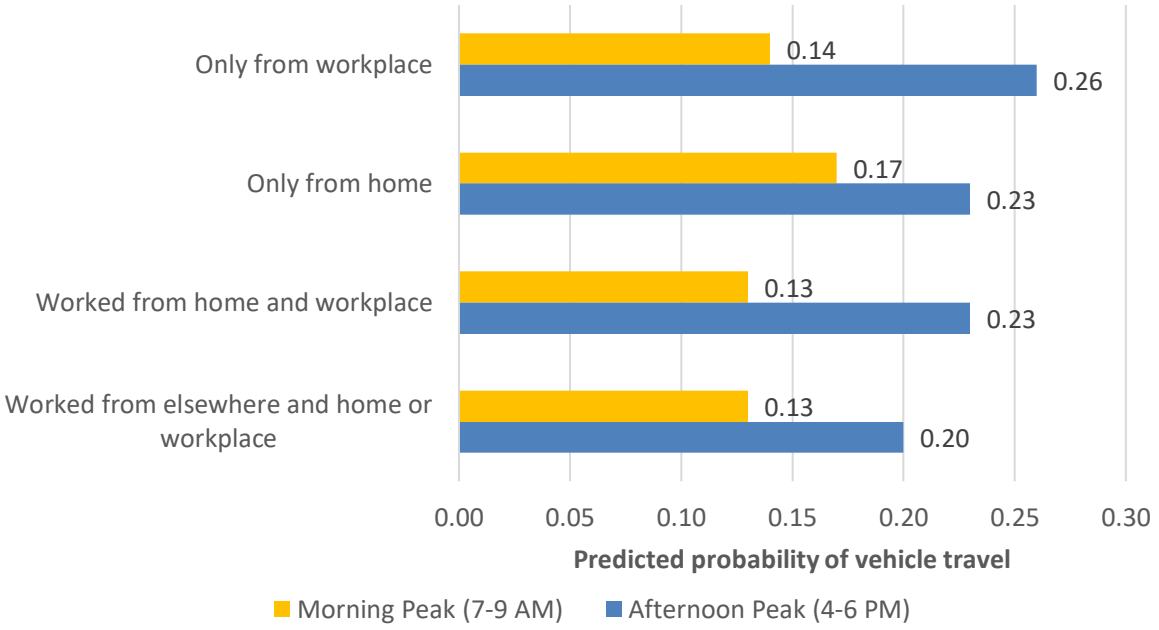
Personal and Household Travel Behaviors and Vehicle Travel

Telecommuting does not just lead to more (non-commuting) work-related travel, it leads to more personal travel as well. Table 1 above shows that U.S. telecommuters, on average, travel about five miles more and about nine minutes more per day for non-work-related trips. Zhu and Mason (2014) also find that telecommuting is associated with more vehicle travel for non-work trips, too, such that for all trips telecommuters average 43.8 daily vehicle miles of travel (VMT), 16.8 percent more than non-telecommuters' 37.5 daily VMT. Some of this can be explained by the added flexibility afforded to workers who work from home with less structured work schedules and less direct supervision. Unlike workers who are required to be present in an office during specific hours, telecommuters can choose to, for example, break up their workday by going to the gym in the late morning or running errands in the early afternoon. Indeed, telecommuting is associated with 44 percent greater likelihood in workers spending at least 30 minutes on physical activity per day and 71 percent higher odds of doing so on a day the worker telecommutes (Chakrabarti, 2018).

[1] Although de Vos et al. (2018) use data from the Netherlands, where commute modes and patterns are demonstrably different from the United States, this study is noteworthy because it tracks the same sample of workers over time and is the only such study we could find to do so. Thus, it is able to demonstrate that when a worker who was once a traditional worker is given the option to telecommute, they ultimately choose to live further from the office, on average.

Many of these added non-commute trips occur outside of peak traffic-congested hours, especially in the afternoon peak. Canadian telecommuters—including those who work only from home, work part of the day in the office and part of the day at home, or work part of the day elsewhere—are less likely than workplace workers to take vehicle trips during the afternoon peak, as Figure 4 shows. However, the same is not true for the morning peak. In fact, Lachapelle et al. (2018) find that telecommuters are more likely to engage in morning peak trips than office workers, which they theorize could be due to working parents driving their children to school or scheduling personal appointments at the beginning of the business day.

Figure 4. Predicted Probability of Peak Hour Travel by Work Arrangement



Source: Lachapelle et al. (2018) using the 2005 Canadian General Social Survey.

This phenomenon of increased vehicle travel among telecommuters is not confined only to North America. As Table 2 shows, several studies published over the past 15 years have found increased total individual vehicle travel among telecommuters in the United Kingdom (Caldarola & Sorrell, 2022; de Abreu e Silva & Melo, 2018a, 2018b) and South Korea (Kim, 2017), even though total number of trips and average trip durations tend to be lower among telecommuters (Caldarola & Sorrell, 2022; Lachapelle et al., 2018). In the U.K., these non-work trip increases lead to an association between telecommuting (both full-time and hybrid) and higher CO_2 emissions, as compared to those who work at a single location (Cerqueira et al., 2020). As noted above, the *most recent* study anywhere that we could find that did not find a positive relationship between telecommuting and overall vehicle travel analyzed data from 1988 to 1998 (Choo et al., 2005).

There is some debate about the effect of telecommuting on the travel of other household members. While Zhu and Mason (2014) find no effect (positive or negative) on other members of the household when a worker telecommutes, Kim (2017) and Caldarola and Sorrell (2022) find that households with a telecommuting head-of-household tend to travel more than households without a telecommuting head-of-household. Among working households in South Korea without telecommuters, days on which the head of household does not commute to work, such as a day off or a weekend, are associated with an additional 1.25 person miles traveled (PMT) and 0.62 VMT per household member per day. However, for households with telecommuters on days when a head of household telecommutes, the positive effect on overall household PMT and VMT is twice that of an office commuter taking a day off (Kim, 2017). And in the U.K., households with at least one worker telecommuting once or twice a week average a 14-percent increase in weekly distance traveled and a 7-percent increase in weekly trips made as compared with households with no telecommuters. Taken together with the increase in work trip distance, U.K. households with workers who telecommute occasionally traveled 16 percent more by private means, on average.[2] While these studies are not all in agreement on the degree to which telecommuting affects overall household travel, *none* find that telecommuting decreases overall household travel.

Table 2. Summary of Telecommuting Research on Effects to VMT and Travel

Study	Location	Years	Data Source	Analysis Variable(s)	Findings
Choo et al. (2005)	United States	1988–1998	Aggregate time series data	Change in Total Annual VMT	–0.8% (upper bound, 90% confidence)
Jin and Wu (2011)	United States	1995, 2001, 2009	National Household Travel Survey	*Several, including miles driven per year by telecommuting frequency:* Almost every day Once a week Once a month < once a month Never	Approximations, 2009 12,000 [a] 17,000 17,000 15,500 15,000
Zhu (2012)	United States	2001, 2009	National Household Travel Survey	*Work trips:* Number of trips Trip distances Trip durations *Non-work trips:* Number of trips	Higher among telecommuters by: +5% +43% +33% +11%

[2] Estimates for household effects among high-frequency telecommuters (≥3 days per week) were not significant, in large part because there were far fewer high-frequency telecommuters (1.4% of all U.K. households in 2019) than medium-frequency telecommuters (7.8%).

				Trip distances Trip durations	+16% +14%
Zhu and Mason (2014)	United States	2001, 2009	National Household Travel Survey	Work trip VMT Non-work trip VMT Total VMT	Higher among telecommuters by: +40% +16% +21%
He and Hu (2015)	United States (Chicago)	2007	Chicago Regional Household Travel Inventory	*Poisson regression result for total trips among (as compared to equivalent non-telecommuters):* Low-income frequent TC Low-income infrequent TC High-income frequent TC High-income infrequent TC	Coefficients: +0.075 (not sig.) +0.153 +0.039 +0.038
Kim (2017)	South Korea	2006	Seoul Metro. Area Household Travel Survey	*Household PMT and VMT effect among households on days:* without a commute with a commute telecommuting	 +1.3 PMT, +0.6 VMT +2.5 PMT, +1.3 VMT
Chakrabarti (2018)	United States	2009	National Household Travel Survey	*Difference among telecommuters (4+ days/month):* Walk trips per week Odds of 1+ transit trip / week Odds of >20,000 VMT/year *Difference among telecommuters on workday:* Odds of walk/bike >1 mi. Odds of 1+ transit trip Odds of <10 VMT	 +15% +56% +27% +41% –71% +358% [b]
de Abreu e Silva and Melo (2018a)	United Kingdom	2005–2012	National Travel Survey	*Path analysis models:* Weekly trips and dist. by mode Weekly trips and dist. by purp.	Teleworking frequency is a function of commute distance
de Abreu e Silva and Melo (2018b)	United Kingdom	2005–2012	National Travel Survey	Weekly travel distance by car, by number of workers in household 1 2	% greater by 1-2 day per week TCers vs. never +47% +36%
de Vos et al. (2018)	Netherlands	2002 – 2014 (biannual)	Labour Supply Panel	Commute duration	+ 5% longer commuting duration +8 hours of telecommuting = 3.5% longer commute dur.
Lachapelle et al. (2018)	Canada	2005	Canadian General Social Survey	Overall travel time Odds of using non-motorized travel mode	–14 min. +77%
Zhu et al. (2018)	United States	2001, 2009	National Household Travel Survey	*Mean one-way commute dist. by metro area population:* <1 mil. 1–3 mil.	Higher for telecommuters by: +52%

