Transportation (2021) 48:2461–2491
https://doi.org/10.1007/s11116-020-10136-6

Working at home and elsewhere: daily work location, telework, and travel among United States knowledge workers

Jonathan Stiles[1] · **Michael J. Smart**[2]

Published online: 5 September 2020

Abstract
The mediation of work practices by information and communication technologies enables knowledge workers to telework from remote non-office locations such as their homes, or to work nomadically from multiple locations in a day. This paper uses data from the American Time Use Survey to explore the relationship between daily work locations and travel in the United States from 2003 to 2017. Outcome variables include travel duration and travel during peak periods. Home is by far the most common non-office work location, but working from other people's homes, cafés/libraries, vehicles, and combinations of multiple locations are also measured. Findings show that working from home only on a day (full-day telework) decreases daily travel duration and increases the likelihood of avoiding peak hour travel for both work and non-work related travel. However, for homeworkers who also conduct work from their workplace on the same day (part-day telework), there is no reduction in daily travel time, and avoiding peak hour travel is limited to work-related travel. Working from other locations such as cafés/libraries or vehicles increases the likelihood of not traveling at peak hours. Findings also indicate that morning peak periods are more affected by work location decisions than evening peak periods. A survival analysis of daily departure times for both full-day and part-day homeworkers provides insight into this mechanism. We conclude on the basis of these findings that demand management policies and peak avoidance incentives would be more effective if they encourage both temporal and spatial flexibility for employees when partnering with regional employers.

Keywords Travel demand management · Peak hour travel · Peak hour avoidance · Telework · Nomadic work

✉ Jonathan Stiles
jonathan.stiles@rutgers.edu

1 Department of Geography, The Ohio State University, 154 North Oval Mall, Columbus, OH 43210, USA

2 Edward J. Bloustein School of Planning and Public Policy, Rutgers, The State University of New Jersey, 33 Livingston Avenue, New Brunswick, NJ 08901, USA

Introduction

The notion of commuting for work often assumes a neat division between a distant single workplace and home. Yet not all jobs take place entirely in a single workplace location. Truck drivers, repairpersons, and traveling salespersons have long challenged this simple conception of work location, and conducting work remotely from one's home has been a viable option for some workers for decades. Recent advances in information and communication technology (ICT) may further diversify work locations for those knowledge workers whose occupations are most capable of being done remotely. Principally, the adoption of mobile cloud computing infrastructure allows workers to be better connected to colleagues, clients and work information from home, but also from locations beyond the home such as cafés, and anywhere else by connection through Internet networks.

This paper explores the relationship between work location and travel among United States knowledge workers using American Time Use Survey data from 2003 to 2017. In this study we seek to test recent findings using Canadian time use data (Lachapelle et al. 2017) in an American context, and build upon it using different analyses on knowledge workers and including trip purpose. These years encompass a large time period of knowledge work practice utilizing Internet software enabled by mobile cloud computing, such as the widespread use of web-accessible email. We define four categories of alternate work location: working from one's own home, working from other people's homes, working from cafés/libraries, and working from vehicles, and construct a nominal variable that captures both single location and multiple location workers.

Using this variable, we first highlight time trends and spatial patterns in the practice of alternate work location in the United States. Secondly, we apply this variable in determining how alternate work location practices interact with daily travel patterns considering both work and non-work-related travel. We do this by modeling the relationship of work location with duration of daily travel and participation in morning and evening peak hour travel period, answering the following two research questions: Which daily work location arrangements are related to decreased or increased travel duration? Which daily work location arrangements are related to peak or off peak travel? We also describe a potential mechanism within this relationship through a survival analysis of daily departure times based on work locations. The conclusion considers how telework might play a larger role in travel demand management strategies in light of our findings.

Background

Telework and travel

Daily travel patterns in a region are related to the participation of individuals in varied activities (Kitamura 1988). Golob and McNally (1997) define three categories of activities that influence travel in different ways: work activities, household maintenance activities including shopping, drop-offs, and medical care, and discretionary activities that are related to leisure, such as social visits. Individuals are constrained in their participation in activities and related travel by their capabilities, relationships, and agency (Hägerstraand 1970). As such, social and demographic factors exert influence on the demand for activities, and the inclusion of activity participation alongside such factors in travel demand models has led to better explanation of travel outcomes (Lu and Pas 1999). Demand for activities differs between workers and non-workers, and between workdays and non-workdays (Yamamoto and Kitamura 1999). Furthermore, time spent working and time spent commuting, measured through time-travel ratios, indicate that individuals trade-off time spent participating in each within a day (Schwanen and Dijst 2002).

Telework allows work activities to be conducted remotely without necessitating a trip, potentially disrupting such constraints and tradeoffs, and influencing both work and non-work-related travel (Dijst 2004). As early as 1976, the person who coined the term "telecommuting" offered it as an alternative practice to the problems of traffic congestion derived from daily work commuting (Nilles et al. 1976). In an early 1988 pilot study conducted in California, travel diary data was collected from state workers enrolled in a telecommuting program as well as from members of a control group; results showed an expected reduction in weekly work trips, but also a reduction in non-work trips by family members (Kitamura et al. 1990). A time series analysis (Choo et al. 2005) found that growth in telecommuting had a small negative effect on vehicle miles traveled. A 2010 meta-analysis (Andreev et al. 2010) considered 35 empirical studies of the effects of telework, and found that nearly all of them showed the relationship between telecommuting and travel to be one of substitution, in which telecommuting reduces travel.

Obstacles to the adoption of telework by organizations have included manager preference for having employees in the office, and concerns from both employees and managers about professional isolation and career development (Duxbury et al. 1987; Cooper and Kurland 2002). Motivations for the decision to telework include commute time, stress, and a desire for independence, yet distractions at home and missing out on workplace socialization act as deterrents (Mokhtarian and Salomon 1997). Additionally, while telework in some structured cases has improved productivity, these effects have not been widely seen. An analysis of Fortune 100 company pilot programs found that productivity was unchanged among home workers compared to in-office workers (Olson 1989).

Recent telework research has strived for more complex modeling such as the distinction between types of telework based on time of day, duration, and interaction with work done at the workplace. Asgari and Jin (2015) consider different patterns of telecommuting, such as the possibility of additional work-related trips over the course of the day. Haddad et al. (2009) find that in the United Kingdom "part-day" homeworking—defined as working from home in addition to attending work on the same day—is more prevalent than full-day homeworking among full-time workers, but that only full-day homeworking is associated with a belief that commuting is a struggle to be avoided. Deng et al. (2015) add "overtime" workers—defined as those who work from home while maintaining their regular commute patterns—to create a three-part categorization of home-based telework. The effects of part-day teleworking on travel may take the form of temporal shifts in commute time rather than the elimination of trips (Lyons and Haddad 2008). Asgari et al. (2016) additionally explore differences in departure times for different types of teleworkers to shed light on such shifts.

Finally, authors have recently been more fully exploring the implications of telecommuting for sustainability. A particular challenge to the reduction of travel through telework is how its benefits may be offset by residential location choice. Hu and He (2016) studied differences in the travel outcomes between part and full-time telecommuters, finding that those who telecommute less frequently tend to have longer trips to work than either those who telecommute more frequently or those who don't telecommute. However Lachapelle et al. (2017) used Canadian time use data to explore the relationship of working from different locations with travel, finding that some patterns of working from home were associated with less overall travel, a decreased likelihood of traveling at peak travel times, and an increased likelihood of using a non-motorized form of transport. Shabanpour et al. (2018) forecast how the increased adoption of full-day telecommuting could reduce traffic congestion and travel-related emissions based on travel diary data from Chicago.

Yet despite empirical findings about telework, doubt has remained about the nature of the relationship between telecommunications and travel. Mokhtarian (2002) argued that even if many short-term studies show a minor substitution effect, in the long-term telecommunications-based interactions and travel-based interactions will grow together, so that even as we interact more online we may also be traveling more. Others similarly argue that the relationship between telecommunications and travel is a complex one requiring new concepts. The notion of activity fragmentation is offered by Couclelis (2004) who argued that activities are now being spread across time and space in ways that they never could before ICTs and that this change is embedded in people's perceptions of action. Alexander et al. (2010) found that ICTs supported a spatial and temporal fragmentation of work activities like emailing, participating in meetings, and web-based work. In a special issue introduction, Schwanen et al. (2008) argued that the substitution/complementarity dichotomy represents a form of technological determinism in that it assumes that a generalizable effect of technology on travel exists. They suggested that the specific contexts in which digital activities interact with physical ones must be considered.

Computer mediated knowledge work

The infrastructure of mobile cloud computing is driving further research into remote work practices, especially for knowledge workers. Kleinrock (1996) noted that in the 1990s, being disconnected from a network was a more normal state than being connected and called for technological infrastructures to better support a lifestyle he called "nomadicity." Hardware technologies to address these challenges have developed in subsequent years, and now a patchwork framework enables mobile computing devices to access the Internet through 3G and 4G data networks and Wi-Fi hotspots. Through mobile cloud computing infrastructure, software is provided "as a service" through the Internet (Mell and Grance 2011). This "anytime/anyplace" computing is especially suited to knowledge work in how it can enable remote collaboration (Davis 2002).

A simple dichotomy of home and office may be inadequate to capture the routines of project-based and team-based knowledge workers in this new context. For teams, collaborative technologies have a centralizing effect on knowledge sharing (Bélanger and Allport 2008). Virtual teams using mobile cloud computing infrastructure can flexibly and remotely collaborate on projects with fewer face-to-face interactions (Townsend et al. 1998). Additionally, nomadic knowledge workers structure their work lives around projects, and both use and reshape the digital infrastructure of nomadicity as they traverse multiple spaces in service of the tasks and relations that comprise a day's tasks (Erickson et al. 2014). The broad category of "mobile workers" include such nomadic workers, as well as those whose work necessitates changing locations or those for whom mobility is work, such as mobile hairstylists and vehicle drivers (Cohen 2010).

