# Commuting behaviour and subjective wellbeing

## A longitudinal perspective

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Yinhua Tao

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**Yinhua Tao**

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# Commuting behaviour and subjective wellbeing

## A longitudinal perspective

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chair of the Board for Doctorates
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Monday 12 June 2023 at 10:00 o'clock

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# Summary

This thesis has investigated the relationship between daily commuting behaviours and long-term subjective wellbeing (SWB) from a longitudinal perspective. The underlying problem that motivated the thesis is the inconsistent research evidence on the commuting-SWB relationship, and more importantly, the insufficient theoretical conceptualisation of this relationship. As a response to the gap between theoretical understandings and empirical research, this thesis used a processual approach to frame the commuting-SWB relationship as an interdependent process over time (Whitehead, 1929; Schwanen, 2018). To operationalise this processual approach, two ways forward were proposed for longitudinal research, namely retrieving the upstream process that leads to changes in commuting behaviours and enriching the contextual understanding of commuting-SWB relationships. The upstream process of commuting changes pertains to the reason for people to (not) change their commuting behaviours, while the contextual understanding relates to the commuting-SWB relationship as time- and place-specific. Following these two ways forward, the empirical analysis of this thesis drew upon different nationwide panel data and longitudinal modelling methods to investigate the relationships between commuting behaviours and SWB over time. The aim of this thesis is not to identify a unidirectional commuting-SWB causality uniform to the general population and across research areas, but to acknowledge, operationalise and better understand the interdependent commuting-SWB relationships situated in the life courses of people and the socio-spatial contexts of places.

## 1 Longitudinal relationships between commuting behaviour and subjective wellbeing

Longitudinal research, or panel research, is a research design that repeatedly observes the same research object over a period of time (Ployhart and Vandenberg, 2010). Different from cross-sectional studies that compare different individuals at a single point of time, the longitudinal research design focuses on within-individual variations of behaviours and behavioural outcomes (e.g., SWB) over time. It is, therefore, regarded as “a golden standard” to infer causal relationships and direct policy designs in quantitative studies. Despite the methodological advance of longitudinal designs, existing research on the commuting-SWB relationship is inconsistent; that is, increasingly long and motorised commuting journeys over time exert negative, insignificant, or even positive effects on long-term SWB outcomes in



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different longitudinal studies. This inconsistency could result from overemphasizing the statistical significance and methodological "regularity in conjunction between preceding dependent variables and independent outcomes" (Schwanen, 2018). However, theoretical conceptualisation of the commuting-SWB relationship is largely overlooked. To bridge the gap between theoretical understandings and longitudinal research, this thesis uses a processual approach to reframe the commuting-SWB relationship as a process (Whitehead, 1929). In this process, commuting behaviours are interdependent with SWB over time, and the interdependent commuting-SWB relationships are (re)shaped by people's past experiences and situational contexts.

Following the processual approach, the first way forward is to understand why commuting behaviours change in the first place, termed the upstream process of commuting changes. Based on the literature review, I summarise three different but interrelated processes that lead to changes in commuting behaviours and complicate the understanding of the commuting-SWB relationship (Tao et al., 2022). They are environmental changes, information/participatory interventions and the events of residential relocation. These upstream processes pertain to whether changes in commuting behaviours occur spontaneously as the travel-related environment evolves over time, or require an intervention to inform and direct alternative commuting choices. Moreover, the reason for changing commuting behaviours can be exogenous to the commuting-SWB relationship, or involves a self-selection process to address the pre-existing behaviour-attitude inconsistency. The second way suggested by this thesis is to understand the commuting-SWB relationships appropriately situated in people's life courses and localised socio-spatial contexts, termed the contextual understanding of the commuting-SWB relationship. This contextual understanding goes beyond the regularity and stability assumed in the unidirectional commuting-SWB causality. Instead, it acknowledges the interdependent commuting-SWB relationships as time- and place-specific. When coming to inconsistent findings, therefore, longitudinal research should interpret the commuting-SWB relationships based on the contextual characteristics, including geographical environment, social atmosphere, cultural norms and past history, of local areas (Schwanen, 2018).