				≥3 mil.	+44% +31%
				Mean one-way commute dur. by metro area population: <1 mil. 1–3 mil. ≥3 mil.	 +32% +26% +26%
Caldarola and Sorrell (2022)	United Kingdom	2005–2019	National Travel Survey for England	*Percent difference from non-teleworkers, for medium-frequency telework trips per week:* Indiv. commute trips, distance Household commute trips, dist. Indiv. business trips, distance Indiv. non-work trips, distance Household non-work trips, dist. *for high-frequency telework [c]:* Indiv. commute trips, distance Household commute trips, dist. Indiv. business trips, distance Indiv. non-work trips, distance Household non-work trips, dist.	*Trips, Distance* –14.9%, +10.9% –5.4%, +19.0% +46.1%, +68.5% +7.8%, +12.9% +7.4%, +13.6% *Trips, Distance* –25.3%, –20.1% –15.6%, not sig. +24.5%, +47.0% +7.4%, not sig. not sig., not sig.

a Note that 2009 differs from the 1995 and 2001 samples, possibly due to the Great Recession; in the two prior survey years, full-time telecommuters generated the highest VMT per year.

b Although we do not dispute the finding that telecommuters are much more likely to fall into the <10 VMT on travel day category, this measures the distribution of telecommuters with respect to vehicle travel bins, and does not measure the overall amount of driving that telecommuters do as a group on their travel day; while telecommuters in this analysis are more likely to be in the lowest VMT/day category, they are also more likely to be in the highest VMT/year category. Findings from Zhu (2012) explore this difference.

c Several results were not significant at the 5% level due to small sample sizes among the high-frequency telework subsample.

What Telecommuters Do Instead of Commuting

On average, telecommuters spend more time on three types of activities: sleep, leisure, and household production activities, like cooking, cleaning, and grocery shopping (Frazis, 2020; Pabilonia & Vernon, 2022). Some of these substitute activities happen inside the home, meaning they do not generate travel; but other activities happen outside the home, which do generate travel. In California prior to the pandemic, for example, only 20 percent of telecommuters stayed home all day (Su et al., 2021).

First, and perhaps unsurprisingly given the reduction in commuting, half of which happen in the early morning hours, telecommuters tend to sleep about 25 minutes more on days they telecommute, compared with days they travel to the office (Frazis, 2020).

The second consistent theme to emerge in how telecommuters spend their time is leisure activities. While this includes a near-universal increase in time spent watching television, it also

includes many out-of-home activities like socializing with friends, exercising, and general recreation (Frazis, 2020; Gimenez-Nadal & Sevilla, 2012).

Third, household production activities can vary across telecommuter characteristics and measurement methods. In particular, female telecommuters with children at home tend to reconfigure their life spheres (Hilbrecht et al., 2013), but male telecommuters also tend to engage in more child care activities (Gimenez-Nadal & Sevilla, 2012). However, the way childcare is accounted for can vary by the study. For example, the American Time-Use Survey allows for respondents to indicate childcare as a secondary activity, such that it can be occurring during the principal activity, including paid work at home but also including other non-home-based activities like errands. Frazis (2020) finds that although *primary* childcare is not significantly related to time use by telecommuters, *secondary* childcare is.

In all of this, telecommuting appears to increase the mode share of private vehicles, likely because teleworkers are less likely to live in or travel to the dense, transit-rich areas where offices often congregate. And although telecommuters (except part-day hybrid commuters) eliminate their commute to work when they work remotely, as discussed above most pre-pandemic research finds that when they do commute it is for longer distances, on average. Because of their schedule flexibility and relative autonomy, telecommuters are more likely to engage in non-work trips that are either short trips on active modes or longer trips in cars (de Abreu e Silva & Melo, 2018a).

Existing research generally treats telecommuting as an all-day decision. However, for workers shifting to a daily hybrid schedule—where, for example, a work may travel to a worksite in the AM peak but leave work in the afternoon to pick up kids from school and then work a couple of more hours from home—the effect on vehicle travel is likely more negligible, even if the PM commute home is much earlier in the afternoon than before.

The Importance of Information Technology

Technology is central to telecommuting. It is one of five attributes Allen et al. (2015) list in defining the practice.[3] California's role in this is unique: not only does technology enable telecommuting, but many of the technology companies that enable telecommuting are located in the Golden State. Videoconferencing technology has been particularly key in enabling the large-scale shift to telecommuting during the pandemic, and nearly all of the leading video-conferencing software providers—Zoom Video Communications, Google, Facebook, and Cisco—are based in Silicon Valley. (Microsoft, which produces Microsoft Teams and Skype, is based in Redmond, Washington.)

Over the course of the pandemic, information and communication technologies (ICT) have enabled many firms and workers to shift from previously working in brick-and-mortar offices to virtual spaces over the internet. These advances not only allow workers to work from home effectively but to work from just about anywhere. Technology has the ability to affect travel behaviors in four ways: substitution, complementarity, modification, and neutrality (Mans et al., 2012; Mokhtarian, 1990; Salomon, 1986).[4] That is, technology can enable a would-be-traveler to eliminate the trip, such as replacing a visit to a friend with a video-conference call. Or technology can complement travel by motivating increased travel demands, such as new interest in scenic vistas spurred by social media posts or added shopping trips to retailers because of online advertising. In modifying travel, technology may change the timing or chaining of trips, such as shifting shopping trips to delivery trips. Or technology may have no effect on trip-taking at all.

Adaptations during COVID-19

Firms and workers who already had experience with working remotely were well-positioned to weather the pandemic compared with those at firms that had not invested in teleworking capacity. Prior to the pandemic, many firms were resistant to virtual work either by policy, by technology, or both. The pandemic changed this both by forcing firms to allow (and early on require) telecommuting and by incentivizing the development and deployment of technologies to do so effectively. The ICTs that enable telecommuting had been evolving for decades, but the pandemic thrust that progress into overdrive. From January to September 2020, the share of new patent applications associated with remote work technology doubled and followed a steep upward trajectory (Bloom et al., 2021). Firms with higher work-from-home feasibility rates

[3] The five are: 1) substituting time spent in office with time spent working away from other employees, 2) doing so for a at least a portion of the week, 3) are part of a larger organization, 4) work principally at home with occasional time elsewhere, and 5) use ICT to engage with coworkers.
[4] Salomon (1986) was the originator of this framework, and Mokhtarian (1990) expanded upon it to create a larger typology. Mans et al. (2012) applied the typology amid more-recent advances in technology.

generally outperformed those with lower capacity for workers to telecommute during the pandemic, but many firms poorer positioned at the outset of the pandemic invested heavily in software to catch up and implement virtual work (Bai et al., 2021).

While these advances were likely to solve pandemic-related challenges of required social distancing and quarantine, the innovations brought forth will likely enhance firms' abilities to support remote work as the pandemic becomes endemic. Here again, though, it is important to acknowledge the differences between the peak of the pandemic and what lies ahead. While during much of 2020 and early 2021 destinations to which one could travel were closed or heavily restricted, the future of elevated remote work will almost certainly be less constrained by technology and policy. Video communications are not confined to computers, and computers are not confined only to offices and homes. These ICT advances will allow remote work, even hybrid remote work, nearly anywhere.

Technology and Work Location

The home was the most common workplace other than the office in the United States from 2003 to 2017, but other locations include others' homes, cafes, libraries, and in vehicles. During that time, working from home rates in the U.S. were gradually increasing, but so too were the rates of working from one or more other locations beyond the workplace. The rates of working in vehicles were increasing, too (Stiles & Smart, 2021).

Why did work from these other locations expand over the past two decades? Certainly, because ICT advances have allowed people to work in places without the need for being tethered to a phone line. When Choo et al. (2005) found that telecommuting was associated with a 0.8 percent reduction in vehicle travel using data from 1988-1998, the state of information and communications technologies was wildly different from today. At that point, Apple was still a decade away from releasing the first iPhone, home internet was accessed via dial-up modem, and "third place"[5] work was almost unimaginable. Today, widely-available broadband internet, powerful, lightweight laptop computers, and always-connected smartphones allow workers a cornucopia of workplace options outside the traditional office.

One statistic that demonstrates this proliferation of options is the growth of a company that first widely capitalized on the "third place": Starbucks. In 1998, when the coffee shop chain had "just" 1,886 locations worldwide (Knoema, 2020), the idea of setting up a laptop computer in a coffee shop with free high-speed internet was almost entirely foreign. A telecommuter could not leave the house and continue working in that era. But pandemic restrictions notwithstanding, today it is commonplace to do so. Now with free WiFi at most of its 31,000 locations, Starbucks built itself around CEO Howard Schultz's vision of providing customers a place that was neither work nor home—the "third place"—which ultimately proved to be an attractive place for many to

[5] The "third place" refers to a neutral space beyond the home and the workplace.

sit with a laptop (Raz, 2017). Further, a concept that has re-emerged only recently is that of the neighborhood telecommuting or co-working center (Bieser et al., 2021).[6]

This is not to say that every telecommuter is working in a cafe every day; rather, there has been a dramatic increase in work location options over the past two decades. Beyond coffee shops, today it is feasible and common to, for example, bring small children to a playground and passively supervise them while also typing out work emails and accessing cloud-based documents on an iPhone. Technology not only enables telecommuting itself, but it also enables telecommuters greater reach and potential destinations during their remote working days.

Work Location and Travel Behavior

Because of this proliferation of workplaces other than homes or offices, it is important to consider travel behaviors across work locations and not just along the binary measure of working from the office or home. Indeed, telecommuters' travel behaviors differ depending on where and when they work. As discussed earlier, across all Canadian workers, telecommuters' peak-period travel behaviors differed such that they traveled more in the morning peak and less in the afternoon peak than workplace workers. Those who worked in a hybrid of locations (work/home, elsewhere/home, or elsewhere/work) saw only a modest decline in predicted probability of traveling in the morning peak, while they saw a greater decline in likelihood of traveling in the afternoon peak than workplace workers (see Figure 4) (Lachapelle et al., 2018).

This comparison differs slightly when examining only knowledge workers[7]. Over a quarter of U.S. knowledge workers worked from somewhere other than their workplace between 2003 and 2017 (Stiles & Smart, 2021). Those who worked exclusively at home represented 7 percent of all knowledge workers. More commonly, 12 percent of pre-pandemic knowledge workers engaged in a hybrid of workplace and home. Other locations included either full days or parts of days spent working at others' homes, cafes, libraries, and vehicles.[8]

Travel behaviors vary among workers depending on these work location combinations. Compared to workplace-only workers, those who work only from home for a full day spend less time traveling and are less likely to travel during the peak periods for both work and non-work travel. (The American Time Use Survey does not include trip distance data.) However, the travel behaviors of the home-workplace hybrid workers are similar to those who work full-time in

[6] Because of the need for landline connections for telephones and faxes and the size and immobility of most computers in the 1980s and 1990s, the first-generation telework centers were essentially a necessity for remote work. As basically offices-way-from-the-main office, they never really caught to the extent that many early telecommuting enthusiasts had hoped.

[7] Knowledge workers refers to those whose primary focus is on creative problem solving (Teodorovicz et al., 2022) and excludes occupations such as "food prep, cleaning, personal care, construction, maintenance, and transportation" (Stiles & Smart, 2021).

[8] A primary weakness of the ATUS is that respondents are, for the most part, only permitted to report one activity at a time. Thus, any work activity that occurs during another principal activity, such as answering emails while supervising children on a playground or having coffee in a café, would likely be recorded as childcare time or eating/drinking time rather than non-office work time.

the workplace. Specifically, Stiles and Smart (2021) conduct a survival analysis of knowledge workers' time spent at home during the day; that is, they separate these workers into groups based on workplace location and analyze when they are likely to first leave home for the day. They focus on five groups: full-day workplace workers, morning-office / afternoon-home workers, morning-home / afternoon-office workers, other locations workers, and full-day home workers. They find that the first two groups – those who begin their days in the office – tend to leave at similar times, both with mean departure times in the 7:00-7:59 AM hour. They find that those who begin their workdays in locations outside the home and office – the third and fourth groups – are similar to each other, with mean departure times in the 8:00-8:59 AM hour. Full-day home workers look dramatically different; their mean departure time is not until 11:40 AM, such that by 10 AM, 55 percent of true WFH workers are still at home. Most notably, this relatively small group of full-day WFH workers are the only group associated with a decrease in travel duration.

Work location affects peak hour travel demand. Full-day home workers are less likely to participate in peak period travel; full-day workplace workers are more likely to do so. However, for workers who are neither fully office-bound nor fully home-bound the effect varies and is principally related to work travel. Stiles and Smart suggest that workers are less likely to travel for work purposes during the peak periods when they are not in the workplace; for example, the group that works in the workplace in the morning and at home in the afternoon tends to avoid peak period travel for work in the afternoon. However, they also find that these same groups do participate in peak period travel they avoided for work trips for *other* trip purposes. They write that this "may indicate workers with household responsibilities using traditional commute times to complete discretionary or maintenance activities while strategically using telework to compensate for lost office time" (Stiles & Smart, 2021, p. 2476). So, while there is some peak-period travel avoidance, it is hardly universal to *all* travel. This also appears to corroborate Lachapelle et al.'s hypothesis that chauffeuring children to school and other activities is a reason for home workers continuing to travel in peak-periods despite work schedule flexibility.

Ultimately, this all suggests that because working remotely is far more nuanced than simply working off-site 100 percent of paid work time, the reductions in travel that one might intuitively expect to glean from an increase in remote work often do not materialize. Even the reduction in peak hour travel appears to extend mainly to full-day home-workers and, for others, only to work trips. With a growing set of work location options and ever-increasing connectivity through ICTs, the research reviewed here suggests remote work is unlikely to be a panacea for solving transportation problems.

Implications of Working from Home

Increases in the share of remote work due to the COVID-19 pandemic have had enormous consequences thus far, and it appears increasingly likely that remote work will continue to influence work, commercial centers and central business districts (CBDs), travel behaviors, residential location, traffic congestion, and energy use, among many other facets of life for years to come. How and whether these changes persist will depend on a variety of factors, including telecommuter types, firm-level policies, and governmental responses.

Importantly, however, remote work has not treated everyone equally during the pandemic, as we described earlier, and its future is not uniform, either. Ton et al. (2022) conducted a latent-class analysis of teleworker typologies based on pre-pandemic and during-pandemic behaviors and post-pandemic desires for telecommuting, which they describe in the six following types, conducted using panel data from Netherlands Railways:

1. **Enthusiastic and always:** These workers largely had telecommuting experience prior to the pandemic, and they are adamant supporters of remote work, generally full-time.
2. **Positive and partially:** These workers generally want a hybrid schedule but look favorably upon telecommuting.
3. **Neutral, new, and frequently:** These are the workers who worked at home during the pandemic, wish to work more after the pandemic than they did prior, but are more neutral toward the concept.
4. **Content self-employed:** By nature of being self-employed, these workers often base their business at home and will continue to do so once we reach an endemic.
5. **Forced and done with:** These teleworkers generally did not have experience with telecommuting prior to the pandemic, and after doing so during the pandemic, wish to return to in-person work.
6. **Indifferent and occasional:** This group is characterized by low telecommuting frequency, both prior to the pandemic and their desired levels for the future.

Ultimately, how workers in the U.S. and in California sort into these various archetypes will determine the overall effects of post-pandemic working from home and its longer-term implications for travel.

Accordingly, in this section we explore likely near-, mid-, and longer-term implications of elevated and enduring remote work. We draw on both the academic and gray literatures to suggest how and why remote work will persist, as well as the effects it will have on downtown office centers, travel behaviors, residential locations, traffic congestion, and energy use.

Near-Term Implications

As of the end of 2022, COVID-19 and its evolving variants continued to complicate planned returns to the office, though less and less over time. The result is a continued elevated level of remote work, and ongoing uncertainty in commercial office markets in the near term. And while personal and commercial vehicle travel have largely returned to pre-pandemic levels, we expect transit use to remain depressed, due largely, but not exclusively, to substantially reduced worker densities in downtowns and other major office centers.

Persistence of Telecommuting

Will telecommuting continue to persist in the immediate future? Indications thus far are that it will, albeit at lower levels and with more hybrid arrangements than we saw early in the pandemic. We see two principal reasons for this: First, remote work has long proven effective in terms of worker productivity, despite many employers' misgivings; and second, the option to work remotely is generally very popular with employees who, in the tight post-2020 labor markets, have been able to negotiate for its continuance.

Despite widespread assumptions about employee slacking off when not under the watchful eyes of supervisors, several pre-pandemic studies have found that working from home is associated with increased job performance (Allen et al., 2015; Bloom et al., 2015, 2022; Gajendran et al., 2015; Golden & Gajendran, 2019). These findings explore outcomes ranging from employee self-reporting to surveilled keystrokes to lines of code written. In what is arguably the most famous of these studies, a team of Stanford economists conducted a work-from-home experiment with the call center group of a 16,000-employee travel agency in China (Bloom et al., 2015). The researchers randomly assigned volunteers to work from home or in the company's office for nine months. In that time, the telecommuter group saw a 13-percent performance increase, nine percent of which was from logging more minutes on the phone, and four percent of which was from a less-distracting work environment. The telecommuter group reported increased work satisfaction and were less likely to leave the firm.

Similarly, another study suggested that increased productivity among telecommuters results from reduced time spent interacting with coworkers, the support and trust of the supervisor, and a suitable place to work at home (Nakrošiene et al., 2019). Other studies also confirm that telecommuters on the whole tend to be happier and more satisfied with their jobs (Gajendran & Harrison, 2007; Golden, 2006; Golden & Veiga, 2005; Troup & Rose, 2012).

