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Gender Gaps in Mode Usage, Vehicle Ownership, and Spatial Mobility When Entering Parenthood: A Life Course Perspective

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Abstract: Entry into parenthood is a major disruptive event to travel behavior, and gender gaps in mobility choices are often widened during parenthood. The exact timing of gender gap formation and their long-term effects on different subpopulations are less studied in the literature. Leveraging a longitudinal dataset from the 2018 WholeTraveler Study, this paper examines the effects of parenthood on a diverse set of short- to long-term outcomes related to the three hierarchical domains of mobility biography: mode choice, vehicle ownership, spatial mobility, and career decisions. The progress of the effects is evaluated over a sequential set of parenting stages and differentiated across three subpopulations. We find that individuals classified as "Have-it-alls", who start their careers, partner up, and have children concurrently and early, significantly increase their car uses two years prior to childbirth ("nesting period"), and they then relocate to less transit-accessible areas and consequently reduce their reliance on public transportation while they have children in the household. In contrast, individuals categorized as "Couples", who start careers and partnerships early but delay parenthood, and "Singles", who postpone partnership and parenthood, have less pronounced changes in travel behavior throughout the parenting stages. The cohort-level effects are found to be driven primarily by women, whose career development is on average more negatively impacted by parenting events than men, regardless of their life course trajectory. Early career decisions made by women upon entering parenthood contribute to gender gaps in mid- to longer-term mobility decisions, signifying the importance of early intervention.

Keywords: life course; mobility biography; parenthood; mode use; gender gap; car ownership; spatial mobility

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1. Introduction

Our daily transportation mode choice (driving, biking, walking, etc.) bears substantial consequences for both the transportation system and the environment in the long term. The process of making mode choice decisions on a daily basis requires considerable effort, leading individuals to develop a repeated routine around their travel behavior, often without much conscious consideration of alternative mode options [1]. Clark et al. and Chatterjee et al. further support this notion and demonstrate that these habitual travel behaviors are more likely to be interrupted by a contextual change to an individual's life situation [2,3]. Hence, gaining insight into the key factors associated with the formation and alteration of these habits is therefore crucial for policymakers in designing effective strategies to encourage sustainable transportation choices, as well as for planners to better anticipate enduring trends and transitions in travel mode usage.

Travel behavior studies have utilized the mobility biography approach to capture the dynamics of travel choices over the life course with a focus on the influence of life

events on individuals [1,4]. With the concept of mobility biographies, life events are linked to an individual's mobility-related decisions from a life course perspective. Among key events that are transport-relevant, entry into parenthood has been identified as having a significant impact on travel behavior. A large body of research provides strong evidence that the parents with young child(ren) tend to exhibit an increase in both car acquisition and car use [5–8]. However, recent literature suggests that this parenting effect on travel behavior can be influenced by a number of factors, including the parents' age, income, education level, as well as the location of their home and workplace, and that increased car-dependency may just be one of many patterns that can emerge [5,9–11]. When looking at gender differences in travel mode choices and car accessibility during parenthood, women are more likely to experience changes in travel behavior than men [7,12–15].

While most transportation literature that studied the effect of having a child focuses on the aggregated change in travel behavior either across a broad population or within a specific subpopulation based on static sociodemographics, limited research has investigated differences that may exist between subpopulations from a long-term perspective. Even less research exists on gender gaps in travel during parenthood among different subpopulations.

To improve the understanding of subpopulation differences in the role of parenthood from a long-term context, longitudinal data are needed for studying factors associated with the formation and persistence of gender gaps in mobility-related decisions over time among heterogeneous populations. In this paper, we rely on the life course cohorts previously derived based on social sequence clustering [16] of the life history calendar portion of the WholeTraveler Transportation Behavior study survey conducted in the San Francisco Bay Area in 2018 [17]. In previous work, we identified that career and family-related milestones, particularly those occurring at an earlier life stage, exhibit a stronger association with changes in mode-use behavior. Moreover, our findings reveal that the relative order of those events can also impact individuals' mode choices [16].

Following the same mobility biography approach, this study aims to take a dynamic perspective on travel choices over an individual's life course with a specific focus on the influence of parenthood on travel behaviors. As the family forming timeline for most people progresses from "no child" to "nesting", then to "having children at home", we differentiate the effect of being in one parenting stage relative to its previous stage. This analytical approach enables us to understand the progression of travel behavior and distinguish the turning points in mobility and career decisions and gender gap formation.

To achieve this, we employ linear regression models to estimate the marginal effects of parenting stages on a comprehensive set of short-term to mid- and long-term outcome variables associated with the three hierarchical domains of mobility biography. These outcome variables encompass diverse aspects of mobility decision making, such as choosing different travel modes (driving, public transportation, and walking or biking), car ownership, spatial mobility as indicated by public transit availability, and career decisions. Through the analysis, we aim to address the following research questions: (1) To what extent does parenting alter the short- (mode use), mid- (vehicle ownership), and long-term (residential location) mobility decisions across subpopulations with different life course trajectories? (2) To what extent does parenting alter career decisions across subpopulations with different life course trajectories? (3) Are these differences further elucidated by differences across gender? By addressing these research questions, we seek to contribute to the existing body of knowledge, advancing our understanding of the complex interplay between parenthood, life course trajectories, mobility decisions, career choices, and gender gaps.

The paper commences with a brief review of relevant studies examining the parenting effect on travel behaviors and gender differences in mobility decision making using the mobility biography approach. Details about the WholeTraveler Transportation Behavior Study survey, the design of the life history calendar, the derivation of life course cohorts, and the model specifications to estimate the marginal parenting effects are presented in Section 3. The results from the model estimations and interpretations are discussed in Section 4. The Section 5 that links the main takeaways with the literature and discusses

the limitations to our study are shown in Section 5. Finally, the paper concludes with a Section 6 that highlights the policy implications and future research.

2. Relevant Literature

The theoretical foundation of mobility biographies is that travel behaviors are generally considered habitual, and people do not tend to change their travel patterns on a daily basis [18–20]. However, habitual travel behavior may be disrupted when major life events occur, providing opportunities to influence mobility decisions [21–27]. The extent and manner in which individuals change their travel mode in response to a specific life event depend on the long-term decision contexts within which these decisions are made. This long-term decision context consists of an individual's current situation, past experiences, and future plans [21], and this context varies across the population.

Traditional travel behavior studies have predominantly relied on the use of cross-sectional survey data to examine mobility decisions and their correlation with concurrent individual attributes, attitudes, and the built environment at a point in time (as discussed in [26,28,29]). However, the dynamic and multi-dimensional decision context can only be revealed in a long-term life history rather than via a life cycle stage lens in which the life cycle stages are defined statically at the moment an event occurs. Schoenduwe et al. conducted an extensive review of transportation studies employing the "mobility biography" approach to analyze the dynamics of travel choices over the life course, providing a longer-term decision context [28]. In a key study within this domain, Beige and Axhausen investigated the interdependence between various life course dimensions, such as changes in education, employment, and mobility behavior [30]. Rau and Manton introduced the concept of "mobility milestone", highlighting the important role of transport-related structural conditions in shaping travel behaviors through major life events [31]. Haas et al. applied a latent transition analysis to examine the effect of life events and other exogenous variables on transitions between different travel patterns [32]. Their findings suggest that individuals who strictly adhere to unimodal travel modes, such as car or bike usage, are less likely to alter their travel patterns in response to life events than those who engage in multimodal travel.

A mobility biography typically consists of three hierarchical domains: travel mode usage (driving, public transportation, and walking or biking), car ownership, spatial mobility (in our case, indicated by public transit availability), and career decisions. Spatial mobility and career decisions at the top level of the hierarchy represent the longest-term decisions that may further condition the short-term travel behaviors and/or serve as fundamental triggers of other related events in the accessibility and mobility domains [33–35]. Dieleman and Mulder and Adhikari et al. have provided evidence showing that residential relocation frequently coincides with significant life events related to both professional and family domains, such as marriage, childbirth, and job change [36,37]. Furthermore, changes of residence may impact the availability and choice of travel mode. Career decisions may also reinforce the labor divisions in the household, which was previously found as an underlying driver of gender gaps in travel behavior [12]. Even though it is beyond our scope, a growing body of literature has started to look at the effect of workplace relocation on commuting behavior, as well as commuting satisfaction and subjective well-being [38,39].

Among key life milestones covered in mobility biography studies, the transition to parenthood is found to have an important impact on all aspects of an individual's life, and gender gaps in mobility and career decisions are evident as the traditional gendered division of labor remains operative in households [8,14,40,41]. While some studies found that being a parent is associated with a decrease in public transit usage and cycling and an increase in car use and ownership [8,15,26,32,42], other studies showed that some parents maintained a similar travel behavior to before having children, or even increased walking and biking [9]. A number of factors can influence the impact of parenthood on travel behavior, including parents' age, income, education, as well as the location of their home and workplace. For example, McCarthy et al. found that individuals living in a city, having

a lower income, having a partner who works part-time or not at all, and not having a second child have a lower likelihood of shifting toward a car-centric lifestyle after childbirth [10]. In a recent California study by Chakrabarti and Joh, childcare infrastructure and greener mode availability are shown to play a part in the decision to change travel behavior in response to the childbirth event [7].

After entering parenthood, care-related journeys become a significant part of everyday mobility in the household [13]. Women are more likely to be responsible for childcare and household tasks, which can lead to an increase in car use by these women [1,12,15]. It is found that the birth of a first child has a significant effect on women's decision to shift car accessibility from shared access to full access [15]. With the need to juggle multiple duties in their daily lives, mothers tend to increase their car dependence more than men [6]. Scheiner summarized underlying drivers of gender differences in travel behavior: spatial ties imposed by household work and caregiving duties make women travel shorter distances; women tend to have more complex trip chaining in order to gain efficiency; more variable activities with more anchor points; and all above reasons encourage women to use flexible modes of transport such as the car to juggle all their duties [1,12].

It is worth noting the reliability concern of conducting mobility biography studies, as the data collection typically relies on retrospective surveys, where individuals are asked to recall changes in their lifestyle domain, accessibility domain, and mobility domain in the past [43]. In most cases, major life events, such as marriage, childbirth, employment, and relocation, are remembered reliably. The acquisition or disposal of means of transport does not happen on a daily basis; thus, recall is less likely to be biased. However, recollection of daily travel patterns may not be as accurate, but any changes in travel behavior triggered by disruptive events might be remembered better [44].

3. Data and Method

3.1. Survey Data Description

We use data collected through the WholeTraveler Transportation Behavior Study, which is part of the U.S. Department of Energy's Systems and Modeling for Accelerated Research in Transportation (SMART) Mobility Consortium. The survey was administered in the nine core counties in the San Francisco Bay Area, California through a survey implementation firm with expertise in large-scale representative sampling and outreach. With a target sample size of 900 respondents, invitations to respond to an online survey were initially sent to 30,000 residential addresses via a mailed letter, given an expected response rate of around 3%. (We set our target sample size at 900 respondents based on two facts. First, we reviewed previous published surveys of technology adoption behavior and use and found their sample sizes to range widely from about 700 to 9000 (as shown in [45,46]). Second, we considered the methodological work that shows that even for a large population, there is little to be gained in terms of margin of error by increasing the sample size beyond 1000 (see, e.g., the discussion in [47]). It quickly became apparent that the response rate was trending lower than anticipated. In response, a reminder postcard was sent to non-respondents of the initial 30,000 households, and the invitation letter was mailed to an additional 30,000 randomly selected residential addresses. Of the 60,000 households that were sent invitations, 997 completed the survey.

Data collected from this survey have been successfully used to study emerging vehicle technology and service adoption [48], travel mode choices [49,50], and the impact of e-commerce on travel demand differentiated by households with and without children [51]. While the portion of female and male respondents closely aligns with the Bay Area population, highly educated and high-income respondents are disproportionally represented in the sample. Overall, the sociodemographics of the WholeTraveler sample are consistent with those of other similarly scaled S.F. Bay Area transportation studies [52–54]. A more detailed discussion regarding the representation of the survey sample and variable defi-

nitions are included in [16]. A breakdown of the sociodemographic characteristics of the WholeTraveler sample is presented in Appendix A.

The retrospective life history calendar portion of the survey design gathered longitudinal data on mobility-related behavioral changes and major life events and circumstances occurring around those changes. Specifically, the respondents were asked to indicate their household composition (childbirth, relocation, cohabitation, and household size), education and employment status, public transit availability, transportation modes, and vehicle ownership on an annual basis starting at age 20 and up to age 50. Respondents less than 20 years of age were not asked to answer the life history calendar portion of the survey. Key variables concerning regularly used (used at least twice per week) transportation modes, car ownership, availability of public transportation, and employment status are used in this study.

Prior to analysis, we cleaned the data to account for missing observations and erroneous responses, which removed 172 respondents. We then restrict the analysis to the 17,777 annual observations from the 569 respondents who were aged 35 or older at the time they took the survey (in 2018) as the sample of the panel regressions, which accounts for 71% of the remaining data. This selection ensures that we observe complete responses between ages 20 and 35 and thus capture a life period that presents the greatest heterogeneity among the population [30,55]. Our sample size may seem small for a survey study; however, our sample size is consistent with previous life history calendar studies in transportation and mobility research reviewed by [4,28,31].

3.2. Description of Life Course Cohorts

In our previous paper [16], we used sequence clustering to construct cohorts of respondents who share similar life course trajectories. Around 85 percent of the respondents fall into three cohorts (listed below and visually described in Figure 1).

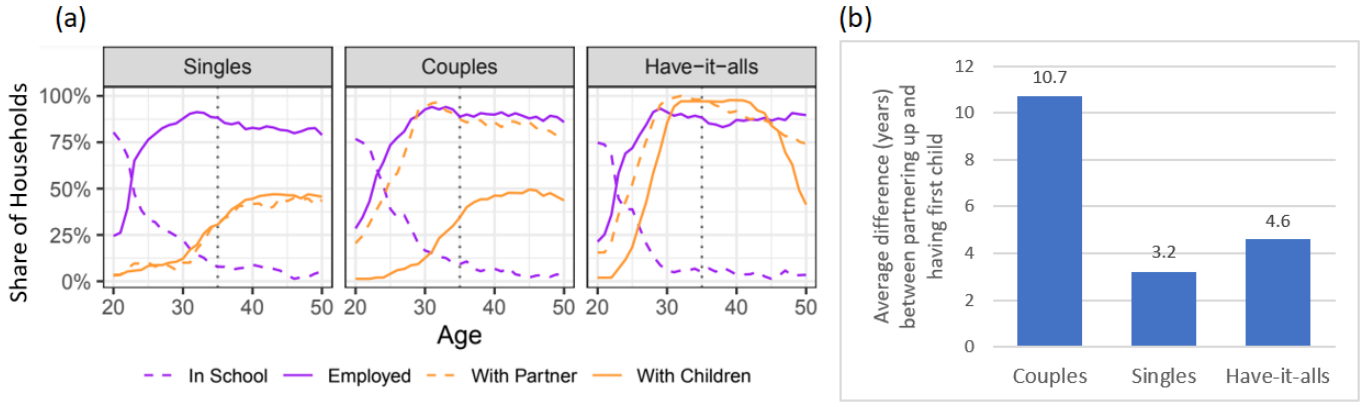

Figure 1. Life course patterns of family and career status in the three major life course cohorts analyzed in this study (**a**), and the average difference in years between partnering up and having a first child for each of the three cohorts (**b**).

- Singles (40% of the sample) tend to finish school and enter the workforce at an earlier age while opting to defer or forgo having a partner or children.
- Couples (27%) tend to finish school, work, and partner up at an earlier age while opting to defer having children.
- Have-it-alls (18%) finish school and enter the workforce early in life, and partner up and have children only very slightly thereafter.

Only these three cohorts are included in our analysis because they have a relatively large sample size and exhibit distinct family patterns, which is the focus of this paper. Specifically, while they all finish school early and become employed early, they differ in the timing of having a partner and children. Since decisions made in the past can affect

the options for long-term decisions in the future, restricting the analysis to these three cohorts that share similar school and career trajectories could help minimize the influence associated with decisions made in the career domain on later decisions in the family domain. Thus, the analysis in this study is restricted to these three cohorts.

3.3. Empirical Analysis Specifications

The research questions we aim to address in this paper are: (1) To what extent does parenting alter the short- (mode use), mid- (vehicle ownership), and long-term (residential location) mobility decisions across subpopulations with different life course trajectories? (2) To what extent does parenting alter career decisions across subpopulations with different life course trajectories? (3) Are these differences further elucidated by differences across gender?

There are seven separate outcome variables of interest (Y_{igt}), which are defined for each person i of age g in year t:

- Three binary choices of transportation modes (more than twice per week on average): drive own car ("Drove"), use public transit ("Public Transit"), walk/bike ("Bike or Walk").
- Two vehicle ownership variables ("NumCar" and "Nor.NumCar"): total number of cars owned and the same quantity normalized by the number of household members above driving age.
- One location-characteristic variable ("PT available"): whether public transit (PT) was available at the residence location, regardless of usage.
- One employment variable ("Employ"): whether the person was employed (worked at least 35 h per week on average).

We run ordinary least squares panel data regressions separately for each outcome variable to estimate the parenting effect on that outcome variable. In the analysis, we separate the parenting event era into two stages: (1) "nesting", defined as the two years prior to the year in which the first child entered the household (To identify the mobility-relevant planning period around the child event, we examine the predictors to the event of "moved, or place of school or work changed" recorded in the life history calendar survey using logistic regression. It is found that two years prior to the first childbirth significantly predicts the move or changes to school or work location even after controlling for other events corresponding to school or work changes and relationship changes.), and (2) "having a child(ren)", defined as having at least one child less than 18 years old at home. We make the distinction between the "nesting" period and the "having a child(ren)" period because our data indicate that people tend to move two years prior to having their first childbirth.

Including this preparation period for parenting can help distinguish the turning points of mobility and career decisions. As the family-forming timeline for most people progresses from no child to nesting, then to having children at home, considering both "nesting" and "having a child(ren)" in the regression can differentiate the effect of being in one parenting stage relative to its previous stage (i.e., "nesting" relative to no child; "having a child(ren)" relative to nesting). In contrast to other studies that focus on the before and after changes of a given event (e.g., [9,56]), our approach estimates the marginal effects averaged over the whole period (or era) of the two parenting stages relative to its previous stage.

We estimate the marginal effects differentiated across the life course cohorts ($cohort_c$) defined by the clustering analysis (Equation (1)).

$$Y_{igt} = \alpha_i + \sum_c (\beta_{c,1} ChildNest_{it} \cdot cohort_c + \beta_{c,2} ChildiHome_{it} \cdot cohort_c) + \delta_g + \varepsilon_{it} \quad (1)$$

$ChildNest_{it}$ is a binary variable that equals one when the respondent (i) is in the "nesting" or having at least one child under the age of 18 at year t, and zero otherwise. $ChildiHome_{it}$ is a binary variable that equals one when the respondent (i) has at least one child under the age of 18 in the household at year t, and zero otherwise. We incorporate a person-fixed effect (α_i) to account for individual-specific characteristics that remain

constant over time, effectively controlling for any inherent differences among individuals. Additionally, an age-fixed effect (δ_g) is included to capture age-specific factors that are experienced by all individuals. The error terms are assumed to follow an independently and identically distributed (IID) normal distribution. To account for serial correlation across time observations within individuals, we cluster the standard errors of the estimates at the individual level. This layered specification of parenting eras (i.e., "*ChildNest*" and "*ChlidinHome*") allows for differentiating the effect of one stage relative to its previous stage as one person progresses from no child (the omitted category) to nesting, to having children at home. Here, the parameter $\beta_{c,1}$ captures the marginal parenting effect during the nesting period relative to the "no child" period, and $\beta_{c,2}$ captures the marginal parenting effects during the child-in-home period relative to the nesting period.

To identify the potential gender effects of parenting within life course cohorts on outcome variables, we add female interaction terms with both parenting eras in the model specification, as shown in Equation (2).

$$\begin{aligned} Y_{igt} = \alpha_i + \sum_c \quad & (\beta'_{c,1} ChildNest_{it} \cdot cohort_c + \beta'_{c,2} ChildiHome_{it} \cdot cohort_c) \\ & + \sum_c (\gamma_{c,1} ChildNest_{it} \cdot cohort_c \cdot fem_i + \gamma_{c,2} ChildiHome_{it} \cdot cohort_c \cdot fem_i) + \delta_g + \varepsilon_{it} \end{aligned} \tag{2}$$

where fem_i is an indicator variable equal to one if respondent i identifies as female, and zero otherwise. Here, the parameters $\beta'_{c,1}$ and $\beta'_{c,2}$ capture the parenting effects of the male respondents, and $\gamma_{c,1}$ and $\gamma_{c,2}$ represent the marginal effects of the female respondents relative to their male counterparts in the same cohort. In order to avoid the confounding effects on car ownership resulting from child(ren) in the household reaching driving age (16 years old), time periods after children turned 16 years old are excluded from the analysis (supporting information available upon request).

3.4. Summary Statistics

Table 1 provides the summary statistics of the life history data used in our analysis, broken down by cohort and gender. Besides variables for "# vehicles in the household", "Normalized # vehicles in the household, "Number of modes used", and "Age in Lifecycle Calendar"), all other variables are binary variables. The mean value indicates the average portion of the life history calendar where the corresponding subpopulation experienced the given event. Equivalently, the mean value can also be interpreted as the average fraction of the subpopulation that experienced the given event between age 20 and age 50. The respondents, on average, were employed during the majority of the time period (70% to 85%) covered in the life history. However, we find a significant difference in employment status between women and men in all three cohorts. Men, on average, have a higher employment rate than women, and the difference is especially considerable among "Have-it-alls". We further investigate the employment status during 30 to 35 years of age of each respondent, which is the period that many key family and career events occur concurrently. An even greater discrepancy in employment status between men and women is found in "Have-it-alls" from 30 to 35 years of age, which suggests that women in "Have-it-alls" likely play the primary childrearing role in the household and may be more likely than their male counterparts to give up their job once children enter the home.

When it comes to car ownership, men on average have higher car ownership between the ages of 20 and 50 than women, except for "Have-it-alls" where women have higher car ownership between the ages of 20 and 50 than men. After normalizing the number of vehicles by the number of household members above driving age, a similar finding holds true. More than 80% of respondents within each cohort and gender group indicated that public transit was available for regular use, whether or not it was used. Most respondents used a personal vehicle as a regular transportation mode (two or more times per week), and relatively few respondents reported taking public transit and walking or biking regularly. In terms of the level of multimodality, it ranges between 1.06 and 1.23 modes in a given year across cohort and gender groups, with significant differences between women and men in "Couples" and "Have-it-alls", but not in "Singles".

Table 1. Life History Calendar Summary Statistics *.

Variables	Couples		Singles		Have-It-Alls	
	Female $N = 73$	**Male** $N = 76$	**Female** $N = 115$	**Male** $N = 111$	**Female** $N = 40$	**Male** $N = 60$
Nesting	0.03	0.04	0.03	0.03	0.07	0.07
Has Child (<18 y.o.) in house	0.14	0.28	0.22	0.22	0.60	0.61
Employed (≥35 h/wk avg) in the year	0.78	0.82	0.76	0.79	0.70	0.85
Employed between 30 and 35 y.o.	0.91	0.95	0.84	0.89	0.67	0.98
# vehicles in the household	1.53	1.64	1.33	1.39	1.80	1.61
Normalized # vehicles in the household	0.83	0.83	0.84	0.86	0.91	0.81
Drove regularly (2+ time/wk)	0.68	0.71	0.60	0.66	0.76	0.71
Took public transit regularly	0.26	0.28	0.34	0.29	0.15	0.29
Walked or biked regularly	0.23	0.22	0.23	0.21	0.14	0.18
Number of modes used	1.19	1.23	1.18	1.19	1.06	1.19
Public transit available	0.85	0.88	0.84	0.83	0.88	0.80
Age in Lifecycle Calendar	33.07	33.69	33.36	33.50	33.49	33.86

* The table provides the mean values of individual-level variables.

Figure 2 illustrates how different mode use and car ownership patterns evolve within each cohort in the life history calendar. Respondents reported increasing regular use of a personal vehicle as they grow older, while there was a decreasing trend in taking public transit and active modes, such as walking and biking, over time. When taking a deeper look at the driving pattern across cohorts, "Singles" started driving more after the age of 20, and the car usage remained constant until it started to drop at age of 45; "Couples" increased their car usage consistently throughout their life between 20 and 50 years old; "Have-it-alls" exhibited a substantial increase in car use between the ages of 20 and 35, and then their car use remained relatively steady. In plot (b), the number of vehicles in the household increased during the period covered under the life history calendar for all cohorts, with the exception that the car ownership of "Have-it-alls" actually decreased after turning 45 years old. As the number of vehicles owned in the household is likely correlated to the household size and household composition, we also plot the normalized number of vehicles trend (shown in light blue, with a corresponding y-axis on the right-hand side). Interestingly, the dark blue and light blue lines overlap with each other very closely for "Couples", which suggests that when Couples partner up, the partner tends to bring an additional vehicle to the household.

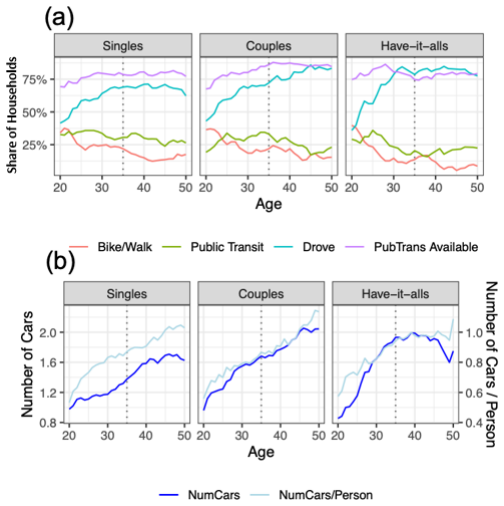

Figure 2. Life course patterns of regularly used modes and public transportation availability (**a**); the number of cars and per-person number of cars in the household (**b**), with dark blue line corresponding to the left y-axis and light blue lines corresponding to the right y-axis.

4. Results

4.1. Effect of Parenting on Mobility and Career Decision by Cohort

The marginal effects $\beta_{c,1}$ and $\beta_{c,2}$, estimated from Equation (1), are the change of the mobility outcomes averaged over a specific parenting era relative to the preceding era. For binary outcomes such as mode choice, public transit availability, or employment status, these coefficients can be interpreted as the percentage point change in the probability of the outcome occurring during this parenting era relative to the preceding era. For the number of cars, these coefficients represent a marginal change in number of cars during this parenting era relative to the preceding era. We explicitly account for the age effect by controlling for it in our analyses as a fixed effect, so our results are meant to represent the effects of parenting events above and beyond the underlying overall socioeconomic status evolution with aging.

Figure 3 summarizes the regression results for each mobility outcome variable (labeled in columns) by cohorts (labeled in rows), with the hollow bars indicating results that are not statistically significantly different from zero and solid bars indicating estimates that are significant at the 10% level or smaller. From left to right, the columns are arranged in the order of short-term, mid-term, then long-term mobility and career decisions.

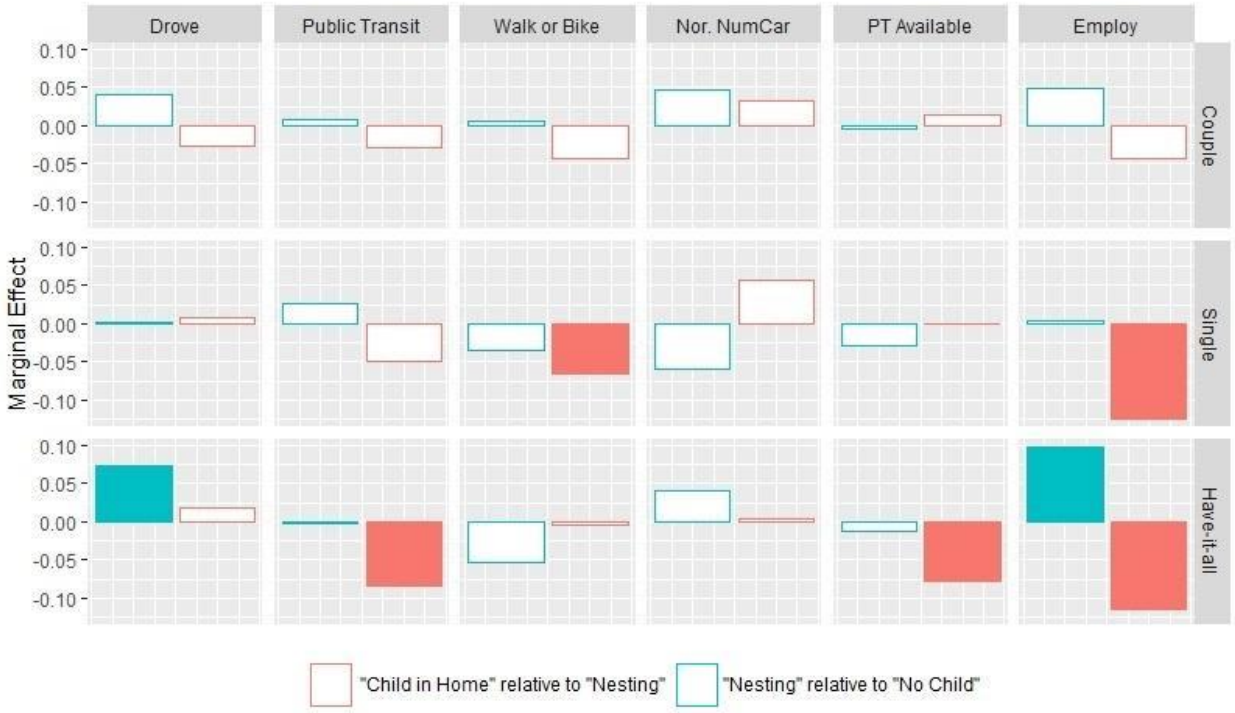

Figure 3. Marginal effects of "Nesting" and "Child in Home" by cohorts. Refer to the column variable definition in Section 3.3. Solid colors indicate significant effects at 10% level.

During the nesting period, no significant change of modes takes place relative to prior to the nesting period, except that driving significantly increases by 7.2 percentage points for the Have-it-alls. The total number of vehicles in the households all significantly increases by 0.27 to 0.33 cars. However, judging by per-person car ownership, the changes are not significant. All three cohorts do not show significant movement between transit-rich and transit-poor areas, as indicated by the changes in public transit availability. There is an increase in employment for Have-it-alls, but no change in employment status for Couples and Singles.

After the child enters the household, the parenting effects are more heterogeneous across the cohorts. Couples, on average, do not further change their mode use, car ownership, home locations, or employment status. Singles further reduce active mode usage

(walk/bike) and employment. Have-it-alls, on average, tend to move to a transit-poor area (indicated by a 7.7 percentage point reduction in their reported transit availability) and simultaneously reduce their public transit use by 8.4 percentage points. Employment for Have-it-alls is reduced by 11.4 percentage points, which offsets the increase we observed during the nesting era and results in an overall decrease in employment over the two parenting events. Overall, car use and per-person car ownership do not change in this parenting era relative to the nesting era across all cohorts.

4.2. Gender Gaps on Mobility and Career Decision by Cohorts

The cohort-level average treatment effects may mask the different gender behaviors, which are further explored in this section. In Equation (2), the parameters $\beta_{c,1}$ and $\beta_{c,2}$ capture the parenting effects of the male respondents, and $\gamma_{c,1}$ and $\gamma_{c,2}$ represent the marginal effects of the female respondents relative to their male counterparts in the same cohort. Figures 4 and 5 summarize the regression results by cohorts for male and female respondents, respectively. Note that the interpretation of the bars in Figure 5 should be the marginal female effect relative to the effect of their male counterparts shown in Figure 4.

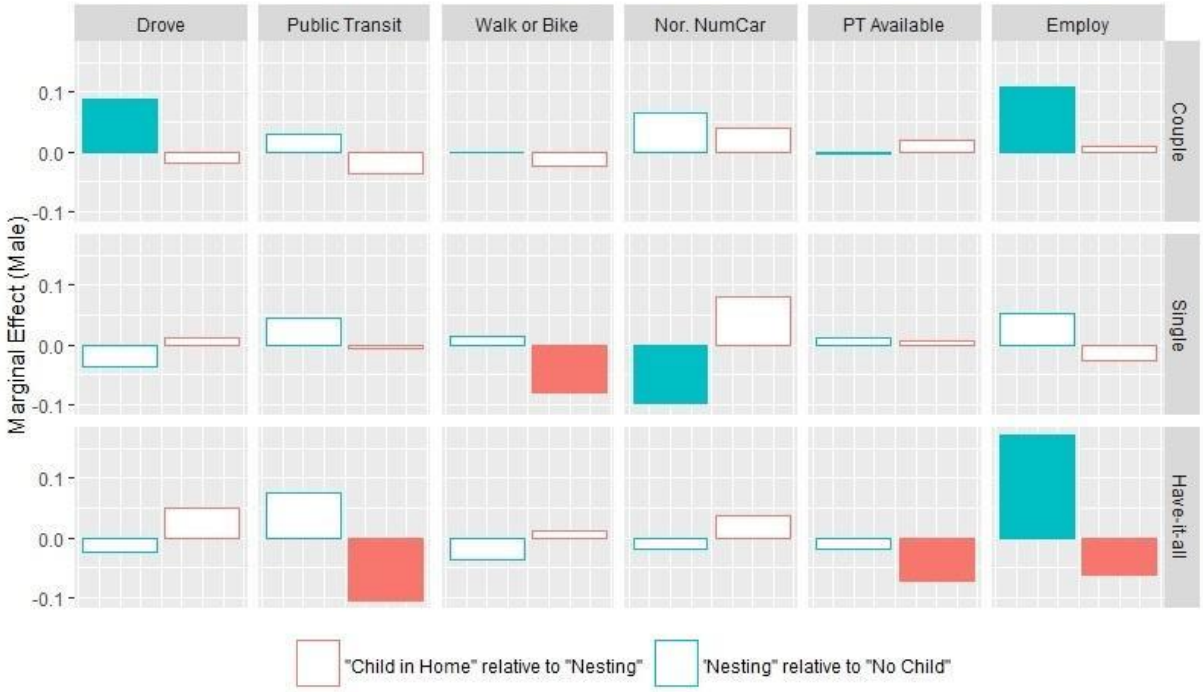

Figure 4. Marginal effects of "Nesting" and "Child in Home" for men by cohorts. Refer to the column variable definition in Section 3.3. Solid colors indicate significant effects at 10% level.

During the nesting phase, male Singles tend to reduce per-person car ownership (0.10 car/person less), which suggests that male Singles' households tend to shed a car. Female Have-it-alls, on the other hand, show a larger increase in per-person car ownership (0.15 car/person more) than their male counterparts during the nesting phase, implying that female Have-it-alls households often acquire additional cars while preparing for the birth of their first child. Unlike the cohort level average behavior in the Couples cohort, male respondents here significantly increase driving (9%) and employment (11%). On the contrary, female Couples drive significantly less and have significantly lower employment than their male counterparts during the nesting phase. Male and female Singles, on average, do not show much difference in terms of transportation mode choices, residential location, and career decisions when they are in the nesting phase.

From the gender analysis, we see that the previously identified cohort-level average behavior of increased car use for Have-it-alls is mainly driven by female Have-it-alls,

whereas the increase in employment is the result of the offsetting effect from male Have-it-alls' increased employment and female Have-it-alls' decreased employment. Even though Have-it-alls at the cohort level do not change their public transit use during the nesting phase, female Have-it-alls significantly reduce their public transit use more than their male counterparts.

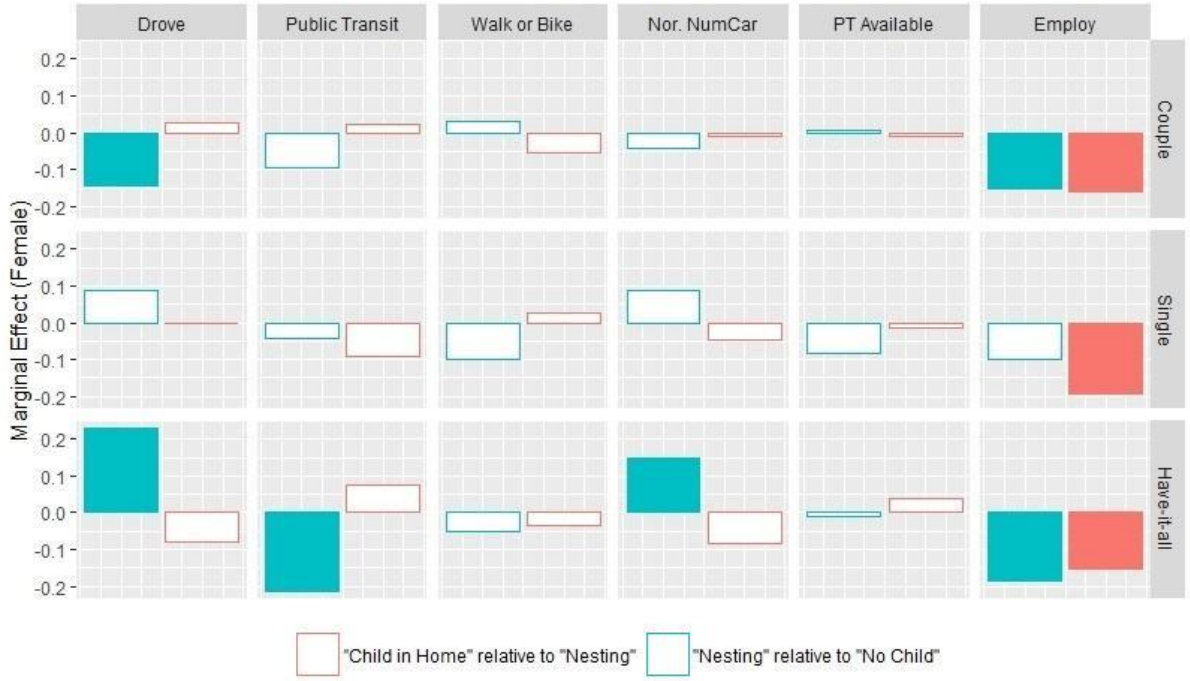

Figure 5. Marginal effects of "Nesting" and "Child in Home" for women relative to men by cohorts. Solid colors indicate significant effects at 10% level.

After the child enters the household, males in the Couples cohort do not change their mobility decisions, car ownership, and career as compared to the nesting phase. However, the results show that female Couples further reduce their employment when having child(ren) at home relative to their male counterparts after an already reduced employment during the nesting phase. In fact, we observe that women across all three cohorts have significantly lower employment than their male counterparts after having child(ren). When adding that to the negative impact of nesting on employment for women, women's career development is, on average, more negatively impacted by parenting events than men, regardless of their life course trajectory. Male Singles take less active modes after the child enters the household.

4.3. Effect of Career Decision on Gender Gaps in the Have-It-Alls Cohorts

When women give up careers upon entry to parenthood, labor division in the household is likely to get reinforced, which may lead to longer-term behavior lock-in. Given the most pronounced heterogeneity observed in Have-it-alls between men and women, we are interested in learning whether the career decisions that female Have-it-alls made between 30 and 35 years old, the period when they entered parenthood, could be an underlying driver of gender gaps in mid- to longer-term mobility.

According to our life history calendar data, Have-it-all women take two distinct career-related paths: (1) women who continue to work full time while forming a family, hereafter referred to as "employed women", and (2) women who gave up working full-time while forming a family, hereafter referred as "underemployed women". Approximately 65% of the Have-it-alls women fall into the "employed women" category, a much lower percentage than women in the other two cohorts (84% in Singles and 89% in Couples).

To explore how employment status interplays with gender differences in relation to parenting events in other mobility decisions, we performed a similar analysis using the model specification in Equation (2) but restricting the sample to only either employed women and employed men or underemployed women and employed men. The estimated marginal effects for employed and underemployed Have-it-all women are summarized in Figure 6. Note that the interpretation of the bars in Figure 6 should be the marginal effect relative to the effect of employed men.

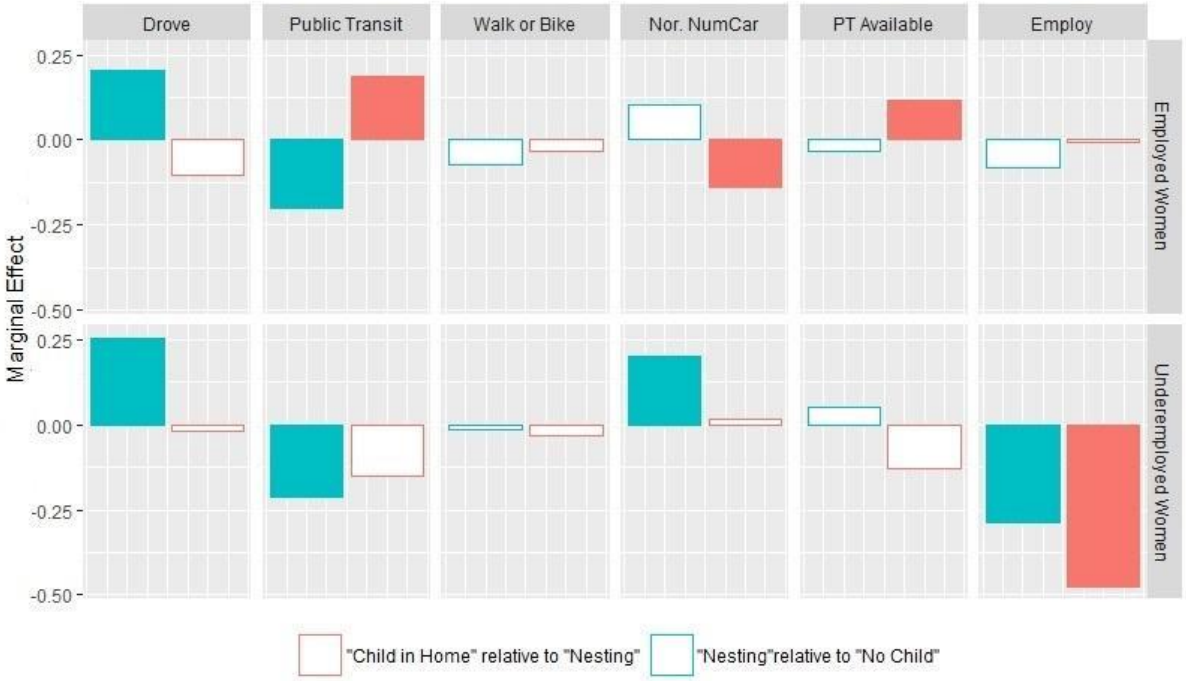

Figure 6. Gender gaps in parenting effects in Have-it-all cohort by early career decision: Have-it-alls women employed during age 30–35 relative to employed men (top); Have-it-alls women underemployed during age 30–35 relative to employed men (bottom). Solid colors indicate significant effects at 10% level.

In transitioning to the nesting period, both employed and underemployed women increase car use and reduce public transit usage relative to employed men. Interestingly, while we see no change in per-person car ownership during the nesting period for employed women, underemployed women have a significantly larger increase in per-person car ownership than employed men. This is likely due to the fact that the employed women households own more cars per person because of the need to commute to work, whereas fewer underemployed women may need a car until they are preparing for their first childbirth.

After children enter the household and over time, employed women tend to relocate to a more transit-friendly neighborhood, increase public transit usage, and reduce normalized car ownership relative to men (Figure 6, first row). On the other hand, there is no change in public transit availability, public transit usage, and car ownership for underemployed women, indicating that the initial behavior shifts toward a car-oriented lifestyle are persistent over the longer term. Regarding long-term career differences, women who remain employed at the beginning of parenthood remain employed at the same level as males over time. In contrast, the gender gap in employment widens over time among women who give up their careers at the beginning of parenthood.

5. Discussion

Many recent travel behavior studies use the mobility biography approach to study the dynamics of people's travel behavior by considering their life course trajectories. This

study builds upon our previous work on exploring the heterogeneous effects of life events on habitual travel modes through a life course perspective by focusing on how the timing of parenting affects short- to long-term mobility decisions and how these impacts differ across three cohorts with distinct life history contexts, namely "Couples", "Singles", and "Have-it-alls". We further disaggregate these impacts by gender and employment status to understand if entering parenthood impacts women and men differently and whether early career decisions drive the trend of gender differences in the mobility domains over the longer term.

Our research framework provides two advancements beyond the traditional approach of mobility biography as applied in gender and travel behavior studies. First, the progression and turning points of mobility decisions are studied among different cohorts, constructed based on the similarity in the timing and order of the sociodemographic attributes rather than all individuals. It allows us to discover the underlying pathway leading to the heterogeneous effects of parenting on travel behavior by subpopulation. Second, we look at the parenting effects on three hierarchical domains, including different travel mode usage (driving, public transportation, and walking or biking), car ownership, spatial mobility as indicated by changes in public transit availability, and career decisions, to provide a comprehensive view on how parenting affects short-, mid-, and long-term mobility decisions.

As shown in [1–3,21], an individual's travel patterns are mainly habitual and developed over time; thus, entering parenthood should cause variable impacts on the mobility decisions of individuals who experience different life trajectories. Past studies have shown mixed results regarding the effect of parenting on patterns of mode use. Some studies found that being a parent is associated with a decrease in public transit usage and cycling and an increase in car use and ownership [8,15,26,32,42], and other studies show that some parents reported maintaining similar travel behavior or even increased walking and biking [9]. Based on our results, we also found differentiated parenting effects on travel behavior across cohorts. Have-it-alls significantly increase their car use during the nesting period; after that, they take less public transit when having children at home and tend to relocate to where public transit is less available. In contrast, we do not observe many changes in mode use for Couples and Singles during the nesting and having-children-at-home periods. As mentioned previously, the most distinct difference between Couples and Singles versus Have-it-alls is the timing of family formation; the first two cohorts have children much later than Have-it-alls. Hence, the life conditions and built environment for Couples and Singles when having children are likely to be at a more stable stage. Thus, their mobility decision is less affected by parenting events.

The gender gaps observed in travel behavior are also found to have different magnitudes of impact among cohorts. We observe the most pronounced gender differences in car use and car ownership in the Have-it-alls cohort. While male Have-it-alls experience no significant change in car use and car ownership during the parenting event era relatively to previously, female Have-it-alls show an increase in car usage, per-person car ownership, and a decrease in public transit use relative to their male counterparts in transitioning to the nesting period, and the gender gap remains after having children at home. Overall, when differentiating the parenting effects on mobility decisions and car ownership by gender, Singles have a minimal gender gap, while Have-it-alls have the widest gender gap in both car ownership and mode uses.

Employment is often tied to one's mobility decisions, as one may change a job or give up their job because of relocation or vice versa [36]; or one could change their travel behavior because of job changes or vice versa [57]. We find that women across all three cohorts have significantly lower employment than their male counterparts after having child(ren). If including the negative impact of parenting on employment during the nesting period for women in Couples and Have-it-alls, the overall impact of having children at home is even more significant in these cohorts. When further looking into the career decisions made by women between 30 and 35 years old, the period when they entered

parenthood, a higher share of female Have-it-alls were not employed during that age period compared to the other two cohorts, and that may be attributed to the imbalanced division of labor between men and women in this particular cohort. We find evidence supporting that the early career decisions made by Have-it-alls women between 30 and 35 years old are associated with the gender difference in mobility observed over mid- to longer terms. Have-it-all women who remain employed at the beginning of parenthood remain employed at the same level as males over time. In contrast, the gender gap in employment widened over time among women who give up their careers at the beginning of parenthood. Although both employed and underemployed Have-it-alls women increased car use and reduced public transit usage during the nesting period relative to their male counterparts, only underemployed Have-it-alls women maintained this in the longer term. Employed women, on the other hand, tend to shift toward less car ownership, relocate to transit-friendly places, and use more public transit and thus gradually close the gender gap over time during parenthood.

These findings indicate that upon entering parenthood, although women who choose to hold on to their careers tend to temporarily become more car-reliant than their male counterparts at the beginning of parenthood, over time, these women are more likely to change mobility lifestyle. In contrast, we see that the gender gap remains the same or widens in the mobility outcome variables among the women who gave up their careers at the beginning of parenthood, which is accompanied by a further widening career gap from men over time. This exemplifies how women's career decisions at the beginning of parenthood could have differentiated impacts on their mid- to long-term mobility decisions.

While our study yields comprehensive insights into the dynamics of travel choices over the life course through the mobility biography approach, it is important to acknowledge certain constraints within the survey scope. First, our study focuses on individuals' travel behavior in a single region. While this approach aligns with many existing mobility biography studies, the generalizability of our results to a broader population is limited. To enhance the applicability of our results in a policy context, future research endeavors should consider deploying surveys with a similar life history calendar approach across a wider geographical region. Such an expansion would contribute to the improvement and robustness of the findings. Second, our survey was conducted prior to the onset of the COVID-19 pandemic. Consequently, certain findings from our study may have limited applicability in the present context due to the substantial life event changes experienced by individuals during the pandemic, which may have influenced their decision-making process around mobility. Nonetheless, the retrospective survey approach presented in this paper still offers significant value for researchers examining the impact of COVID-19 on individual travel behavior. Lastly, given the scope of our work, we adopted a more limited perspective regarding gender, specifically focusing on the binary categorization of men and women. The inclusion of gender into our analysis primarily illustrates the contrasting mobility patterns during parenting events between men and women. However, we did not delve into the examination of power dynamics within a gendered social context, which significantly influence the varied mobility patterns as discussed in [58].

6. Conclusions

Our results highlight the role of life course context on the dynamics of the short- (mode use), mid- (vehicle ownership), and long-term (residential location) mobility decisions, and career decisions in response to parenting events. The clear distinction in the mode use changes across the life trajectory cohorts signifies the importance of both past experiences and future expectations in mobility decision-making. Further differentiating the parenting effects by gender and employment status can help planners and policymakers better understand the tendencies and constraints faced by different individuals.

Our study identifies the Have-it-all cohort as the primary driver of gender gaps observed at the population level. Both short- and mid-/long-term travel behaviors of Have-it-all women are significantly influenced by parenting events, potentially because their

family and career formation are intertwined at the same time. Therefore, implementing a transportation policy designed to address the unique needs of this particular subpopulation in the event of childbearing and caring for child(ren) may incentivize them to have a less car-centric travel pattern. Additionally, as women's career decisions in early parenthood are found to have lasting effects on mobility over time, more targeted policies could be tailored to help these vulnerable subpopulations during this particularly challenging life phase. For example, as supported by our empirical analysis, helping career moms remain employed (such as providing a flexible schedule and child care support) may help them recover from car dependency and become more accepting of multimodal lifestyles later on. Such policy measures are especially important given current circumstances, as career women have shown to be disproportionally affected by the caregiving responsibilities associated with children at home than their male counterparts since the onset of the COVID-19 pandemic in early 2020 [59–61].

While our research centers on the effect of parenting life events on mobility decisions, the data collection method and mobility biography approach used here can be applied to studying the impact of many other life events in the world reshaped by the COVID-19 pandemic. Although certain effects stemming from the stay-at-home measure may be temporary, such as limited mobility, increased e-commerce activities, and reduced ride-hailing usage, the pandemic has also triggered major life events that would have a long-lasting impact on individual travel patterns [62–64]. For instance, the growing demand for larger living spaces and access to natural amenities has led to the relocation from high-density city centers to suburban areas, potentially resulting in increased car dependency. Job loss or job switching due to the economic slowdown has the potential to disrupt one's commute routine. These long-term impacts of COVID-19 on mobility decisions through the triggering of major life events may also differ across heterogeneous populations, which highlights the need to understand an individual's mobility biography when studying their travel behavior.

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Appendix A

Table A1. Sociodemographic characteristics of the WholeTraveler sample.

	Percentage in Sample
Education	
12th grade or less, no diploma	0.4%
High school diploma/GED	1.5%
Some college	7.9%
Associate's degree	4.9%
Bachelor's degree	37.8%
Master's degree	30.6%
Professional degree (for example: M.D., DDS, DVM, J.D.)	5.6%
Doctoral degree (for example: PhD, EdD)	8.6%
N/A	2.8%
Income	
Less than USD 10,000	1.4%
USD 10,000 to USD 14,999	1.1%
USD 15,000 to USD 24,999	2.5%
USD 25,000 to USD 34,999	2.5%
USD 35,000 to USD 49,999	5.9%
USD 50,000 to USD 74,999	9.3%
USD 75,000 to USD 99,999	10.6%
USD 100,000 to USD 149,999	18.4%
USD 150,000 to USD 199,999	12.6%
USD 200,000 to USD 299,999	12.9%
USD 300,000 to USD 399,999	5.1%
USD 400,000 or more	3.1%
N/A	14.7%
Employment	
Self-employed	2.1%
Out of work and looking for work	0.3%
Out of work but not currently looking for work	0.1%
A homemaker	0.7%
A student	2.8%
Retired	1.8%
Unable to work	0.3%
Prefer not to answer	2.9%
Multiple	88.9%
N/A	0.2%
Ethnicity	
White	54.2%
Hispanic, Latino, or Spanish origin	6.0%
Black or African American	2.3%
Asian	25.5%
Middle Eastern or North African	1.2%
American Indian or Alaska Native	0.8%
Native Hawaiian or Other Pacific Islander	1.4%
Some other race or origin	1.9%
Prefer not to answer	6.6%
N/A	0.2%
Gender	
Male	48.9%
Female	47.4%
Other	0.1%
N/A	3.6%

Table A1. *Cont.*

	Percentage in Sample
Household has any children	
No	84.5%
Yes	15.5%
Speak another language at home	
No	69.4%
Yes	24.7%
N/A	6.0%

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