Potential of telecommuting for different employees in the Indian context beyond COVID-19 lockdown

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A B S T R A C T

During the last decade, telecommuting has become quite popular whereas, in developing countries like India, this phenomenon is limited to a select group of employees due to various factors. The COVID-19 pandemic, the nationwide lockdown and the subsequent new normal scenario, has made the adoption of telecommuting by different type of employees indispensable thus giving us the opportunity to conduct empirical research towards understanding the factors influencing telecommuting adoption, productivity and activity-travel behaviour during telecommuting in India. The data used in this survey has been collected in two phases to capture the evolving situation of the pandemic. The analysis has been done based on revealed preference data considering three time periods i.e., before COVID-19, during COVID-19 nationwide lockdown, after the termination of the lockdown (after first wave) and for the post-COVID 19 scenario where stated preferences are considered. In the first step, telecommuting behaviour, activity-travel pattern during telecommuting and productivity is estimated based on aggregate sample data for various socio-economic groups for the period before and during COVID-19 (1. during lockdown 2. during new normal). Next, factors influencing telecommuting adoption and productivity are determined which has been used in our stated preference survey conducted in the second phase. A logistic regression model has been developed to test the association of existing telecommuting behaviour, activity-travel pattern, factors influencing productivity, socio-economic characteristics and occupation categories with future telecommuting adoption. The findings of this research can not only provide insights to urban planners and policymakers to design sustainable travel demand management strategies but can also help employers to design appropriate telecommuting strategies at the organization level which will help to attain the desired productivity levels. Our empirical analysis reveal two major findings, i.e., a large percentage of employees can achieve their desired productivity by working from home and the 'rebound' effect as identified in literature seems to have little impact in the Indian context. The novelty of this research lies in the comprehension of the adoption process, and the behavioural analysis including adoption, productivity, activity, and travel of telecommuters in the context of a developing country for the first time.

1. Introduction

During the last few decades, several researches have been conducted to understand telecommuting behaviour and its adoption and to determine the efficiency of telecommuting policy as a sustainable measure. The telecommuting issue again came at the forefront in many parts of the world as people were forced to work from home during COVID-19 lockdown. Since last year, a significant amount of researches (Arimura et al., 2020; Beck et al., 2020; Beck and Hensher, 2020a, 2020b; Borkowski et al., 2021; Crowley et al., 2020; de Haas et al., 2020; Habib et al., 2021; Irawan et al., 2021; Shamshiripour et al., 2020; J. Zhang et al., 2021) have been conducted across the globe and even in developing countries (Anwari et al., 2021; Bhaduri et al., 2020; Dandapat et al., 2020; Ivanova et al., 2021; N. Zhang et al., 2021) to assess the impact of the pandemic on lifestyle (i.e. increase of online shopping, telecommuting, etc.) followed by changes in the activity-travel pattern of citizens, to comprehend the future mobility pattern of urban commuters for the post-COVID 19 period and to recommend suitable policies in response to the pandemic as well as for safe and sustainable future city mobility. However, in these researches, the physiological impact on telecommuters followed by telecommuters' adoption behaviour has been ignored which made it difficult to conclude the long-term

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feasibility of telecommuting policy. On the other hand, another group of researches (Bhaduri et al., 2020; Chang et al., 2021; Hallman et al., 2021; Kumar et al., 2021; Prihadi et al., 2021; Vyas and Butakhieo, 2020) focused on the impact of pandemic on the telecommuters' productivity and their mental and physical health. A comprehensive analysis of telecommuters' adoption behaviour, efficacy, and activity-travel behaviour during the pandemic is still lacking which is required to assess the viability of telecommuting as a sustainable policy measure post COVID-19. This encouraged us to study telecommuters' behaviour in the context of a developing country like India and to understand the implication and opportunities of telecommuting both during COVID and in the post-COVID scenario. While initially, telecommuting has been heralded as an effective policy to reduce total travel kilometers, travel time, and other transportation-related externalities such as congestion and pollution (Choo et al., 2005; Glogger et al., 2008; Helminen and Ristimäki, 2007; Koenig et al., 1996; Lachapelle et al., 2018; Mokhtarian and Varma, 1998; Pendyala et al., 1991; Sangho Choo et al., 2002; Shabanpour et al., 2018), the introduction of the 'rebound theory' has raised doubts regarding its efficacy as a sustainable measure (e Silva and Melo, 2018; Koenig et al., 1996; Silva and Melo, 2017; Zhu, 2012; Zhu and Mason, 2014). This further highlights the need for comprehensive research to analyse the impact of telecommuting on travel patterns (Kim, 2017). On the other hand, research on this phenomenon is limited with regard to the context of understanding the workers' propensity to work from home which depends on several factors such as demographic status, family structure, economic condition, car ownership, an inclination for face-to-face interaction, lifestyle, residential and job location, accessibility, quality of the working environment at home, etc. While few studies have been conducted to classify or define telecommuters based on the variations of telecommuting behaviour concerning time and place of working and on the variation in duration and frequency of telecommuting (Handy and Mokhtarian, 1995; Pratt, 2000; Varma et al., 1998), other studies have focused on the spatial and temporal context of telecommuting adoption in different countries (Handy and Mokhtarian, 1995; Varma et al., 1998). In one of the earlier studies in California, Handy and Mokhtarian (1995) highlighted the difference between telecommuting penetration (the percentage of telecommuters) and telecommuting level (the number of telecommuting occasions). Another study in San Diego in the USA introduced a new research direction by establishing an interesting relationship among the preferences, choice, and possibility (Mokhtarian and Salomon, 1996a) of telecommuting. This study showed that, while a large percentage of people (57%) prefer to telecommute, only a small percentage (11%) can do so either due to lack of awareness (4%), job unsuitability (44%), and manager disapproval (55%). In this line, based on time-series data, another study has concluded that the reason behind quitting is not the unwillingness to pursue telecommuting, but rather due to the nature of the job (70%) or employers (45%) or both (21%) (Varma et al., 1998). Similarly, other studies on adoption of telecommuting behaviour particularly from developed countries like USA or Australia have identified socio-economic factors at individual (i.e. gender, educational attainment, marital status, presence of driving licence) and household level (i. e. presence of little children in the household, household size, number of vehicles in the household, and family orientation among household income level) (Drucker and Khattak, 2000; Mannering and Mokhtarian, 1995; Popuri and Bhat, 2003; Singh et al., 2013; Yap and Tng, 1990; Yen and Mahmassani, 1997), travel characteristics (i.e. change in departure time for personal reasons, flexible work start time, avoiding annoying work trips) (Mannering and Mokhtarian, 1995; Singh et al., 2013; Yap and Tng, 1990; Yen and Mahmassani, 1997), work characteristics (i.e. nature of occupation; working in private company or part-time working, suitable nature of work doing at home, degree of control over the scheduling of different job tasks, the supervisory status of the respondent, the ability to borrow a computer from work if necessary) (Mannering and Mokhtarian, 1995; Popuri and Bhat, 2003; Singh et al., 2013; Yap and Tng, 1990; Yen and Mahmassani, 1997), locational attributes (i.

e. free parking at work, residing in urban and suburban areas or lower household density or high employee density) (Drucker and Khattak, 2000; Singh et al., 2013), accessibility (i.e. residing in areas with high accessibility to recreation, restaurants, religious facilities, auto-repair centres, personal business, and medical centres) (Drucker and Khattak, 2000; Singh et al., 2013), attitudinal variables (i.e. attitudes towards telecommuting) (Mannering and Mokhtarian, 1995; Yen and Mahmassani, 1997) and employer's incentives (Yap and Tng, 1990; Yen and Mahmassani, 1997) to impact telecommuters' adoption decision and choice of frequency of working from home. In most cases, however, these studies have failed to identify the influencing and restraining factors for telecommuting. This lack of narratives make it difficult to conclude on the appropriateness and possibilities of telecommuting in the context of developing countries like India where activity and travel pattern is quite different and complex from developed countries due to different family structure and lifestyle, resource constraints and other socio-economic characteristics. The continuation of lockdown for more than four months (nationwide followed by selected state-wise) in India, has made the adoption of telecommuting in several occupations indispensable thus giving us the opportunity to conduct empirical research towards understanding the extent and barriers to telecommuting adoption and its impact on activity and travel behaviour of urban commuters in India. In this context, this research also intends to identify several new potential occupations and socio-economic groups of employees where even after the termination of lock-down, telecommuting could be a viable option.

Before the COVID-19 lockdown, unlike developed countries, telecommuting in India was relatively uncommon except for a few probably due to infrastructure constraints, larger family size, different lifestyles, lack of quality of the working environment at home, and inclination towards face-to-face interaction, etc (Raghuram, 2014). Hence, this study has focused on the identifications of these factors among other aspects. In terms of employees productivity, Yen & Mahmassani (1997) found that supervisor's encouragement, family disruptions, the ratio of telecommuting hours to total work hours were correlated with telecommuting satisfaction and productivity simultaneously whereas, child care issues, demographic and occupational characteristics are not significantly correlated. Other studies have also been conducted to identify factors influencing telecommuting productivity and satisfying telecommuting behaviour (Hartman et al., 1991). Hence, in the current study, we explore the factors impacting productivity and satisfaction in telecommuting adoption which would enlighten policymakers and employers for the successful implementation of this policy. In addition, conducting this research during the COVID-19 peak and trough during the first wave has provided us the opportunity to explore the effectiveness of the telecommuting policy to cope both during and post COVID-19.

Accordingly, a set of research questions have been identified and shown below.

a) How telecommuting behaviour varies across socio-economic strata in India?
b) What is the impact of COVID-19 on telecommuters' productivity and their telecommuting behaviour?
c) What are the impacts of telecommuting on the activity-travel behaviour of urban employees?
d) What are the influencing factors in the adoption behaviour and productivity of telecommuters in India?
e) Who are the potential telecommuters in India?

Most of the earlier studies on telecommuting adoption have been conducted based on stated preferences of the responders (Yen and Mahmassani, 1997) which have shown a discrepancy in the number of people willing to telecommute and those actually telecommuting (Mokhtarian and Salomon, 1996b). This may be due to several factors including discouragement from the company (Mokhtarian and Salomon,

1996b; Yen and Mahmassani, 1997). Hence, in the latter studies, researchers have stressed on revealed preference data to analyse telecommuting adoption (Mannering and Mokhtarian, 1995; Mokhtarian and Salomon, 1996b; Popuri and Bhat, 2003; Wells et al., 2001). Since this study has been conducted during the COVID-19 lockdown and no restriction i.e. new normal period, both revealed and stated preference data has been collected to analyse current trends and to predict the applicability of this policy post-COVID-19 period respectively.

In several studies, employees who perform overtime work at home in addition to working in an office, self-employed workers, and workers at public locations such as coffee shops, parks, and libraries have been considered as potential teleworkers (Helminen and Ristimäki, 2007; Schweitzer and Duxbury, 2009). Since these employees have a lower potential to reduce work trips these categories are excluded from this research. This study also ignores employees who telecommute for a few hours to shift their work trip from peak-hours to off-peak hours as they are only able to create a minor impact on peak-hour duration and congestion (Haddad et al., 2009; Rietveld, 2011), but fail to have a significant contribution on emission reduction.

The remaining part of the paper is divided into five sections. In the next section, the methodology adopted in this research has been discussed followed by the description of the survey procedure (conducted in two phases) for the collection of revealed and stated responses of telecommuters during the national lockdown period and the new normal situation (after the termination of the national lockdown). This is followed by a summary of the sample characteristics. Section three includes the results of the analysis to address the research questions followed by the detailed discussion on policy implications in section four and the last section includes the conclusion and suggestions for future research.

2. Methodology

The analysis has been done based on revealed preference data considering three time periods i.e., before COVID-19 spread, during COVID-19 nationwide lockdown, during the new normal and for the post-COVID 19 scenario where stated preferences are considered. In India, during the early phase of the coronavirus pandemic, a nationwide lockdown was imposed for 21 days starting from 24th March 2020 which got further extended to 31st May with conditional relaxation. During the first phase of lockdown (between 24th March to April 14, 2020) the restrictions were most intense and essential services were only allowed. We refer to this period as' COVID-19 nationwide lockdown'. From 1st June 2020, phase-wise 'unlocks' (i.e. withdrawal of restrictions) were started and by the middle of January 2021 travel and other restrictions were almost withdrawn and most activities were back to normal. During the 4th week of March, the COVID-19 cases again started increasing which is now considered to be the start of the second wave in India which led to further lockdowns. In this research, the 'new normal situation' refers to the time period after the final phase 'unlock' and before the second wave when travel and other restrictions were minimum. 'Post covid-19 scenario' refers to the speculated near-future time period when travel and other restrictions would be withdrawn after the elimination or control of the pandemic for which stated responses have been collected.

In the first step, telecommuting behaviour, activity-travel pattern and productivity of employees is estimated based on aggregate sample data for various socio-economic groups for the period before and during COVID-19 pandemic (1. during lockdown 2. during new normal). Next, factors influencing telecommuting adoption and productivity are determined which has been used in our stated preference survey conducted in the second phase. Finally, based on stated responses, a logistic regression model has been developed to test the association of existing telecommuting behaviour, activity-travel pattern, factors influencing productivity, socio-economic characteristics and occupation categories with future telecommuting adoption. Policy implications of our findings

are next discussed considering the consolidated analysis of results from existing telecommuting behavioural analysis and future telecommuting adoption choice model incorporating activity-travel pattern and productivity factors. This will help decision-makers and planners to adopt measures to encourage telecommuting effectively in India.

2.1. Survey and data collection

The data used in this survey has been collected during two periods to capture the evolving situation of the pandemic. The first phase survey starting from the last week of March 2020 has been conducted over a period of 21 days using social media (Facebook) platform and using a survey questionnaire prepared using Google forms (https://forms.gle/4EvAKLsXDbfuHggd9), after the declaration of a nationwide lockdown in India. A similar procedure has been followed to conduct the second phase survey (https://forms.gle/H5WaywBPhVmy3pPT6) starting from last week of March 2021 over a period of 15 days. This is also the period when COVID-19 cases started increasing again in India possibly due to the casual behaviour on the part of individuals and is now considered to be the start of the second wave in India. A total of approximately 13500 individuals were reached which resulted in 235 responses in phase 1 and then 258 responses in phase 2 surveys respectively. During the second survey there were no restrictions and minimum case load. All the responses collected through Google forms are complete by themselves and free from missing values and a single response by each responder has been ensured by making the sign-in option mandatory to avoid data duplication issue. The unwanted observations are removed and responses are validated via PIN code provided for home and office locations. Employees who perform overtime work at home in addition to working in an office, self-employed workers, and telecommuters who work at public locations such as coffee shops, parks, and libraries instead of working from home are excluded in this research due to their lower potential to reduce work trips. In addition, the data consistency was ensured through cross-checking among responses, e.g. vehicle ownership and work mode, number of children at home and age of children, highest education level, designation in the office and monthly individual income level. The data cleaning has been performed by using MS excel 2010 and IBM SPSS Statistics 23. Finally, 431 completed responses are accepted among which 213 and 218 responses are accepted from phase 1 and phase 2 surveys respectively.

The survey questionnaire is divided broadly into two parts; the first part to capture the socio-economic status of the respondent and the second part to capture their travel and telecommuting behaviour for all the three-time periods mentioned earlier. Eleven variables are included to capture the socio-economic characteristics at the household level (household size, number of wage earners in the household, number of children and the youngest and the second youngest children's age) and at the individual level (gender, age, education level, marital status, vehicle ownership, occupation, monthly income). The data based on the age of the children is collected to perceive the impact of extra responsibilities for parents and the potential activities of children of different age groups. The telecommuting behaviour survey is divided into three sections as per the three-time periods i.e., before COVID 19 spread, at present (i.e. nationwide lockdown for first phase survey and new normal situation for second phase survey) and post-COVID 19 as discussed earlier. People working from home (partially and fully) during this pandemic period can only respond to these sections. The questions related to telecommuting behaviour include working time slots, productivity achieved compared to working at the office, jobs performed during telecommuting, the requirement of special software to perform the job, telecommuting nature (partial or full) and any hindrances faced in the adoption of telecommuting or achieving desired productivity have been recorded. To understand the change in the telecommuting adoption process due to COVID-19 lockdown, the revealed telecommuting behaviour of telecommuters who worked from home at least once in a

year before the lockdown is considered. Next, if telecommuters are willing to work from home after the termination of lockdown (in phase 1 survey) or in post COVID 19 situation (in phase 2 survey), their stated preferences related to their telecommuting behaviour, the reason for telecommuting and activity during the time saved by eliminating work trip is recorded to estimate the future potential of this policy as a sustainable measure in India. The respondents unwilling to pursue telecommuting also expressed their reason behind the choice which will enlighten policymakers for the successful implementation of this policy in future. Additionally, work nature (number of non-telecommuting working days, the designation of the respondent), the scale of the office, the employees' attitude towards telecommuting and work-related travel behaviour of partial telecommuters on non-telecommuting days (starting and end time of the office, the possibility of shifting duty hours, the main and alternative modes used, average travel time and average travel cost, the travel distance calculated from home and office location) before COVID 19 phase and during pandemic (after the termination of the lockdown) is also collected.

The combined sample collected from two phase surveys reflects heterogeneity across various socio-economic variables such as marital status (single 54%; married 46%), highest education level (Below graduate = 5%; graduate = 38%; post-graduate or higher degree holder = 57%), monthly individual income (in INR) (<10 k = 9%; 10 k to 30 k = 24%; 30 k to 50 k = 27%; 50 k to 1 Lakh = 24%; 1 Lakh to 1.5 Lakh = 6%; >1.5 Lakh = 10%), age groups (18–30 = 57%; 30 to 40 = 26%; 40 to 50 = 10%; 50 to 60 = 5% and above 60 = 2%), household size (1 = 5%; 2 = 13%; 3 = 29%; 4 = 30%; ≥5 = 23%), and number of wage earners in family (1 = 37%; 2 = 48%; ≥3 = 15%). Respondents in the age group 'above 60' are low since this is approximately the retirement age of most workers. Additionally, the lower percentage of respondents in the lower-income group as well as with lower education level might be due to involvement in elementary profession where telecommuting is not possible or there is poor access to internet facility or people are incompetent to take part in online survey. The respondents' occupation has been classified into 7 categories (Managers = 14%; Science and engineering professionals (S&E) = 29%; Teaching professionals (TP) = 12%; Technicians and associate professionals (T&A) = 21%; Information & communication technology professional (ICT) = 17%; Health professionals (HP) = 3%; Service and sales workers (S&S) = 4%) based on 'International Standard Classification of Occupation' (ISCO-08) proposed by United Nation. Since, in this study, workers who are telecommuting during COVID-19 lockdown have been considered, the survey response rate for 'service and sales workers' and 'health professionals' are found to be low since working from home is a non-viable option for these workers. Among the respondents, 69% own either a 2-wheeler (30%) or car (23%) or both (16%) and 24% of the respondents own cycle. The socio-economic distribution of the final sample is provided in Table 1.

3. Results and discussion

Our analysis reveals that, 34% of the respondents telecommuted at least once in a week before COVID-19, and 61% among these respondents are 'partial' telecommuters. 'Partial' telecommuters are defined as those individuals who physically visit offices on certain working days and during the rest of the working days they work from home. Our survey also reveal that, while the percentage share of full-time telecommuters increased to 70% during national lockdown, during the new normal situation this number has almost halved but still a large number of workers are now telecommuting (76% of respondents including both partial and full-time telecommuters) as shown in Fig. 1. Since the survey has been conducted online, respondents are mostly workers who are either partially or entirely working from home during the COVID-19 lockdown. The online mode of the survey is likely to exclude people lacking internet facility, people who are technologically challenged, and busy working professionals belonging particularly to health care and other allied services.

3.1. Telecommuting behaviour before pandemic in India

This sub-section provides insights on how telecommuting behaviour differs among various socio-economic population groups in India before COVID-19 spread. This also describes telecommuting behaviour in a stress-free situation. Telecommuting behaviour has been measured in terms of frequency, average working hours/day, preferred working slots, and productivity achieved based on revealed responses regarding the pre-COVID19 situation collected during the first phase of the survey. It has been observed that, married males telecommute more frequently within a week than single men and women and married women more frequently work from home compared to single women probably because of more household responsibilities (Fig. 2a). But, due to household responsibilities, female and married persons are able to contribute lower number of working hours/day compared to men and single persons respectively (Fig. 3a). In addition, the presence of children brings down the telecommuting frequency as well as working hours/day for both men and women as their presence may create a disturbance which results in lower work productivity (Figs. 2b and 3b).

Individuals having higher household sizes are likely to work from home more frequently (Fig. 2d). This is because other members share household responsibilities which in the case of the single-member household are infeasible (Fig. 3d). Most of the full-time telecommuters (83%) also work 4–10 h per day which is in line with the workplace schedule (Fig. 3f).

The telecommuters mostly work during the common working hours (10:00–18:00) with a lunch break between 14:00–16:00 h for single women and between 12:00–14:00 h for others (Fig. 4a). A moderate percentage of workers prefer to work during evening hours (18:00–22:00) among which the percentage of the married male is very high while a substantial percentage of both single and married women shift their work from evening to night hours (22:00–2:00) as they may be busy with household work during the evening. All the age groups, full-time and part-time telecommuters, as well as workers with different household sizes, follow the same pattern starting work from 10:00 and then continuing till 18:00 with a lunch break in-between. However, a certain percentage of the senior-most working group works during the evening hours (18:00–20:00) after taking a break in the late afternoon (16:00–18:00) (Fig. 4b). Telecommuters belonging to single-member households sometimes choose to work at night (22:00–00:00) due to their need to perform household activities during the evening and late evening hours (Fig. 4c). It is interesting to note that, full-time telecommuters work during evening hours (16:00–20:00) as compared to partial telecommuters who are more likely to work during late-night hours (22:00–00:00) (Fig. 4d). The presence of children do not influence the

Table 1
Overview of the sample.

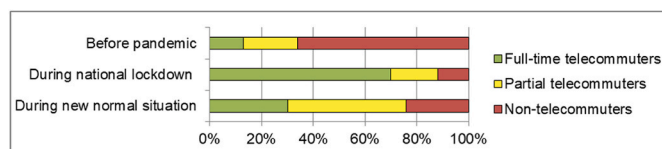|	
Female	34%
Age	μ = 32.79 (s = 9.38)
Household Size	μ = 3.5 (s = 1.2)
Number of wage earner at home	μ = 1.73 (s = 0.66)
Having children	36%
Age of Youngest child	μ = 8.03 (s = 5.59)
Age of second youngest child	μ = 10.19 (s = 5.5)

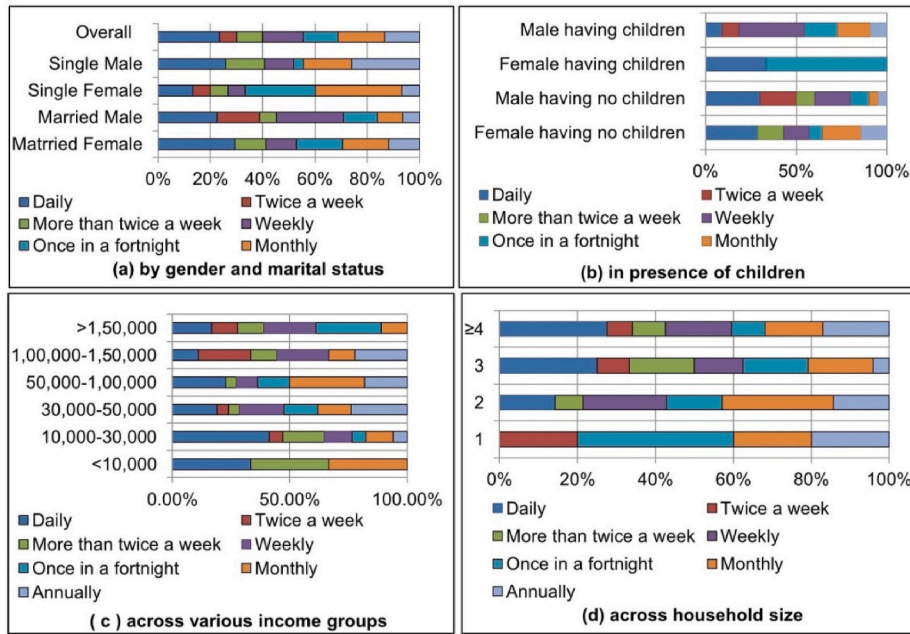**Fig. 1.** Telecommuting status before and after COVID-19 spread.

Fig. 2. Variation in telecommuting frequency across various socio-economic population groups before COVID-19.
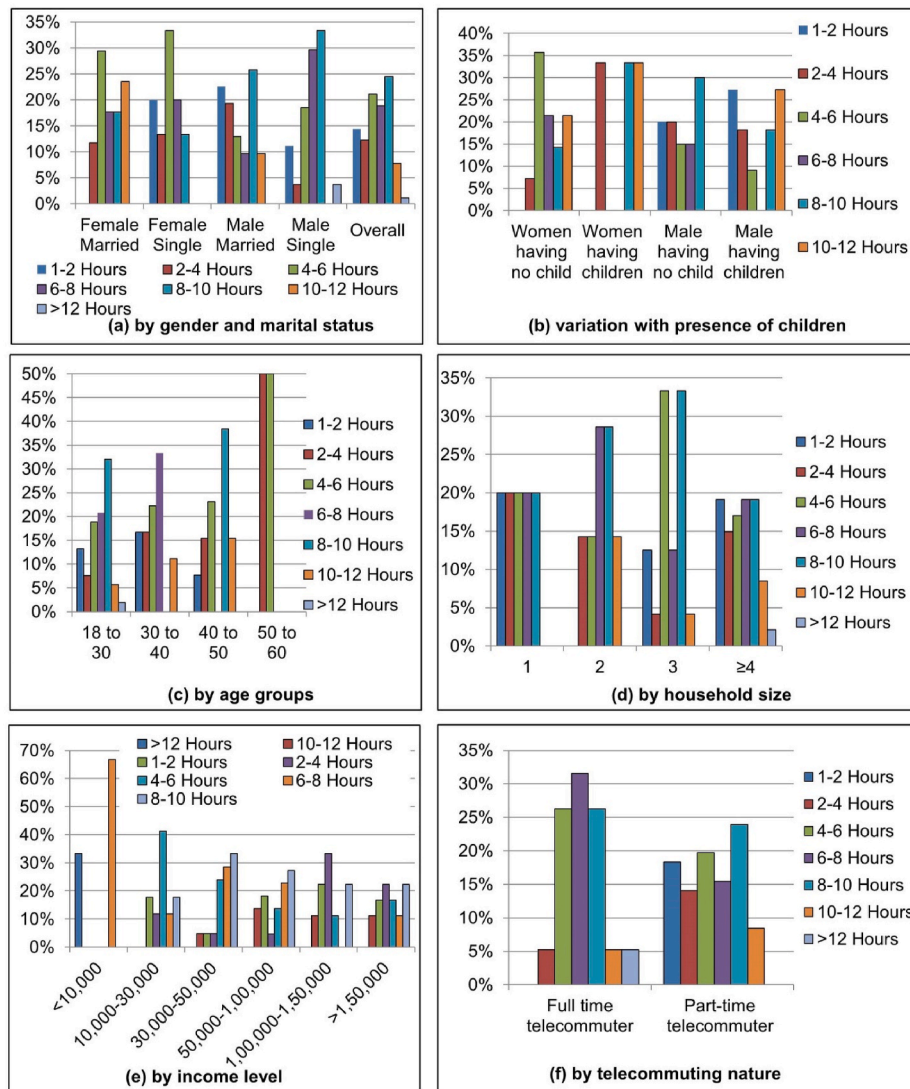

Fig. 3. Telecommuting hours/day (average) across various socio-economic groups before COVID-19.
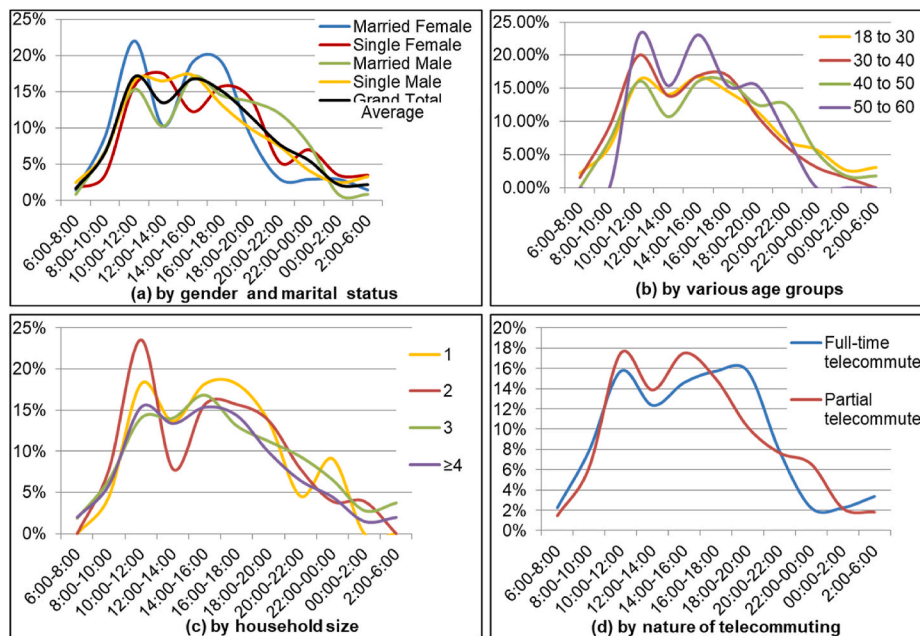
Fig. 4. Telecommuters' preferred working slots before COVID-19 spread.
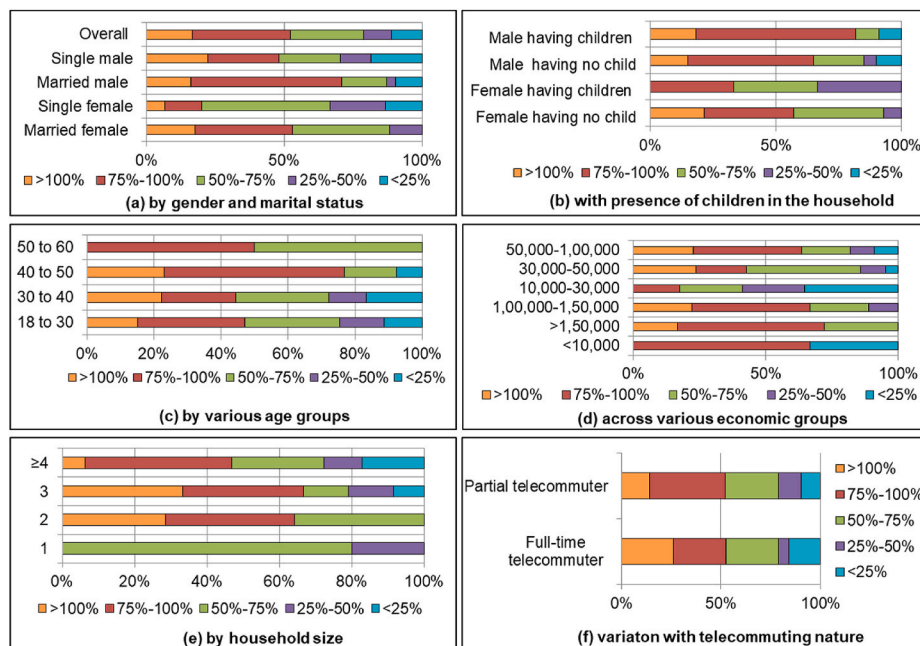

Fig. 5. Productivity achieved during telecommuting compared to working from the workplace before COVID-19.

distribution of the working slots of telecommuters.

A substantial amount of telecommuters in India are able to achieve the desired productivity when working from home. Women are found to be less likely than men in achieving desired productivity through telecommuting and interestingly single women are found to be the least productive (Fig. 5a). The presence of children declines female workers' productivity significantly compared to male workers (Fig. 5b). Experience, in-depth domain knowledge, and the nature of jobs make it easy to achieve desired productivity by senior workers compared to younger professionals who may require multiple interactions with colleagues, instructors, and clients (Fig. 5c). It is found that employees working from home having household sizes 2 or 3 are suitable to achieve desired

productivity compared to single-membered households where a worker has to perform household activities alone and larger households where the presence of family members results in additional disturbance (Fig. 5e). Both full-time and part-time telecommuters achieved similar productivity levels (Fig. 5f).

3.2. Impact of COVID-19 pandemic on telecommuting behaviour

In this subsection, exploratory analysis has been performed to investigate the change in telecommuting behaviour due to pandemic (i. e. the change from before pandemic to during pandemic) as well as the variation in telecommuting behaviour with the transforming pandemic
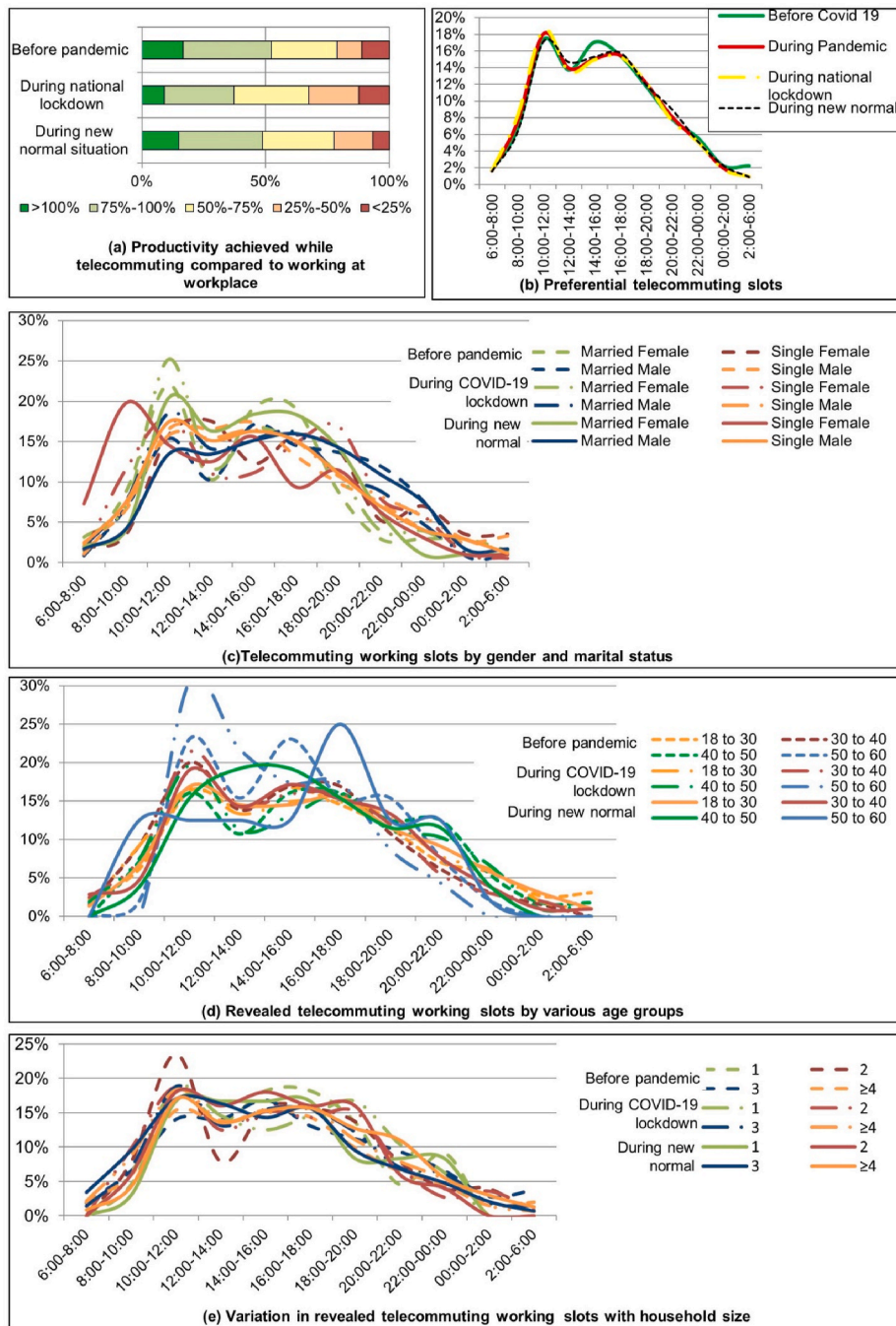
Fig. 6. Telecommuting behaviour before and after COVID 19 spread.

situation (i.e. the variation between 'during national lockdown' and 'new normal' situation). During the COVID-19 national lockdown, a slight decline in productivity is observed across all the socio-economic groups (Fig. 6a). One of the major reasons as confirmed by 35% of the respondents is stress due to continuous lockdown and uncertainties resulting from the pandemic. However, during the 'new normal' situation (i.e. after the termination of the national lockdown) productivity is observed to improve (at least 75% and 50% productivity compared to working at workplace by 49% and 78% of the telecommuters respectively) to pre-pandemic levels. A slight deviation in the preferred working slots is also observed (Fig. 6b). During the pandemic telecommuters are found to distribute their working hours across the whole day evenly reducing working time at night (after midnight) expect workers with higher household size who prefer to work at night may be to avoid

distraction by other household members (Fig. 6e). Deviation in the working pattern is observed mainly for single women (Fig. 6c), the oldest working-age group (Fig. 6d) and telecommuters with household size 2 (Fig. 6e).

3.3. Impact of telecommuting on travel pattern before and during the pandemic

In this section, the impact of telecommuting on travel patterns 'before the pandemic' situation has been analysed based on first phase survey data to anticipate whether telecommuting can reduce transport-related externalities by reducing trips or not. Next, the change in activity-travel pattern during the pandemic, i.e., during the 'new normal' situation from 'before the pandemic' period has been explored
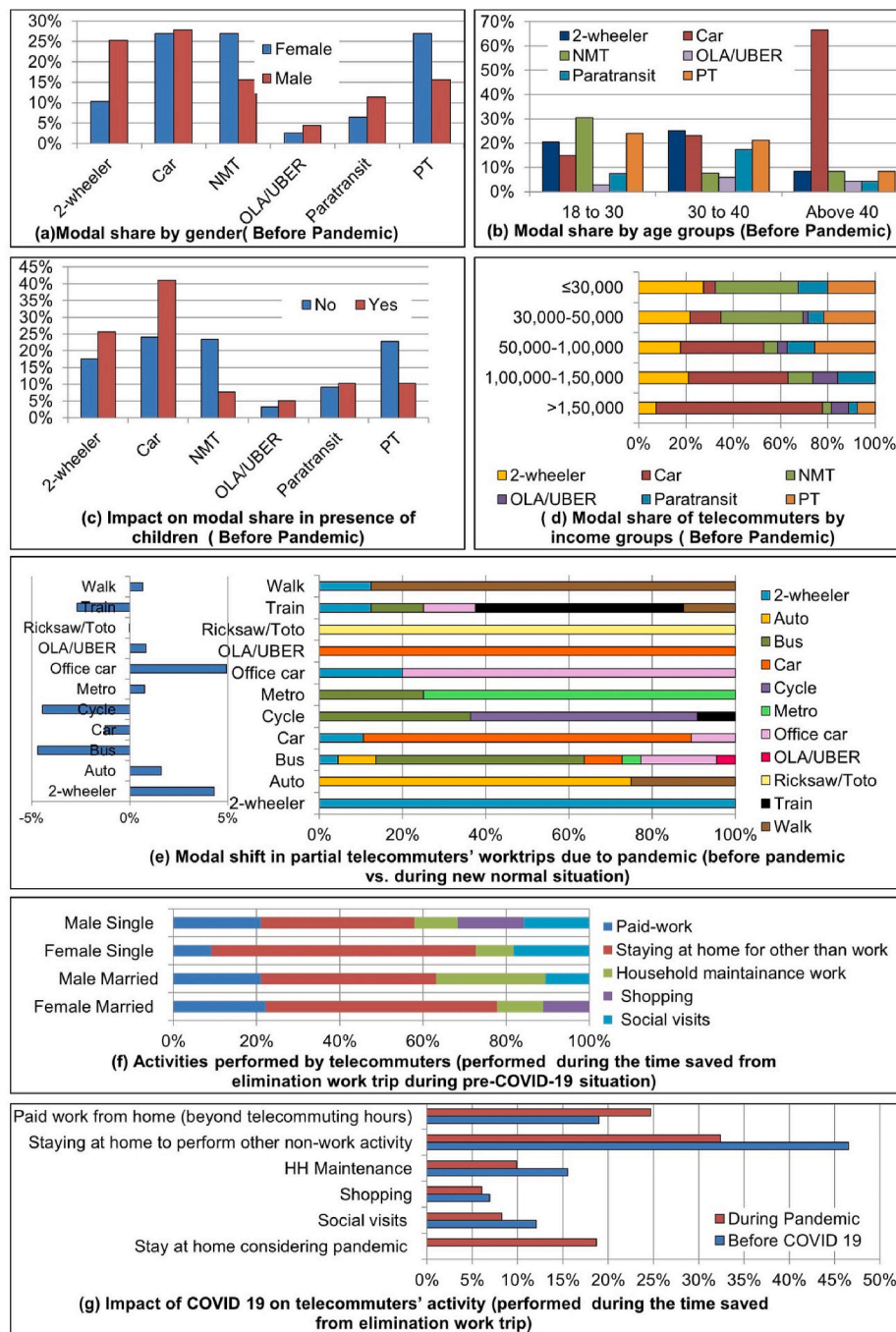
Fig. 7. Activity-travel pattern of telecommuters.

based on second phase survey data. The 'national lockdown' period was not considered since travel and out-of-home activities were restricted for most of the urban commuters. The modal share of telecommuters' work trips on non-telecommuting days across their socio-economic characteristics before COVID-19 is explored to determine the likely personal vehicle users and the results reveal that male workers, workers having children, higher-income groups and senior workers are more likely to use 2-wheeler and cars compared to others (Fig. 7 a,b,c,d). During the new normal situation, a considerable modal shift (from bus to personal vehicle) has been observed for work trip by partial telecommuters which is due to the increased need for social distancing during the pandemic. This has resulted in an increase in the trips by 2-wheeler, paratransit (auto-rickshaw) and on-demand car services (Fig. 7 e). There is also a significant increase in office car ridership which is an initiative taken by

many employers to combat COVID-19.

Next, to test the 'rebound' effect, activity by the telecommuters during the time saved from elimination of work trips is analysed which shows that, before COVID-19, most respondents (47%) choose to stay at home to perform leisure activities, exercise, online activities, hobbies or to spend time with family members, a few (19%) utilize this time for work and the rest (34%) for travelling to undertake social visits, shopping or household maintenance works, drop-off & pick-up children, etc. Further research is required to determine if the trips undertaken by telecommuters will increase the total vehicle kilometer travelled. Another important finding is that, females are more likely to stay at home (Fig. 7f). During the new normal situation, a significant percentage of telecommuters limited their out-of-home activity and preferred to stay at home due to the pandemic (Fig. 7g). It is interesting to note that
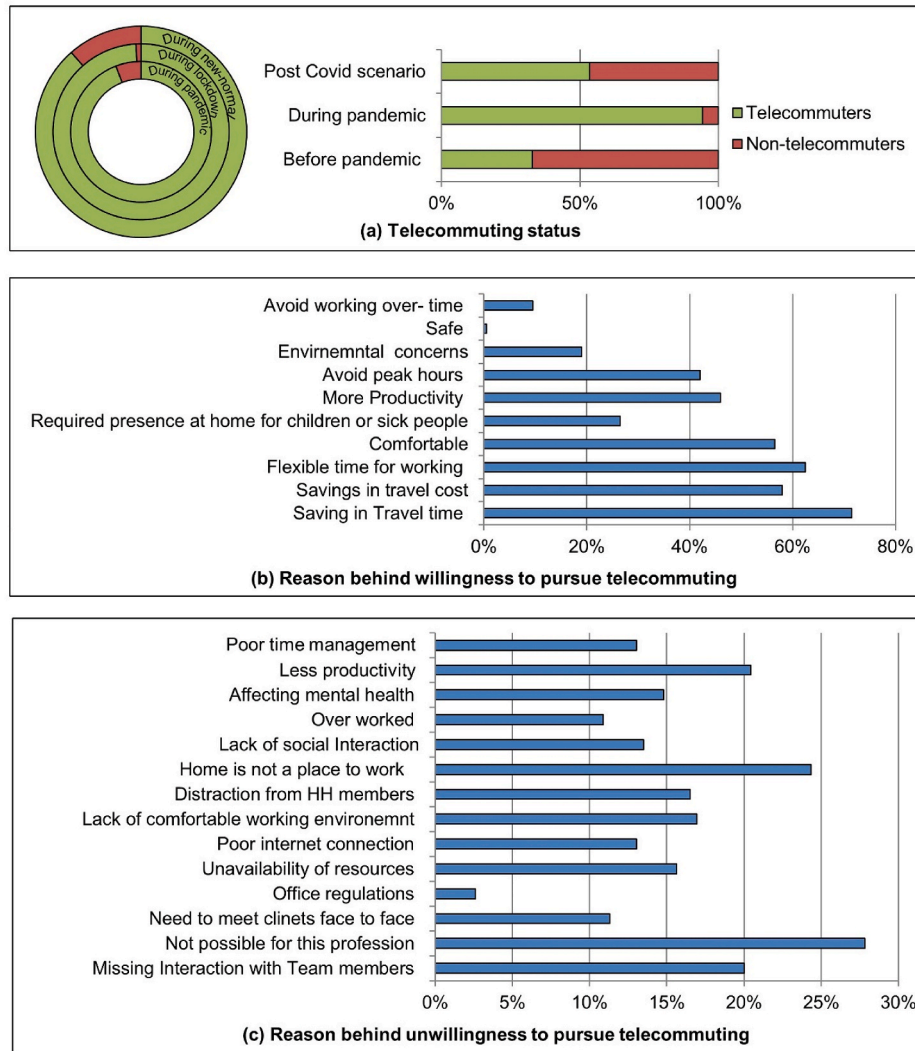
Fig. 8. Factors impacting telecommuting adoption.

more number of telecommuters devote their saved time for paid work which might be due to the increased convenience of working from home (Fig. 7g).

3.4. Factors impacting telecommuting adoption and productivity

While, before COVID-19, 34% of the respondents are found to be working from home at least once a week, 52% of respondents expressed their willingness to work from home at least once a week post-COVID-19 (Fig. 8a). Additionally, the reasons behind their willingness and unwillingness to telecommute post-COVID situation were identified by using open-ended questions in the preliminary survey that guided us to identify the factors impacting telecommuting adoption and productivity and use them in our second phase survey to determine if these factors influence future telecommuting adoption decision. The primary reasons identified by respondents preferring to telecommute are to save travel time (72%), save travel cost (58%), avoid peak hours (42%), the flexibility of working hours (63%), comfort at home (57%), and interestingly due to increase in productivity (46%) (Fig. 8b). A very few respondents also listed their willingness to telecommute for household responsibilities (27%) and concern for the environment (19%). On the other hand, the factors associated with respondents' profession like unsuitable job nature (28%), lack of interaction with other team members (20%), lower productivity during telecommuting (20%), need to meet the client face to face (11%) are the main reasons for non-telecommuting (Fig. 8c). Several psychological factors such as a home

is not a place to work (24%), mental health gets affected (15%), lack of social interaction (13%), feeling of being overworked (11%) are also identified by several respondents. In addition, a large percentage of respondents reported the distraction caused by other household members (17%) and lack of comfortable working environment (17%) which might be responsible for their lower productivity, feeling of home as an unsuitable workplace and poor time management (13%). Telecommuters also faced infrastructure constraints (16% faced unavailability of files/software/hardware) and poor internet connectivity (13%). Several influencing factors directly or indirectly related to telecommuting adoption and productivity are finally identified from the above for the second phase survey such as, household related factors (e.g. working environment at home, household responsibilities, distraction by other household members, stress due to lockdown, network connectivity), profession related attributes (e.g. resource constraints due to difficulties in access to resources like software, files, hardware etc., work-related communication like interaction with other team-members/clients/instructors, opportunity for extra paid-work from home, mandatory field work), individual level factors (social interaction and time-management) and time saving from the exemption of work-trips.

3.5. Potential employees suitable for telecommuting in India

In this section, first, telecommuting adoption and employee productivity are analysed as per employee occupation. While the percentage of employees willing to undertake telecommuting in future 'after
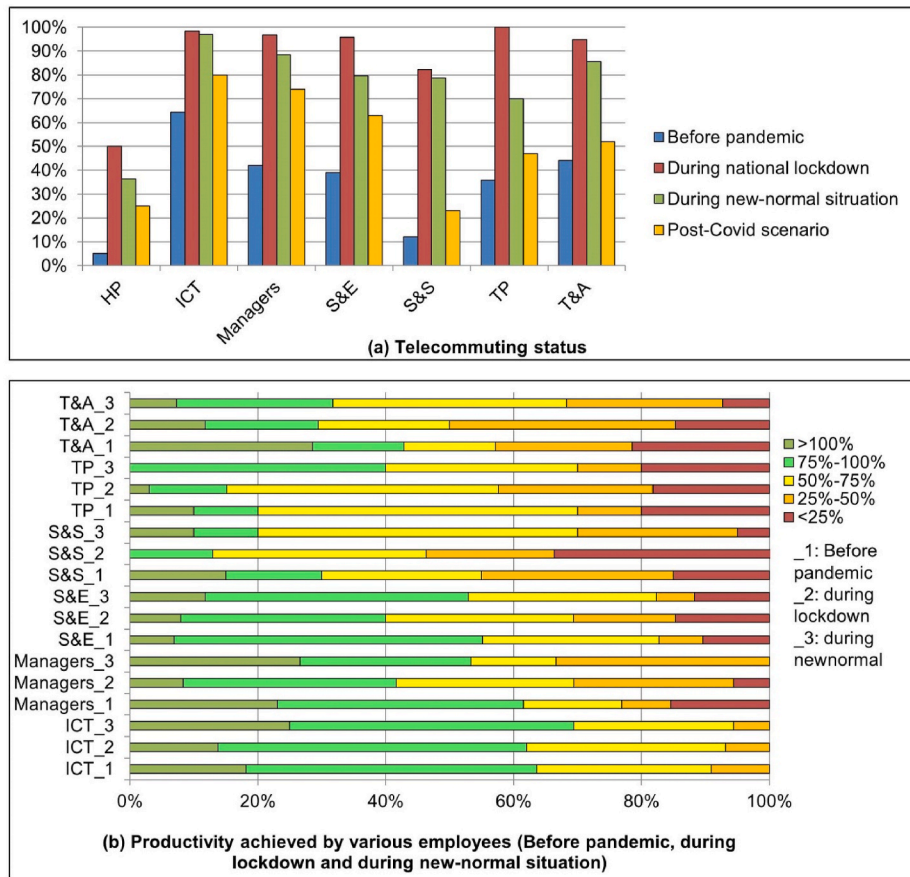
Fig. 9. Telecommuting willingness and productivity across different employees.

COVID-19' computed based on stated responses of employees for post-pandemic scenario (collected during both phases of surveys) is a direct way to understand telecommuting potential (Fig. 9a), productivity achieved by different occupation groups (Fig. 9b) 'before the pandemic', during 'national lockdown' (while stress was high due to pandemic and continuous lockdown) and during the 'new normal' situation can also help in the development of a narrative that could be useful for implementing policies regarding telecommuting by different employers. Similar insights can also be developed based on the different socio-economic groups as shown in section 3.1.

Next, a binary logistic regression model is estimated to test the association of existing telecommuting behaviour, activity-travel pattern, factors influencing productivity, socio-economic characteristics, occupation categories with adoption choice decision for telecommuting after COVID-19. This model has been developed based on 370 responses collected from both phase of the survey, but responder who have already participated in the first phase of survey have been excluded to avoid double counting. Individual socio-economic characteristics such as age, gender, occupation, marital status, education level, household characteristics such as household size, presence of children, vehicle ownership, travel characteristics such as commuting time and modal choice of work trips (for partial and non-telecommuters), activity pattern (types of activities performed during the time saved from exempting work-trip) and several interaction terms were considered while developing the model. In addition, the factors influencing telecommuting adoption behaviour and productivity which have been identified in the previous section (section 3.4) are also included.

Table 2 shows the model specifications and the variables significant at 95% confidence level. The model indicates that, willingness to telecommute increases with the increase of education level and decreases

with the increase of household size and age of the responder. It is also interesting to note that employees having personal vehicle(s) and females not having children are less likely to telecommute whereas, married females are more likely to telecommute. Employees belonging from all sectors (science & engineering, information & communication technology, managers, teaching, technicians and associate professionals) except services and sales are likely to telecommute and the odds-ratio indicated that managers and science & engineering professionals are more likely to telecommute compared to other professions. The travel related attributes like travel time and modal choice are also tested. While travel time is not found to be significant, modal choice has been found to be highly correlated with vehicle ownership.

On telecommuting days employees who utilize their time saved from the exemption of work trip by working from home in discretionary activities (i.e. exercise/leisure/social) at home, doing extra paid-work from home, out-of-home household maintenance activities (i.e. paying bills, escorting children etc.) prefer to telecommute whereas, employees indulging in out-of-home discretionary activities like shopping and social visits do not prefer to telecommute. Next, several factors influencing telecommuting adoption behaviour and productivity are tested and the results show that the willingness to telecommuting increases with the increase of household responsibility, opportunity for extra paid-work from home, satisfactory network connectivity, ability to manage time, satisfactory work-related communication from home whereas decreases with the increase of resource constraint, distraction by other HH members, stress due to pandemic, fulfilment of the desire of social communication by communicating with other household members. Employers can use internal surveys to determine employee responses regarding the productivity factors and activity pattern to determine the likely telecommuters in future.

Table 2
Logit model explaining telecommuting adoption choice.

Model summary Constant Variables in the Equation	B	Sig.	Exp(B)	Classification table obsrved	Predicted		Percentage correct
					No	Yes	
	-.217	.038	.805	No	186	19	90.7
	Chi-square	df	Sig.	Yes	14	151	91.5
Omnibus tests of Model coefficients	3479.473	34	.001	Overall percentage			91.1

Variables in the Equation	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for EXP (B)	
							Lower	Upper
HH size	-.619	.187	10.979	1	.001	.539	.373	.777
Age	-.212	.042	25.513	1	.000	.809	.745	.878
Gender (1) by marital status (1)	1.681	.713	5.559	1	.018	5.369	1.328	21.706
Child presence (1) by gender (1)	−1.294	.632	4.195	1	.041	.274	.080	.946
Post graduate or higher			22.183	2	.001			
< Graduate	2.442	1.085	5.064	1	.024	11.497	1.370	96.463
Graduate	2.656	.578	21.133	1	.001	14.243	4.590	44.203
VO_none			11.094	4	.026			
VO_2-wheller	−1.255	.729	2.961	1	.045	.285	.068	1.919
VO_both car& 2-wheller	-.512	.737	.482	1	.488	.599	.141	2.544
VO_car	−1.601	.786	4.153	1	.042	.202	.043	.941
VO_cycle	−3.157	1.007	9.826	1	.002	.043	.006	.306
HP			30.547	6	.001			
ICT	8.495	2.367	12.880	1	.001	4889.939	47.261	505949.76
Managers	8.975	2.361	14.450	1	.001	7899.966	77.273	807645.55
S&E	5.661	2.172	6.792	1	.009	287.357	4.070	20289.121
Services & Sales	−24.187	6721.84	.001	1	.997	.000	.000	
TP	4.907	2.172	5.102	1	.024	135.220	1.914	9552.188
T &A	5.489	2.207	6.188	1	.013	242.053	3.203	18292.423
Travel time	.007	.007	.916	1	.338	1.007	.993	1.020
IF_Resource constraints	−2.093	.609	11.826	1	.001	.123	.037	.407
IF_ work-related communication	2.189	.662	10.920	1	.001	8.926	2.437	32.696
IF_distraction by other HH members	−2.415	.728	11.018	1	.001	.089	.021	.372
IF_ uncomfortable working environment	-.884	.698	1.604	1	.205	.413	.105	1.622
IF_ stress due to pandemic	−2.671	.801	11.116	1	.001	.069	.014	.333
IF_ household responsibility	2.867	.729	15.469	1	.001	17.588	4.214	73.411
IF_ social communication satisfied at home	2.060	.730	7.960	1	.005	7.843	1.875	32.799
IF_ opportunity for extra paid-work from home	5.010	1.226	16.704	1	.001	149.927	13.565	1657.041
IF_ satisfactory network connectivity	5.762	1.267	20.982	1	.001	317.917	26.538	3808.535
IF_time management	3.864	1.089	12.591	1	.001	2487.22	158.101	39128.690
IF_mandatory field work	−3.981	2.033	3.834	1	.050	.019	.000	1.004
AP_extra paid workfrom home	3.574	.820	18.929	1	.001	35.646	7.142	177.907
AP_in-home discretionary	7.819	1.406	30.926	1	.001	2487.222	158.101	39128.690
AP_social visits	-.371	1.520	.059	1	.807	.690	.035	13.568
AP_shopping	−6.841	2.019	11.479	1	.001	.001	.000	.056
AP_maintenance	4.794	1.529	9.829	1	.002	120.765	6.031	2418.164
AP_stayed home due to pandemic	5.671	1.273	19.848	1	.001	290.424	23.959	3520.461
Constant	−8.927	4.051	4.857	1	.028	.001		

VO= Vehicle owned; IF = influencing factors; RC = Reference category; AP: Activities performed during saved time; Gender (1) = Female (RC: male); Marital status (1) = Married (RC: single); child presence (1) = No (RC:Yes).

4. Discussion

Our empirical analysis has revealed two major findings, i.e., a large percentage of employees can achieve their desired productivity by working from home compared to working at the workplace which establishes telecommuting as a viable alternative option for various professionals. Technicians and associate professionals and to some extent teaching professionals show relatively less productivity levels which is due to the nature of their job. The other finding is that, the 'rebound' effect as identified in literature seems to have little impact in the Indian context since only a small percentage of employees expressed their desire to undertake non-work related trips during telecommuting in the post-COVID situation which proves the applicability of telecommuting as a long term sustainable policy measure in the Indian context.

Though, willingness to telecommute decreases with the increase of household size, employees with household size of 2 or 3 are found to be most efficient from employees' perspective (section 3.1). Since females report lower productivity compared to men and females having no children are unwilling to telecommute, priority can be given to male

employees in the selection of telecommuters from employers' point of view. Though the willingness to telecommute decreases with employees' age, telecommuters from the age group 40–50 (middle age group of the working population) achieve the highest productivity, and can be considered as potential telecommuters from the employer's perspective. In terms of employee categories, ICT professionals, managers and S&E profession are found to be the most promising telecommuters considering both future adoption behaviour and productivity standpoint.

During the new normal situation, a considerable modal shift from public transport or shared modes to personal vehicles or office cars during work trip is observed raising several concerns related to increase in congestion level and resulting pollution which calls for immediate attention. Thus, telecommuting can be an alternative solution in response to this emergency. Hence, planning authorities may develop guidelines and pursue employers for adopting teleworking for suitable professions. As shown in section 3.3, male workers, workers having children, higher income, senior workers (>40 years old) are more likely to use personal vehicles, thus, facilitating telecommuting for them would result in relatively higher levels of reduction in vehicular

emission.

In regards to the factors enhancing telecommuting adoption and productivity, employers (whether government organizations or private) may take initiatives to reduce the resource constraints by organizing and digitizing files for easy access by employees. In addition, employers should facilitate creation of a comfortable working environment by providing required software and hardware support. Training sessions can be conducted for new telecommuters as well as guidelines can be prepared by experienced telecommuters for achieving desired productivity without extra time consumption. Besides, experienced and senior telecommuters or instructors should maintain regular communication and take feedback of other team members which would help in maintaining their workflow as well as improve client engagement. In addition, initiatives should be taken by authorities to take care of the mental health of the employees.

Finally, this study provides a general framework based on employees' socio-economic attributes, activity-travel pattern during telecommuting, profession, productivity and its influencing factors for determining potential telecommuters from employers' and sustainability perspective. This framework can be applied in any geographic area (country/city/specific locality) as well at an institutional level (organization level) to find out suitable socio-economic groups for telecommuting which will help concerned authority to formulate relevant policies and guidelines.

5. Conclusion

This research envisages providing an assessment of the applicability of telecommuting policy in the Indian context based on derived and stated preferences of employees working in different professions. The two-phase online survey helped us to capture the responses based on the actual telecommuting experience of employees in regard to their activity-travel pattern, productivity and its influencing factors both during the lockdown and during the no restriction (new normal) period. This was followed by assessment of post-COVID 19 telecommuting adoption based on stated responses of these current telecommuters. The analysis has been conducted in five steps in response to the research questions of this article.

A significant increase in telecommuting is observed during the COVID-19 spread in India. No significant change in the telecommuting behavioural pattern is observed during the pandemic except for a certain percentage of telecommuters who shifted their working time from afternoon to morning which may be due to restriction of out-of-home activities like daily shopping, exercise in parks, morning walks etc. during the pandemic. Based on the experience of telecommuters during the pandemic several factors influencing telecommuting adoption and productivity has been identified in the current research such as working environment at home, household responsibilities, distraction by other household members, network connectivity, access to resources like software, hardware etc., interaction with employees and clients, opportunity to work overtime etc. in addition to their socioeconomic characteristics and activity-travel pattern during telecommuting which are also found to play a significant role in any future decision on telecommuting adoption in India.

While, many new groups of employees such as managers, science & engineering (S&E) professionals expressed their desire to telecommute after COVID -19, consolidated analysis of results based on existing telecommuting behavioural analysis and future telecommuting adoption choice model incorporating activity-travel pattern and productivity factors, helped us to conclude that male falling in the age group 40–50 with household size of 2 or 3 and belonging to ICT, Managers or S&E profession could be recommended as the potential telecommuters.

The novelty of this research lies in the comprehension of the adoption process, and the behavioural analysis (adoption, productivity, activity, and travel) of telecommuters in the context of a developing country for the first time. This empirical research has also explored the

impact of individual and household level socio-economic heterogeneity on telecommuting behaviour which can help in designing group-specific interventions to increase telecommuting. The methodology developed in this study to identify future potential telecommuters through consolidated analysis of telecommuters' adoption process and their behavioural dynamics (adoption, productivity, activity, and travel pattern) will provide insights to urban planners and policymakers to target appropriate employees (who commute by personal vehicles, who does not amplify 'rebound effect', whose home to workplace distance is larger than average, etc.) for partial and full-time telecommuting and to specify working days or working slot within a day for telecommuting in order to achieve desired productivity along with reduction of traffic-related externalities (e.g. congestion, vehicular emission). This will not only allow urban planners and policymakers to design sustainable travel demand management strategies, but will also help employers to design appropriate telecommuting strategies at the organization level which will help to attain the desired productivity levels with satisfied employees. The impact of the pandemic on telecommuting behaviour and adoption as explored in the study will also help in emergency response planning by different employers and city authorities. This research can also be extended in the future to understand the impact of telecommuting on other household members' activity-travel behaviour. In addition, based on the experience of telecommuters during the pandemic several factors influencing telecommuting adoption and productivity have been identified which can be invertigated for other geographic areas. In future, advanced multivariate statistical methods like structural equation modelling can also be applied incorporating ordered responses (e.g. Likert scale values) for a limited set of these factors identified in this research to understand their influence in detail on telecommuting adoption behaviour and productivity.

CRediT authorship contribution statement

Declaration of competing interest

None.

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