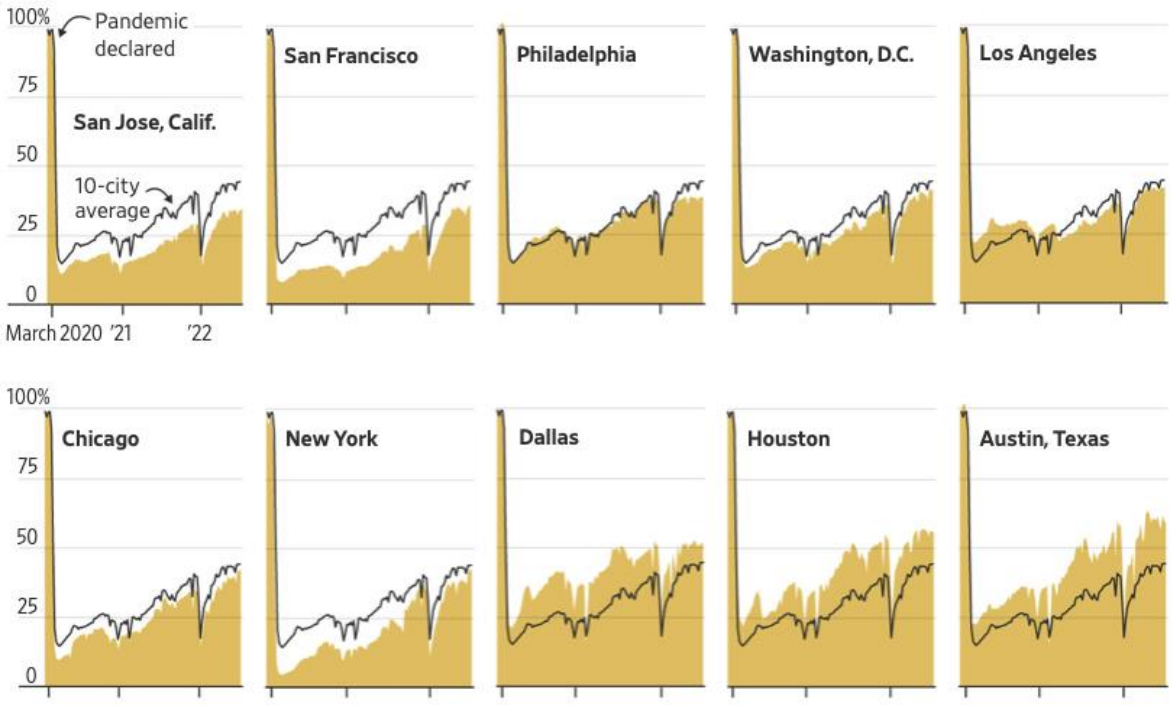
Early pandemic (April to July 2020) public sentiment toward working remotely was generally, though by no means uniformly, positive. Zhang et al. (2021) identified positive trends on Twitter regarding collaboration tools, productivity benefits, and flexibility. They also found negative sentiments toward poor internet connections, inadequate home office setups, team engagement, and cybersecurity. Indeed, while there were many work-from-home winners in this public health crisis, there were also losers as well. Tahlyan et al. (2022) used a multiple-indicator multiple-cause model to identify traits associated with successful telework during COVID-19, finding that most workers were successful, especially those ages 25-44, identifying

as white, suburbanites, zero-car households, and those with bachelor's degrees. However, they also found that younger and older workers, Black workers, workers who live alone, and workers with children in online school tended to have less successful work-from-home experiences, perhaps due to limitations for career advancement established by prior studies (which we explain more in the next section).

Office and Commercial Centers

The COVID-19 the pandemic hollowed out downtowns and other office centers in 2020, and workers have been exceedingly slow to return since then. In June 2022, office buildings nationwide saw their highest occupancy rate since the pandemic began: just 44 percent (Weber et al., 2022). Large cities lagged behind this level, particularly those in regions with stronger public health responses like Chicago, New York, Philadelphia, and San Francisco. The *Wall Street Journal* published data from Kastle Systems that examines office workers' keycard swipes into buildings each day, illustrated here as Figure 5. Such stunningly low levels of attendance in office buildings suggests not only that many of the buildings' occupants are still working remotely, but also that firms have not yet adjusted their spaces — both in terms of use and in terms of possession and size — amid this new labor landscape.

Figure 5. Percent of Pre-Pandemic Office Visitations by Workers



Source: *Wall Street Journal* (Weber et al., 2022)

The effect of these workers' absences extends not only to office buildings but also to the surrounding businesses that depend on office workers for their financial livelihoods. Restaurants and other customer service businesses like dry cleaners have been especially hurt by the dramatic decrease in office occupancy since early 2020. And while many in these industries have sought to adapt – through adjusted hours, finding new customer bases, or implementing new services like delivery and online ordering – in general these operations are still well short of their revenues and operation levels of February 2020 (Anderson et al., 2021). Over two years into the pandemic and considering diminished sources of revenue upon which they had long relied, many of these businesses closed, particularly in high-rent downtown centers where costs are higher and current office occupancy rates are lower, like Midtown Manhattan or Downtown San Francisco.

Travel, Commuting, and Residential Patterns

An important aspect of working from home is greater temporal flexibility, which affects activity participation and travel in the near-term. A defining characteristic of workplaces since the Industrial Revolution has been their generally highly structured operations in both space and time. Whereas previously office workers were long confined to a worksite office—in some cases dubbed "cubicle farms"—and a set work schedule, telecommuters typically have considerably more discretion over when and where they work. On top of that flexibility, they have available to them time they would otherwise have spent commuting, which returns both time and peace of mind. And finally, that flexibility has caused some workers to reconsider living in expensive big cities near downtowns and other dense office clusters.

Not only do telecommuters spend less time commuting on days they work remotely; they also spend less time working (albeit more productively) on average. Evidence from the United States, United Kingdom, and the Netherlands all suggests that telecommuters in those countries work fewer minutes when they work from home (Alexander et al., 2010; Giménez-Nadal et al., 2019).[9] In the United States, Giménez-Nadal et al. (2019) find that telecommuters spend up to 30 percent less time on work activities, and Bloom et al. (2022) found that hybrid workers spent about 1.3 hours less on work when doing so remotely. Bloom et al. (2022) also found that hybrid workers either had a neutral or positive relationship to different performance metrics compared to the control group that did not have a hybrid WFH option. Hybrid workers overall exhibited an 8% increase in lines of code written. Their findings suggest that hybrid workers can accomplish at least as much as full-time on-site workers despite spending less time working.

Remote workers also spend less time working during regular business hours, and more time working outside of it. In Giménez-Nadal et al. (2019)'s data, teleworkers spend less than 60

[9] One key difference between Bloom et al. (2015) and the other three studies cited is that Bloom et al. conducted their experiment only on call center employees, whereas Alexander et al. (2010), Giménez-Nadal et al. (2019), and Morris et al. (2020) all use survey data that examines a wide variety of work types. Call center jobs are relatively straightforward and do not require much collaboration. Indeed, when Bloom et al.'s subjects needed collaboration in the form of training, it happened in-person at the company's office.

percent of their working minutes during normal working hours. And in addition to finding a minor (3%) reduction in working hours for Dutch telecommuters, Alexander et al. (2010) find that they begin and end their workdays later than traditional commuters; only 40 percent of the participants in their study began their workday between 8:30 and 9:00 AM. So, in addition to working fewer hours overall, these data suggest that those working from home spread their diminished time spent working over more hours of the day, interspersed with other non-work activities.

For those who do not commute to and from work, there is the added benefit of not having to do an activity that is almost universally loathed. In other words, reducing commuting is likely beneficial if only by cutting the toll it takes on the average workers' happiness. By standard economic logic, workers should be willing to accept a longer commute for a better or higher-paying job. However, a wide array of studies suggest that commuting is consistently related to lower levels of happiness and subjective well-being (Chatterjee et al., 2020; Clark et al., 2019; Hilbrecht et al., 2014; Stutzer & Frey, 2008), both in the short-term and long-term (Choi et al., 2013). Stutzer and Frey (2008) call this the "commuting paradox," that commuting may be so universally disliked that it on its own diminishes work and life satisfaction and, all else equal, longer commutes to better jobs may only make matters worse. With the option of telecommuting, many workers can shift away from these apparently miserable commutes by shifting them outside of peak periods (for those who split workdays between the office and home), making them less frequent (for those who split work weeks between office and home), or eliminating them altogether (for those who work only at home). And because public transit systems long played an outsized role in shuttling office workers into and out of downtowns, the transformation of office work continues to decimate ridership on many commuter-focused systems like BART in the San Francisco Bay Area and Metrolink in Greater Los Angeles.

Congestion, Emissions, and Energy Use

The near-term effects of working-from-home on traffic congestion, emissions, and energy use are tied mostly to individual behaviors. Although both pre-pandemic and recent studies (reviewed above) find that telecommuting may actually induce more vehicle travel, these added miles are more likely to occur in off-peak hours, especially for work-related travel (Lachapelle et al., 2018; Stiles & Smart, 2021). Many destinations for telecommuters during the workday are trips that need not occur at a given time in the way a commute typically must end at a worksite between 8:00 and 9:00 AM for many workers. The combination of a lack of commute and a typically diminished number of hours spent working spread over a longer workday time span suggest that many telecommuters' trips—trips to run errands, for example—occur during the day, instead of being chained onto commute trips in the morning or afternoon peak periods.

Decreasing time spent in congestion has positive effects for street and highway systems, the economy, the environment, and individual workers. Congestion, crowding, and unpredictability all lead to increased stress during a commute, which can be further compounded by increases in commute duration (Chatterjee et al., 2020). This stress is not confined to just the commute itself; its effects can linger into time spent at the destination, including at the workplace. Conversely, shorter commute durations (including a zero duration) or journey-to-work travel via

so-called active modes (like biking or walking) can positively affect happiness levels (Clark et al., 2019). Car use may also have a positive effect on the commute experience, but that may be due to the greater access to destinations a car provides when compared with other modes (Bergstad et al., 2011).

The story for energy use, however, is different. While energy use during the mid-2020 pandemic lockdowns decreased in large part due to firms fully or partially closing (Coutellier et al., 2021), forecasting the future of working-from-home, commuting, and energy use is much more complex than it may initially seem (O'Brien & Yazdani Aliabadi, 2020), and many previous studies on energy use neglect indirect effects (Hook et al., 2020). For example, in addition to increases in non-work travel we discussed earlier, many telecommuters may be working in homes or other locations that are less energy-efficient than traditional workspaces, and those workspaces may still be consuming substantial energy to now host fewer workers.

Mid-Term Implications of Working from Home

In the mid-term, we expect remote work to continue playing an important role in U.S. employment, but we expect there to be some further sorting out of who works remotely and how often they do so. As this happens, firms and workers alike will adjust their behaviors, spaces, and locations accordingly.

