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RESEARCH ARTICLE

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Activity and time-use diary for a neighborhood telecommuting centre living lab in Stockholm, Sweden

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ABSTRACT

Neighborhood telecommuting centers (NTCs) are professional workplaces located in residential areas that offer a closer alternative to long-distance commuting. By integrating telecommuting with mobility services, NTCs have the potential to support sustainable travel behaviors, reduce commuting burdens and alleviate space constraints for organizations. This paper adopts a longitudinal, mixed-methods living-lab approach to examine factors influencing NTC use compared to employer offices and home offices. Data from a real-life NTC living lab in Stockholm, Sweden, were analyzed using a three-week time-use diary (27 participants; 572 day-level observations) and panel regression models to identify determinants of workplace choice. Qualitative interviews were used to contextualize inconsistencies between participants' expectations and actual usage. Findings indicate that NTCs can reduce commuting times and provide a professional environment closer to home; however, adoption is constrained by organizational norms, logistical barriers and continued reliance on private cars for trip-chaining. The results suggest that embedding NTCs within mobility-as-a-service (MaaS) like frameworks, through coordinated workplace access, public transport subscriptions and micromobility solutions, while aligning employer policies and institutional practices, is critical for supporting hybrid work models and advancing sustainable urban mobility.

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1. Introduction

1.1. Background

Rapid socio-economic changes have transformed urban form and increased spatial separation between residential areas and workplaces, contributing to longer commutes and growing car dependency (Bramley & Kirk, 2005). As housing costs rise and cities expand, many workers reside farther from employment centers, increasing pressure on transport systems and contributing to congestion and environmental impacts. Sustainable travel practices and alternative workplace arrangements are therefore increasingly important.

Advances in information and communication technology (ICT) have enabled virtual accessibility and expanded opportunities for telecommuting (Maeng & Nedovic-Budic, 2010). Telecommuting is commonly defined as the use of telecommunications technology to partially or completely replace commuting to work (*P.* Mokhtarian, 1991). Two types of telecommuting have been identified in the literature; home-based telecommuting and telework centers (Bieser & Coroamă, 2021; Bramley & Kirk, 2005; Mokhtarian, 1991). The impacts of home-based telecommuting on travel behavior have been widely studied. While several studies report reductions in commuting distance and car use on teleworking days (Elldér, 2020; Hertel et al., 2008; Hamer et al., 1991; Jaff & Hamsa, 2018; O'Keefe et al., 2016; Shabanpour et al., 2018), others highlight rebound effects such as increased non-work travel (Chakrabarti, 2018; He & Hu, 2015; Hu & He, 2016; Zhu, 2013).

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Telework centers represent an alternative form of remote work. According to the typology proposed by Fritz et al. (1995), telework centers can be grouped into traditional and non-traditional telework locations, such centers may include satellite offices and neighborhood-based facilities. Neighborhood telecommuting centers (NTCs) are shared workspaces located close to residential areas, enabling employees from different organizations to access professional facilities without commuting long distances. Although earlier studies indicate that center-based telecommuting may reduce commute-related travel (Balepur et al., 1998; Koenig et al., 1996; Mokhtarian & Varma, 1998), empirical evidence from real-world deployments remains limited.

NTCs have gained increasing attention as a potentially viable solution for reducing commuting burdens while offering professional work environments (Bieser & Coroamă, 2021; Deskmag, 2019). Deskmag Deskmag Deskmag as a work center shared by two or more people working under different employers, allowing remote access to data from different parts of the world to collaborate and share knowledge as well as replace their physical presence at the employer's office thus avoiding long-distance commutes (Mokhtarian, 1991). NTCs show promising potential in reducing travel-related environmental impacts as well as play a significant role in transforming an individual's travel patterns and quality of life (Kramers et al., 2015; Ringenson et al., 2018; Sopjani et al., 2018; Vaddadi et al., 2020b). This set-up could help to resolve issues related to the scarcity of space by allowing both companies and authorities to provide a flexible work environment (Weijs-Perrée et al., 2019).

NTCs could be considered a complex and dynamic travel alternative with the ability to compete with current traditional travel modes (Erdmann et al., 2004). If combined with mobility services and physically active modes such as shared e-bikes, access to public transport subscriptions, etc. NTCs could provide optimal work and travel arrangements tailor-made to cater to an individual's specific travel needs while promoting a better quality of life. However, as stated above, working at NTCs can also have unintended side effects, e.g. increased travel for people who would have worked at home otherwise. Therefore, it is important to be mindful of all the potential impacts. There is a gap in the literature as there is a lack of real case analysis and the focus on only a particular aspect of the NTC concept as highlighted above. This limits us in gaining a full understanding of the wider impacts of such interventions and may lead us to biased policy design and undesirable impacts at a later stage.

1.2. Objective of this study

In Stockholm, suburban commuting times have increased, and car use has grown, although public transport remains significant (Bastian & Börjesson, 2018; Trafikanalys, 2020). Due to the radial design of the public transport network, many commuters must travel indirectly via central areas. In this context, NTCs may offer a decentralized alternative to both employer offices and home offices. While the concept of co-working has been heavily adopted in the central locations of Stockholm city (e.g. Coworker, MatchOffice, Regus), NTCs are not as prevalent. Based on the research gap stated in the previous subsection, and the fact that NTCs are not available in the suburban areas of Stockholm, a living lab 20 km south of Stockholm was set up to investigate how NTCs can impact an individual's travel and leisure life. This living lab offers a digital platform integrating accessibility and mobility services to approximately 60 participants to allow them to book, plan and travel. It offers an activity-based workplace close to home and gives access to electric bikes and peers to peer carpooling. With such an arrangement, it is expected that NTCs could significantly reduce commuting and are not associated with deficits of working from home.

In order to gain a better understanding of the use and the possible impacts of NTC on the travel and work behavior of individuals, efficient data collection is of utmost importance. While the cross-sectional observation of one representative day of regular activities and trips (survey), has been a common practice in understanding travel behavior over many years, the method fails to provide insights into individual's real travel needs and demands which are subjected to changes (Flyvbjerg et al., 2005; Fox, 1995). In contrast to this method, a comprehensive panel data collection in the form of time-use diaries has gained quite popularity in recent studies and provides insight into an individual's activity–travel pattern considering spatial and temporal constraints (Jones, 2009; Schönfelder & Axhausen, 2002). This approach also helps gain a better understanding of factors that contribute to day-to-day variability, repetition, flexibility and/or systematic variabilities such as weather, location, preference of workplace, and preference of travel

modes for commuting and leisure, workplace norms commitments and obligations, familial needs, etc. (Axhausen et al., 2002; Bayarma et al., 2007; Buliung & Remmel, 2008; Chikaraishi et al., 2011; Huff & Hanson, 1986; Susilo & Axhausen, 2014). The individual has different sets of activities each day and there is no typical or superior day at any given time (Dharmowijoyo et al., 2015; Kang & Scott, 2010; Susilo & Kitamura, 2005).

Therefore, a cross-sectional observation of one representative day regarding daily activities and travel behavior will not be adequate to measure the complexity and variability that might arise in a setting such as an NTC (Schlich & Axhausen, 2003). In order to study the impacts of an NTC on individuals' daily activity–travel patterns, a comprehensive panel of data is required. This paper aims to describe such a data collection with the use of a three-week time-use diary to understand the impacts of an NTC living lab space set up in the south of Stockholm to provide deeper insights into the individual's activity–travel decision-making processes and systematically analyze the relationships between individual's activities and travel behaviors. The structure of the paper is as follows: Section 2 describes the NTC living lab setup and data collection and model formulation; Section 3 presents the results and discussions based on the analysis; Section 4 concludes with key findings and avenues for future work.

2. Materials and methods

2.1. The NTC case setup

The NTC living lab was established in January 2019 in Tullinge, south of Stockholm, to investigate how providing a professional workspace close to participants' homes influences travel and work behavior (see Figure 1). The setup predated the COVID-19 pandemic, which later reshaped telecommuting norms. While this study focuses on pre-pandemic data collected in 2019, follow-up interviews conducted after the pandemic provide additional insight into evolving work practices. The living lab was designed by a KTH

Figure 1. Location of the NTC with respect to the employer's office and participants' neighborhoods.

research group in collaboration with the local municipality and a partner organization as part of a broader initiative exploring sustainable mobility solutions.

The NTC provided an activity-based workspace near a commuter train station, including fourteen bookable ergonomic desks, a conference room, three telephone booths, printers, office supplies and kitchen and bathroom facilities. To promote sustainable mobility, two electric bicycles and one cargo e-bike were available for booking via an app (see Figure 2). On days participants worked at the NTC instead of their employer's office, reported commute time savings reached up to 75 minutes under typical traffic conditions. The living lab operated until early 2020, when the COVID-19 pandemic disrupted in-person activities.

2.2. Data collection

To evaluate the impacts of the NTC on multiday activity–travel patterns, a mixed-methods approach combining quantitative and qualitative data was employed. Participants were recruited in two phases: 32 local commuters through advertisements and social media (Group 1), and 35 employees from a partner organization (Group 2). By February 2020, 67 participants were registered at the NTC, of whom 52 regularly worked there and 27 completed the three-week time-use diary.

Data collection comprised three components: an online survey, semi-structured interviews, and time-use diaries. The survey gathered baseline socio-demographic information, travel habits, remote working arrangements and household characteristics. Interviews were conducted in multiple phases to explore expectations, travel routines, workplace practices and perceived impacts. Initial interviews lasted 45–70 minutes, and follow-up interviews with eight participants examined barriers and behavioral changes associated with increased NTC use (Vaddadi et al., 2022).

The three-week time-use diary recorded daily activities and travel modes, including time spent commuting, working at different locations, performing chores and engaging in leisure activities. Modes included private car, public transport, walking, cycling and other shared mobility options (Bieser et al., 2021; Vaddadi et al., 2020). Together, these methods provide a detailed understanding of behavioral adaptation and NTC adoption processes.

2.3. Data

In this section, we use the data collected from the time-use diaries and the demographic survey to perform descriptive analysis and quantify the impacts of different variables which were collected over a 3-weeks' time period with the panel regression model. As it has been consistently confirmed by previous studies (Schlich & Axhausen, 2003; Susilo & Axhausen, 2014) that there is no such concept as a typical day, thus it is important to analyze the individual decision in using NTC, and how this decision impacts the rest of individual's activity–travel patterns, from multiday perspectives. Along with that, we use the qualitative

Figure 2. The NTC interiors (left); E-bikes parked outside the NTC (right).

data obtained from various interviews conducted with the participants as additional support to the results of the quantitative analysis (the detailed methodology, analysis and results of the qualitative data obtained through interviews conducted with the participants can be found in Vaddadi et al. (2020, 2022). While data from a survey could give us a view of a typical day, panel data collected via time-use diaries could not only provide insight into the choices of the participants for different travel and work-related activities on a given day but also show the variations in their choices each day.

2.3.1. Overall participants' characteristics

Tables 1–3 provide overall participants' characteristics as well as characteristics of the time-use diary participants. The majority of participants (77% overall and 100% of time-use diary participants) were 45 years or older, with a large proportion working as engineers or managers. The lack of time-use diary respondents under 45 years old suggests that this study primarily reflects the behaviors and preferences of senior adults. Most participants (58% overall; 51% time-use diary) commuted 30–60 minutes one way to their employer's main office in the south of Stockholm, with public transport, specifically the commuter train, being the dominant travel mode for work-related trips.

While general trends in suburban commuting indicate a significant shift towards private car usage in recent years (Bastian & Börjesson, 2018; Trafikanalys, 2020), the majority of our participants commuted to their workplaces by public transport (73% overall; 74% time-use diary participants), largely reflecting the availability and convenience of the commuter train network in their residential areas. This distinction underscores the specific context of our participant group, who were recruited from neighborhoods with good access to public transport, potentially skewing the results toward sustainable transport preferences. However, for leisure travel, most participants (54% overall; 63% time-use diary participants) preferred private cars, highlighting contrasting modal preferences for different travel purposes.

A significant portion of participants lived within close proximity to the NTC , with 71% overall and 55% of time-use diary respondents residing within 0–4 kilometers of the center. Furthermore, 40% overall and 74% of time-use diary participants expressed a preference for using commuter trains for work-related travel, aligning with their residential locations and prior commuting habits. Despite limited flexibility in pre-existing remote work agreements-46% overall and 55% of time-use diary participants were allowed to work from home only 1–3 days per month-participants expressed an openness to negotiating new work

Table 1. Shows an overview of the demographic characteristics of the participants.

Variable		*All NTC participants (n = 52)*	*Time-use diary respondents (n = 27)*
Age (in years)	25–34	2	*0*
	35–44	10	*0*
	45–55	19	*12*
	Over 55	21	*15*
Gender	Male	31	*21*
	Female	21	*6*
Household size	1	1	*0*
	2	17	*13*
	3	7	*5*
	4	17	*3*
	5 or more	10	*6*
No. of years at current residence	0–10	6	*1*
	10–20	16	*10*
	20 and above	18	*16*
	No data	12	*0*
No. of children in the household	None	18	*12*
	1	6	*5*
	2	18	*4*
	3	9	*5*
	4	1	*1*
Children's age group	0–10	14	*4*
	10–20	15	*6*
	20 and above	7	*5*
Type of Job	Engineers	10	*10*
	Managers	23	*7*
	IT Professionals	9	*5*
	Others	10	*5*

Table 2. Work-place preferences of the participants.

Variables		*All NTC participants (n = 52)*	*Time-use diary respondents (n = 27)*
Type of current set-up at employer's office	Activity based open workspaces	7	*5*
	Open workspaces with fixed desks	27	*22*
	Office shared with other employees	3	*0*
	Private office	3	*0*
Days/week at the employer's office	5	16	*12*
(before the NTC was introduced)	4	17	*11*
	3	6	*4*
Days/week at the home office	1–3 days/month	24	*15*
(before the NTC was introduced)	2	2	*2*
	1	8	*7*
	0	3	*3*
Expectations of working from the NTC	1–3 days/month	9	*6*
(days/week)	2	6	*4*
	1	20	*14*
	0	1	*3*
Satisfaction with workplace set-up at the employer's office	Satisfied	22	*11*
	Somewhat satisfied	11	*4*
	Not satisfied	7	*12*

Table 3. shows the travel preferences of the participants.

Variables		*All NTC participants (n = 52)*	*Time-use diary respondents (n = 27)*
Commuting mode preferences	Car	12	*4*
(the main travel mode used for commuting)	Public transport	38	*20*
	Active modes	2	*3*
	Other modes	0	*0*
Leisure travel mode preferences	Car	28	*17*
(the main travel mode used for leisure travel)	Public transport	6	*4*
	Active modes	13	*5*
	Other modes	1	*1*
Commuting time (in mins)	0–30	2	*0*
(time spent commuting from home to employer's office (one way))	30–60	30	*14*
	60–90	19	*13*
	90 and above	1	*1*
Distance from residence to the NTC *(in kms)*	0–4	37	*15*
	4–8	12	*11*
	8–12	1	*0*
	12 and above	2	*1*

arrangements. Notably, 38% overall and 52% of time-use diary respondents indicated a willingness to work at the NTC at least one day a week, should their employers agree.

2.3.2. Time-use diaries

A total of 572 time-use diary observations were recorded during the 3-week observation period from 27 participants, a week-wise breakdown of which is presented in Table 4. Majority of the diary days were spent at the employer's office, followed by the days at NTC and from the home office. There were also days during which the participants spent time at various work locations (moving between employer's office,

Table 4. A breakdown of 3-week time-use diary observations (in days) from 27 participants.

Type of activity	Week 1 *(days)*	Week 2 *(days)*	Week 3 *(days)*	Total *(days)*
NTC	22	27	28	77
Employer's office	78	73	72	223
Home office	19	16	15	50
Meetings outside of employer's office	0	0	1	1
No work	3	6	0	9
Mixed days	14	19	14	47
Weekends	33	32	36	101
Missing information	20	23	21	64
Total	189	196	187	**572**

NTC, home office and meetings outside of employer's office), on meetings outside of employer's office (conferences and/or events, working from clients' office, etc.) during the weekdays or were on vacation.

The breakdown of time spent on different work-related and travel-related activities per week is shown in Figure 3. On the employer's office days, over the three weeks, the average time spent working was mostly consistent. No significant changes were noticed in the amount of time spent on personal activities such as everyday chores. There was also a slight increase in the amount of time spent commuting by car and a decrease in the amount of time spent on public transport. This could be because during the duration of the Time-use Diary, the commuter train (the mode often used for commuting by the participants) was experiencing delays. No significant change was observed in time spent on active modes as most

Figure 3. Average time spent (in mins, y-axis) on different activities & travel modes (x-axis) on NTC (top), Employer's office (middle) & home office (bottom) days during weeks 1, 2 and 3.

participants combined commuting by public transport with active modes (mostly walking). The amount of time spent on NTC days is almost the same as the amount of time spent on employer's office days. However, there was an increase in everday chores on the NTC days as Compared to the employer's office days. While most participants preferred to combine public transport and active modes for their commute to the NTC, there were some that preferred to commute by car in order to combine work and non-work-related activities together. It was observed, on the NTC days, that participants often combined working at the NTC (which includes virtual meetings) with everyday chores and often commuted to the NTC using a combination of active modes and car. On a typical home office day, participants combined work (which includes virtual meetings) with everyday chores. Compared to both the employer's office and NTC days, on home office days, participants spent less time working and significantly more time on everyday chores. As there is no commute during home office days, the time spent on travel activities is usually related to everyday chores such as grocery shopping, pick up and drop off for children, etc.

2.4. Study limitations and scope

The living-lab design adopted in this study represents a unique empirical deployment of a fully operational neighborhood Telecommuting Center (NTC) in a real-world suburban context. Rather than relying on stated preference data or hypothetical scenarios, the study follows participants throughout the process of adoption and examines how the introduction of the NTC interacts with their daily activity–travel patterns over time. This 'walk-and-learn' approach allows observation of behavioral adaptation as it unfolds in practice. While the scale of the study reflects the structural constraints of a place-based intervention, the depth of engagement and longitudinal design provide detailed insight into mechanisms that are difficult to capture through larger cross-sectional surveys.

The empirical material collected in this living lab combines qualitative interviews with three-week time-use diaries from 27 participants, resulting in 572 day-level observations. Of these, 405 weekday observations were included in the panel regression analysis. Participation required sustained engagement in a functioning NTC, and recruitment was therefore limited by the physical capacity of the site and the size of the commuter population in the surrounding suburban context. As a place-based intervention, the study does not aim to provide statistically representative estimates of the broader working population. Rather, it examines behavioral mechanisms and adaptation processes associated with the introduction of an NTC in a real-world setting.

The longitudinal diary design enables the analysis of day-to-day variability in workplace and mobility choices. By focusing on within-individual variation over time, the study captures how routines and trade-offs evolve as the NTC becomes integrated into everyday life. At the same time, the three-week observation period may not capture less frequent behaviors or longer-term adjustments that could emerge over extended time horizons. Future research could extend this approach across multiple sites, longer diary periods and larger samples to assess the transferability and durability of the patterns identified here.

The participant group is skewed toward older age cohorts and includes a lower proportion of female participants, while younger age groups (25–44) are underrepresented. These demographic characteristics may influence workplace and mobility preferences and should be considered when interpreting the results. The findings therefore reflect the behavioral responses of this specific participant group within the living-lab context rather than those of the general population.

2.4.1. Model formulation

While it can be assumed that participants in the living lab aim to perform activities in the most efficient way to maximize utility, these activities are often constrained by spatial or temporal factors (Schlich & Axhausen, 2003b). With the introduction of the NTC, choices related to workplaces (the NTC, employer's office and home office), personal activities and factors such as commute modes and weather contribute significantly to behavioral variability (Hanson, 1980). The objective of this section is to understand the extent to which these factors influence time-use decision-making processes in day-to-day life. To achieve this, panel linear regression models are employed, allowing for the analysis of dynamics within a short time series collected through repeated observations over a cross-section of data. This approach is particularly

insightful as it enhances the quality and quantity of data compared to cross-sectional observations of a single representative day.

Panel linear regression models offer various analytical frameworks. In this paper, the focus is on fixed effects and random effects models (Baltagi, 2005). In a fixed effects model, individual-specific effects are estimated using within-individual variation, explicitly capturing variable effects for each individual. In contrast, a random effects model estimates individual-specific effects using both within- and between-individual variation. If substantial within-individual variation exists, the fixed effects model is more appropriate as it controls for unobserved individual-level factors. Conversely, if between-individual variation dominates, the random effects model may be more suitable as it estimates both within- and between-individual variations to compare their magnitudes.

In theory, fixed and random effects can be applied to any given variable effect. However, in this study, these effects are used solely to differentiate intercept effects, while 'pooled' effects are estimated for other explanatory variables. If the random effects assumption holds, the model is generally more efficient than the fixed effects model (Baltagi, 2005; Webel, 2011; Vogt, & Johnson, 2016). To determine which model best fits the panel data, the Hausman test is performed. The Hausman test evaluates the significance of an estimator against an alternative estimator, with the null hypothesis favoring the random effects model for higher efficiency and the alternative hypothesis favoring the fixed effects model. If the Hausman test fails, the random effects model is considered inconsistent (Vogt & Johnson, 2016).

In this paper, the independent variables are grouped into three categories: demographics, time spent on different modes and time spent on various activities. Using survey data and the time-use diaries of 27 participants, these variables are analyzed to observe changes in participants' travel and work behaviors. The dependent variables include time spent working at the NTC, home office and employer's office. To account for inter- and intra-variability among participants, both fixed and random effects models are applied, recognizing each participant's unique characteristics.

To estimate the fixed and the random effects, the following models was used:

For Fixed Effects- Equation 1:

$$Y_{it} = \beta X_{it} + \delta_i + \epsilon_{it} \tag{1}$$

For Random Effects- Equation 2:

$$Y_{it} = \beta X_{it} + \alpha_i + \epsilon_{it} \tag{2}$$

where

Y_{it} = *total time spent at different workplaces by the participant (i) on a given day (t) in minutes (employer's office, NTC, home office).*

X_{it} = *vector of explanatory variables, including demographics, time spent on different modes and time spent on different activities.*

δ_i = *parameter representing the fixed effect of individual i.*

α_i = *individual-specific random error.*

$\in_{it}$ = *random error.*

3. Results and discussion of the panel data analysis

The tables in the next sub-sections show the results of the fixed effects and the random effects models for the three dependent variables: *time spent working from the NTC, the home office and the employer's office*. The categories and description of the explanatory variables are presented in the columns, and the values are presented in the form of estimate value, the standard error, the t-value, and the *p*-value representing estimates of fixed effects and indicating the significance of each independent variable in influencing the value of the given dependent variable. The independent variables that significantly influence the dependent variables at [0, 0.001] '***' (0.001, 0.01] '**' (0.01, 0.05]'*' significance level are indicated by stars (***, **, *). The positive and negative significant coefficients in the tables below represent the relative changes. A negative coefficient indicates a decrease in *time spent working from the NTC, home office and the employer's office* while the positive coefficient indicates an increase in the *time*

spent working from the NTC, home office and the employer's office. Based on the results in following sub-sections, the paper dives deeper into the factors that influence the time spent at the three main workplaces: at the NTC, at home office and at the employer's office with support from the qualitative data collected through interviews with the participants.

3.1. Which factors are associated to time spent working at the NTC?

The Hausman Test was performed to determine which model is a better fit for the dependent variable: *Time spent working at the NTC*. The test yielded a *p*-value of 7.676e−07 and since the *p*-value is 7.676e−07 < 0.05. Therefore, as the Hausman test suggests, *the fixed effects model is a better fit* for understanding the relative nature of time spent working from the NTC and time spent on different modes, time spent on different activities and the variability across the individuals.

Table 5 presents the results of the fixed-effects model. The first set of variables pertains to the time spent on different modes of transport. The results of the fixed -effects model show that while the *time spent in a car* was found not statistically significant ($p > 0.05$), the *time spent on a train* has a significant negative effect ($p < 0.001$). This could be because the main motivation behind the participants using the NTC was '*to save or reduce travel time*' as most of these participants often spent long hours commuting to their employers' office. The *time spent on a bike and e-bike* do not have statistically significant effects on work

Table 5. Results of the fixed effects model for time spent working at the NTC.

Time spent working at the NTC *(Fixed-effects model: oneway (individual) effect within model)*					
Unbalanced panel: number of individuals = 27; number of observations per individual: 14–16 days; number of observations = 405					
Category	Variable	Estimate	Std. Error	t-value	Pr(>|t|)
Time spent on different modes	*Car*	−0.380	0.265	−1.432	0.152
	Train	−1.175	0.214	−5.474	8.12e−08***
	Bike	0.110	0.584	0.189	0.850
	E-bike	0.730	0.997	0.732	0.464
	Foot	0.928	0.454	−2.044	0.041*
Time spent on different activities	*Virtual Meetings*	0.436	0.127	3.437	0.001***
	Everyday Chores	0.111	0.159	0.698	0.485
Variability across the individuals	*ID 1*	72.388	54.575	1.326	0.185
	ID 2	33.065	49.318	0.670	0.502
	ID 3	280.727	66.994	4.190	3.485e−05***
	ID 4	197.666	48.764	4.053	6.149e−05***
	ID 5	44.495	47.283	0.941	0.347
	ID 6	138.134	48.121	2.870	0.004**
	ID 7	122.594	49.104	2.496	0.012*
	ID 8	361.978	50.811	7.124	5.489e−12***
	ID 9	52.494	58.817	0.892	0.372
	ID 10	155.881	55.847	2.791	0.005**
	ID 11	−4.894	69.795	−0.070	0.944
	ID 12	278.364	49.117	5.667	2.917e−08***
	ID 13	184.171	49.600	3.713	0.0002***
	ID 14	291.343	47.220	6.169	1.790e−09***
	ID 15	196.272	50.032	3.922	0.0001***
	ID 16	2.189	46.400	0.047	0.962
	ID 17	126.969	47.014	2.700	0.007**
	ID 18	147.461	54.064	2.727	0.006**
	ID 19	401.497	51.324	7.822	5.429e−14***
	ID 20	−15.732	73.596	−0.213	0.830
	ID 21	62.028	47.491	1.306	0.192
	ID 25	134.770	51.127	2.636	0.008**
	ID 26	25.372	52.054	0.487	0.626
	ID 27	57.764	54.746	1.055	0.292
	ID 28	96.812	57.686	1.678	0.094.
	ID 29	168.153	48.928	3.436	0.001***
	ID 34	264.807	53.236	4.974	1.004e−06***

*Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.'*

Note: IDs were assigned to all 52 NTC participants. Of these, 27 fully completed the travel diaries, and their data were included in the analysis. The numbering in the table is not continuous because IDs for incomplete diaries were excluded.

Total sum of squares	Residual sum of squares	R-Squared	Adj. R-squared	F-statistic	*p*-value
12527000	10825000	0.13586	0.058997	8.33272 on 7 and 371 DF	1.844e−09

time ($p > 0.05$). However, *time spent on foot* has a significant positive effect ($p < 0.05$). As the NTC was located in very close proximity to the participants' homes, they would often walk or spend less than 5–10 minutes in the commuter train to reach the NTC. While the time spent in the car was not statistically significant, during the interviews, a small number of participants did state that they would often use their car to access the NTC as they would prefer to do trip chaining by combining activities like working at the NTC, going to the gym, picking up or dropping off kids going home for lunch etc. as the NTC is located in the neighborhood along with other facilities. One participant stated in their interview:

> *" The oldest daughter started a new school. She's in seventh grade and walks to school on her own. But today I dropped her off. (How did you drop her off?) With the car. (So, you came here by car?) Yes."*

The results of the fixed effects model also showed that activities such as the *time spent on virtual meetings* has a significant positive effect ($p < 0.001$), while *time spent on everyday chores* does not have a statistically significant effect on *time spent working at the NTC* ($p > 0.05$). The NTC was often pictured as an alternative for working at home office as well working from the employer's office. As the NTC was equipped with required equipment for virtual meetings such as closed telephone booths, conference room and headphones, this enabled participants to engage in meetings with their colleagues remotely. During the interviews participants also stated that working at the NTC promoted a similar type of discipline that their employer's office promotes which allows them to work without being distracted by other household activities, especially for virtual meetings.

The fixed effects model also shed light on the variability across the participants in terms of their time spent working at the NTC. The estimates represent the individual-level effects. While some participants have statistically significant positive or negative effects on the time spent working at the NTC, others do not. For example, ID 3, ID 4, ID 8, ID 12, ID 13, ID 14, ID 15, ID 17, ID 18, ID 19, ID 29 and ID 34 have statistically significant positive effects on their time spent working at the NTC. ($p < 0.05$ or $p < 0.001$) after the controlling of the given explanatory variables. These particular participants were regulars at the NTC who spent a significant amount of time working there. Due to its prime location, several participants viewed the NTC as an alternative between their employer's office and home office, especially on days when they would attend external meetings to avoid commuting back to employer's office. One of the participants stated in their interviews:

> *"...I also think that sometimes when you are in meetings in the town it's not a good idea to go back to work (employer's office), but then you would be willing to come here (NTC) instead and work the rest of the day here"*

At the operational level, NTC access can be bundled with subscription products (for example, combined PT + NTC day-passes or flexible 'commute bundles' that include shared e-bike or on-demand shuttle credits), thereby aligning spatially-distributed workplace opportunities with modal options for the first/last mile. The observed positive association between walking time and NTC use implies that proximity-oriented hubs are particularly well-suited to complement active and micromobility modes within a MaaS package. At the institutional level, the findings highlight that MaaS integration is unlikely to be sufficient in isolation: employer policies (booking rules, allowances and norms around visibility and meetings) and the persistence of car trip-chaining must be addressed in parallel to realize modal shifts. We therefore view MaaS not as a single solution but as a set of deployable instruments, subscriptions, micromobility credits, dynamic routing and last-mile services, that, combined with employer incentives and local hub design, can enhance the viability and attractiveness of neighborhood telecommuting.

3.2. Which factors are associated to time spent working at the home office?

For the variable *time spent working at the home office*, the Hausman test *the fixed effects model is a better fit* for understanding the relative nature of time spent working at the home office and time spent on different modes, time spent on different activities and the variability across the individuals. The test yielded a p-value of 7.191e−08 which is less than 0.05.

Table 6 presents the results of the fixed-effects model. The results of the fixed effects model show that *time spent in car, train, bike, e-bike and foot seem to have a* significant negative effect on time spent working from the home office. This could be due to the fact that since participants were working from home, the travel time they recorded in their travel diaries was associated to personal travel and not

Table 6. Results of the fixed effects model for time spent working at the home office.

Time spent working at the home office *(Fixed-effects model: oneway (individual) effect within model)*					
Unbalanced panel: number of individuals = 27; number of observations per individual: 14–16 days; number of observations = 405					
Category	Variable	Estimate	Std. Error	t-value	Pr(>|t|)
Time spent on different modes	*Car*	−0.408	0.205	−1.993	0.046*
	Train	−0.970	0.166	−5.849	1.086e−08***
	Bike	−1.917	0.451	−4.246	2.756e−05***
	E-bike	−1.766	0.770	−2.294	0.022*
	Foot	−2.124	0.351	−6.059	3.359e−09***
Time spent on different activities	*Virtual Meetings*	0.217	0.098	2.211	0.027*
	Everyday Chores	0.444	0.123	3.601	0.0003608***
Variability across the individuals	*ID 1*	136.595	42.133	3.242	0.001**
	ID 2	84.748	38.074	2.226	0.026*
	ID 3	76.892	51.720	1.487	0.138
	ID 4	181.481	37.646	4.821	2.091e−06***
	ID 5	359.253	36.503	9.842	<2.2e−16***
	ID 6	300.138	37.151	8.079	9.279e−15***
	ID 7	252.862	37.910	6.670	9.302e−11***
	ID 8	104.458	39.227	2.663	0.008**
	ID 9	6.220	45.408	0.137	0.891
	ID 10	45.532	43.115	1.056	0.291
	ID 11	134.019	53.883	2.487	0.013*
	ID 12	111.090	37.919	2.930	0.003**
	ID 13	164.069	38.292	4.285	2.335e−05***
	ID 14	67.442	36.455	1.850	0.065.
	ID 15	216.205	38.626	5.597	4.237e−08***
	ID 16	27.715	35.822	0.774	0.439
	ID 17	233.141	36.295	6.423	4.087e−10***
	ID 18	116.411	41.738	2.789	0.005**
	ID 19	148.847	39.623	3.757	0.001***
	ID 20	160.550	56.818	2.826	0.005**
	ID 21	156.738	36.664	4.275	2.434e−05***
	ID 25	44.638	39.471	1.131	0.258
	ID 26	66.289	40.186	1.650	0.099.
	ID 27	109.025	42.265	2.580	0.010*
	ID 28	163.650	44.534	3.675	0.000***
	ID 29	160.508	37.773	4.249	2.716e−05***
	ID 34	121.478	41.099	2.956	0.003**

*Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.'*

Note: IDs were assigned to all 52 NTC participants. Of these, 27 fully completed the travel diaries, and their data were included in the analysis. The numbering in the table is not continuous because IDs for incomplete diaries were excluded.

Total sum of squares	Residual Sum of Squares	R-Squared	Adj. R-Squared	F-statistic	*p*-value
8759700	6451500	0.2635	0.19799	18.9617 on 7 and 371 DF	<2.22e−16

commute. Time spent on everyday chores also has a significant positive effect ($p < 0.001$). On one hand, there were participants who mentioned that working from home proved slightly less efficient as they were often distracted by household matters (running errands or picking up and dropping of children). On the other hand, some participants preferred their home office as an alternative for remote work as they could get household chores done while at home.

While working remotely was heavily regulated by the participants' employer, some of them negotiated with their managers to work from home at least 1 day a week before the NTC was introduced which allowed them to take meetings from home with their international as well as colleagues. As the results from the fixed effects model suggest, time spent on virtual meetings has a significant positive effect on time spent working at the home office ($p < 0.05$). Participants mentioned that they focussed better working from home compared to the NTC and more importantly, stated that as they had a well-equipped work from home set up that made working remotely more efficient:

'Work is very undisturbed and focused from home'.

'*If I need to sit in concentration, it can be better to sit at home to avoid getting interrupted. But it is important to have contact with work mates'.*

'The job hub (NTC) has a hard time competing with the "home hub". In general, I work remotely to save travel time. Everything is set up at home, I just need to sit down'.

The fixed effects model also shed light on the variability across the participants in terms of their time spent working at the home office. The estimates represent the individual-level effects. While some participants have statistically significant positive or negative effects on time spent working at the home office, others do not. For example, ID 4, ID 5, ID 6, ID 7, ID 11, ID 13, ID 15, ID 17, ID 20, ID 21, ID 27, ID 28 and ID 29 have statistically significant positive effects on time spent working at the home office ($p < 0.05$ or $p < 0.001$), after controlling the explanatory variables. Socio-demographic differences, home location or other unobserved characteristics contribute to this difference presented in the individual-level effects.

3.3. Which factors are associated to time spent working at the employer's office?

The Hausman Test yielded a p-value of 0.1145 and since the p-value is $0.1145 > 0.05$, we find that the random effects model is a better fit for understanding the relative nature of time spent working at the home office and demographic characteristics, time spent on different modes and time spent on different activities.

Table 7 shows the results of the random-effects model, along with the reference variables. The results indicate that the intercept term is statistically significant, indicating that there is a significant overall effect on time spent working at the employer's office ($p < 0.001$). Demographic characteristics such as gender, age-group, household size, number of children in the household, location of residence, type of residence and type of occupation do not have significant effects on time spent working from the employer's office this could be due to the small sample size as socio-demographic characteristics do not vary over time. Hence, the variability shown is due to the differences between individuals.

In terms of the time spent in travel modes, the results indicate that the that time spent in a car, train and bike has a significant positive effect on time spent working from the employer's office ($p < 0.01$). These

Table 7. Results of the random effects model for time spent working at the employer's office.

Time spent working at the employer's office *(oneway (individual) effect random effect model (Swamy-Arora's transformation))*					
Unbalanced panel: number of individuals = 27; number of observations per individual: 14–16 days; number of observations = 405					
Category	Variable	Estimate	Std. error	t-value	Pr(>|t|)
(Intercept)		405.103	119.922	3.378	0.000***
Gender	*The participant is a male*	−18.512	88.825	−0.208	0.834
	The participant is below 45 (reference)	N/A	N/A	N/A	N/A
Age group	*The participant is 45–50 years of age*	−144.216	122.639	−1.176	0.239
	The participant is 55–60 years of age	−139.901	82.141	−1.703	0.088.
Household size	*The participant lives in a two- person household*	−122.050	101.605	−1.201	0.229
	The participant lives in three person household and above (reference)	N/A	N/A	N/A	N/A
Number of children in the household	*The participant has no children in the household*	−101.122	106.606	−0.949	0.342
Location of residence	*The participant lives in Tumba*	−48.625	82.590	−0.589	0.556
	The participants live in Tullinge	−69.655	80.244	−0.868	0.385
	The participants do not live in Tumba and Tullinge (reference)	N/A	N/A	N/A	N/A
Type of residence	*The participant lives in a villa*	64.347	79.114	0.813	0.416
	The participant lives in an apartment (reference)	N/A	N/A	N/A	N/A
Type of occupation	*The participant is an engineer*	−76.137	84.655	−0.899	0.368
	The participant is a manager	−64.877	79.815	−0.813	0.416
	The participant is an IT professional or other (such as HR, academic etc.) (reference)	N/A	N/A	N/A	N/A
Time spent on different modes	*Car*	0.918	0.300	3.060	0.002**
	Train	1.976	0.241	8.215	<2.2e−16***
	Bike	2.167	0.660	3.284	0.001**
	E-bike	0.911	1.092	0.834	0.404
	Foot	3.763	0.508	7.401	1.35e−13***
Time spent on different activities	*Virtual meetings*	−0.395	0.141	−2.814	0.004**
	Everyday chores	−0.352	0.171	−2.061	0.039*

*Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05.*

Total sum of squares	Residual sum of squares	R-squared	Adj. R-sSquared	F-statistic	*p*-value
21835000	14861000	0.31938	0.28948	181.762 on 17 DF	<2.22e−16

three modes were the topmost preferred modes for commute for the participants, the commuter train being the most popular option. However, participants often complained about the long travel time with the commuter train, traffic jams during rush hours when traveling by car, time spent looking for parking spots and needing to wake up early to avoid rush hour traffic. Additionally, the results also indicate that time spent on everyday chores has a significant negative effect ($p < 0.05$). Participants often mentioned that it was difficult to balance their work and free time due to the amount of time spent in commuting on employer's office days. One such participant stated:

'It is very tiring and tolling with the travel time and having time for private life'.

As mentioned in the previous sections, for most participants the commute time was a hassle and they often mentioned that working at the NTC would help 'save time'. While the participants had higher expectations in terms of using the NTC more often, the norms and regulations at their workplace prevented them from doing so. Some participants also went through changes in the occupational role which led them to spend more time working at their employer's office and reduce their time working remotely. Once such participant stated:

"Got a new role in the team, an operational role and being a product owner. Must make sure others do their jobs, not just me doing my job. Then it felt better to be at work./Needed to have more meetings. Then it did not work so well."

Most of the participants had the habit of doing hands on work with their colleagues when working from the employer's office and reserving their online meetings on the days they worked remotely) either from the NTC or from their home office). This is clearly reflected in the results of the random effects analysis as the time spent on virtual meetings has a significant negative effect on work time. ($p < 0.01$). Additionally, some participants thought working from the employer's office could not compete with working from the NTC or their home office as their employer's office work set was highly well equipped. While the NTC reduced long commutes, participants' continued reliance on private cars for trip-chaining reflects the challenges in promoting sustainable transport behaviors. This underscores the potential for integrating NTCs with MaaS platforms to enhance their accessibility and sustainability (Ringenson & Kramers, 2021). For instance, MaaS services could enable the active use of alternatives to private cars, such as public transport, bike-sharing, or ride-sharing services. Tailored incentives, such as grocery discounts or free gym memberships, could further promote the use of sustainable travel modes while positioning NTCs as hubs for local communities. NTCs combined with MaaS services could also address challenges such as congestion and overcrowding during peak travel hours, making them a viable option for promoting local lifestyles and reducing traffic and public transport pressure.

4. Conclusions

This paper uses a comprehensive panel dataset collected via a three-week time-use diary, complemented by qualitative interviews, to understand the impacts of an NTC living lab. The study provides deeper insights into the relationships between individuals' activities, travel behavior, and their choice of workplaces. The results demonstrate significant individual and day-to-day variability, indicating the absence of a 'typical' behavioral pattern. This highlights the value of longitudinal approaches in understanding learning processes and trade-offs in a multiday context. By combining qualitative and quantitative data, this analysis sheds light on the differences between participants' expectations for the NTC and their actual usage during the three-week time-use diary period. Factors such as travel preferences, time spent on different activities and existing workplace norms and roles significantly influenced how participants utilized the NTC.

The study highlights three key findings. First, participants' choices between the employer's office, home office and NTC were influenced by a combination of organizational norms, logistical constraints and personal preferences. While the NTC provided a convenient alternative for reducing commute times and integrating work with personal errands, its adoption was limited by employer requirements for physical presence and the additional planning effort compared to home offices. These findings emphasize the importance of aligning NTC features and policies with diverse user needs to enable broader adoption.

Second, although the NTC offered proximity and convenience, many participants continued to rely on private cars for trip-chaining purposes, such as combining work-related travel with grocery shopping, gym visits and child drop-offs. This persistent car dependency highlights a critical barrier to sustainable travel. Addressing trip-chaining needs through multimodal mobility solutions, such as integrating NTCs within MaaS deployment frameworks, could encourage a shift toward active or shared transport modes. In this regard, NTCs can function as complementary components within coordinated MaaS systems, where workplace access, public transport subscriptions and micromobility services support first- and last-mile connectivity. However, as the findings indicate, such integration must be accompanied by supportive employer policies and organizational norms to translate potential into measurable modal shifts.

Third, the study revealed substantial day-to-day variability in workplace and travel choices and notable discrepancies between participants' stated intentions and recorded behavior. While many participants expressed interest in using the NTC to save time and improve work-life balance, their actions often did not align with these intentions, reflecting the complexities of real-world decision-making. The results demonstrate that NTCs can serve as a middle ground between employer offices and home offices, reducing commute times while maintaining access to professional work environments. However, their effectiveness depends on addressing logistical barriers and aligning organizational policies.

Participants indicated that the NTC was particularly useful for tasks requiring focus, such as virtual meetings, but limited use of the NTC was often attributed to workplace policies requiring physical presence and the additional effort involved in planning a day at the NTC compared to working from home. Since the conclusion of this living lab, workplace norms have shifted significantly due to the COVID-19 pandemic, with remote working becoming more widespread. Although this analysis is based on pre-pandemic data, follow-up interviews indicate evolving attitudes toward remote and hybrid work arrangements.

While the findings are context-specific and based on a limited participant group within a single living-lab deployment, they provide insight into the mechanisms through which neighborhood-based telecommuting may influence daily mobility practices. Building on these insights, future research should expand sample sizes, include more demographically diverse participant groups, particularly younger age cohorts and incorporate longer diary periods and post-pandemic data to better understand how shifting workplace norms shape telecommuting adoption over time. This study provides valuable baseline evidence from a pre-pandemic living-lab deployment and contributes to understanding how neighborhood telecommuting centers, when aligned with MaaS deployment and employer policies, may support hybrid work models and more sustainable urban mobility.

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Author contributions

Bhavana Vaddadi: Original draft preparation, Conceptualization, Methodology, Writing, Visualization, Data curation and analysis; Chengxi Liu: Methodology, Writing, Data Analysis; Yusak Susilo: Original draft preparation, Writing-Reviewing and Editing, Supervision.

Disclosure statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability statement

The anonymized time-use diary and interview datasets generated and analyzed during the current study are available from the corresponding author (bhavana@kth.se) upon request.

Generative artificial intelligence (AI)

Chat GPT 4.o was used to grammatically improve the text in this manuscript.

Ethics statement

This study involved non-interventional behavioral research conducted within a living-lab setting. In accordance with institutional and national regulations governing social science research in Sweden, formal ethical approval was not required. All participants provided informed consent prior to participation, and all data were anonymized before analysis.

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