Contribution

This paper contributes to the existing literature by creating knowledge about four aspects of the relationship between work location and travel in the United States. Firstly, empirical research has focused largely on remote working from home only. Here we will additionally explore working from locations such as cafés, vehicles and other people's homes, which may be conducted through ICTs. Secondly, while much past research has largely considered full-time and full-day telework, this paper's analysis allows for the inclusion of multiple work locations in a single day, thus including part-day teleworking in order to contribute to that important growing body of research. Thirdly, because working affects travel outcomes related to activities beyond work, we will also explore the effects of diverse work locations on non-work maintenance and discretionary activities. Finally, in addition to looking at total travel duration, this research considers the relationship of work location with both peak hour travel and initial departure times in part to inform demand management and peak hour avoidance policies. In doing so it supports an application of telework knowledge as a policy tool to be applied in specific contexts for specific purposes.

Data and methodologies

All analyses in this paper use data from the American Time Use Survey (ATUS) conducted by the Census Bureau on behalf of the Bureau of Labor Statistics (BLS). This annual cross-sectional survey was first conducted in 2003, and seeks to shed light on the amount of time Americans spend doing various activities by asking respondents about the 24-h prior to a telephone interview. The unit of analysis for ATUS is a 24-h period of activities for members of selected households that participate in the Current Population Survey. These households are originally selected using a multistage stratified sampling strategy. ATUS observations are weighted to ensure that final estimates demographically reflect the US population, and to adjust for the oversampling of weekend days. These ATUS-provided survey weights are applied to all our modeling and estimations.

A primary shortcoming of the ATUS is that it only allows respondents to report doing one activity at a time. A respondent who dined with friends has to choose between reporting such an activity as "eating/drinking" or as "socializing," but could not report both. Similarly a respondent who composes and sends a work email while watching TV cannot report that activity as both "work" and "leisure/relaxing." However we consider this to not be problematic, but rather beneficial for this study, as our intention is to capture the more focused and intentioned episodes of work that both respondents and employers would consider as time spent "working." Occasional smartphone check-ins with work is an interesting practice, but one that would be best captured in a different study.

Our sample of US knowledge workers on a workday was constructed by limiting the full ATUS sample in several ways. Firstly we limited the sample to non-holiday weekdays, and excluded unemployed individuals or any employed individuals who reported conducting no work on that day. Secondly, because the focus of this study is on knowledge work, individuals in manual occupations were excluded, such as food prep, cleaning, personal care, construction, maintenance, and transportation. Thirdly, we excluded workers who travelled by plane on the diary day because it likely indicates an atypical day of travel for them. Finally, we exclude self-employed workers, who are overrepresented among alternate location workers, yet whose lack of an employing firm makes for different policy prescriptions regarding trip reduction and peak-avoidance.

Using repeated cross-sectional data from 2003 to 2017, there are 26,636 observations used for descriptive and trend analysis, and 24,392 observations used for modeling due to missing income and work classification data. The levels of measurement for all variables included in all analyses and models are shown in Table 1. Our primary variable of

Table 1 Measurement of variables included in analyses

	Variable	Measurement
Daily travel	Daily travel time (By work, maintenance, and discretionary)	Ratio scale
	Peak travel participation (By work, maintenance, and discretionary)	Nominal
	Peak travel morning and evening, Peak travel morning only	
	Peak travel evening only, No peak travel	
	Initial departure from home in minutes	Ratio scale
Daily work	Total daily work time in minutes	Ratio scale
	Daily work locations	Nominal
	Home only, Other home only, Café/library only, Vehicle only, Unspecified only, Workplace and home only, Workplace and other home only, Workplace and café/library only, Workplace and vehicle only, Workplace and unspecified only, Workplace and 2 or more, Home not workplace and 1 or more	
Employment characteristics	Is part time worker	Binary
	Is paid hourly	Binary
	Occupation	Nominal
	Industry	Nominal
Family and demographic characteristics	Education level	Ordinal
	Is married	Binary
	Number of children	Ratio scale
	Family income	Ordinal
	Is female	Binary
	Race	Nominal
	Age in years	Ordinal
Locational and time characteristics	In metro area	Binary
	Day of the week	Nominal
	State	Nominal
	Year	Nominal

Italics indicate the category names for selected nominal variables interest is a work location summary variable indicating whether an individual worked at a given location on the diary day, and the time and duration they worked at that location. These locations include workplace, own home, other person's home, café/library, vehicle, or unspecified. These variables alone do not constitute a mutually exclusive nominal categorical variable, since individuals may work from multiple locations in a single day, such as the combination of workplace and home. Therefore a single nominal work location variable was constructed that accounts for both those who worked from a single location and those who worked from different combinations of multiple locations.

The variable for total daily travel time sums all time periods when the respondent indicated they were traveling by any mode in categories for work, maintenance, and discretionary purpose. Work-related travel includes time spent commuting and time spent working in a vehicle such as in a car or on transit. The study also creates a measurement of daily participation in peak hour travel. The choice of whether or not to participate in peak hour travel on a given day is often highly constrained by organizational norms, however the enabling of remote work through the capabilities of ICT can loosen these constraints to the extent that occupational requirements allow it. For the purpose of this analysis, peak travel times are defined as being 6 a.m. to 9 a.m. in the morning and 4 p.m. to 7 p.m. in the evening, although other levels were tried yielding similar findings. Each case of a US worker on a workday is tagged as having traveled during these peak times or not on that day. The final nominal peak participation variable indicates whether an individual traveled at peak times in both the morning and evening, in the morning only, in the evening only, or during neither peak travel time.

After an analysis of alternate work location prevalence and trends, we analyze the relationship between our measure of work location with both daily travel duration and peak hour travel, using firstly, three ordinary least squares regression models with natural log-transformed daily minutes of work-related, maintenance, and discretionary travel time as dependent variables, and secondly, three multinomial logistic regression models with peak travel participation across the same three categories as the dependent variables. The independent variables in all models are nominal workplace location, along with employment, family, demographic, locational and time characteristics as listed in Table 1. The year variable was tried as both a continuous trend variable and as year-specific dummies to loosen the linear assumption of a time trend and to investigate potential effect from a period economic recession. Weekend days were excluded from all models. While this study's goal for assessing relationships is in part exploratory, expected findings are that home-based working is associated with decreased overall travel, and a decreased likelihood of participation in peak hour travel. The peak hour model is finally augmented with a survival analysis of initial departure times for workers who conduct some or all work at home.

Results

Results are presented in four sections below. The first section describes the prevalence of working from locations other than the workplace during the study period, as well as year-to-year trends for work location, and the characteristics of workers that reported conducting work from home and elsewhere. The second section presents the results of the daily travel duration ordinary least squares regression models. The third section presents the results from the peak hour travel participation multinomial logistic regression models, and the final section augments this with a survival analysis of initial departure times to shed light on a mechanism of morning peak hour avoidance related to home-based work.

Prevalence and trends

More than 30% of US knowledge workers on a workday reported working from a location other than just their workplace over the study period. Figure 1 shows all the categories of the nominal work location variable except for the largest category of "workplace only" which accounted for 73.7% of US non-self employed knowledge workers on a workday. Of the remaining 26.3%, 9.1% worked from a single type of location—own home, other home(s), café/library, vehicle, or unspecified. The remaining 17.2% worked from some combination of types of these locations and/or their workplace. For both one-location workers and multiple-location workers, the most prevalent categories involve homeworking, with 6.8% working from their own home only (full-day homeworkers), and 12.2% working from their own home and their workplace on a workday (part-day homeworkers). It is also notable that nearly 1% of workers worked from their own homes plus one or more non-workplace locations, and 1.3% worked from their workplace and 2 or more other locations. The "unspecified" categories are assumed to be largely those who are working from others' work locations, such as auditors, consultants, and salespeople.

Trends in alternate work location across these location types are shown in Fig. 2. Full-day homeworking among non-self employed knowledge workers shows a clear upward trend, and more than doubled, from a low of 4% in 2003 to a peak of 10% in 2017. Part-day homeworking was consistently more prominent but only shows a slight growth trend. Working from vehicles—only or in combination with other

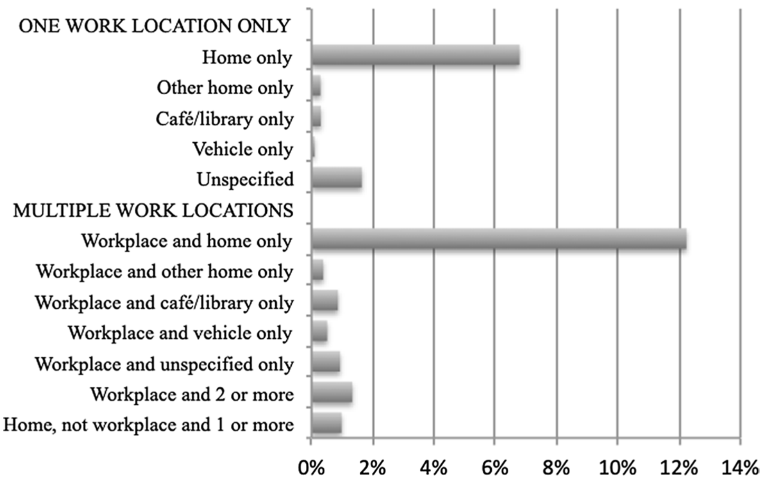


Fig. 1 Distribution of types of work locations over the study period 2003–2017 (US knowledge workers on workday, n = 26,636). *Note*: Base category "Workplace only" is excluded and accounts for 73.7% of non-self employed US knowledge workers on a workday. *Source*: American Time Use Survey

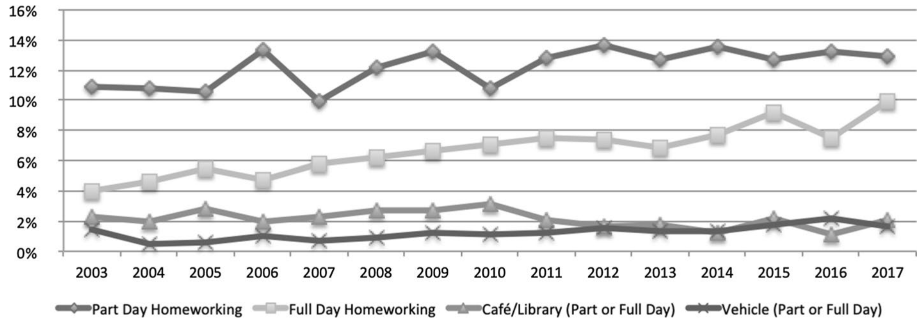
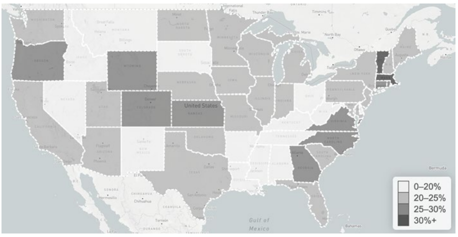


Fig. 2 Trends in types of work locations over the study period 2003–2017 (US knowledge workers on workday, n = 26,636). *Source*: American Time Use Survey



MSA Size	Pct.
Over 5M	23.6%
2.5M to 5M	23.4%
500K to 2.5M	21.3%
250K to 500K	19.6%
100K to 250K	20.4%
Under 100K	18.9%
Not identified	18.3%

Fig. 3 Prevalence of reported home-based work by state and metropolitan statistical area size over the study period 2003–2017 (US knowledge workers on workday; n = 26,636). *Source*: American Time Use Survey

locations—also appears to show an upward trend from 0.5% in 2004 to a high of 2.2% in 2016 although with an unexplained outlier in 2003. Finally conducting some or all work from cafes or libraries shows a slight downward trend although with a higher degree of variability. The peak in 2010 of 3.2% could be related to a recession during that period.

The distribution of non-self employed homeworking is shown in Fig. 3 for only the latter years of the study period (2010–2017) to reflect recent changes. There are clear differences between states and differently-sized urban areas. Appalachian states such as West Virginia and Kentucky, and southern states such as Mississippi and Louisiana have notably lower levels of homeworking. Coastal states generally have higher levels, and there are several exceptional states such as Vermont, Massachusetts, Colorado, North Dakota, and Wyoming. Despite some rural states excelling, homeworking tends to occur at a higher rate in larger urban areas as shown in Fig. 3. Metropolitan statistical areas larger than 2.5 million persons and five million persons had the highest rates of 23.4% and 23.6% respectively.

There are statistically significant differences in the characteristics of those who work from home and other alternate work locations compared to the general population of US workers over the study period (Table 2). In terms of gender, a higher percentage of knowledge workers are female, and full-day homeworking reflects this, however part-day homeworkers and those who work from other locations including cafes or vehicles tended to be slightly more male. Higher levels of education and income are also seen among alternate location workers, especially both full and part-day homeworkers. In terms of occupations, those who work from home and other non-workplace locations are more likely to have a management occupation and less likely to have an administrative position. Computer,

Table 2 Comparison of selected characteristics of overall knowledge workers with alternate work location subgroups (US knowledge workers on a workday 2003–2017). *Source*: American Time Use Survey 2003–2017

	Overall knowledge workers	Alternate work location subgroups		
		Home only workers	Workplace and home only workers	Other type(s) of location workers
Female	53%	53%	46%***	46%***
Age in years	41.5	44.5***	42.7***	42.0
Has col. degree or higher	52%	64%***	73%***	60%***
Has fam. income > $100 K	30%	37%***	40%***	31%
Occupation:				
Management	19%	23%***	24%***	25%***
Computer and math. science	5%	8%***	7%***	30%***
Education, training, and library	10%	14%***	19%***	11%
Arts, design, ent., sports	3%	7%***	5%***	6%***
Sales and related	16%	15%	13%***	18%***
Office and admin.	20%	10%***	8%***	14%***
Minutes of working	488	326	555	458
Minutes of work travel	42.6	2.4***	45.3***	70.9***
Minutes of maintenance travel	30.3	39.6***	26.5***	43.6***
Minutes of discretionary travel	9.2	11.8***	7.1***	12.1***
Participation in peak travel				
None	12%	45%***	8%***	12%
Morning only	12%	9%***	13%*	12%
Evening only	14%	31%***	13%	23%***
Both morning and evening	62%	14%***	66%***	54%***

Stars indicate significance of Chi2 or Wilcoxon rank sum test for subgroup in comparison to overall: *$p < 0.10$; **$p < 0.05$; ***$p < 0.01$

education, and design occupations are also correlated to alternate work location among knowledge workers. Home-only workers work for less minutes in the day than part-day homeworkers or overall knowledge workers. Differences also exist in travel between each subgroup and overall knowledge workers, both in terms of daily travel times and participation in peak travel. These differences will be explored through modeling in the two subsequent sections.

Models: work location and minutes of daily travel

The first set of models seeks to explain daily travel duration through work location, while controlling for characteristics of employment, family, demographic, location, and day of the week. Table 3 shows results from three log-linear regressions with daily work-related travel time, daily maintenance travel time, and daily discretionary travel time as dependent variables. Work-related travel time is composed of time spent commuting, other self-reported time spent traveling for work, and any time spent working in a vehicle. An initial examination of residuals from ordinary least squares multiple linear

Table 3 Results from multiple log-linear regression of daily travel duration in minutes (US knowledge workers on workday 2003–2017; n = 24,392)

	Work-related travel daily minutes		Maintenance travel daily minutes		Discretionary travel daily minutes	
	Coef.	Factor Chg.	Coef.	Factor Chg.	Coef.	Factor Chg.
Duration of work in minutes	0.001***	1.001	−0.003***	0.997	−0.002***	0.998
Work location (base: workplace only)						
Home only	−3.14***	0.04	−0.44***	0.65	−0.13**	0.88
Other home only	−0.96***	0.38	0.42**	1.52	−0.15	0.86
Café/library only	−0.26	0.77	0.42**	1.52	0.36	1.43
Vehicle only	1.80***	6.03	0.03	1.03	0.08	1.08
Unspecified	−0.39***	0.68	0.03	1.03	0.15	1.16
Workplace and home only	−0.04	0.96	0.14***	1.15	0.00	1.00
Workplace and other home only	0.29***	1.34	0.34	1.41	0.32	1.38
Workplace and café/library only	0.39***	1.48	0.25**	1.29	0.10	1.11
Workplace and vehicle only	1.28***	3.61	0.00	1.00	−0.25	0.78
Workplace and unspecified only	0.27***	1.31	0.56***	1.75	0.20*	1.23
Workplace and 2 or more	0.65***	1.92	0.48***	1.61	0.24**	1.27
Home, not workplace and 1 or more	−0.03	0.97	0.39***	1.47	0.10	1.10
	$R^2 = 0.4229$		$R^2 = 0.1191$		$R^2 = 0.0565$	

Control variables are shown in "Appendix"; stars indicate significance: *$p < 0.10$; **$p < 0.05$; ***$p < 0.01$

regressions showed that the normality assumption would be violated without transforming the dependent travel time variables. Both log transformation using constants to address the presence of zero values, and square-root transformation were tried yielding similar results, and only the former strategy is presented here. Model fits as measured by R^2 suggest that work-related travel is explained much better by these variables than non-work related travel.

Work-related daily travel time is significantly lower for full-day homeworkers, compared to the base category of workplace only. The coefficient of −3.14, indicates that working from home only is associated with a change in work-related travel time by a factor of 0.04 ($e^{-3.14} = 0.04$) or a decrease of 96%. This is not surprising since full-day home-based workers do not engage in a commute at all. Working from another person's home or an unspecified location are also associated with less work-related travel. Working at the combination of home and workplace only—part-day homeworking—has no significant effect on work-related travel time. Other categories of multiple work location are all predicted to increase work-related travel time. Vehicle-based work is associated with the largest increases in work-related travel time, both as part of multiple locations or on its own. For example, working from both a vehicle and workplace in a day is associated with an increase of work-related travel by a factor of 3.6 (260%). However these categories represent only a small percentage of knowledge workers as shown in Fig. 1.

Non-work maintenance and discretionary travel are also reduced by full-day homeworking, by 35% and 12% respectively. Additionally, the duration of time worked on a given day is associated with more non-work travel. This finding helps explains why home-only workers—who work less per day on average—have slightly higher average maintenance and discretionary travel times than overall knowledge workers as shown in Table 2, suggesting they may reallocate work time towards other activities. For part-day homeworkers, maintenance travel is estimated to be 15% higher than for workplace only workers. Finally, working from two or more locations in addition to a workplace is associated with both more maintenance and discretionary travel, which could be related to trip chaining patterns among these more mobile workers.

Models: work location and peak hour travel

Results for the multinomial logistic regressions on peak hour travel participation are shown in Table 4 for the independent variable of interest, daily work locations. As in the previous section, three models are presented with dependent variables for peak hour travel for work purposes, peak hour travel for maintenance purposes, and peak hour travel for discretionary purposes. Working from home only on a workday greatly decreases the likelihood that a worker will participate in any period of peak travel that day. Someone working from home only is at least 98% less likely to engage in any or both periods of peak hour travel for work purposes than someone working from their workplace only. Again this is expected because of the lack of a work commute altogether. However they are also less likely to travel during peak periods for non-work maintenance or discretionary purposes, such as being over 50% less likely to travel for maintenance reasons during the morning peak.

Part-day homeworking while also attending a workplace has mixed effects on participation in peak hour travel. These workers are 42% less likely to travel for work purposes during both peaks and 45% less likely to travel during the morning peak only. Yet they are also more likely to travel in those same peak periods for maintenance purposes—and in the morning peak period for discretionary travel, suggesting there is either some offset or that they travel for maintenance before their commute as part of a trip chain. As with full-day homeworking, part-day homeworking lacks significant effects that lower the likelihood of evening only peak travel across models. Furthermore this pattern is seen in other categories, such as those working from two or more locations in addition to a workplace, suggesting workers are more likely to avoid peak hour morning travel than to avoid peak hour evening travel for work purposes. Finally, just as in the previous set of models, participation in peak period travel for work purposes is better explained by these variables than participation in peak period travel for non-work purposes.

Kaplan–Meier survival analysis for daily departure time

The final analysis looks at the extent to which workers that work from home may use work location to delay their morning departure in a way that avoids peak hour commuting. In the model just presented, homeworkers are shown as more likely to engage in just one period of peak hour travel (morning or evening) over engaging in both morning and evening peak

Table 4 Odds ratios from multinomial logistic regression for peak travel outcome (US knowledge workers on workday 2003–2017; n = 24,392)

(Bases: no peak travel)	Work-related travel			Maintenance travel			Discretionary travel		
	Morning only	Evening only	Both peaks	Morning only	Evening only	Both peaks	Morning only	Evening only	Both peaks
Duration of work in minutes	1.002***	1.001***	1.003***	0.998***	0.997***	0.996***	0.998***	0.998***	0.996***
Work location (base: workplace only)									
Home only	0.01***	0.02***	0.01***	0.49***	0.53***	0.28***	0.86	0.62***	0.44**
Other home only	0.25***	1.12	0.2***	1.12	0.83	0.93	1.01	0.34**	0.56
Café/library only	0.32***	0.94	0.23***	1.16	0.57	0.16***	0.86	0.92	0.00***
Vehicle only	0.16***	1.00	0.05***	0.12**	0.61	0.96	0.92	0.60	0.00***
Unspecified	0.32***	0.54***	0.22***	0.88	1.10	0.88	1.29	0.89	1.97*
Workplace and home only	0.65***	1.12	0.58***	1.25***	0.99	1.31***	1.36**	0.93	1.06
Workplace and other home only	0.40**	1.75	0.86	1.66	1.78	2.58***	0.41	1.24	2.18
Workplace and café/library only	0.95	1.20	1.27	0.71	0.83	1.02	0.91	0.72	1.35
Workplace and vehicle only	0.49**	1.46	0.77	0.55*	1.30	0.79	1.36	0.55	0.46
Workplace and unspecified only	0.93	1.42	1.00	1.10	1.29	1.69**	0.65	1.08	5.49***
Workplace and 2 or more	0.51***	1.78**	0.77	1.27	1.00	1.35	1.71	1.31	2.11
Home, not work and 1 or more	0.12***	0.68*	0.05***	0.92	0.98	0.80	0.99	0.77	1.38
	Pseudo R^2: 0.1371			Pseudo R^2: 0.0663			Pseudo R^2: 0.0336		

Control variables are shown in "Appendix"; stars indicate significance: *$p < 0.10$; **$p < 0.05$; ***$p < 0.01$

hour travel, with a greater likelihood of avoiding morning peak hour commutes. Other categories of work location also showed an orientation towards greater likelihood of not participating in morning peaks. The following survival analysis seeks to show how home-workers—in particular part-day homeworkers—offset their departures in a way that results in avoiding morning peak hour travel.

The Kaplan–Meier estimator is a statistical technique used to estimate survival probabilities over time for groups under study. Before settling on this approach we first tried a Cox hazard regression, which would have allowed for the inclusion of the same independent variables as in the above models. However testing indicated that the assumption of proportionality required by Cox regression was not met. Kaplan–Meier survival analysis is most frequently applied in health studies to estimate the survival of patients in different treatment groups over time (Jager et al. 2008), however it has also been applied by other disciplines to the analysis of events such as exit from homelessness (Caton et al. 2005). In our usage, time is represented as minutes on a workday and rather than surviving, our subjects are merely delaying their initial departure from home. In place of treatment groups we use the following categories of work location on the diary day: Workplace only, Home only, Home in the morning and workplace, Workplace and home in the afternoon or evening, and More than 2 types of locations.

The plots shown in Fig. 4 indicate clear differences in probability of departure at given times based on work location practices that contribute to shaping the morning peak period. Workplace-only workers, with a mean departure time of 7:19 a.m., have the steepest curve indicating that they have a higher probability of earlier departures. At 8 a.m., 24% are estimated to remain at home not having engaged in any travel, and at 10 a.m., only 5% remain at home. For part-day teleworkers who conduct work at both their workplace and home on a given day, the survival plots differ depending on whether home-based work was done in the morning before attending the workplace, or in the afternoon/evening after attending the workplace. Knowledge workers conducting work at home before attending work, with a mean departure time of 8:14 a.m., have a similarly shaped plot to workplace-only workers yet it is shallower and shifted to the right indicating delayed departures. By 8 a.m., 48% are

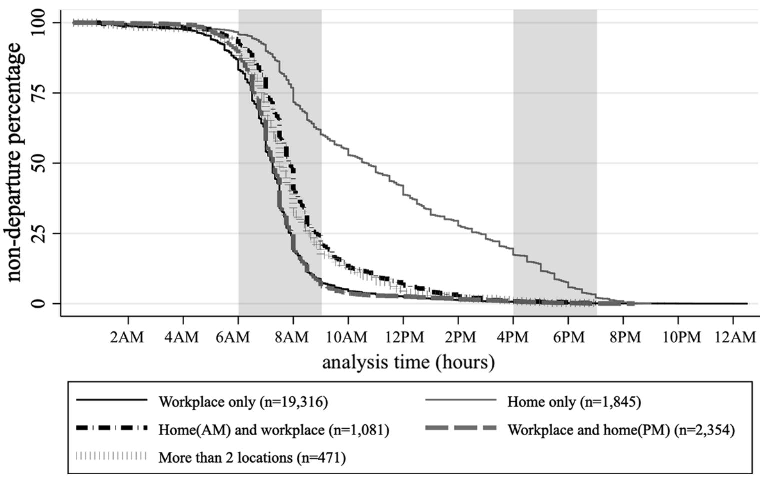


Fig. 4 Survival plot for daily departure time by work location (US knowledge workers on a workday, 2003–2017)

estimated to remain at home, and by 10 a.m., 15% remain at home. The plot for workers attending their workplace first and conducting work in the afternoon or evening afterwards, begins very slightly offset to the right, but is otherwise nearly identical to the plot for workplace-only workers.

The shallowest curve is for home-only workers, which we consider to be full-day teleworkers. These workers have a much later mean departure time of 11:40 a.m. At 8 a.m., 77% of home-only workers are estimated to remain at home not having engaged in any travel, and by 10 a.m. that number has only declined to 55%. The final plot is shown for workers who indicated that they work from more than two types of locations in a day. Beyond work and home these may include conducting work from a café, vehicle or other office. This group shows a pattern of delayed departure very similar to that of part-day teleworkers who conducted work from home in the morning. At 8 a.m., 40% of these multiple-location workers are estimated to remain at home, and by 10 a.m. that number has declined to 13%. This survival analysis shows that three groups have higher probabilities of later departures compared to workplace-only workers: home-only workers, part-day teleworkers who conduct work from home in morning, and multiple-location workers. Within the sample, the number of workers in these three groups (3397 total) is small compared to workplace-only workers (19,316), yet it is still consequential for travel outcomes, and points to one mechanism of the reduced participation in morning peak period travel based on work location that was observed in the previous model.

Findings

Over 26% of non-self employed American knowledge workers on a workday conducted work from one or more alternate work locations, such as homes, vehicles, cafés, other offices, and combinations of such locations with their workplace. In this study we have confirmed in an American context previous findings from the Canadian context (Lachapelle et al. 2017), such as that teleworkers are more likely to avoid some peak periods and that full-day telework is associated with reduced travel time. This agreement shows how alternate work location practices matter to travel outcomes and deserve a place in policy making and demand forecasting. We have also extended this topic through a focus on knowledge workers, an exploration of interactions of work location with work and non-work trip purposes, and through an analysis of departure time by daily work location. The major findings of our study, based on data from the American Time Use Survey spanning 2003 to 2017 are as follows:

Work location affects peak hour travel demand

Findings show that work location has a strong effect on peak hour travel among knowledge workers. Full-day homeworkers are more likely to avoid peak hour travel in the morning only, evening only, or at both times on a workday. This effect is strongest for work-related travel as these workers by definition have no commute. However the effect is also seen for non-work maintenance and discretionary travel. Part-day homeworkers who also attend their workplace are more likely to avoid travel for work purposes during peak periods, but are less likely to avoid travelling for non-work purposes at those times. 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. Other work location practices such as café working, working from other homes, and working from vehicles, are also associated with avoiding peak hour travel for work purposes. When we combine homeworking with other non-workplace locations, such as someone who works at home in the morning and goes to a café to work later in the day, the higher likelihood of avoidance of at least some peak hour work travel remains.

Morning peaks are more affected by work location than evening peaks

Those who work from alternate locations are more likely to avoid peak hour travel in the morning than in the evening. With homeworking being the largest category of alternate work location, the analysis points to a mechanism of shifted morning departure times. According to our survival analysis, both part-day homeworkers who conduct work in the morning, and full-day homeworkers are seen as shifting their departures to later times within or after peak hours. Additionally many of the other categories of both single-location and multiple-location work, showed strong or significant effects for avoiding peak hour morning work-related travel but not for avoiding peak hour evening travel. However it is notable that this difference in morning and evening peaks holds true largely for work-related travel, and not for non-work related travel. Our full models ("Appendix") showed that number of children is correlated with peak period maintenance travel, and as such we consider that working parents in particular lack the flexibility to avoid morning peaks altogether.

Only full-day homeworking is associated with less daily travel

Full-day homeworking influences both work and non-work travel in ways that reduce travel with benefits for sustainability. Findings show that working from home only on a workday is predicted to decrease work-related travel time by 96% and maintenance-related travel time by 35%. While full-day homeworkers were found on average to travel slightly more for non-work purposes than workplace workers as they reallocate time from shorter daily working hours, their overall daily travel time remains much lower on average. Furthermore, this additional non-work travel may have benefits for wellbeing. Part-day homeworking—working at home and attending the workplace on the same day—was not predicated to reduce daily travel time among knowledge workers. Furthermore, all other work locations and combinations of work locations were predicted to increase either work or maintenance-related travel time. Working from vehicles was predicted to greatly increase daily time spent traveling, based on an imperfect assumption that vehicle-based work is comprised of traveling.

Working from home and working from vehicles are growing in the US

Homeworking is on the rise in the United States for knowledge workers. The upward trend appears especially strong for those who only work from home, whose prevalence nearly doubled between 2003 and 2017. But it also appears for those who work from home and from one or more other locations including their workplace. The associations of homeworking with the highest level of education, and with management and professional occupations suggest that homeworking is related to information and communication technologies. Vehicle-based working also is on the rise, although it remains relatively rare.

Limitations

There are limitations to this study related to both its data and the national scale of its analysis. First and foremost, the lack of smaller geographies for this dataset, such as census tracts, mean that our models don't effectively account for the role of the built environment in the relationships being studied, such as the distinction between urban and suburban contexts. Another key limitation is the absence of data about particular individual work tasks. The broad categories of industry and occupation supported by the American Time Use Survey do not give us an accurate measurement of the daily tasks in which a worker is expected to engage and the suitability of those tasks for being done remotely, which also form an important part of these relationships. In terms of the national scale of analysis, because peak travel periods are different in different metropolitan areas, our choice of how we broadly defined these periods may not be accurate in some locations. Altogether these limitations mean that we are limited in how we strongly we can speak to the applicability of our findings in particular contexts, however we can draw conclusions about these relationships applicable to the United States broadly.

Policy discussion

Our findings firstly have implications for travel demand forecasting, as models that do not account for the likely continued adoption of full-day home-based telework may overestimate peak period travel demand. Models should consider the role of part-day telework in contributing to reduced or flattened peak periods, especially regarding the morning commute. Additionally, the forced adoption of telework by many knowledge workers in relation to COVID-19 draws attention to its practice, and creates an opportunity for promoting its strategic application as part of demand management solutions to transportation-related challenges such as congestion and greenhouse gas emissions.

In light of this, our findings could contribute to the development of more effective regional travel demand management (TDM) and incentive-based peak hour avoidance policies. TDM is the collaborative effort among private and public sector actors to manage demand for usage of the transportation system through the elimination or altering of peak hour trips. It can be enacted as regular policy to reduce congestion, or implemented during events that may worsen congestion, as TDM was used during the 1984 Los Angeles Olympics (Giuliano 1988). A recent demand management policy of interest is peak hour avoidance incentives, in which rewards are given to users in exchange for avoiding travel during peak times (Ettema et al. 2010).

Telework has long been considered as one strategy for the elimination of trips in TDM (Meck 2002). However implementations of TDM have in practice focused more on encouraging temporal flexibility, such as through work schedule shifts (Ferguson 1990). Our findings concerning the relationship of work location to peak hour travel, supports the usefulness of also encouraging spatial flexibility in TDM such as through telework. Given a choice, some employees may choose to temporally shift their work schedule by traveling before peak times and arriving at the workplace early. Other employees may choose to shift spatially only, by starting work at home, commuting after the peak hour, and then continuing work in the workplace. Still other employees may creatively combine spatial and temporal flexibility to suit their own needs. Employers and employees benefit from less time wasted in travel congestion while transportation agencies benefit from reduced peak hour usage. Furthermore full-day teleworking has the benefit of reduced travel and can be oriented toward lowering greenhouse gas emissions.

The message to employers from TDM partnerships could thus be one of permitting flexibility of *both* schedule and location for those employees for whom it is possible. And incentive programs can adapt to this dual flexibility by not providing overly narrow targets for incentivized outcomes. For example the 2016 trial "BART Perks" peak avoidance program provided incentives to riders in the form of points, to nudge morning commutes into small windows either one hour before or one hour after the peak morning hour (Bay Area Rapid Transit 2016). A preliminary evaluation of the program found that out of 18,000 signups, an average of 250 riders shifted their commute time each day of the program, while 15 companies signed up as partners in encouraging flexible work schedules. (Bay Area Rapid Transit 2017). The effect of the program on peak hour travel might have been larger if a wider window were granted for shifts in travel, and if the partnership with employers was designed to encourage both temporal and spatial flexibility. Similar programs can also encourage occasional full-day teleworking to reduce emissions. Based on the findings of this analysis of American Time Use Survey data, we argue that only by including spatial flexibility can the full benefits from new flexible work styles be realized.

Acknowledgements A previous version of this research was presented at the 2017 Transportation Research Board Annual Meeting.

Author's contribution JS: literature search and review, research methodology, data preparation, model development, interpretation of results, manuscript writing. MJS: research methodology, model development, interpretation of results, manuscript editing.

Funding This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Appendix

Full model results for Tables 3 and 4 (see Tables 5, 6).

Table 5 Results from multiple log-linear regression of daily travel duration in minutes (US knowledge workers on workday 2003–2017; n = 24,392)

	Work-related travel daily minutes		Maintenance travel daily minutes		Discretionary travel daily minutes	
	Coef.	Factor Chg.	Coef.	Factor Chg.	Coef.	Factor Chg.
Duration of work in minutes	0.001***	1.001	−0.003***	0.997	−0.002***	0.998
Work location (base: workplace only)						
Home only	−3.14***	0.04	−0.44***	0.65	−0.13**	0.88
Other home only	−0.96***	0.38	0.42**	1.52	−0.15	0.86
Café/library only	−0.26	0.77	0.42**	1.52	0.36	1.43
Vehicle only	1.80***	6.03	0.03	1.03	0.08	1.08
Unspecified	−0.39***	0.68	0.03	1.03	0.15	1.16
Workplace and home only	−0.04	0.96	0.14***	1.15	0.00	1.00
Workplace and other home only	0.29***	1.34	0.34	1.41	0.32	1.38
Workplace and café/library only	0.39***	1.48	0.25**	1.29	0.10	1.11
Workplace and vehicle only	1.28***	3.61	0.00	1.00	−0.25	0.78
Workplace and unspecified only	0.27***	1.31	0.56***	1.75	0.20*	1.23
Workplace and 2 or more	0.65***	1.92	0.48***	1.61	0.24**	1.27
Home, not workplace and 1 or more	−0.03	0.97	0.39***	1.47	0.10	1.10
Employment characteristics						
Is paid hourly	−0.06***	0.94	−0.10***	0.90	0.06**	1.06
Is part time	−0.08**	0.92	−0.18***	0.84	−0.05	0.95
Has multiple jobs	0.09***	1.10	0.08	1.09	0.10*	1.11
Is government worker	−0.12***	0.89	0.06	1.07	0.06	1.06
Is nonprofit worker	−0.04	0.96	0.04	1.04	0.04	1.04
Occupations						
Base: Office/admin						
Management	0.00	1.00	−0.03	0.97	−0.01	0.99
Business and financial	0.08**	1.09	−0.04	0.96	0.06	1.06
Computer and math. Science	0.07*	1.08	−0.06	0.94	−0.16***	0.85
Architecture and engineering	0.00	1.00	−0.05	0.95	−0.09	0.92
Life, physical, and social science	0.03	1.03	−0.01	0.99	−0.07	0.93
Community and social service	0.02	1.02	−0.03	0.97	−0.07	0.93
Legal occupations	0.04	1.04	−0.12	0.88	0.20*	1.22
Education, training, and library	−0.11***	0.90	−0.07	0.93	−0.07	0.93
Arts, design, ent, sports	0.06	1.06	0.09	1.09	−0.19**	0.83

Table 5 (continued)

	Work-related travel daily minutes		Maintenance travel daily minutes		Discretionary travel daily minutes	
	Coef.	Factor Chg.	Coef.	Factor Chg.	Coef.	Factor Chg.
Healthcare practitioner/technical	0.00	1.00	−0.11*	0.90	−0.12**	0.88
Sales and related	0.01	1.01	−0.13**	0.87	−0.05	0.95
Industries						
Base: Prof. and business services						
Agriculture	−0.45***	0.64	0.10	1.10	0.07	1.07
Mining	0.46***	1.58	−0.34	0.71	−0.14	0.87
Construction	0.14**	1.15	−0.03	0.97	0.02	1.02
Manufacturing	−0.03	0.97	0.03	1.03	−0.05	0.95
Wholesale and retail trade	−0.08**	0.92	−0.12**	0.89	−0.01	0.99
Transportation and utilities	−0.02	0.98	0.05	1.05	−0.03	0.97
Information	0.02	1.02	−0.17**	0.85	−0.02	0.98
Financial activities	0.00	1.00	−0.01	0.99	−0.03	0.97
Education and health services	−0.04	0.96	−0.14**	0.87	0.01	1.01
Leisure and hospitality	−0.04	0.96	−0.15	0.86	−0.11	0.89
Other services	−0.12**	0.88	−0.08	0.93	0.07	1.07
Public administration	0.16***	1.17	−0.19**	0.83	−0.18***	0.83
Education						
Base: High school or less						
Associates degree	−0.08***	0.92	−0.12***	0.89	−0.11***	0.90
Some college	−0.07***	0.93	0.08**	1.08	−0.01	0.99
College degree or more	0.00	1.00	0.03	1.03	−0.01	0.99
Family/demographic characteristics						
Is married	0.08***	1.09	−0.09*	0.91	−0.23***	0.79
Number of children	0.02*	1.02	0.12***	1.13	−0.03**	0.97
Family income						
Base: less than 50 K						
50 K to 100 K	−0.07***	0.93	−0.09***	0.91	−0.07**	0.93
More than 100 K	0.01	1.01	0.06	1.06	0.06**	1.07
Is female	−0.02	0.98	0.13***	1.14	−0.18***	0.84
Race/Ethnicity						
Base: White non-Latino						
Black non-Latino	0.04	1.05	0.03	1.03	0.01	1.02
Latino any race	0.04	1.04	0.02	1.02	0.02	1.02
Other	0.02	1.02	−0.11*	0.89	−0.09	0.92
Female * number of children	−0.06***	0.94	0.17***	1.19	−0.04*	0.96
Female * married	−0.04	0.97	0.02	1.02	0.09*	1.10
Age in years	−0.002**	1.00	−0.004***	1.00	−0.01***	0.99

Table 5 (continued)

	Work-related travel daily minutes		Maintenance travel daily minutes		Discretionary travel daily minutes	
	Coef.	Factor Chg.	Coef.	Factor Chg.	Coef.	Factor Chg.
Location and time						
In metropolitan area	0.19***	1.21	−0.01	0.99	−0.04	0.97
State						
Base: Pennsylvania						
Alabama	−0.05	0.95	0.38***	1.46	0.02	1.02
Alaska	−0.18	0.84	0.33	1.39	0.00	1.00
Arizona	−0.05	0.95	−0.21*	0.81	0.13	1.14
Arkansas	−0.3***	0.74	0.09	1.09	0.02	1.02
California	0.03	1.03	0.13	1.14	−0.06	0.94
Colorado	−0.11	0.90	0.23**	1.26	−0.09	0.91
Connecticut	−0.16**	0.85	−0.04	0.96	−0.05	0.96
Delaware	0.10	1.11	−0.45*	0.63	−0.38**	0.68
District of Columbia	−0.05	0.95	0.06	1.06	−0.23	0.80
Florida	0.02	1.02	0.08	1.08	−0.09	0.92
Georgia	0.05	1.05	0.03	1.03	0.03	1.03
Hawaii	−0.17	0.84	0.61**	1.85	−0.12	0.89
Idaho	−0.07	0.93	−0.21	0.81	0.12	1.13
Illinois	0.01	1.01	0.10	1.11	−0.02	0.98
Indiana	−0.05	0.95	0.08	1.08	−0.06	0.94
Iowa	−0.21***	0.81	0.06	1.07	−0.09	0.91
Kansas	−0.16**	0.85	0.18	1.20	−0.10	0.90
Kentucky	−0.18***	0.83	0.11	1.11	0.08	1.08
Louisiana	−0.2***	0.82	0.10	1.11	−0.09	0.91
Maine	−0.05	0.96	−0.04	0.96	−0.42***	0.66
Maryland	0.19***	1.21	−0.05	0.95	−0.14	0.87
Massachusetts	0.16***	1.18	0.03	1.03	−0.16	0.86
Michigan	−0.17***	0.84	0.14	1.15	0.06	1.06
Minnesota	−0.08	0.92	0.00	1.00	−0.02	0.98
Mississippi	−0.07	0.93	−0.03	0.97	0.03	1.04
Missouri	−0.13**	0.88	0.17	1.18	−0.04	0.96
Montana	−0.22*	0.80	−0.17	0.84	0.26	1.30
Nebraska	−0.24***	0.78	0.26*	1.30	0.02	1.02
Nevada	−0.05	0.95	−0.13	0.88	−0.15	0.86
New Hampshire	−0.01	0.99	0.11	1.12	0.22	1.25
New Jersey	0.14**	1.15	−0.09	0.91	−0.18**	0.84
New Mexico	−0.29***	0.75	0.07	1.07	−0.01	0.99
New York	0.07	1.07	0.02	1.02	−0.01	0.99
North Carolina	−0.11*	0.89	0.25**	1.28	0.06	1.06
North Dakota	−0.29**	0.74	0.00	1.00	−0.03	0.97
Ohio	−0.08	0.93	0.09	1.09	0.10	1.11
Oklahoma	−0.24***	0.79	0.05	1.05	0.01	1.01
Oregon	−0.14**	0.87	−0.07	0.93	0.08	1.09

Table 5 (continued)

	Work-related travel daily minutes		Maintenance travel daily minutes		Discretionary travel daily minutes	
	Coef.	Factor Chg.	Coef.	Factor Chg.	Coef.	Factor Chg.
Rhode Island	−0.05	0.95	0.32	1.38	−0.05	0.95
South Carolina	−0.17**	0.84	0.43***	1.54	0.05	1.06
South Dakota	−0.38**	0.69	−0.19	0.83	0.24	1.27
Tennessee	−0.18**	0.84	0.20*	1.22	0.29***	1.34
Texas	−0.06	0.94	0.12	1.13	0.08	1.09
Utah	−0.03	0.97	0.11	1.11	0.11	1.12
Vermont	0.01	1.01	0.19	1.21	−0.05	0.95
Virginia	−0.01	0.99	0.15	1.17	−0.14*	0.87
Washington	−0.01	0.99	−0.06	0.94	−0.05	0.95
West Virginia	−0.18	0.84	−0.08	0.92	0.12	1.13
Wisconsin	−0.08	0.93	0.09	1.09	0.05	1.06
Wyoming	−0.24	0.79	−0.15	0.86	−0.26	0.77
Year						
Base: 2003						
2004	−0.05	0.95	0.00	1.00	0.00	1.00
2005	0.00	1.00	−0.08	0.92	0.00	1.00
2006	−0.03	0.97	−0.06	0.95	0.05	1.05
2007	−0.07**	0.93	−0.09	0.92	−0.09	0.92
2008	−0.06	0.94	−0.07	0.93	−0.11**	0.89
2009	0.00	1.00	−0.15**	0.86	0.00	1.00
2010	0.04	1.04	−0.18***	0.84	−0.10*	0.90
2011	−0.02	0.98	−0.20***	0.82	−0.01	0.99
2012	−0.01	0.99	−0.18***	0.83	−0.03	0.97
2013	0.00	1.00	−0.17***	0.85	−0.10*	0.91
2014	−0.01	0.99	−0.18***	0.84	0.04	1.04
2015	0.02	1.03	−0.23***	0.80	−0.01	0.99
2016	0.00	1.00	−0.07	0.94	−0.03	0.97
2017	0.02	1.02	−0.12*	0.89	−0.07	0.93
Day of week						
Base: Wednesday						
Monday	0.00	1.00	−0.05	0.96	−0.14***	0.87
Tuesday	0.04	1.04	−0.04	0.96	−0.11***	0.89
Thursday	0.01	1.01	0.06	1.07	0.00	1.00
Friday	−0.02	0.98	0.33***	1.39	0.11***	1.11
Constant	2.94		4.11		2.49	
	$R^2=0.4229$		$R^2=0.1191$		$R^2=0.0565$	

Stars indicate significance: *$p<0.10$; **$p<0.05$; ***$p<0.01$

Table 6 Odds ratios from multinomial logistic regression for peak travel outcome (US knowledge workers on workday 2003–2017; n = 24,392)

(Bases: no peak travel)	Work-related travel			Maintenance travel			Discretionary travel		
	Morning only	Evening only	Both peaks	Morning only	Evening only	Both peaks	Morning only	Evening only	Both peaks
Duration of work in minutes	1.002***	1.001***	1.003***	0.998***	0.997***	0.996***	0.998***	0.998***	0.996***
Work location (base: workplace only)									
Home only	0.01***	0.02***	0.01***	0.49***	0.53***	0.28***	0.86	0.62***	0.44**
Other home only	0.25***	1.12	0.2***	1.12	0.83	0.93	1.01	0.34**	0.56
Café/library only	0.32***	0.94	0.23***	1.16	0.57	0.16***	0.86	0.92	0.00***
Vehicle only	0.16***	1.00	0.05***	0.12**	0.61	0.96	0.92	0.60	0.00***
Unspecified	0.32***	0.54***	0.22***	0.88	1.10	0.88	1.29	0.89	1.97*
Workplace and home only	0.65***	1.12	0.58***	1.25***	0.99	1.31***	1.36**	0.93	1.06
Workplace and other home only	0.40**	1.75	0.86	1.66	1.78	2.58***	0.41	1.24	2.18
Workplace and café/library only	0.95	1.20	1.27	0.71	0.83	1.02	0.91	0.72	1.35
Workplace and vehicle only	0.49**	1.46	0.77	0.55*	1.30	0.79	1.36	0.55	0.46
Workplace and unspecified only	0.93	1.42	1.00	1.10	1.29	1.69**	0.65	1.08	5.49***
Workplace and 2 or more	0.51***	1.78**	0.77	1.27	1.00	1.35	1.71	1.31	2.11
Home, not work and 1 or more	0.12***	0.68*	0.05***	0.92	0.98	0.80	0.99	0.77	1.38
Employment characteristics									
Is paid hourly	0.68***	0.82**	0.63***	0.90	0.91**	0.80***	1.30***	0.99	1.35
Is part time	0.66***	1.14	0.35***	0.90	0.70***	0.63***	0.93	0.88	0.68
Has multiple jobs	0.82*	1.26*	1.00	1.05	0.98	0.86	1.21	1.08	1.12
Is government worker	1.46***	1.28*	1.19*	0.90	1.23***	1.12	0.96	1.18**	1.21
Is nonprofit worker	1.24**	1.35**	1.22*	0.91	1.07	1.04	0.95	1.10	1.96*

Table 6 (continued)

(Bases: no peak travel)	Work-related travel			Maintenance travel			Discretionary travel		
	Morning only	Evening only	Both peaks	Morning only	Evening only	Both peaks	Morning only	Evening only	Both peaks
Occupations									
Base: Office/admin									
Management	1.05	1.13	0.96	1.01	1.05	0.88	0.92	0.98	0.98
Business and financial	1.13	1.11	1.13	1.04	1.01	0.91	0.97	1.18	0.51*
Computer and math. Science	1.00	1.17	1.07	0.78*	0.97	0.97	0.7	0.93	0.60
Architecture and engineering	1.11	1.09	1.12	0.97	1.05	0.83	0.91	0.93	0.4*
Life, physical, and social science	1.05	0.66	0.75	0.83	1.07	0.79	0.88	1.02	0.57
Community and social service	0.85	0.97	0.83	1.07	0.84	0.79	1.12	0.94	0.39*
Legal occupations	1.68**	1.05	1.54**	0.70*	0.85	0.95	1.37	1.22	1.63
Education, training, and library	1.22	0.96	0.86	0.93	1.12	0.82	0.94	0.86	0.89
Arts, design, ent, sports	0.85	1.09	0.74*	0.81	1.06	0.70*	0.48**	0.59***	1.10
Healthcare practitioner/technical	0.83*	1.03	0.57***	0.83	0.84*	0.66***	1.02	0.7***	0.58
Sales and related	0.96	1.29**	0.80**	1.00	0.88	0.65***	1.18	0.88	0.85
Industries									
Base: Prof. and business services									
Agriculture	0.60	0.60	0.45*	0.66	1.08	0.85	0.53	1.24	2.23
Mining	1.53	2.03	3.18	0.25***	0.56*	0.25***	0.20	0.86	1.27
Construction	1.12	1.36	1.40	0.62**	0.98	0.62**	0.67	1.22	1.11

Table 6 (continued)

(Bases: no peak travel)	Work-related travel			Maintenance travel			Discretionary travel		
	Morning only	Evening only	Both peaks	Morning only	Evening only	Both peaks	Morning only	Evening only	Both peaks
Manufacturing	0.93	0.91	0.84	0.74***	1.10	0.92	0.74	1.00	0.68
Wholesale and retail trade	0.53***	0.70**	0.53***	0.74**	0.86	0.77**	1.10	0.82*	0.51*
Transportation and utilities	0.48***	0.71*	0.45***	0.78	0.92	0.87	1.06	0.83	0.71
Information	0.66***	0.67**	0.78*	0.98	0.75**	0.68**	0.86	0.88	0.47
Financial activities	1.05	0.88	1.13	0.86	0.97	1.07	0.90	1.01	0.62
Education and health services	1.00	0.81	0.95	0.88	0.92	0.87	1.02	1.10	0.53*
Leisure and hospitality	0.41***	0.77	0.33***	0.65**	0.63***	0.43***	1.04	0.77	0.55
Other services	0.86	1.16	0.80	1.00	0.99	0.77	1.72*	0.97	0.41
Public administration	0.77*	1.03	1.08	0.79	0.79**	0.85	0.89	0.76**	0.27***
Education									
Base: High school or less									
Associates degree	0.62***	1.00	0.60***	0.90	0.83***	0.76***	0.88	0.82**	0.83
Some college	0.76***	1.09	0.70***	1.07	1.01	0.95	0.92	0.90	0.82
College degree or more	0.94	0.96	0.96	1.04	1.03	0.99	0.96	0.91	0.86
Family/demographic characteristics									
Is married	0.93	1.31**	1.25**	1.27**	0.97	1.42***	1.00	0.76***	0.82
Number of children	1.13***	0.96	1.06	1.31***	1.04	1.45***	0.90	0.95	1.27
Family income									
Base: Less than 50 K									
50 K to 100 K	0.96	0.96	0.92	0.97	0.90*	0.90	0.92	0.91	1.10
More than 100 K	0.91	0.84*	0.88*	1.04	1.01	0.99	1.17	1.12*	1.25
Is female	1.26***	1.00	1.20**	1.13	1.30***	2.13***	0.84	0.85**	1.59

Table 6 (continued)

(Bases: no peak travel)	Work-related travel			Maintenance travel			Discretionary travel		
	Morning only	Evening only	Both peaks	Morning only	Evening only	Both peaks	Morning only	Evening only	Both peaks
Race/Ethnicity									
Base: White non-Latino									
Black non-Latino	0.81***	0.86	0.64***	1.28***	0.87**	0.95	0.97	0.96	1.54*
Latino any race	0.79***	0.98	0.81**	1.18*	0.87*	1.12	0.89	0.97	0.81
Other	0.66***	0.75**	0.75***	0.96	0.90	0.83*	1.03	0.78**	0.36
Female * number of children	0.99	0.90	0.88**	1.46***	1.15***	1.54***	1.09	0.98	0.62**
Female * married	1.62***	1.06	1.28**	0.83	1.07	0.68***	0.76	1.24**	1.02
Age in years	1.00	1.00	1.00	1.00	1.00	0.99**	1.01	0.99***	1.01
Location and time									
In metropolitan area	0.99	1.11	1.11	0.85*	0.96	0.94	1.08	0.84**	0.69
State									
Base: Pennsylvania									
Alabama	1.09	0.77	1.00	1.01	1.67***	1.28	1.06	0.86	1.72
Alaska	2.38	2.67	2.74*	3.37***	2.20*	1.41	0.35	0.63	14.6***
Arizona	0.92	0.89	1.05	0.65*	0.89	0.86	2.16*	0.87	1.87
Arkansas	0.85	0.88	1.04	1.10	0.95	1.06	1.21	0.93	3.99*
California	1.11	1.01	1.07	1.38**	1.00	1.05	1.07	0.91	0.59
Colorado	1.26	1.30	1.22	1.82***	1.39**	1.03	0.57	0.68**	2.41
Connecticut	1.34	1.24	1.02	1.11	1.05	1.17	1.29	0.85	1.41
Delaware	0.82	1.29	1.18	0.56	1.00	0.59	1.39	0.48	0.00***
District of Columbia	1.76	0.99	1.49	0.78	1.15	1.55	0.79	0.58	1.67
Florida	1.26	1.04	1.22	1.26	1.09	1.07	1.32	0.76*	1.44
Georgia	0.96	0.72	0.99	1.33	0.89	0.84	1.02	0.95	0.87

Table 6 (continued)

(Bases: no peak travel)	Work-related travel			Maintenance travel			Discretionary travel		
	Morning only	Evening only	Both peaks	Morning only	Evening only	Both peaks	Morning only	Evening only	Both peaks
Hawaii	1.26	1.36	0.73	2.29*	2.05*	0.98	0.82	0.67	0.00***
Idaho	2.06*	2.80**	2.15**	0.50	0.78	0.44**	3.01**	1.06	1.00
Illinois	1.15	1.02	1.14	1.28	1.24	1.10	1.45	0.94	1.84
Indiana	1.38	1.18	1.56**	0.97	1.08	0.95	0.38**	1.18	1.21
Iowa	0.88	0.84	0.89	1.23	1.22	1.04	1.19	0.84	2.14
Kansas	1.37	1.38	1.82**	1.68**	1.14	1.85**	0.65	0.77	0.37
Kentucky	1.07	1.03	1.01	1.11	1.10	1.31	1.34	1.15	0.91
Louisiana	1.22	0.73	1.28	1.07	1.35	1.18	0.86	0.94	1.32
Maine	1.22	0.34*	0.87	1.28	0.96	1.19	0.40	0.52*	0.00***
Maryland	1.75***	1.77**	1.72**	0.89	0.95	0.79	0.95	0.82	0.61
Massachusetts	1.37	0.89	1.41	1.29	1.02	0.92	1.02	0.69**	1.26
Michigan	0.89	0.66*	0.86	0.86	1.14	1.09	0.86	1.10	0.82
Minnesota	1.39*	1.26	1.30	1.00	1.23	0.92	0.91	0.94	1.46
Mississippi	1.41	0.91	1.14	1.09	0.93	1.65*	1.70	1.17	1.00
Missouri	1.36	0.89	1.12	1.44*	1.67***	1.24	1.01	0.96	0.80
Montana	2.27*	1.16	1.75	0.97	0.51*	1.11	0.30	1.21	0.00***
Nebraska	1.04	0.84	1.29	1.02	1.12	1.36	0.90	0.82	1.98
Nevada	0.80	1.30	1.02	0.95	1.03	0.76	0.39	0.67	1.02
New Hampshire	1.49	1.08	0.72	1.64	1.56*	1.48	0.19**	0.93	1.15
New Jersey	1.47*	1.33	1.49**	1.24	0.94	1.05	0.82	0.66**	0.85
New Mexico	1.41	0.56	1.33	1.63	1.27	1.05	1.18	0.96	1.40
New York	1.12	1.12	0.92	1.21	0.95	1.09	1.03	0.89	0.97
North Carolina	1.18	0.89	0.97	1.45*	1.42**	1.46*	1.07	0.95	2.12
North Dakota	0.91	0.28	1.18	0.76	1.15	0.81	1.35	1.48	1.15

Table 6 (continued)

(Bases: no peak travel)	Work-related travel			Maintenance travel			Discretionary travel		
	Morning only	Evening only	Both peaks	Morning only	Evening only	Both peaks	Morning only	Evening only	Both peaks
Ohio	0.99	1.06	1.03	1.16	1.26*	1.01	1.00	0.97	1.99
Oklahoma	2.06***	1.33	1.50	1.06	1.31	1.31	1.26	1.05	2.25
Oregon	1.34	0.92	1.30	0.78	1.08	1.10	0.82	1.06	1.56
Rhode Island	2.42**	0.68	2.18*	1.62	1.69*	1.28	1.68	0.58	0.00***
South Carolina	1.29	0.91	0.86	1.15	1.84***	1.65**	1.65	1.01	0.19
South Dakota	1.06	1.27	1.51	1.91	0.72	1.28	1.18	1.40	0.71
Tennessee	1.16	0.72	0.84	1.43	1.34*	0.99	1.49	1.23	3.46*
Texas	1.31*	1.02	1.20	1.16	1.17	1.06	0.97	1.06	1.60
Utah	1.00	0.88	0.90	0.74	1.11	0.46**	2.10*	0.80	2.08
Vermont	3.04*	4.66**	3.46*	0.71	1.05	0.55	0.96	0.70	0.00***
Virginia	1.38*	0.83	1.27	1.17	1.10	1.05	0.85	0.82	0.71
Washington	1.07	0.98	0.90	1.05	1.09	1.15	1.00	1.10	0.91
West Virginia	1.13	0.59	1.01	1.63	1.11	1.32	1.61	0.98	3.96
Wisconsin	1.63**	1.50	1.22	1.10	1.35*	0.96	1.59	0.96	1.73
Wyoming	2.01	3.22	3.30*	0.84	0.78	0.89	2.64	0.53	0.00***
Year									
Base: 2003									
2004	0.73***	0.78	0.81*	1.21	0.87	1.05	1.20	0.87	1.18
2005	0.96	1.05	0.87	1.08	0.91	0.90	0.77	0.99	0.93
2006	1.05	1.08	0.90	1.11	1.07	1.19	1.00	1.11	1.16
2007	0.76**	0.86	0.77**	1.03	0.95	0.82	0.82	0.89	0.68
2008	0.85	0.68**	0.84	1.23	1.04	1.12	1.12	0.80**	0.80
2009	0.90	0.92	0.80*	1.08	0.84*	0.90	1.17	1.05	1.03
2010	1.10	1.16	1.06	0.97	0.90	0.85	1.05	0.90	1.48

Table 6 (continued)

(Bases: no peak travel)	Work-related travel			Maintenance travel			Discretionary travel		
	Morning only	Evening only	Both peaks	Morning only	Evening only	Both peaks	Morning only	Evening only	Both peaks
2011	0.93	1.11	0.91	1.12	0.86	0.74**	1.38	1.00	1.03
2012	0.82	0.73*	0.79**	1.07	0.87	0.89	0.79	0.99	0.77
2013	0.85	0.86	0.82	1.03	0.96	0.92	1.11	0.90	0.47
2014	0.69***	0.84	0.84	1.13	0.82**	0.78**	1.27	1.03	1.39
2015	0.77**	0.87	0.75**	1.21	0.87	0.82	0.95	0.95	1.36
2016	0.92	0.91	0.76**	1.18	1.10	1.00	0.92	0.93	1.25
2017	1.06	1.11	0.93	1.03	0.89	1.04	1.13	0.92	1.11
Day of week									
Base: Wednesday									
Monday	0.97	0.98	1.02	0.87	0.88*	0.95	0.91	0.77***	1.06
Tuesday	1.00	0.88	1.00	0.81***	1.02	0.92	0.85	0.79***	0.74
Thursday	1.01	0.96	0.95	0.90	1.05	0.94	1.02	0.93	1.00
Friday	0.96	0.89	0.89	0.99	1.38***	1.13	0.97	0.95	1.10
Constant	1.16	0.46	0.68	0.41	2.06	1.38	0.08	1.65	0.08
	Pseudo R^2: 0.1371			Pseudo R^2: 0.0663			Pseudo R^2: 0.0336		

Stars indicate significance: $*p<0.10$; $**p<0.05$; $***p<0.01$

References

Alexander, B., Ettema, D., Dijst, M.: Fragmentation of work activity as a multi-dimensional construct and its association with ICT, employment and sociodemographic characteristics. J. Transp. Geogr. **18**, 55–64 (2010). https://doi.org/10.1016/j.jtrangeo.2009.05.010

Andreev, P., Salomon, I., Pliskin, N.: Review: State of teleactivities. Transp. Res. Part C Emerg. Technol. **18**, 3–20 (2010). https://doi.org/10.1016/j.trc.2009.04.017

Asgari, H., Jin, X.: Toward a comprehensive telecommuting analysis framework: setting the conceptual outline. Transp. Res. Rec. J. Transp. Res. Board **2496**, 1–9 (2015). https://doi.org/10.3141/2496-01

Asgari, H., Jin, X., Du, Y.: Investigation of commute departure time to understand the impacts of part-day telecommuting on the temporal displacement of commute travel. In: Transportation Research Board 95th Annual Meeting (2016)

Bay Area Rapid Transit. About BART perks (2016). https://www.bart.gov/sites/default/files/docs/About%20Perks_0.pdf. Accessed 31 Aug 2020

Bay Area Rapid Transit. Incentives shift BART riders out of the morning rush (2017). http://www.bart.gov/news/articles/2017/news20170308. Accessed 31 Aug 2020

Bélanger, F., Allport, C.D.: Collaborative technologies in knowledge telework: an exploratory study. Inf. Syst. **18**, 101–121 (2008). https://doi.org/10.1111/j.1365-2575.2007.00252.x

Caton, C.L., Dominguez, B., Schanzer, B., Hasin, D.S., Shrout, P.E., Felix, A., McQuistion, H., Opler, L., Hsu, E.: Risk factors for long-term homelessness: findings from a longitudinal study of first-time homeless single adults. Am. J. Public Health **95**, 1753–1759 (2005). https://doi.org/10.2105/AJPH.2005.063321

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

Cohen, R.L.: Rethinking 'mobile work': boundaries of space, time and social relation in the working lives of mobile hairstylists. Work Employ. Soc. **24**, 65–84 (2010). https://doi.org/10.1177/0950017009353658

Cooper, C.D., Kurland, N.B.: Telecommuting, professional isolation, and employee development in public and private organization. J. Organ. Behav. **23**, 511–532 (2002). https://doi.org/10.1002/job.145

Couclelis, H.: Pizza over the Internet: e-commerce, the fragmentation of activity and the tyranny of the region. Entrep. Reg. Dev. **16**, 41–54 (2004). https://doi.org/10.1080/0898562042000205027

Davis, G.B.: Anytime/anyplace computing and the future of knowledge work. Commun. ACM **45**, 67–73 (2002). https://doi.org/10.1145/585597.585617

Deng, H., Mokhtarian, P.L., Circella, G.: Factors influencing full-day, part-day, and overtime telecommuting: investigation of Northern California workers. In: Transportation Research Board 94th Annual Meeting (2015)

Dijst, M.: ICTs and accessibility: an action space perspective on the impact of new information and communication technologies. In: Beuthe, M., Himanen, V., Reggiani, A., Zamparini, L. (eds.) Transport Developments and Innovations in an Evolving World, pp 27–46. Springer, Berlin (2004)

Duxbury, L., Higgins, C., Irving, R.: Attitudes of managers and employees to telecommuting. INFOR **25**, 273–285 (1987). https://doi.org/10.1080/03155986.1987.11732043

Erickson, I., Jarrahi, M.H., Thomson, L., Sawyer, S.: More than nomads: mobility, knowledge work, and infrastructure. In: Proceedings of the European Group for Organizational Studies Colloquium (2014)

Ettema, D., Knockaert, J., Verhoef, E.: Using incentives as traffic management tool: empirical results of the "peak avoidance" experiment. Transp. Lett. **2**, 39–51 (2010). https://doi.org/10.3328/TL.2010.02.01.39-51

Ferguson, E.: Transportation demand management planning, development, and implementation. J. Am. Plan. Assoc. **56**, 442–456 (1990). https://doi.org/10.1080/01944369008975448

Giuliano, G.: Testing the limits of TSM: the 1984 Los Angeles Summer Olympics. Transportation (Amst) **15**, 143–161 (1988). https://doi.org/10.1007/BF00837579

Golob, T.F., McNally, M.G.: A model of activity participation and travel interactions between household heads. Transp. Res. Part B Methodol. **31**, 177–194 (1997). https://doi.org/10.1016/S0191-2615(96)00027-6

Haddad, H., Lyons, G., Chatterjee, K.: An examination of determinants influencing the desire for and frequency of part-day and whole-day homeworking. J. Transp. Geogr. **17**, 124–133 (2009). https://doi.org/10.1016/j.jtrangeo.2008.11.008

Hägerstrand, T.: What about people in regional science? In: Papers of the Regional Science Association, vol. 24 (1970). https://doi.org/10.1007/BF01936872

Hu, L., He, S.Y.: Association between telecommuting and household travel in the Chicago Metropolitan Area. J. Urban Plan. Dev. **142**, 04016005-1–04016005-8 (2016). https://doi.org/10.1061/(ASCE)UP.1943-5444.0000326

Jager, K.J., Van Dijk, P.C., Zoccali, C., Dekker, F.W.: The analysis of survival data: the Kaplan–Meier method. Kidney Int. **74**, 560–565 (2008). https://doi.org/10.1038/ki.2008.217

Kitamura, R.: An evaluation of activity-based travel analysis. Transportation (Amst) **15**, 9–34 (1988). https://doi.org/10.1007/BF00167973

Kitamura, R., Nilles, J.M., Conroy, P., Fleming, D.M.: Telecommuting as a transportation planning measure: initial results of California pilot project. Transp. Res. Rec. J. Transp. Res. Board **1285**, 98–104 (1990)

Kleinrock, L.: Nomadicity: anytime, anywhere in a disconnected world. Mobile Netw. Appl. **1**, 351–357 (1996)

Lachapelle, U., Tanguay, G.A., Neumark-Gaudet, L.: Telecommuting and sustainable travel: reduction of overall travel time, increases in non-motorised travel and congestion relief? Urban Stud. **55**, 2226–2244 (2017). https://doi.org/10.1177/0042098017708985

Lu, X., Pas, E.I.: Socio-demographics, activity participation and travel behavior. Transp. Res. Part A Policy Pract. **33**, 1–18 (1999). https://doi.org/10.1016/S0965-8564(98)00020-2

Lyons, G., Haddad, H.: Commute replacement and commute displacement: the rise of part-day home working. Transp. Res. Rec. **2082**, 1–7 (2008). https://doi.org/10.3141/2082-01

Meck, S.: Growing Smart Legislative Guidebook: Model Statutes for Planning and the Management of Change. American Planning Association, Chicago (2002)

Mell, P., Grance, T.: The NIST definition of cloud computing. NIST Special Publication 800-145. National Institute of Standards and Technology, Gaithersburg (2011)

Mokhtarian, P.L.: Telecommunications and travel: the case for complementarity. J. Ind. Ecol. **6**, 43–57 (2002). https://doi.org/10.1162/108819802763471771

Mokhtarian, P.L., Salomon, I.: Modeling the desire to telecommute: the importance of attitudinal factors in behavioral models. Transp. Res. Part A Policy Pract. **31**, 35–50 (1997). https://doi.org/10.1016/S0965-8564(96)00010-9

Nilles, J.M., Carlson, R., Gray, P., Gerard, H.: Telecommunications–Transportation Tradeoff: Options for Tomorrow. Wiley, New York (1976)

Olson, M.: Work at home for computer professionals: current attitudes and future prospects. ACM Trans. Inform. Syst. **7**, 317–338 (1989). https://doi.org/10.1145/76158.76891

Schwanen, T., Dijst, M.: Travel-time ratios for visits to the workplace: the relationship between commuting time and work duration. Transp. Res. Part A Policy Pract. **36**, 573–592 (2002). https://doi.org/10.1016/S0965-8564(01)00023-4

Schwanen, T., Dijst, M., Kwan, M.: ICTs and the decoupling of everyday activities, space and time: introduction. Tijdschr. Econ. Soc. Geogr. **99**, 519–527 (2008). https://doi.org/10.1111/j.1467-9663.2008.00489.x

Shabanpour, R., Golshani, N., Tayarani, M., Auld, J., Mohammadian, A.K.: Analysis of telecommuting behavior and impacts on travel demand and the environment. Transp. Res. Part D Transp. Environ. **62**, 563–576 (2018). https://doi.org/10.1016/j.trd.2018.04.003

Townsend, A.M., DeMarie, S.M., Hendrickson, A.R.: Virtual teams: technology and the workplace of the future. Acad. Manag. Perspect. **12**, 17–29 (1998). https://doi.org/10.5465/ame.1998.1109047

Yamamoto, T., Kitamura, R.: An analysis of time allocation to in-home and out-of-home discretionary activities across working days and non-working days. Transportation (Amst) **26**, 231–250 (1999). https://doi.org/10.1023/A:1005167311075

Jonathan Stiles is a Postdoctoral Researcher in the Department of Geography and the STEAM Factory at The Ohio State University. His research interests include sustainable transportation, road safety, and the ways information technologies influence travel.

Michael J. Smart is an Associate Professor of urban planning at the Edward J. Bloustein School of Planning and Public Policy at Rutgers University. His research focuses on travel behavior and the linkages between transportation and economic upward mobility.