Persistence of Telecommuting

Although telecommuting appears poised to remain elevated well above pre-pandemic levels in the near-term, its future is less clear in the mid-term. On the one hand, telecommuting remains popular, and firms with high capacity for their employees to work from home during the pandemic saw greater employment rates than those that did not (Barrero et al., 2021a). Many workers who have now experienced working from home do not want to return to the office full-time; Barrero et al. (2021b) found that of those who worked at home in 2021, 40 percent would seek a new job if forced to return to the office full-time, and that most employees would view a job with similar pay and the option for part-time remote work favorably. One study used a structural equation model to forecast a 75 percent increase in working from home from pre-pandemic levels in Melbourne, Australia, after COVID-19 is no longer a factor (Jain et al., 2021).

However, there is some evidence to suggest that remote work and the desire to work from home might decline as time passes. During the pandemic up to late-2022, many firms were operating on a "remote first" approach whereby all tasks and events were assumed to be conducted virtually even if some employees are in the office. This suits remote workers well, but it also disincentivizes individual workers from returning to the office. If even one member of a team is remote on a workday, all members of that team are likely to conduct a meeting virtually. But as more employees return to the office (if and) when COVID-19 becomes fully endemic, that approach may shift back to "office first." Amidst the overheated labor market and very low levels of unemployment in 2021 and 2022, workers had the upper hand in negotiating for part- or full-time work at home arrangements. But as interest rates rise and the economy may cool in 2023, employers may be in more of a position to dictate employment terms. If so,

they may bring back some of the organizational and management norms we saw prior to the pandemic where remote participation in, for example, meetings was the exception and not the rule.

Somewhat lost among the many recent studies of working from home is the finding that pre-pandemic telecommuters were less likely to receive a promotion (Bloom et al., 2015), though this may have changed with remote work becoming the rule for many jobs rather than the exception. Evidence from the U.S. indicated that telecommuters found the degree of physical isolation from their fellow workers to be negatively associated with perceived respect from coworkers and supervisors (Bartel et al., 2012), and longitudinal data showed that earnings were equal among telecommuters and on-site workers alike through 40 work hours per week, but that on-site overtime work yielded significantly higher earnings than remote overtime work, paid or unpaid (Glass & Noonan, 2016). The common finding in this research is that when it comes to promotion and pay decisions, those workers who were physically visible to supervisors were more likely to be rewarded. So even if full- or part-time working from home remains common and popular, there may be an incentive for workers to trek to the office more often to increase their face time with supervisors — a return that many workers may personally dislike and one that may bias against workers who find great benefit in remote work, especially parents with childcare responsibilities (a burden that often falls on women).

Further, unlike the employees in the sci-fi thriller *Severance*, workers do not exist in a 9-to-5 vacuum; outside factors will play a role in whether they decide to continue working from home or return to a worksite. Telecommuting gives workers relatively more flexibility and autonomy on when, where, and how to work, which can allow them to better adapt to their home life demands (Golden, 2006). However, the lack of physical separation can also lead to a blurring of work and home life boundaries. On days working from home, employees tend to experience more home-to-work conflict than work-to-home conflict; meaning, teleworkers are more likely to have their work interrupted by household obligations than they are to have their household obligations interrupted by work (Delanoeije et al., 2019). While this may have been an acceptable trade-off during the pandemic or even in the near-term future, it is possible that some telecommuters and their employers will want to return to a greater separation of work and household.

Indeed, even Barrero et al. (2021b) acknowledge that this will likely play out as a re-sorting of workers along lines of preference for remote work. Work-from-home policies will naturally vary firm-to-firm and industry-to-industry. Because much of the ability to work from home hinges on the feasibility of a job to be performed remotely as well as on the policy of the company enabling it, many workers with strong remote work preferences will likely transition to new jobs allowing them to work from home, while many other workers without those strong preferences for workplaces will back-fill those vacancies in firms that return to primarily on-site work, increasing quit rates and job vacancy rates in the mid-term.

Office and Commercial Centers

As that sorting of workers continues, so too will the sorting of office spaces and the spaces that surround them. Many firms are in the process of or are seeking to trim their physical office

footprints, particularly in high-priced major cities. But this process is not immediate, as commercial office leases are often multi-year. One survey of 185 businesses with a physical presence in the U.S. found that just over half of the companies expected to shrink their office square footage by 2025 (Maurer, 2022).

But not all firms are in the same situation. Only about 40 percent of U.S. jobs can even be done remotely. Far fewer actually will be. Accordingly, in that same survey, about 40 percent of companies intend to *expand* their office square footage. This suggests that while the future of office centers may be bleak currently, the mid-range and longer-term futures may be a bit rosier as various firms adjust to their new needs.

This process of office re-sorting appears to have begun in four ways, of which we provide an early example of each. First, companies have begun looking for office space closer to where their workers live but outside of CBDs. Through the pandemic, business establishment flows generally favored low- and mid-density areas over CBDs (Bloom & Ramani, 2021). But as offices have (at least partially) re-opened, workers have expressed that the commute itself is an obstacle to their desire to work in-office, and as leases have expired, firms have relocated to spaces that fit their new needs and their existing workers. In New York City, where only 8 percent of office workers were working fully in-person, office vacancy rates have remained stable in Brooklyn, while office vacancy rates in Manhattan have nearly doubled (Haag, 2022).

Second, some firms have abandoned plans for new office space, but that has not deterred other firms from leasing newly available space. In a famous early-pandemic example from Seattle, Recreational Equipment Inc. (REI) had been set to open a new corporate headquarters building in Bellevue, just east of Seattle; but after the early stages of the pandemic hurt sales badly, REI sold the campus to Facebook before ever occupying the building, with plans to increase the amount of remote work its employees engage in (Long, 2020).

Third, while occupancy of first-class office space in downtowns remains depressed, and many firms are shrinking their office footprints, this freed-up first-class downtown office space is unlikely to sit vacant, especially if rents drop. It may be that each building will host substantially more tenants than before, each occupying less square footage than prior to the pandemic. In this reconfigured space, many more workers will come to these offices less frequently, perhaps by sharing offices or occupying shared workspaces. It is thus possible that the density of workers on a given day in this first-class downtown space may return to pre-pandemic levels, but with more firms hosting more workers who come in less often. The losers in this scenario are the second- and especially third-class office spaces, where we might expect to see climbing vacancy rates over time that result in the conversion of the space to other uses (such as warehousing) or replacement altogether (Kortum, 2020). This scenario, while far from certain, would be a best-case scenario for public transit systems seeking to lure back commuters.

And fourth, while businesses in the CBD may be struggling for survival, some businesses that existed prior to or have opened since the pandemic in residential neighborhoods are thriving. One example of this is in neighborhoods across Brooklyn and Queens. Before 2020 many of these neighborhoods' residents flocked to Manhattan during the day, but since the pandemic

began remote and hybrid work schedules have allowed their residents to take advantage of businesses new and old where they live. Business openings during 2020 and 2021 were up in Brooklyn Heights, Crown Heights, and Fort Greene (Brooklyn), and Astoria, Flushing, and Jackson Heights (Queens) (Bellafante, 2022).

There is a potential fifth way office re-sorting can occur: through the conversion of unused office space into needed residential space, especially in the highest-demand urban real estate markets like New York and London. However, this process has proved more difficult than some may have anticipated, and accordingly is still rare. One complication is that residential buildings have different needs and code requirements, like decentralized plumbing and opening windows, that commercial buildings do not need, which makes conversion an elaborate and expensive undertaking (Kolachalam, 2022). A second complication is that while daily occupancy rates may still be down in city centers, actual office *vacancy* rates remain relatively close to pre-pandemic levels: 8.4 percent of London's office building area was vacant in 2022, which is only a modest increase from its five percent rate before the pandemic (The Economist, 2023). And a related final complication is that vacancies are often unevenly distributed, but conversions require concentrated vacancies in entire or substantial portions of buildings to be empty. Since such vacancies are unlikely to occur all at once, this requires the additional expense of moving tenants prior to conversion. Accordingly, one study found that only six percent of Denver CBD building area even had the potential for office-to-residential conversion (Kolachalam, 2022). With residential rents remaining comparatively lower than commercial rents per square foot, even in 2022, this concatenation of complications makes office-to-residential conversions unlikely for most city centers.

Travel Behaviors, Commuting, and Residential Patterns

In tandem with this employment location re-sorting, we have begun to see a residential re-sorting among and within metropolitan areas. Over the mid-term, reduced commuting frequency allows hybrid and most-of-the-time telecommuters to accept longer distances between home and work (de Vos et al., 2018). Perhaps because of this weakened tethering of home and work locations, housing demand decreased in neighborhoods with high population densities and high home values during the pandemic (Liu & Su, 2021).

Although many news stories emerged of remote workers fleeing major metropolitan areas for far-flung small cities and towns during the pandemic, Bloom and Ramani (2021) analyzed United States Postal Service address change data from 2017 to 2021 to determine that most relocations after February 2020 happened *within* metropolitan areas rather than between them. They found that a remarkable 15 percent of households and businesses had moved from business district zip codes to suburban districts during the first year of the pandemic, in what they term "the donut effect." Further, they postulate that, combined with other evidence like metro area size, wages, amenities, and rents, this suggests employees and firms alike are headed toward a future of hybrid work after the pandemic, where workers take advantage of decreased commute frequency to consume more and/or cheaper housing farther from workplaces.

This allows occasional, if longer distance, visits to work than would be possible if they were to leave the metro area completely. But it also means that with residential locations more dispersed, trip distances may increase not only between home and work but between home and *other* destinations, too, as suggested by myriad studies listed in Table 2 that indicate increased non-work-related travel among telecommuters compared with in-person workers.

This may also spell trouble for public transit systems. The mostly pre-pandemic studies summarized in Table 2 collectively find that telecommuters tend to, if anything, drive more and not less, and tend to shift their travel modes toward the private car on their days at home. Fragmentary evidence suggests that these two patterns have persisted during the pandemic, to the particular detriment of public transit ridership. In a study of the McGill University community in Montreal, DeWeese et al. (2022) found that among the 1,580 people who continued to travel to campus during the Fall 2020 semester, the share who did so in a private car tripled from their pre-pandemic levels. While certainly some of this shift was due to fears of virus spread in shared spaces like transit vehicles at that time, even if only half of those new vehicle commuters don't eventually revert to their previous travel patterns, the consequences for both public transit systems, vehicle travel and emissions, and traffic congestion will be substantial.

Congestion, Emissions, and Energy Use

While telecommuting is unlikely to be the *deus ex machina* that will meaningfully reduce vehicle miles traveled and associated emissions that many might have hoped, there is potential for it to lead to reduced peak-hour congestion and improved environmental sustainability outcomes even if *not* by reducing overall VMT. These outcomes result from spreading trips and miles over more parts of the city over more parts of the day, rather than concentrating them in one direction each during the morning and afternoon peak periods. This shift in the time of travel may result in lower travel durations, which reduce emissions and energy use as well. Reducing traffic congestion can result in both lower criteria pollutant emissions (like hydrocarbons and fine particulate matter) and lower greenhouse gas (GHG) emissions, with the former especially benefiting those who live, work, and play near freeways (Currie & Walker, 2011). If telecommuting reduces congestion in the peak periods by spreading trips across other parts of the day, even a (modest) increase in VMT could conceivably lead to improved air quality and health outcomes if travel speeds and associated emissions do not rise to very high levels.

However, it is likely that achieving these outcomes would require some additional policy interventions. First, shifting travel away from the peaks does not mean it will stay away (Downs, 2005); further interventions, like pricing, could ensure that the combination of fewer workers needing to travel during peak hours is not counteracted by more people wanting to travel for non-work purposes during those hours.

Second, such a scenario assumes that workers collectively spread their telecommuting days roughly evenly across the week. But this is hardly guaranteed. For one, workers tend to prefer the middle of the week for in-person work and the days adjacent to the weekend for remote work. When given the choice of two days of remote work per week in a survey, 56 percent chose Monday and 64 percent picked Friday; only 18 percent picked Wednesday (Zetlin, 2021).

If most hybrid firms leave this choice up to their workers and, accordingly, default to Tuesdays, Wednesdays, and Thursdays as their in-office days and leave Mondays and Fridays for all employees to work from home, then it is possible that mid-week congestion levels will return to pre-pandemic levels, even if Mondays and Fridays see less peak direction, peak period congestion delays.

Longer-Term Implications of Working from Home

The longer-term implications for increased working from home on travel are of course harder to forecast. However, we can confidently suggest that remote work, at whatever levels it may persist, will play an increasing role in major decisions by workers and firms alike, which will in turn affect a variety of sectors.

Persistence of Telecommuting

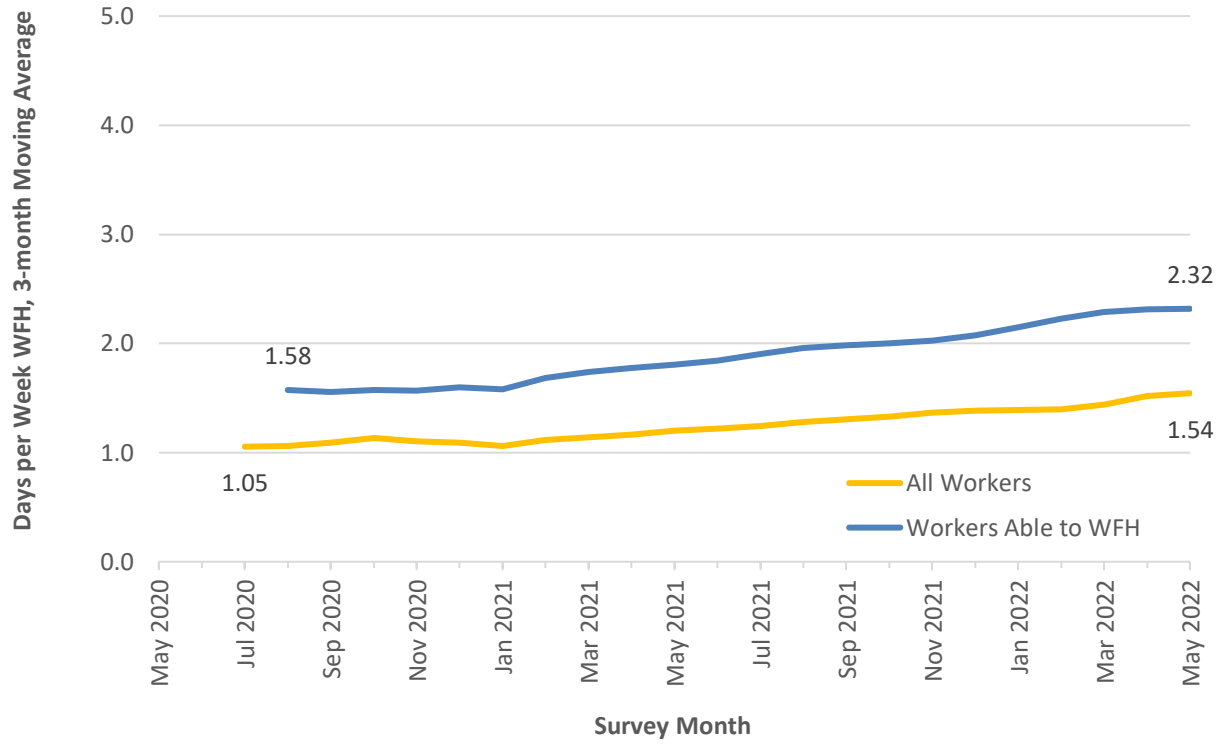
The long-term future of working from home is uncertain. All projections we reviewed point toward some long-term increase relative to pre-pandemic levels, which if nothing else would continue the slow but steady increase in working from home seen in the past half-century. As Figure 6 depicts, Barrero et al. (2021a) predict that 30 percent of full workdays — and just shy of half for those with remote-capable jobs — will happen remotely when the dust settles from the pandemic, but that number has been steadily increasing since the pandemic began. Overall, employees report roughly twice as high a percentage of desired work-from-home days as they report their employer's plan for them post-pandemic.

Even though most employees who are able to work from home have expressed at least some level of positivity toward remote work arrangements, employers have generally been more ambivalent and arguably have more power to shape the longer-term future. On the positive side, employers will be able to use full-time remote work to overcome local hiring and labor pool constraints when needed (even if not desired) (Soroui, 2021). But on the negative side, firms may not be as easily able to recoup some of the benefits of having their employees hybrid or remote (see next section on shared workspaces). Regardless, the way work arrangements and locations evolve will depend on continued remote worker productivity and satisfaction, ongoing employment re-sorting, and a variety of other external factors.

One such factor is the labor market. As we noted in our discussion of mid-term effects, while many executives and employers have expressed the desire to have their workers back in-office, to date labor market conditions have not allowed them to compel their workers to do so (Vincent, 2022). Even with prices and interest rates rising in beginning mid-2022, the job market in early 2023 still heavily favored workers. With the ongoing reshuffling of workers based on job responsibility and remote work preferences, many firms have struggled to hire and retain workers, such that workers have been in a position to easily find a new job if their employer does not meet their remote work demands (Barrero et al., 2021b). However, the U.S. economy was in a period of expansion from the summer of 2020 (Radin, 2021) into at least the winter of 2023. What will happen when we inevitably experience another recession, even a modest one? We suspect that some power over work location decisions will shift back to the

employers, who will then be able to wrest control over remote work policies and offerings, rather than often finding themselves at the mercy of their employees' preferences as they do now. But by then the number of employees working remotely at least part-time and their comfort with these arrangements may diminish their drag reluctant workers back to the office.

Figure 6. Employer-Planned Days per Week Working from Home



Source: Barrero et al. (2021a)

Office and Commercial Centers

Much of the recent literature points to hybrid schedules as the future of office work. What has arguably been lost in this prognostication, however, is that the concept of *hybrid* work rests on there being an office to work at some of the time. This means that even though workers may only be in the office three days per week, their employer will need to provide space for them. This is where the post-COVID office will become (even more) complicated. While utilization is lower than pre-COVID rates, it is not clear that space can be lower. In order to achieve space reductions, firms will need to thoroughly coordinate employees' schedules such that only certain teams are in the office on certain days, with other teams to take their places on the opposite days. However, this runs up against two issues: First, this would restrict teams to no more than 2.5 days per week, if split evenly in-office; a three day in-office week would mean difficult trade-offs for two-day-per week workers. Second, sharing space like this would mean that not all employees would get the most popular days for working from home; indeed, someone would

need to make the unpopular Wednesday one of their work-from-home days. Short of such sharing arrangements, firms would be faced with the prospect of leasing office space that would sit vacant nearly 60 percent of the time.

The reopening of other sectors of the economy, including the service industry, tourism, and arts and entertainment, have all proven to some degree more difficult than many had anticipated. This has been made only more difficult with the seemingly continuous emergence of new SARS-CoV-2 variants (though the recent trend of such variants has been increasingly contagious but decreasingly virulent). There is little to suggest that fully reopening offices has been, or will be, any easier. Rather, it may even be more difficult. Those other sectors have largely returned: relative to pre-pandemic levels, the *New York Times* reports N.B.A. game attendance is at 95 percent, T.S.A. checkpoints 89 percent, and OpenTable dining reservations at 87 percent (Goldberg, 2022). What about the return to the office? "Chaos" is how one staffing agency president described the transition. Some companies opened their doors only to have no one return. *The Economist* has argued that "[d]isruptive though it was, last year's abrupt transition to remote work may, ironically, prove considerably smoother than the shift to whatever counts as normal in the post-pandemic era" (The Economist, 2021).

We are not suggesting that workers will not return to offices. Most probably will, to some degree, just like other sectors have seen workers and customers return. Even a return with 30 percent remote days would still be an office occupancy of 70 percent on weekdays, which is far greater than the current rate of 44 percent. But sorting out *how* office work returns will take time and is unlikely to settle into a new normal any time soon.

Travel Behaviors, Commuting, and Residential Patterns

The principal long-run change for individuals and households resulting from remote work is that it may allow them to change where they live *and* how much space they require in their home. Travel behaviors and commuting patterns then flow from these decisions. However, what we have seen thus far in the pandemic may not be a true indication of what will happen in the long run.

At the outset of the pandemic, many people were working remotely from makeshift setups in spaces not designed for work. And many workers were living in locations they chose strategically based on their commute. But for a hybrid remote worker, these temporary setups will be increasingly unsustainable in the long run. Telecommuters have already shown a propensity to accept longer commutes to the office for when they do trek in (de Vos et al., 2018). It is likely that they would also seek out more space in their homes if they spend more time there, in particular homes that include adequate office space. One way of doing this is by moving to less-dense areas on the urban periphery, with more of housing costs devoted to larger houses and less to the land on which they sit, as Bloom and Romani (2021) found with "the donut effect."

However, many workers who have moved into larger homes with adequate workspaces more distant from the office have proven more resistant to returning to office work. When Google required some 200 contract workers for its Maps platform to return full-time to an office in

Bothell, Washington (northeast of Seattle), workers expressed their frustration with having to commute to the office given the combination of high gas prices, a lack of affordable housing in Bothell, and low salaries (Grant, 2022). Such complaints about increased worker time and expenses to do formerly remote work in an office might seem supportive of remote work, and it may well be. On the other hand, given that commutes are so widely disliked by workers, even a return to work part-time may put the brakes on increasing home/work distances.

But if home prices continue to rise in coastal metros, the research reviewed here suggests that the near- and mid-term implications for remote work and travel behavior are an increase in vehicle travel, based on both pre-pandemic evidence and pandemic patterns. It is likely that many remote workers will reinforce these trends, especially if increasing home/work separation does not abate and continues to grow.

Congestion, Emissions, and Energy Use

Even if remote workers increasingly move to the suburbs and reduce their peak-period, peak-direction travel, such shifts may well exacerbate traffic congestion and vehicle travel. While the commute trips on remote workdays (for hybrid and full-time telecommuters) may diminish, the research cited above is clear that telecommuters also tend to engage in more non-work trip-making. It is thus possible, perhaps even likely, that much of the peak-hour road space freed up by telecommuting may well be replaced by household-serving and chauffeuring (of, say, children to and from school) trips by remote workers. Some of these trips may have been previously chained to commutes but now are distinct tours with a return trip, some may be trip shifted to peak periods and directions from other times, other routes, and other modes, and some may be new trips altogether. In other words, while the highest demand in the peak hours and peak directions may ease, this may be accompanied by more driving, energy consumption, and traffic delays on other parts of the road networks in peaks (particularly in the afternoon) spread over more hours.

Many prior studies and private firm strategies alike have suggested remote work can lead to decreases in GHG emissions, but often these studies consider only direct effects—for example, they might claim that a company work-from-home policy has reduced driving because it eliminated the need for commuting and allowed a firm to reduce its office footprint (O'Brien & Yazdani Aliabadi, 2020). However, such a view considers neither the extended effects of workers' increased travel with the temporal flexibility that remote work affords nor the effects of energy use in the home during the workday. Both workers and firms alike will need to consider energy consumption (and associated emissions) as well as vehicle emissions as they adapt their lives and operations to the new post-pandemic work paradigms; otherwise, any hoped-for GHG savings will likely continue to be neutral at best and negative at worst (Hook et al., 2020).

O'Brien and Yazdani Aliabadi (2020) offer an overview of what the worst, moderate, and best energy scenarios would be for both office and home office configurations, which we consolidate in

Table 3. In sum, they advocate for offices that are flexible in arrangement focused on occupancy of the space and for home offices with targeted energy zones and good use of existing space and resources. Absent such changes to home and work offices, non-vehicular energy consumption may well increase with vehicular energy consumption.

Table 3. Workspace Configurations and Effect on Energy Consumption

	Office	Home Office
Worst	Open-office plan with scheduled occupancy Scheduled heating, cooling, and lighting regardless of occupancy Office equipment remains powered on most of the time regardless of occupancy	Teleworker purchases larger house to accommodate home office House has central heating and cooling system without zones to confine to home office space during day Home office equipment is energy-intensive
Moderate	Open-office plan or private offices with assigned seating Heating, cooling, and lighting has high-resolution occupancy sensing and small control zones Office equipment power based on occupancy	Teleworker has a home office Home office has separate zone for heating, cooling, and lighting Energy-efficient office equipment
Best	Open-office plan with hoteling and near-full capacity each day Heating, cooling, and lighting controlled at high spatial and temporal resolution based on occupancy Office equipment power based on occupancy	Multiple teleworkers use existing spaces for work Home has zoned heating, cooling, and lighting for areas used for work Energy-efficient office equipment

Source: O'Brien and Yazdani Aliabadi (2020, p. 8 and 9)

Findings and Conclusions

Forecasting the likely patterns and levels of working-from-home coming out of the COVID-19 pandemic is not easy and predicting these effects on travel and transportation systems is even more uncertain. However, the research reviewed here from before and early in the pandemic points us toward five principal findings:

1. Remote work increased dramatically with the onset of the pandemic and appears likely to remain elevated for many years to come.
2. Not everyone can work remotely, but for those who can, the option to do so, at least part-time, is extremely popular with workers.
3. Employers tend to be more skeptical of remote work, but the research does not support fears of declining productivity in the near term. In addition, the tight labor market in 2021 and 2022 has given workers leverage to insist on remote work options.
4. Telecommuting has long been touted as a potential solution to chronic transportation problems like traffic congestion and vehicle emissions, but research has generally found no change or, more often, increases in driving among remote workers, and not the hoped-for decreases in vehicle travel.
    a. This extra driving has been due both to hybrid workers living farther from work, on average, and to all remote workers making more household-serving and personal trips when they work from home.
    b. Research on remote work and driving post-2020 is in its infancy, but vehicle travel data from 2021 and 2022 suggest that driving has not diminished appreciably due to the increased prevalence of remote work.
5. The future of many public transit systems, which draw an outsized share of their riders from commuters to downtowns and other major job centers, will depend on whether and to what extent those job centers re-densify with workers in the months and years ahead. There is not yet enough evidence on whether this will or will not happen.

Finally, we note that much of the literature we review here is rooted in pre-pandemic data. However, we have strong reason to believe that behaviors of telecommuters in the future post-pandemic world with an open-economy will much more strongly resemble those of pre-pandemic telecommuters than those forced to work at home during the peak of the COVID-19 crisis, though we acknowledge that this supposition is far from certain.

Remote Work is Part of the Future

While telecommuting has been talked about for decades, the actual incidence of working from home prior to the COVID-19 pandemic was comparatively rare. In 1980, 2.3 percent of U.S. workers worked from home; just prior to the pandemic that figure had climbed to a still-modest

5.3 percent, despite the dramatic revolution in information and communications technologies during this period. Over this same period, working from home in California began a bit lower (1.9% in 1980) and finished a bit higher (6.0% in 2018).

This all changed, and changed dramatically, with the onset of the COVID-19 pandemic in the spring of 2020. In just two months, the incidence of working from home increased by over 10 times to about 62 percent of all workers in May of 2020. As the pandemic has matured, COVID-19 vaccines and treatments have developed, and most workers have either the opportunity or have been required to return to worksites, the share of workdays from home has settled down to about half (31%) of that early pandemic peak, which is still *five to six times greater* than before the pandemic Barrero et al. (2021a). While it is possible that work from home rates will drop further below the current stable rate of just over 30 percent, we see no evidence pointing to a return to the low levels of working from home (5 to 6%) we saw prior to the pandemic. Remote work, in other words, appears here to stay.

Remote Work is Popular with Most Workers, but Not Everyone Can

While working from home topped out at more than 60 percent early in the pandemic, many of those working from home on public health grounds in the spring of 2020 were in jobs (such as elementary school teacher) not well-suited to remote work. Indeed, only about 4 in 10 jobs can reasonably be performed remotely (Drucker & Khattak, 2000; Holgersen et al., 2021).

But for those who can, working remotely has proven popular, and many such workers indicate a desire to continue working from home at least part of the time moving forward (Barrero et al., 2021a). They favor the flexibility it offers to mix work and home responsibilities over the course of the day or week, the ability to dress more casually, and the opportunity for partial to complete relief from one of their least favorite activities: commuting to and from work.

Workers Have Had Leverage to Insist on Remote Work Options

Since the pandemic began, workers have had the upper hand in determining their remote work status if they wished to telecommute. First, COVID-19-related closures forced them to work from home. Then, as offices reopened, teams that were split between office and remote found inefficiencies that swayed work toward a remote-first orientation. Additional variants of the Sars-CoV-2 virus further complicated these return attempts. As of late 2022, an overheated economy has given workers the power in determining when and how often to return to work, though this leverage will likely diminish in the next economic downturn.

Underlying this, however, is the strong suggestion in the pre-pandemic literature that telecommuting, for those who choose to do it, does not have an adverse effect on work performance, even as remote workers spend slightly less time working that is interspersed with

non-work activities spread, on average, over a longer span of daily time. In fact, many studies indicate it may actually improve performance, notwithstanding persistent concerns by some employers that working from home undermines employee commitment and collaborative creativity (Giang, 2022). While debates over the effects of remote work on job performance will undoubtedly persist in the years ahead, research on the topic simply does not point to diminished performance for many types of remote work.

Telecommuting is Likely Not a Solution for Transportation Problems

Telecommuters tend to have longer commutes when they do travel to a worksite. Many workers choose home and work locations with a weekly or monthly commute time "budget" in mind, such that fewer commutes among telecommuters allow for longer commutes within that time budget. In addition, the need for home offices in addition to living spaces likely pushes some workers to more distant suburbs where larger houses are more affordable.

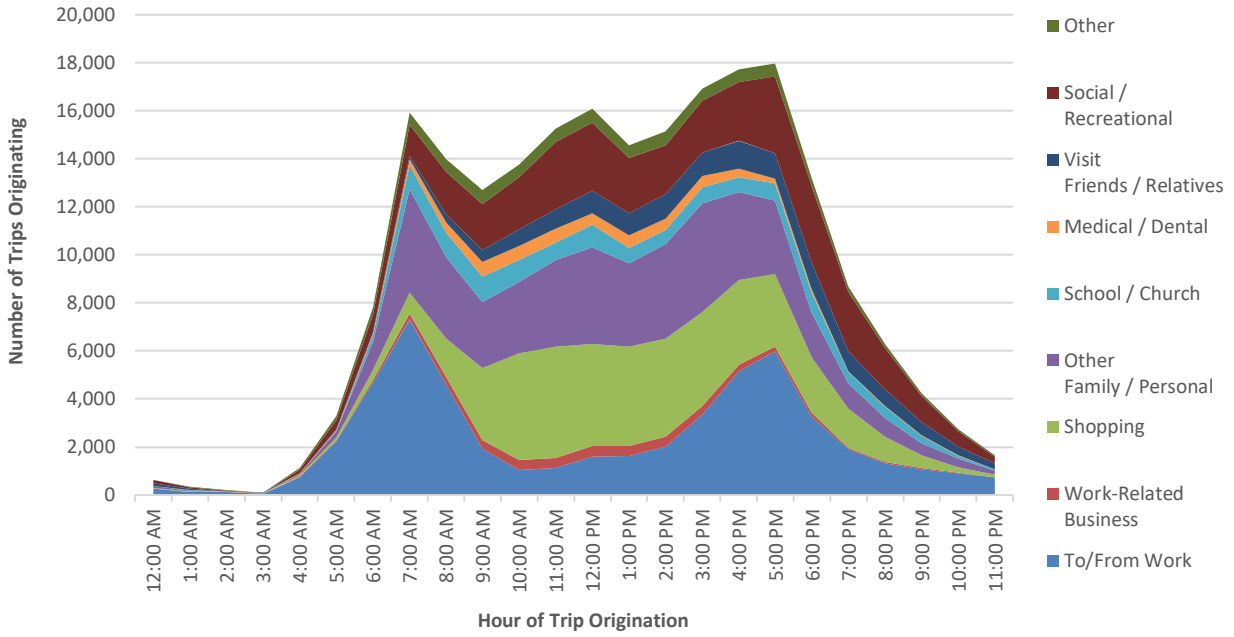
With respect to overall vehicle travel, telecommuting research at the end of the 20th century pointed toward a slight decrease in vehicle travel among remote workers, while more recent (21st century) pre-pandemic studies suggested a slight vehicle travel increase for those working from home. Unfortunately, we have not yet been able to identify sufficient new research on working from home and travel drawing on data from 2021 or later. However, since the collapse in travel in the spring of 2020, the rapid return of vehicle travel to pre-pandemic levels even as remote work remains a substantially larger share of the current employment landscape suggests that those hoping for vehicle travel savings due to remote work are likely to be disappointed.[10]

How can it be that remote workers often drive more than those who commute to work? The evidence suggests that higher levels of vehicle travel among telecommuters is a function of both longer average home-to-work commute distances when they do travel to and from work, as well as more vehicle travel for other household and personal purposes (Caldarola & Sorrell, 2022; Kim, 2017). Indeed, while the consensus is that most forms of working from home decrease the likelihood of peak-period, work-related travel, the findings are much more mixed for non-work travel. And while work travel is largely responsible for peak-period trip-making, even during the peak hours commuting it is a minority of both trips and VMT. Figure 7 illustrates this showing U.S. trip-making by hour in 2017. During the morning peak hours (7–9 AM), commute trips constitute just under 40 percent of all trips and 47 percent of VMT; during the evening peak

[10] Despite the proliferation of both remote work and the research into it, the gap we noted at the outset persists: Telecommuting remains a phenomenon with a cloudy definition and inconsistent treatment by researchers. Accordingly, future research should go beyond considering telecommuting as a binary (1) yes or no activity and (2) entailing only a worksite versus home office. While estimates of future shares of remote work have yet to converge, we can say with reasonable certainty that hybrid work schedules (both over workdays and work weeks) will be far more common coming out of the pandemic than they were prior, meaning research needs to consider not just if a worker telecommutes but also how often, when, and from where.

hours (4–7 PM), commutes are less on both fronts (33% and 30%, respectively). So, while an increase in telecommuting may indeed reduce the share of peak-period work trips, the overall effect of this shift on peak period traffic may be muted or negated by clustered in-office days during the middle of the week, as well as by substituting personal trips for work trips on work-from-home days.

Figure 7. Trips by Purpose, Hourly by Start Time, 2017 U.S.



Source: 2017 National Household Travel Survey (Federal Highway Administration, 2018).

Relatedly, it appears that working from home frees up the remote worker to attend to other personal and household needs and activities during the workday that they would not be able to do in a traditional office setting, including household production activities (Pabilonia & Vernon, 2022). But the literature has not yet established how two-adult households distribute tasks when *both* adults are working remotely, which has become increasingly common during the pandemic. It is unlikely, for example, that both teleworkers would each increase their shopping and errand running for the same household. On the other hand, errand running interspersed throughout a workday may add to VMT by substituting multiple un-(or less-)chained household trips for ones that were previously chained onto peak-hour commute trips.

The Future of Public Transit Systems in Large Metros Will Depend on Job Centers

While the rise of working from home in the pandemic has had negligible effects on overall levels of vehicle travel (although the underlying patterns of this travel have shifted), the effects on public transit systems could hardly be more dramatic. Public transit ridership remains below half of pre-pandemic levels more than two years into the pandemic. Fixed-route, fixed-schedule transit systems are especially well-suited to moving large numbers of people in the same direction at the same time, which makes them especially well-suited to serve large central business districts with high concentrations of workers and limited parking capacity.

So, the fate of public transit in the large metropolitan areas of California, the U.S., and indeed around the world is tied substantially to what happens to central business districts in the months and years ahead. Should they substantially repopulate — with more firms, each occupying less office space than before, and more workers, each commuting downtown fewer times each week than before — then public transit ridership may substantially rebound to former levels. Such ridership demand could be further enhanced by new construction of downtown housing to replace declining need for office space.

However, if the overall density of downtown office work does not return to pre-pandemic levels, it is unlikely that transit use will fully rebound in the mid-term, and perhaps ever. This would suggest the need for transit agencies to adapt to the new needs of riders, perhaps through innovations like microtransit.

Conclusion

Despite the widely held view that telecommuting should reduce driving and travel, many of the studies reviewed here have found just the opposite. We think that dissonance between conventional wisdom and empirical reality is that the issues involved are often viewed in a vacuum. A firm may tout that their remote work policy reduces driving because its workers no longer commute to their worksite and that it reduces emissions because it has scaled back energy usage at its office facility. But such estimates fail to consider the cascading behavioral effects of working from home. Workers (during traditional work hours) can now drive to other destinations, engage in household activities like chauffeuring children to school and grocery shopping during work hours instead of chaining those trips to an existing commute trip. They can also live further away from an office that they may still need to commute to occasionally on their hybrid work schedule. And home offices still consume energy; in fact, if a telecommuter is consuming electricity during the day while an office space sits empty, they are likely increasing energy consumption overall.

Understanding this dissonance—and how it has or has not persisted in today's world of increased remote work prevalence—requires substantially more research. While we believe that the days of fully-at-home work in 2020 amid high COVID-19 infection rates without vaccines will be an anomaly in the long run, we recognize there are several issues now that require more investigation, including but not limited to households with two adults working remotely (a rarity prior to 2020), the role of e-commerce in affecting travel behaviors especially among remote workers, and the varied long-run effects of hybrid and remote work on populations that were typically unlikely to or excluded from working remotely prior to the pandemic.

In the meantime, though, while pandemic-induced increases in working from home are dramatically changing work life for tens of millions of U.S. workers, and these changes have substantially curtailed downtown transit commuting, the overall effect of driving, traffic, and emissions has been, and will likely remain, remarkably modest overall.

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