## 2 Research aim and questions

**This thesis aims to better understand why this inconsistency occurs when examining the relationships between commuting behaviours and long-term SWB.** To achieve this aim, this thesis answered three main research questions in five studies – one review study and four longitudinal studies. The first research question of this thesis was how to understand the gap between the theoretical conceptualisation of the commuting-SWB relationship and the outcome of empirical

longitudinal studies. To answer this question, Chapter 2 reported on a literature review to combine two areas of research that was developing separately – theory/review research that theoretically conceptualised the commuting-SWB relationship and longitudinal research that empirically examined this relationship. Secondly, the thesis asked how the relationships between commuting behaviours and long-term SWB varied after taking into account different upstream processes of commuting changes. This question was investigated from Chapters 3 to 5 at the individual level. Each chapter discussed a specific process that leads to within-individual changes in commuting behaviours in China, the UK and the Netherlands, respectively. Finally, the thesis turned to the household level to answer the third research question: How did the commuting-SWB relationships manifest themselves from a household perspective (see Chapter 6)?

## 3 Data and methods

Longitudinal data including both commuting and SWB information are required to study changes in commuting behaviour and SWB for the same individual over time. This kind of longitudinal data with a good representation of general commuting populations is limited. In this thesis, not one but three nationwide panel datasets from China, the UK and the Netherlands were used to examine the complexity of commuting-SWB relationships in different contextual areas. These nationwide panel datasets are China Health and Nutrition Survey, the UK Household Longitudinal Study (or Understanding Society) and the Netherlands Mobility Panel, respectively. Longitudinal research conducted in three different countries does not aim at comparing the results of the commuting-SWB relationship between them. Instead, the contextual specificity for understanding this relationship is the interest of this thesis. For example, the contextual characteristics studied in these countries include the government-led and land-driven urban growth in urban China, the mandated working from home during the COVID-19 pandemic in the UK, and greater chances of residential self-selection in the Netherlands (due to polycentric urban regions and advanced transportation infrastructure).

Two types of methods were used in this thesis, i.e. the systematic review method for the review research and longitudinal modelling methods for the empirical research. Chapter 2 followed the guideline of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 to systematically collect existing longitudinal studies on commuting-SWB relationships. The collected literature served as a library for the critical review research. Chapters 3-6 used quantitative modelling methods to analyse commuting-SWB relationships appropriate for each longitudinal design. Specifically, Chapter 3 employed the multilevel models with the difference-in-



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difference design to examine how changes in commuting mode choices were related to long-term psychological stress for residents from different neighbourhoods. Chapter 4 applied the fixed-effect models to estimate how within-individual changes in SWB after homeworking depended on the pre-COVID-19 commuting behaviours. Considering the complex decision-making process underlying residential relocation, Chapter 5 conducted the structural equation modelling analysis to explore the direct and indirect relationships between family- and job-related life events, changes in accessibility and neighbourhood built environment, and changes in commuting mode choices and preferences before and after residential relocation. In Chapter 6, seemingly unrelated regression models with random effects were developed to inspect the within-individual and spill-over effects of commuting time on life satisfaction for couples.

## 4 Summary of the research results

The literature review in Chapter 2 collected existing longitudinal studies that investigated the relationship between commuting behaviours and SWB over time. Results from these longitudinal studies were far from consistent. Therefore, questions remained unanswered regarding the extent to which motorised and long commuting journeys resulted in low levels of SWB in the long term. To account for inconsistent longitudinal findings, Chapter 2 postulated that understanding commuting-SWB relationships should start from integrating theories from different disciplines, including the utility equilibrium theory from economics, habit and attitude theories from social psychology, and the mobility biographies approach from transport geography. Based on the interdisciplinary theories, the commuting-SWB relationship was conceptualised as an interdependent process over time, (re)shaped by people's past experiences, present circumstances, and future expectations. This directs future longitudinal research to distinguish different processes that lead to changes in commuting behaviours, including environmental changes, information or participatory interventions, and the events of residential relocation together with other life events and long-term processes in life. The processual approach enriches the temporal scope of longitudinal research and contributes to a better understanding of the interdependent commuting-SWB relationships situated in people's life courses and corresponding socio-spatial contexts.

Based on the processual approach as introduced in Chapter 2, this thesis selected three upstream processes of commuting changes for research in the following three chapters. Specifically, Chapter 3 focused on the process of urban growth in China. This process is exogenous to the commuting-SWB relationships, because individuals have little control of government-led urban growth in China and hardly notice its impact on daily commutes in the short term. In this regard, Chapter 3 examined to

what extent people maintained commuting mode choices over time and whether this was associated with long-term psychological stress, using data from the China Health and Nutrition Survey (2006-2015). A time-varying composite scale – urbanicity – was also included to characterise the expansion of urban space and to investigate geographic variations in commuting-stress relationships. The results show that long-duration active commuting relieved psychological stress, while long-duration motorised commuting trips by car or public transport led to higher stress levels. Surprisingly, urban growth did not induce more motorised commuting trips and greater psychological stress in a linear fashion. In medium-level urbanicity areas, rather than high-level ones, the commuting-related stress risks were noticeable the most because of the extremely high duration of commuting by public transport. By focusing on the exogenous process of urban growth, the chapter finally suggested that Chinese cities should change the growth path from expanding urban development land to improving urban amenities and urbanites' wellbeing (Wu, 2015).

Chapter 4 shifted the focus to another exogenous process of commuting changes, mandatory working from home during the COVID-19 pandemic, to analyse how homeworkers reflected on their pre-COVID-19 commuting behaviours. Compared to the gradual process of urban growth, the exogenous shock of COVID-19 contributes to estimating the effect of commuting behaviours on long-term SWB for two reasons. The first reason is the exclusion of any possible compensations from housing and job markets to observe the net impact of reduced or cancelled commuting journeys, and the second reason is that mandatory homeworking regulations enforced a large number of working populations to break habitual commuting routines and deliberately reconsider their commuting wellbeing (Kroesen, 2022). Using the Understanding Society data from the UK, the results from the fixed-effect models only found a positive effect of working from home on affective wellbeing for long-distance commuters (one-way commuting distance > 30 miles). In contrast, commuters who had frequently walked or cycled to work reported worse affective wellbeing and life satisfaction after switching to homeworking. This real-world experiment during the COVID-19 pandemic adds to a stronger claim that daily commutes do influence long-term SWB, and what commuters really appreciate is walking or cycling to work over short distances.

In Chapter 5, residential relocation was regarded as a key event in stimulating changes in commuting mode choices and preferences. Compared to the exogenous process of commuting changes, relocation decision-making might involve a self-selection process, or termed an endogenous process of commuting changes. Specifically, the inconsistency between commuting modes and mode-specific preferences would cause dissatisfaction, which prompted the choices of residential locations and commuting behaviours (Cao et al., 2009). Moreover, changes in commuting behaviours following

the relocation could be a result of changes in residential built environment or/and an adaptation to concurrent life events (Coulter and van Ham, 2013). To examine this, the chapter used the Netherlands Mobility Panel data to analyse the longitudinal relationships between changes in residential built environment, the occurrence of life events, and changes in commuting mode choices and preferences pre-post residential relocation. Netherlands is an interesting case to study because of competitive commuting alternatives to cars (e.g., prevalent cycling culture and well-developed public transport systems) and the polycentric urban regions with diverse housing markets for residential self-selection. The results from the longitudinal structural equation models supported residential self-selection from pre-existing preferences for car and public transport use, while residents would adjust downwards the active commuting preference after moving to a more suburban neighbourhood with longer distances to the job locations and public transport stations. Besides, life events in the household and employment domains, such as childbirth and job changes, often coincided with the relocation event and underlay greater demand for car use.

The above three chapters are based on the individual-level analysis, ignoring that commuting decisions are often reached at the household level, involving gendered power relations in negotiations with other family members. To this end, Chapter 6 took a household perspective to compare gendered commuting-SWB relationships between husbands and wives in urban China. The results from the panel version of seemingly unrelated regression models indicate that husbands and wives similarly had worse life satisfaction as the commuting time of their own increased. Moreover, the results demonstrate the spill-over effects of commuting utility between husbands and wives at different family life stages. Specifically, husbands' life satisfaction was more negatively affected by wives' commuting time than vice versa, while wives' commuting utility was more related to the time pressure from caring for preschool-aged children and the social support from extended family members (i.e., children's grandparents in this study). Especially in a nation putting much weight on the patriarchal and collective culture of the family as China, co-residing with the grandparents contributes to alleviating the utility loss from long commutes for young parents, especially for working mothers (Ta et al., 2019).

## 5 Synthesis of research results, and lessons learned

The overarching aim of this thesis was to understand why existing research evidence comes to inconsistent findings regarding the relationships between commuting behaviours and long-term SWB. By following people through time, this thesis concludes that commuting journeys in daily life constitute an important component of people's SWB in the long term. However, this does not imply that longer commuting journeys always result in worse SWB outcomes in a linear fashion, even though this

unidirectional causal inference is often claimed for favouring longitudinal research designs over the cross-sectional ones (Suppes, 1970). Learning from the processual approach, the thesis posits that longitudinal studies should expand the reasoning process and enrich the contextual interpretation for better understanding the commuting-SWB relationships. The first way forward is actually a step backwards to retrieve the upstream process of commuting changes. The second way forward is to acknowledge the fact that the commuting-SWB relationship cannot be easily generalised over space and time. Instead, it is sensitive to the socio-spatial contexts under study, including the individual and family life stages of people and the geographic and socio-cultural backgrounds of places. Following these two ways forward does not mean that there is a uniform commuting-SWB causality, but it does contribute to better understanding the interdependent commuting-SWB relationships over time.

Theoretically, understanding the commuting-SWB relationship requires an integrative theoretical perspective. The economic framework of individual utility equilibrium alone does not suffice to encapsulate the commuting-SWB relationship. The longitudinal analysis of this thesis shows that people were less happy and satisfied with overall life as their commuting journeys prolonged over time. This result contradicts the utility equilibrium but corroborates the phenomenon of the commuting paradox; that is, individuals do not gain equivalent housing- and job-related compensations to balance off the disutility from longer commutes (Stutzer and Frey, 2008). Furthermore, the thesis has examined whether there is a household-level utility equilibrium. Again, the phenomenon of the commuting paradox appeared in the household – husbands were worse off in SWB outcomes as their wife's commuting time increased, while a wife's life satisfaction was related to her own commuting time and moderated by family life stages, resulting in a net commuting disutility at the household level. However, this paradoxical phenomenon does not mean that commuting journeys should be cancelled for improving people's SWB outcomes. This is evidenced by the homeworking experience during the COVID-19 pandemic. Those former commuters missed the benefit of walking or cycling to work by showing worse SWB outcomes when they were mandated to work from home, or put it in another way, people appreciated active commuting over short distances.

Methodologically, this thesis has piloted different longitudinal research designs to examine the interdependent relationships between commuting behaviours and long-term SWB over time. Despite increasing availability of nationwide panel data, designing and implementing such longitudinal designs is not easy. It does not only require isolating different upstream processes of commuting changes, but it also requires caution to situate the longitudinal analysis of commuting-SWB relationships appropriately in the socio-spatial contexts of research areas. Equally important, appropriate longitudinal modelling methods should be matched with the research designs. In longitudinal

studies, particularly, fixed-effect modelling analysis is widely used to investigate the impact of changes in commuting behaviours on changes in SWB outcomes without serious consideration. The cost is that those person-year observations with no or little change in commuting behaviours are implicitly dropped out of the longitudinal analysis. Concerning the problems and biases involved in panel data collection and analysis, longitudinal behaviour research should be more cautious in sample screening, selection and description before diving into sophisticated modelling analysis.

Practically, the longitudinal findings of this thesis provide implications for place-based and people-based policy-makings in intervening commuting behaviours and improving commuters' SWB. From a place-based perspective, urban planning initiatives, such as smart urban growth, transit-oriented development and walkable neighbourhoods, play a structural role in steering environmentally and socially desirable commuting patterns. These place-based initiatives have shown effectiveness in reducing local job-housing mismatch and encouraging the uptake of sustainable means of transport (Banister, 2008; Zhao and Li, 2017). This thesis further indicates their potential in satisfying the preference for active commuting over short distances and thus enhancing the SWB outcomes of the commuting population. Besides these place-based planning initiatives, flexible workplace settings (e.g., working from home on some days of the week) and some novel travel modes (e.g., e-bicycle) are also promising to alleviate the burden from long-distance motorised commuting. From a person-centred perspective, travel demand management should be tailored to social groups with heterogeneous travel demands and preferences. To reduce car commuting trips, for example, behaviour interventions should target those neighbourhoods with fewer car lovers and those people who are about to experience major changes in life (e.g., relocating to a suburban housing and giving birth to a child). Possible intervention strategies include educational and information campaigns on environmental awareness, targeted information on sustainable travel alternatives for housing-seeking families and equipping accessible public transport stations around the neighbourhood.

## 6 Implications for future research and policy-makings

The processual approach is a promising direction for future longitudinal research to enrich the understanding of commuting-SWB relationships. This thesis theoretically conceptualises people's commuting behaviours and SWB as an interdependent process situated in people's life courses and corresponding socio-spatial contexts. From a life-course perspective, future longitudinal research is warranted to investigate how the travel domain and other life domains interact with each other in the long term. Particularly, it is interesting to study how people adjust commuting behaviours by anticipating,

immediately responding to, or lagging behind the occurrence of life events, and how these major changes in life jointly contribute to long-term health status and SWB. Moreover, the learning process during childhood and the succession from the older generation are also possible pathways for shaping people's commuting habits and predisposing their travel-related attitudes. To further the understanding of commuting-SWB relationships, therefore, more longitudinal analyses are expected to expound the process of commuting changes and the dynamics in commuting-SWB relationships over the life course.

The processual approach can also be exercised in behaviour-oriented intervention experiments and relevant policy-makings. In the intervention experiments, participants are often directed to pilot alternative commuting choices (e.g. switching from commuting by car to cycling to work) for a short period of time. To stimulate expected behaviour changes, it is necessary to monitor not only changes in commuting behaviours but also changes in SWB outcomes, such as commuting satisfaction, over time. This is because people are more likely to adjust their travel-related attitudes and develop new travel routines if they find the commuting alternative satisfactory (De Vos et al., 2022). To sustain the behaviour changes, participants' commuting behaviours and SWB should be followed over a longer time period after the intervention. This necessitates the integration of temporary intervention experiments into long-term policy development and evaluation. In the programs of residential estate, for example, trial mobility packages combining free public transport tickets and bike sharing offers can be issued to the newly relocated residents to impede prevalent car use. Furthermore, the ongoing follow-ups after the end of trial mobility packages should be incorporated into the program assessment to ensure that desirable commuting patterns and SWB outcomes are sustained in the long term.

Based on the findings of this thesis, future longitudinal research could develop the processual way of thinking and the contextual way of understanding to investigate the interdependent commuting-SWB relationships over time. When the longitudinal findings for commuting-SWB relationships are inconsistent with each other, they should not be regarded as a barrier for research to reach a general conclusion, but as a prompt for researchers to use existing longitudinal evidence more cautiously, to design the longitudinal research more carefully, and to interpret inconsistent longitudinal findings more critically. Accordingly, policy implications should carefully consider ways to steer the process of commuting changes and to conduct the intervention tailored for different places and social groups, with the ultimate goal of promoting environmental sustainability and social wellbeing in the long term. As this thesis demonstrated, daily commuting behaviours matter for long-term SWB, but to better understand the commuting-SWB relationships, longitudinal research needs to answer why commuting behaviours change or do not change in the first place and how the commuting-SWB relationships manifest themselves specific to local socio-spatial contexts.

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# Samenvatting

Voor dit proefschrift werd de relatie tussen dagelijks forensgedrag en subjectief welbevinden (subjective wellbeing, SWB) op lange termijn in longitudinaal perspectief onderzocht. Het probleem dat aan dit promotieonderzoek ten grondslag ligt, is de inconsistentie in wetenschappelijke onderzoeksresultaten wat betreft de relatie tussen forensgedrag en SWB, en, belangrijker nog, de gebrekkige theoretische conceptualisering van deze relatie. