A Comparison of Time-use for Telecommuters, Potential Telecommuters, and Commuters during the COVID-19 Pandemic

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The California Resilient and Innovative Mobility Initiative (RIMI) serves as a living laboratory – bringing together university experts from across the four UC ITS campuses, policymakers, public agencies, industry stakeholders, and community leaders – to inform the state transportation system's immediate COVID-19 response and recovery needs, while establishing a long-term vision and pathway for directing innovative mobility to develop sustainable and resilient transportation in California. RIMI is organized around three core research pillars: Carbon Neutral Transportation, Emerging Transportation Technology, and Public Transit and Shared Mobility. Equity and high-road jobs serve as cross-cutting themes that are integrated across the three pillars.

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ABSTRACT

Throughout the ongoing COVID-19 pandemic, changes in daily activity-travel routines and time-use behavior, including the widespread adoption of telecommuting, have been manifold. This study considers how telecommuters have responded to the changes in activity-travel scheduling and time allocation. In particular, we consider how workers utilized time during the pandemic by comparing workers who telecommuted with workers who continued to commute. Commuters were segmented into those who worked in telecommutable jobs (potential telecommuters) and those who did not (commuters). Our empirical analysis suggested that telecommuters exhibited distinct activity participation and time use patterns from the commuter groups. It also supported the basic hypothesis that telecommuters were more engaged with in-home versus out-of-home activity compared to potential telecommuters and commuters. In terms of activity time-use, telecommuters spent less time on work activity but more time on caring for household members, household chores, eating, socializing and recreation activities than their counterparts. During weekdays, a majority of telecommuters did not travel and in general this group made fewer trips per day compared to the other two groups. Compared to telecommuters, potential telecommuters made more trips on both weekdays and weekends while non-telecommutable workers made more trips only on weekdays. The findings of this study provide initial insights on time-use and the associated activity-travel behavior of both telecommuter and commuter groups during the pandemic.

Keywords: Time-use, 2020 ATUS, activity participation, telecommuters, COVID-19

INTRODUCTION

Telecommuting is defined as the use of telecommunication technologies to work at home or at a location close to home, instead of commuting to a conventional workplace at the conventional time (*1*). The advancements in telecommunication technologies and its wide penetration in various job markets (e.g., outsourcing, freelancing) have made telecommuting a growing trend as one of the more common alternative work arrangements (*2*). Moreover, due to the COVID-19 pandemic and its subsequent travel restriction policies, telecommuting (or work from home) arrangements have significantly increased during 2020 compared to prior years (*3*, *4*, *5*). Planners and policymakers have always considered telecommuting to be an effective travel demand management and an environmental management tool in reducing overall travel and greenhouse gas emissions. To assess the effectiveness of telecommuting in reducing travel demand, it is important to better understand the activity-travel scheduling and time allocation behavior of telecommuters. The ongoing pandemic has triggered tremendous disruptions in our day-to-day schedules, however, it also provides a rare opportunity to experiment with how prospective telecommuters respond to the changes imposed by such a disruption, including when and where work is performed, and how other activities and travel are scheduled.

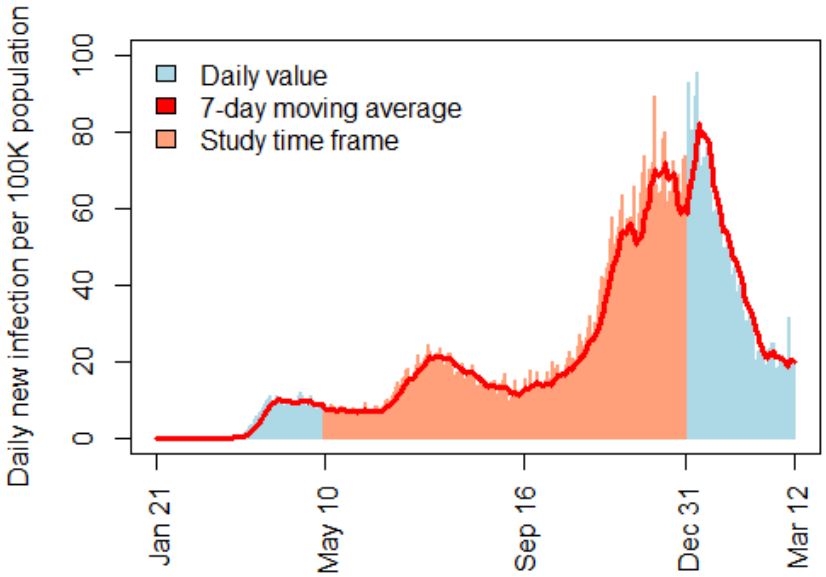
Recent research during the pandemic has examined the rise of the work from home phenomena, changes in work productivity associated with new work arrangements, and prospects for the future. Brynjolfsson et al. (*5*) found that between February and May 2020, over one-third of the American labor force replaced in-person work with working from home, which increased the share of remote working to nearly 50 percent of the nation's workforce. Barrero et al. (*6*) reported the total time savings in the U.S. due to not commuting to workplaces was about 10 billion hours during the pandemic's first six months. They also noted that one-third of these savings were allocated to the primary job and the rest was spent in leisure and household activities including childcare. Based on primary survey data, Beck and Hensher (*3*) found in Australia that work from home was a positive experience among individuals and its practice might continue after the pandemic is over. Several other studies also supported the prospects of a continuation of telecommuting in the post-pandemic future (*7*, *8*).

If telecommuting is to continue at or near pandemic levels, it is important to understand how the activity-travel demands and time allocation of workers may influence transportation and land-use policy. The recently published (July 22, 2021) 2020 American Time Use Survey (ATUS) has provided a unique opportunity to investigate the activity-travel engagement and time-use behavior of telecommuters during the pandemic. In this context, based on the 2020 ATUS data, the major goal of this study is to address two questions: first, how did telecommuters expend activity-travel time during the pandemic and, second, was activity participation and time-use distinct from conventional commuter groups? Findings of this empirical study can provide preliminary insights on time-use and the associated activity-travel behavior of both telecommuter and commuter groups during the pandemic and, thus, can facilitate the development of initiatives to manage transportation and land-use related demands in the current and post-pandemic periods.

DATA SOURCE AND TIME FRAME

The recently published 2020 American Time Use Survey (ATUS) data was used for this study. This annual survey was conducted by the U.S. Census Bureau and sponsored by the Bureau of Labor Statistics (*9*). This dataset provided nationally representative estimates of how, where, and with whom Americans spent their time for various activity-travel purposes including personal care, household activities, work, consumer purchase, socializing, eating, and other activities. ATUS randomly selected households from the Current Population Survey and collected time-use and socio-demographic information for one household member (aged 15 years and above) for one pre-assigned day (1440 minutes). The 2020 ATUS provided a *unique* opportunity to observe "a day in the life" with in- and out-of-home activity and travel for one 24-hour period during the first year of the COVID-19 pandemic. Due to the initial outbreak, data collection was suspended from mid-March to mid-May of 2020. The data thus contained 10-months of data and the total number of respondents was 8,782.

For this study, we considered the 8-months of data from May to December 2020 to focus on "during pandemic" time-use behavior. The spread of COVID-19 in the U.S. over the one-year period and the study time window are depicted in Figure 1.



Data source: The New York Times, 2020 (*10*)

Figure 1. Daily new COVID-19 cases and selected study time frame for the U.S.

The study defined three worker groups: telecommuters, potential telecommuters, and commuters. We first filtered individuals who were employed and worked on the travel diary day. Among them, those who worked at home but did not make any commute trips on the diary day were defined as *telecommuters*. The rest of those employed were split into two groups based on their occupation. If they reported an occupation in telecommutable jobs, which included jobs in management, professional, and related occupations; service; and sales and offices sectors (see U.S. Census Bureau (*11*) occupation codes for details), then they were considered as *potential telecommuters*. Workers who worked in non-telecommutable jobs were deemed *commuters*. Note that members of the last two groups reported commutes to work on the diary day. These criteria yielded a sample size of 2,122 with 808 telecommuters, 983 potential telecommuters, and

331 commuters. The next two sections discuss the socio-demographic characteristics and time-use behavior of these worker groups.

SOCIO-DEMOGRAPHIC CHARACTERISTICS

Who telecommuted during the pandemic and who was unable to do so? We consider worker characteristics that affect the ability to adopt telecommuting during the pandemic. Insights were drawn from the household and person-level socio-demographics and locational characteristics. Table 1 provides the 2020 ATUS data distributions over socio-demographic and location characteristics, split by (a) overall population, (b) telecommuters, (c) potential telecommuters, and (d) commuters.

In terms of *household-level* characteristics, the distribution of household members of telecommuters resembled the general population distribution. The percentage of households with three and more members was slightly higher for the two study groups than the national percentage. Telecommuters were more likely married: the presence of a spouse was reported in 64 percent of telecommuter households compared to about 51 percent for both the commuter groups and the population as a whole. A higher percentage of telecommuters were from dual-earner households. About 10.4 percent of telecommuters belonged to Asian households, a percentage that was higher than the general population, potential telecommuters, and commuters (5.5%, 3.6%, and 1.7%, respectively). This finding is consistent with prior research by Rafiq et al. (*12*) where it was reported that White and Asian households had a higher proportion of telework. In contrast to White and Asian households, more Black households were part of the commuter group (14.6% of Black households for commuters versus 8.4% for telecommuters and 12.6% for the general population). Hispanics reported less telecommuting but more commuting, which aligns with the pre-pandemic finding of telecommuters made by Jin and Wu (*13*). The percentage of telecommuters who reported a household income above $100K was about 57 percent, while the corresponding percentage was 33 percent for the whole nation and 26 percent for commuters, which implied that telecommuters were disproportionately from higher-income households. A similar finding was observed by Su et al. (*14*) for the pre-pandemic period and by Rafiq et al. (*12*) and by Beck and Hensher (*3*) during the pandemic.

In terms of *person-level* characteristics, a higher percentage of workers aged 36 – 45 were telecommuters whereas a higher percentage of workers aged 18 to 35 were commuters and potential telecommuters, indicating that older workers tend to have greater flexibility in choosing work from home options. A similar finding was reported in Su et al. (*14*). The telecommuter group consisted of a higher percentage of female workers (53.8%) while the commuter group reflected a considerable portion of male workers (83.7%). Beck and Hensher (*3*) and Brynjolfsson et al. (*5*) reported similar findings regarding gender during the pandemic. A higher education level had a positive association with telecommuting (see Table 1) with 72.6 percent of telecommuters having had at least a bachelor degree, while the corresponding percentage for commuters and the general population were 10.5 percent and 36.1 percent respectively. McNally et al. (*15*) found similar findings for the pre-pandemic period. Compared to the other groups, a slightly higher percentage of potential telecommuters reported part-time and multiple jobs while a higher percentage of commuters reported doing jobs in the private sector.

TABLE 1. Socio-demographic and residential location characteristics of the study groups

	2020 ATUS population (%)	Telecommuters (%)	Commuters	
			Potential telecommuters (%)	Commuters (%)
Total Respondents	N = 8,782	N = 808	N = 983	N = 331
Household Characteristics				
Household size				
HH size = 1 – 2	49.87	48.08	**43.47**	**43.85**
HH size 3 and above	50.13	51.92	**56.53**	**56.15**
Presence of spouse/partner				
Spouse present	50.62	**64.09**	50.65	51.95
No spouse/partner present	43.98	29.84	42.49	41.64
Household structure				
Dual earner couple	27.77	**55.42**	44.00	34.59
Single earner couple	10.13	14.73	13.50	23.77
Single (one earner)	23.49	29.84	**42.50**	**41.64**
Number of children				
Number of children 0	63.57	58.52	60.02	58.04
Number of children 1 – 2	29.11	**36.55**	32.9	33.92
Number of children > 2	7.32	4.93	7.08	8.04
Race				
White only	79.70	80.19	81.24	80.06
Black only	12.63	8.36	12.38	**14.63**
Asian only	5.47	**10.39**	3.59	1.67
Other Races	2.2	1.06	1.05	2.12
Ethnicity				
Hispanic	17.10	12.58	17.06	**28.45**
Non-Hispanic	82.90	**87.42**	82.94	71.55
Family income distribution (yearly)				
<$20K	9.30	2.20	5.03	4.82
$20K - $60K	33.27	16.81	27.39	**42.21**
$60K - $100K	24.27	24.41	30.51	26.90
> $100K	33.16	**56.59**	37.07	26.07
Personal Characteristics				
Age of respondent				
Age 18-35	27.65	28.87	**34.80**	**39.81**
Age 36-45	14.02	**23.31**	18.76	17.73
Age > 45	50.19	44.50	40.56	40.38
Gender: Female	51.58	**53.82**	50.75	**16.35**
Employed: Yes	60.00	100.00	100.00	100.00
Educational attainment				
Less than Bachelor degree	63.88	27.37	**61.66**	**89.55**
Bachelor degree	22.69	**40.14**	24.07	8.46
Graduate	13.44	**32.49**	14.27	2.00
Holding multiple jobs				
Yes	5.46	9.59	**11.86**	6.91
No	54.83	90.41	88.14	93.09
Employment status				
Full-time	47.04	83.83	76.55	88.77
Part-time	13.25	16.17	**23.45**	11.23
Class of workers				

	2020 ATUS population (%)	Telecommuters (%)	Commuters	
			Potential telecommuters (%)	Commuters (%)
Total Respondents	N = 8,782	N = 808	N = 983	N = 331
Private	50.16	68.30	71.81	**82.29**
Government	9.41	17.11	14.55	6.56
Location Characteristics				
Geographic location of residence				
Northeast	17.51	**22.45**	18.33	15.50
Midwest	22.57	22.23	23.52	21.06
South	38.25	32.28	38.78	**44.34**
West	21.67	**23.04**	19.37	19.10
Residence metropolitan status				
Metropolitan area	85.93	**92.73**	87.80	85.88
Non-metropolitan area	13.37	6.82	11.68	**13.69**

Note: The table shows weighted values that reflect the population. The total percentage of some variables did not sum up to 100% since a few respondents refused to answer survey questions.

Regarding residential *location* characteristics, a higher percentage of telecommuters resided in metropolitan areas compared to other groups and the nation as a whole. Since metropolitan areas generally have a higher fraction of households with internet access and workers in telecommutable jobs, they can better accommodate stay-at-home orders imposed during the pandemic by substituting work from home for in-person work. Jin and Wu (2011) observed similar findings in their pre-COVID telecommuting study. In terms of geographic regions, the South had a greater share of commuters whereas the Northeast and West regions had a greater share of telecommuters. This finding is consistent with Brynjolfsson et al. (2020).

ACTIVITY-TRAVEL PARTICIPATION AND TIME-USE

The COVID-19 pandemic has led to tremendous changes in our daily activity-travel scheduling and time-use behavior. The participation rate and time-use behavior of the three study groups during the pandemic were analyzed from several perspectives including work and non-work activity purposes, time-of-day, location (in- or out-of-home), and day-of-week (weekday vs. weekend).

Participation Rate and Time-use by Activity Purpose

How did telecommuters expend activity time during the pandemic? Was activity participation and time-use distinct from commuter groups? Table 2 shows how the selected study groups - telecommuters, potential telecommuters, and commuters - participated in activities and travel (participation rate) and spent their time on those activities (time-use) during the pandemic. We estimated the statistical significance of differences in the activity participation rate and time-use among the groups of workers via two non-parametric tests. A Chi-square test was conducted for participation rate variables since these variables can be considered as categorical (specifically, binary variables for whether or not a respondent participated in a particular activity). A Kruskal-Wallis (KW) test was conducted for continuous activity duration variables. For the chi-square test, we used the Dunn-Bonferroni post-hoc test (*16*) whereas for the KW test we used the Conover-Iman post-hoc test (*17*). The results of non-parametric tests are shown in Table 2.

TABLE 2. Aggregate participation rate and time-use by activity purpose

Activity purpose	Participation rate (%)			Mean duration (weighted) of activity participation (minutes)		
	Telecommuters	Potential telecommuters	Commuters	Telecommuters	Potential telecommuters	Commuters
	N = 808 (a)	N = 983 (b)	N = 331 (c)	N = 808 (a)	N = 983 (b)	N = 331 (c)
Work	100.0	100.0	100.0	397.21[bc]	473.75[ac]	520.33[ab]
Caring for HH members	32.7[bc]	25.3[ac]	20.5[ab]	104.72[bc]	85.68[a]	66.08[a]
HH activities	82.9[bc]	70.8[a]	64.5[a]	123.16[bc]	77.66[a]	85.82[a]
Shopping	27.4	30.1	27.6	43.45[bc]	29.92[ac]	25.28[ab]
Socializing and recreation	96.1[bc]	93.2[a]	89.9[a]	250.64[bc]	204.48[a]	202.31[a]
Eat and drink	97.4	95.7	94.1	68.64[bc]	57.68[a]	60.01[a]
Personal care	100.0	100.0	99.9	533.87[c]	543.92[c]	518.25[ab]
Travel	48.6[bc]	98.0[a]	97.2[a]	52.77[bc]	62.97[ac]	71.00[ab]

Note: HH refers to household. The table shows weighted values that reflect the population. Mean duration of an activity purpose is calculated considering those people who participated in that activity. Only four participation rate variables (caring for HH members, HH activities, socializing, and travel) but all activity duration variables were jointly significant at a 5% significance level in χ^2 test and KW tests, respectively. Superscripts a, b, and c indicate that values were significantly different (at 5% significance level) from values for telecommuters, potential telecommuters, commuters, respectively, in post-hoc tests.

A higher percentage of telecommuters reported caring for household members (e.g., childcare), doing household tasks, and socializing and recreation activities relative to the other worker groups. A significantly lower fraction of telecommuters, however, made trips during the diary day than their counterparts since they reported work from home (WFH) and did not make work trips on that day. It also indicated that a higher fraction of this group of workers did not make any non-work trips as well on the travel day (discussed below).

The activity duration data suggests that telecommuters spent less time on work activity compared to potential telecommuter and commuter groups. Caring for household members, household chores, eating, socializing and recreation activities consumed a greater portion of time than the other two groups. The shorter work duration was apparently consumed by non-work activities. There was no significant difference in the participation rate for shopping among the three worker groups. Notably, commuters spent more time on work but less time on personal care and more time for travel among the three groups.

Figure 2 depicts the distributions of activity participation rates over the 24-hour period on a typical *weekday* for the three study groups. The participation rate for work activity was lower from morning to early afternoon for telecommuters (Figure 2a). Potential reasons include the flexibility of scheduling work starting and stopping times spread throughout the day for telecommuters rather than confined to “9-to-5” work. Another possible reason is that multi-

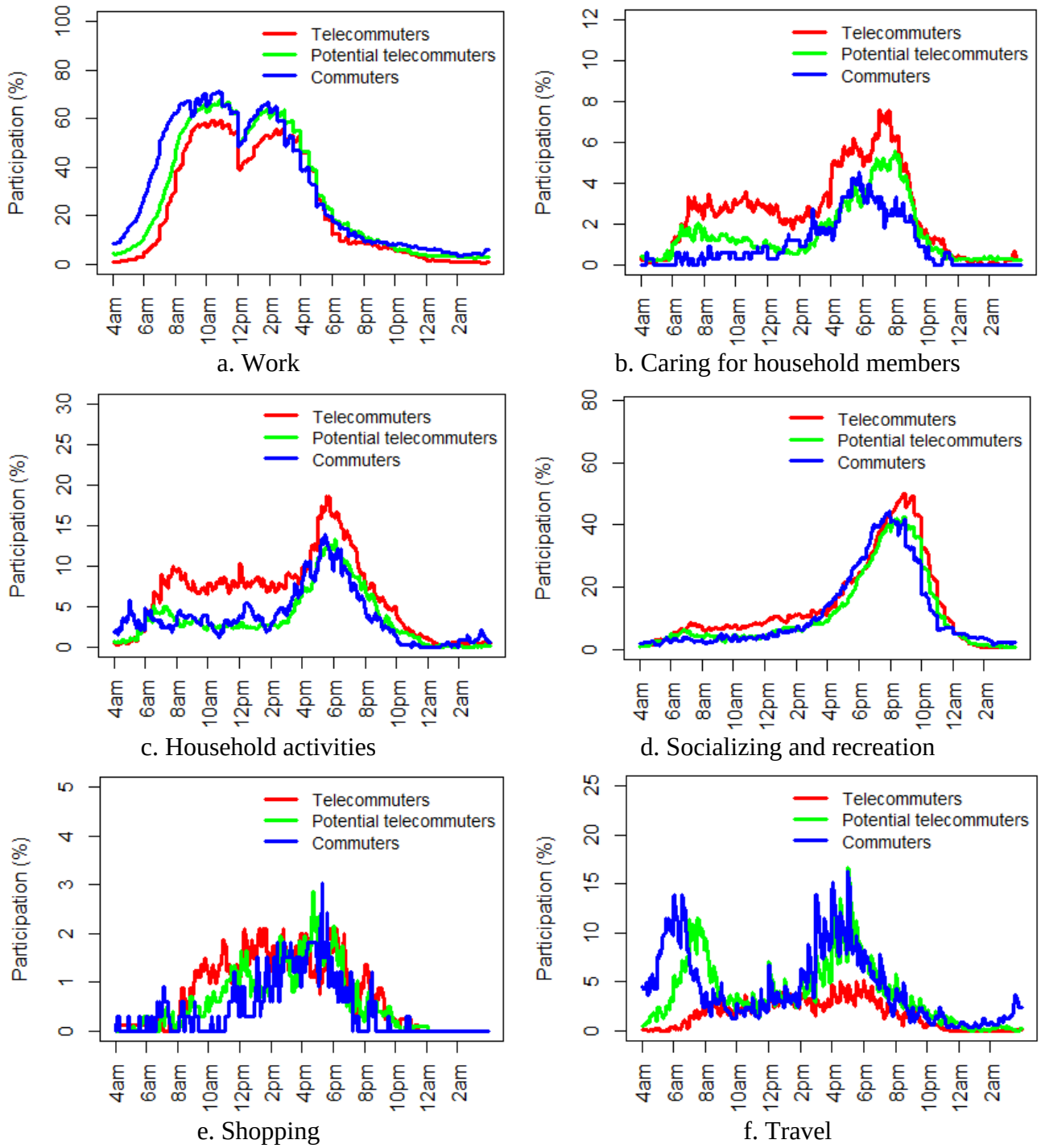


FIGURE 2. Time in motion by activity purposes on a typical weekday by worker groups

tasking was more common for telecommuters (for example, childcare or household chores while working) and thus less work participation and more household activities were reported (Figures 2b and 2c). Workers in a conventional workplace setting are also more likely to report mandated work hours rather than the actual starting and ending times. Note that in ATUS data, multiple activities were not allowed to be recorded simultaneously. Compared to other activities, fewer workers (at most nearly 3 percent) reported doing shopping over the day. A slightly higher

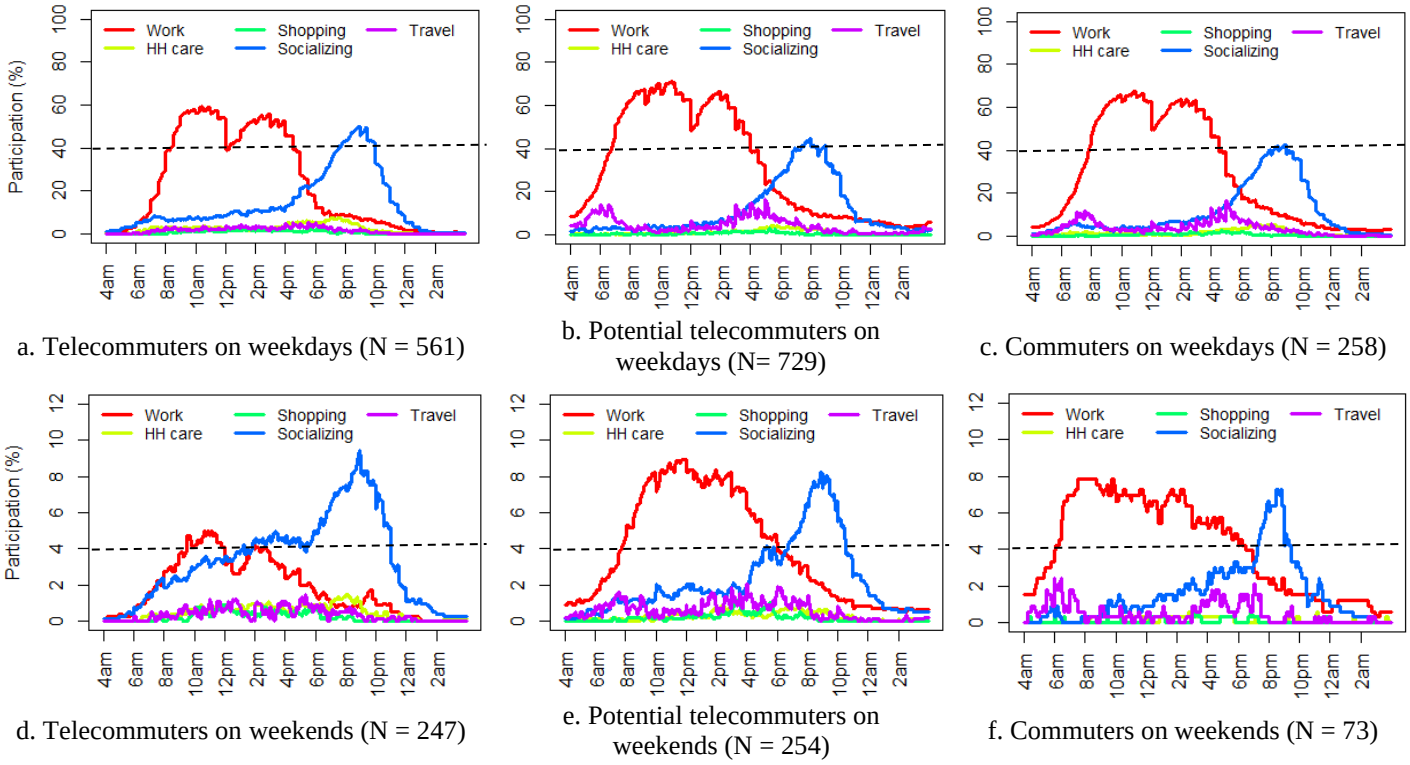
fraction of telecommuters did shopping during the morning peak period compared to other groups (Figure 2e).

In terms of travel, two peaks were observed during morning and afternoon periods indicating the departure from and arrival at home for potential telecommuter and commuter groups (Figure 2f). The morning peak was sharper but the afternoon peak took more of a jagged shape, perhaps indicating multiple non-work stops on the return home commute and thus a wide range of departure times. Compared to the other two groups, telecommuters' travel pattern was more spread out and stable. Although telecommuters could make non-work trips at any time due to their work time flexibility, only 3 – 5 percent traveled at any specific time throughout the day (Figure 2f). The implication may be that telecommuters were more adherent to stay-at-home orders and thus traveled less. During the morning peak period, commuter work departure times were shifted left from that for potential telecommuters (Figure 2f) which might reflect the nature of the occupations of those who are not potential telecommuters (e.g., those employed by hospitals, restaurants). No such morning peak, of course, was observed for telecommuters. That means, in the morning peak hour traffic flow, potential telecommuters contributed more than the other two groups, which has several policy implications (to be discussed below) regarding congestion and its associated impacts.

Activity-travel Participation by Days of a Week

Did weekday activity participation and time-use vary in comparison to weekends during the pandemic? This section analyzes how the three worker groups participated in work and non-work activities on weekdays and weekends. Figure 3 shows the percentage of workers who participated in various activities at different times in a day during weekdays (upper row) and weekends (lower row).

The weekday activity patterns were different from the weekend patterns. During weekdays, a sharp downward spike in the work activity participation curve (red color) was noticeable around noon for all the worker groups (Figure 3a – 3c), which corresponds to lower fraction of workers who reported work, likely due to a lunch break. However, no such spikes were observed during weekends except for the telecommuter group (Figure 3d). It indicates that whether working on weekdays and weekends, telecommuters took a break for lunch hour. During weekends, a lower fraction of telecommuters reported work at any particular time during the day (4 compared to 8 percent in Figure 3d – 3f). The reason might be that, during the pandemic, work from home was closely associated with the traditional "8 hours a day" and "5 days a week" work pattern. Telecommuters recorded more participation in socializing whereas commuters reported more work but less socializing during weekends.



a. Telecommuters on weekdays (N = 561)

b. Potential telecommuters on weekdays (N= 729)

c. Commuters on weekdays (N = 258)

d. Telecommuters on weekends (N = 247)

e. Potential telecommuters on weekends (N = 254)

f. Commuters on weekends (N = 73)

FIGURE 3. Time in motion by activities and days in a week for worker groups

Activity Participation and Time-use by Location

Did telecommuters participate in more out-of-home activities than commuters during the pandemic? As previously discussed, telecommuters spent less time working but reported more social, childcare, and household activity time than the two commuter groups. In this section, we discussed whether telecommuters engaged more with in-home or out-of-home activity compared to their counterparts. Table 3 reports participation rates and time spent on activities by activity location (in-home versus out-of-home). A significantly higher fraction of telecommuters reported caring for household members, running household chores, eating, and socializing at home compared to the other groups. Although the participation rate in online shopping is relatively low, significantly more telecommuters recorded this activity than potential telecommuter and commuter groups. This suggests that working from home had a positive association with online shopping. On the other hand, a significantly higher fraction of potential telecommuters participated in in-person shopping. In addition, both the commuter groups reported significantly higher participation in eating (possibly recorded restaurant visits for lunch in or near workplaces) and socializing/recreation activities outside home, relative to telecommuters. It appears evident that, during the pandemic, telecommuters engaged more with in-home than out-of-home activity compared to the other worker groups. The time spent both in-home and out-of-home was similar for potential telecommuter and commuter groups, except for shopping and socializing/recreation activities. Commuters spent significantly less time on in-person shopping and out-of-home socializing/recreation than the other groups.

TABLE 3. Activity participation rate and time-use at home and out-of-home

Activity Purpose	Location	Participation in the activity purpose-location alternative (%)			Mean duration of participation by activity purpose-location alternative (minutes)		
		Telecommuters	Potential telecommuters	Commuters	Telecommuters	Potential telecommuters	Commuters
Work	In-home	100.0^{bc}	17.4^{ac}	6.1^{ab}	397.21^{bc}	156.37^{a}	144.50^{a}
	Out-of-home	0.0^{bc}	100.0^{a}	100.0^{a}	0.00^{bc}	446.52^{ac}	511.49^{ab}
Caring for HH members	In-home	27.4^{bc}	19.7^{ac}	11.8^{ab}	105.82^{bc}	85.21^{a}	85.59^{a}
	Out-of-home	12.9	11.8	12.5	41.03	41.50	27.48
HH activities	In-home	82.4^{bc}	67.2^{a}	6126^{a}	115.72^{bc}	74.64^{a}	84.96^{a}
	Out-of-home	10.3	10.9	9.7	65.48	44.16	35.37
Shopping	In-home	5.1^{bc}	2.3^{a}	1.3^{a}	35.24	19.65	19.58
	Out-of-home	24.9^{b}	28.9^{a}	26.3	40.70^{bc}	29.58^{ac}	25.55^{ab}
Socializing and recreation	In-home	94.3^{bc}	86.5^{ac}	82.5^{ab}	223.02^{bc}	183.52^{a}	188.11^{a}
	Out-of-home	30.1^{bc}	40.2^{a}	40.0^{a}	101.88^{bc}	79.09^{ac}	67.36^{ab}
Eat and drink	In-home	96.4^{bc}	81.9^{a}	74.7^{a}	65.49^{bc}	39.45^{a}	38.33^{a}
	Out-of-home	6.7^{bc}	57.7^{ac}	70.8^{ab}	55.43^{bc}	39.75^{a}	39.33^{a}
Personal care	In-home	100.0	100.0	100.0	533.87^{c}	543.92^{c}	518.25^{ab}
Travel	Out-of-home	48.6^{bc}	98.0^{a}	97.2^{a}	52.77^{bc}	62.97^{ac}	71.00^{ab}

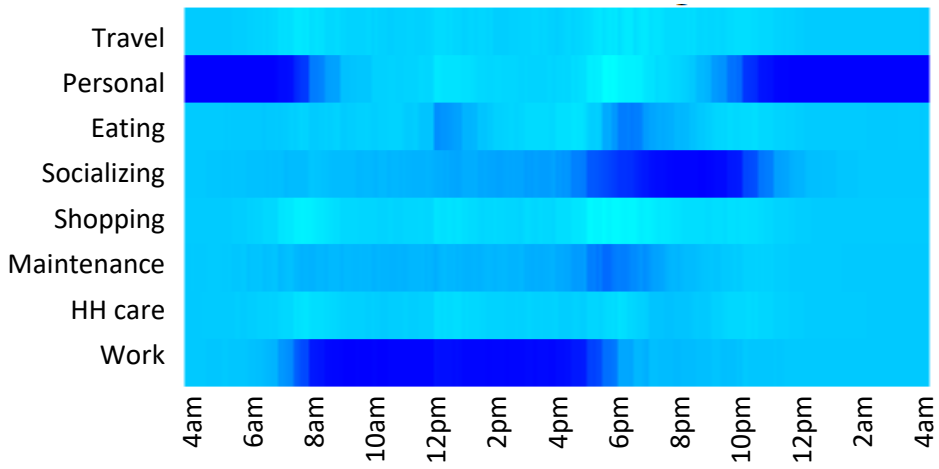
Note: The table shows weighted values that reflect the population. Mean duration of an activity purpose is calculated over only those workers who participated in that activity. Non-parametric test results are shown for participation rate and mean duration variables. All participation rate variables (except for out-home HH activities, out-home HH care, and personal care) and all duration variables (except for out-home HH activities, out-home HH care, and in-home shopping time) were jointly significant at a 5% significance level in χ^2 and KW tests respectively. Superscripts a, b, and c indicate that values were significantly different (at 5% significance level) from values for telecommuters, potential telecommuters, commuters, respectively, in post-hoc tests.

Activity-travel Patterns by Time-of-day

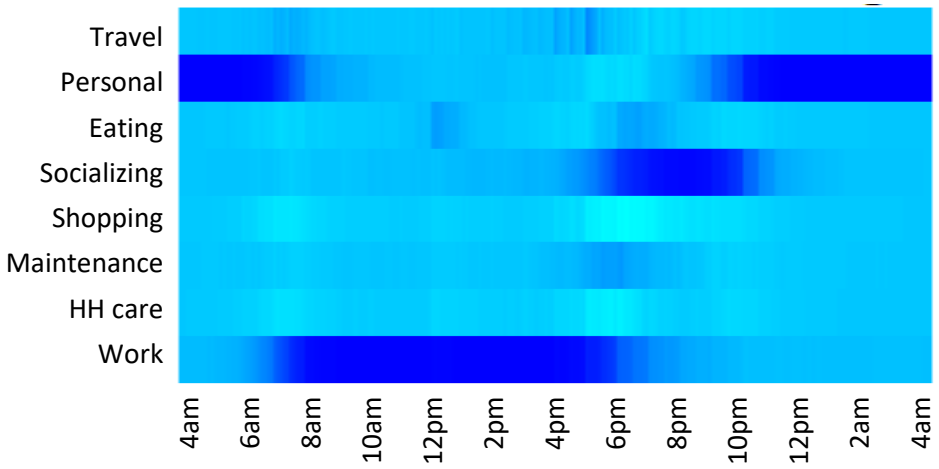
Were daily activity-travel patterns for telecommuters different from commuters during the pandemic? In this section, we examine the sequence of activity-travel participation at different times of day (activity-travel patterns) across three study groups by using participation heat maps (see Figure 4). These maps show the participation rate by activity purposes over the 24-hour day. Darker shades indicate higher rates of participation.

The general sequence of activities was similar across the three groups: personal activities in the early morning followed by typical 9-to-5 work activities, then socializing and recreation after work hours, and ending the day with personal care activities (e.g., sleeping). However, the participation rate in activities varied throughout the day among the study groups. The length of the darker segment of the personal activity strip during the morning is shorter for commuters than the other groups. But the length for work activity is longer, which implies that commuters spent less personal time in the morning and started their work activity earlier than others (Figure 4c). On the other hand, since telecommuters were on average more independent in terms of their work start time, they reported starting their work activity later (Figure 4a). This group reported

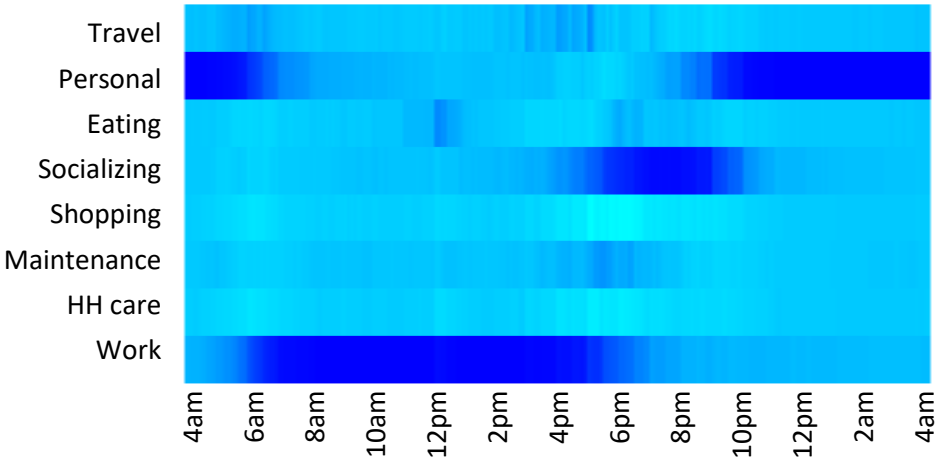
socializing throughout the day as evident from the presence of comparatively darker shades of this activity on the socializing strip in Figure 4a. A higher fraction of telecommuters reported eating during midday and in the later evening period (Figure 4a).



a. Telecommuters (N = 808)



b. Potential telecommuters (N = 983)



c. Commuters (N = 331)

FIGURE 4. Participation heat map by activities and time of day for worker groups

Travel Participation Rate and Duration

Did telecommuters travel more or less during the pandemic? Table 4 summarizes participation rates and time spent on travel for work and non-work activity purposes. Overall, telecommuters traveled less to stores, restaurants/bars, and social activity places compared to potential telecommuters and commuters. The overall distribution is similar to the weekday distribution. However, during weekends a slightly higher fraction of telecommuters made visits to these activity locations than the other two groups. Among the three groups, commuters traveled less to non-work places during weekends.

TABLE 4. Travel participation rate and duration by days of a week and activity purposes

	Telecommuters		**Potential telecommuters**		**Commuters**	
Weekday	Participation (%)	Duration (min)	Participation (%)	Duration (min)	Participation (%)	Duration (min)
HH activities	4.5	32.6	3.9	17.6	3.7	46.3
HH care	7.8	38.2	6.8	34.2	7.4	34.0
Work	0.0	0.0	80.5	**43.0**	84.4	**51.4**
Shopping	**19.5**	32.2	**24.4**	28.4	**24.6**	28.9
Eating	**3.7**	32.5	**10.3**	22.9	**13.0**	21.6
Socializing	**5.5**	35.2	**11.3**	23.7	**8.8**	26.8
Recreation	5.2	29.1	5.8	23.5	1.1	11.6
Weekend	Participation (%)	Duration (min)	Participation (%)	Duration (min)	Participation (%)	Duration (min)
HH activities	1.1	24.9	0.5	25.5	0.7	16.0
HH care	0.7	49.1	0.8	46.0	0.3	38.3
Work	0.0	0.0	11.0	**33.1**	9.9	**57.5**
Shopping	**6.1**	34.3	**4.2**	28.1	**2.2**	29.2
Eating	**2.2**	52.1	**1.8**	22.7	**1.4**	22.0
Socializing	**2.4**	38.4	**2.9**	25.9	**1.5**	24.5
Recreation	1.4	33.2	0.7	52.3	0.2	16.5
Overall	Participation (%)	Duration (min)	Participation (%)	Duration (min)	Participation (%)	Duration (min)
HH activities	5.6	31.1	4.4	18.4	4.4	41.3
HH care	8.5	39.0	7.6	35.4	7.7	34.2
Work	0.0	0.0	91.5	**41.8**	94.3	**52.1**
Shopping	**25.6**	32.7	**28.6**	28.4	**26.7**	28.9
Eating	**5.9**	39.8	**12.1**	22.9	**14.4**	21.6
Socializing	**7.9**	36.2	**14.2**	24.1	**10.3**	26.5
Recreation	6.5	30.0	6.5	26.6	1.3	12.3

Note: The table shows weighted values that reflect the population. Mean duration of travel was calculated considering only those workers who reported traveling.

Next, we analyzed the average number of trips made and the total time spent on travel (travel time budget) in a day by the three study groups (see Table 5). On a typical weekday, a

majority of telecommuters did not report any travel at all (53.6 percent). On the other hand, during weekends, nearly 60 percent of telecommuters made trips to non-work activity places. Overall, telecommuters made fewer trips in a day compared to the potential telecommuters and commuters (1.64 vs. 3.32 and 3.24). Here, the average number of trips and average travel duration variables were computed considering all the workers in a particular study group. The difference in the average number of trips between telecommuters and two commuter groups varied between weekdays and weekends. During weekends the difference was comparatively less but during weekdays the difference was quite high. While potential telecommuters reported a higher number of trips in both weekdays and weekends, the other commuter group reported more trips only during weekdays. Of the three worker groups, telecommuters spent less time in travel whereas commuters reported higher travel time in both weekdays and weekends. The higher travel time might be due to the longer work commute of this group of workers (see Table 4)

TABLE 5. Number of trips made and travel time budget by three worker groups

Study groups	**Percentage of people by the number of trips**	**Weekday**	**Weekend**	**Overall**
Telecommuters	# trips = 0	**53.56**	**39.17**	51.39
Potential telecommuters	# trips = 0	0.00	0.00	0.00
Commuters	# trips = 0	0.00	0.00	0.00
Telecommuters	# trips = 1 – 2	24.72	25.61	24.85
Potential telecommuters	# trips = 1 – 2	45.82	47.19	45.99
Commuters	# trips = 1 – 2	45.35	56.38	46.57
Telecommuters	# trips > 2	21.73	35.22	23.76
Potential telecommuters	# trips > 2	52.23	50.60	52.02
Commuters	# trips > 2	52.15	38.50	50.64
Study groups		**Weekday**	**Weekend**	**Overall**
Telecommuters (a)	**Average number of trips**	**1.53^{bc}**	**2.25^{bc}**	**1.64^{bc}**
Potential telecommuters (b)		3.33^{a}	3.28^{ac}	**3.32^{ac}**
Commuters (c)		**3.28^{a}**	**2.93^{ab}**	**3.24^{ab}**
Study groups		**Weekday**	**Weekend**	**Overall**
Telecommuters (a)	**Average travel time**	**23.63^{bc}**	**39.60^{bc}**	**26.03^{bc}**
Potential telecommuters (b)	**budget (minutes)**	63.68^{ac}	58.32^{a}	63.01^{ac}
Commuters (c)		**72.46^{ab}**	**67.95^{a}**	**71.97^{ab}**

Note: The table shows weighted values that reflect the population. The average number of trips and travel time budgets were calculated considering all members in a worker group (who traveled on the diary and who did not). The average number of trips and average travel time variables are jointly significant at a 5% significance level in KW test. Superscripts a, b, and c indicate that values were significantly different (at 5% significance level) from values for telecommuters, potential telecommuters, commuters, respectively, in post-hoc tests.

DISCUSSION AND CONCLUSIONS

This exploratory study analyzed the socio-demographics, activity-travel participation, and time-use behavior of three selected groups of workers: telecommuters, potential telecommuters, and commuters, during the COVID-19 pandemic. The major findings, drawn from descriptive analyses, non-parametric tests, and visual analysis using the recently published 2020 American Time Use Survey data, are summarized below:

(a) Findings on socio-demographics

- Telecommuters mostly belonged to non-Hispanic, White and Asian, dual-earner couple, higher-income families. Unlike telecommuters, a greater percentage of commuters were from single-earner, low to medium-income households, and from Black and Hispanic households. The household characteristics of potential telecommuters closely resembled commuters except for household income. Compared to commuters, a higher fraction of potential telecommuters belonged to higher-income cohorts.
- In terms of personal characteristics, a higher percentage of telecommuters were highly educated females aged 36 years and above. In contrast, commuters were predominantly males who worked in the private sector and did not have a bachelor or higher degree. Compared to the other two groups, a higher percentage of potential telecommuters were part-time, multiple job holders.
- A higher percentage of telecommuters resided in non-metropolitan areas compared to the other two commuter groups and the nation as a whole.

(b) Findings on activity participation and time-use

- During the pandemic, a significantly higher percentage of telecommuters reported caring for household members, doing household tasks, and socializing and recreation activities than did potential telecommuters and commuter groups.
- By location, telecommuters were more engaged with in-home than out-of-home activity compared to their counterparts. During weekends, telecommuters reported less work but more participation in socializing, a pattern reversed in the two commuter groups.
- Telecommuters had distinct allocations of activities and travel time from the commuter groups. They spent less time on work activity than potential telecommuters and commuters. The shorter work duration was consumed by household care, household chores, eating, socializing and recreation activities.
- Commuters spent more time on work but less time on personal care and more time for travel among the three groups.

(c) Findings on travel participation and time-use

- During weekdays, a majority of telecommuters did not report any travel. Overall, this group made fewer trips in a day compared to potential telecommuters and commuters.
- During weekdays, telecommuters traveled less to stores, restaurants/bars, and social activity places compared to potential telecommuters and commuters. However, the reverse pattern was observed on weekends.
- Potential telecommuters reported more trips on both weekdays and weekends whereas commuters with non-telecommutable jobs reported more trips only on weekdays.
- Of the three worker groups, commuters had higher travel times on both weekdays and weekends.

The findings of this study have important policy implications. For example, in a typical weekday, commuters were observed to depart for work comparatively earlier in the morning than potential telecommuters due to their nature of occupations. No such morning travel presumably exists for telecommuters. As shown in Figure 2f, the potential telecommuter group contributed more to the morning peak hour traffic flow than the other two groups. Since telecommuting involves fewer work trips and reductions in peak-hour traffic flow, an effective policy to reduce severe peak-hour congestion might be to identify potential telecommuter groups and to facilitate more work from home options for them.

We observed that telecommuters had a higher tendency of doing online shopping than the other worker groups. It indicates that besides reducing work trips, telecommuting could also reduce the number of non-work trips by two means: making fewer non-work activities associated with work commute and doing more online shopping. The reduction in non-work activities associated with conventional commuting might negatively affect daytime business activity near workplaces because workers would not be accessing conventional activity centers as frequently due to telecommuting. Effective land-use policies should address such issues. From Figures 3a and 3d it can be seen that a higher percentage of telecommuters reported taking lunch hour work breaks on both weekdays and weekends. Retail businesses, including restaurants, grocery stores, and gyms, would need to reconsider location accessibility relative to telecommuter residential locations.

There are some limitations in this study. ATUS data did not provide detailed spatial data (e.g., travel distance, population density, land-use mix) or vehicle ownership information, thus we were unable to explore the association of these variables with particular worker groups. Since ATUS data contains single-day diary data, the activity-travel behavior reported in the ATUS is specific to the survey date. We recognize these limitations, however, research suggests that single-day travel surveys of appropriate sample size can capture the underlying distribution of behaviors. While the day in question may not be typical of an individual respondent, the sum total over all respondents can captures the overall distribution.

In summary, the findings of this study provide initial insights on time-use and the associated activity-travel behavior of both telecommuter and commuter groups during the pandemic. The results of this and on-going analysis of time use could help policy makers to identify particular groups of workers based on their demographics, to recognize how they responded to changes in activity-travel scheduling imposed by the pandemic, and to understand what might be their particular travel needs at different times in a day, which would facilitate the development of policy initiatives to manage relevant transportation and land-use related demands in the current and post-pandemic periods.

AUTHOR CONTRIBUTION STATEMENT

The authors confirm contribution to the paper as follows: study conception and design: R. Rafiq, M. G. McNally; data processing: R. Rafiq; analysis and interpretation of results: R. Rafiq, M. G. McNally; draft manuscript preparation: R. Rafiq, M. G. McNally. All authors reviewed the results and approved the final version of the manuscript.

CONFLICT OF INTEREST

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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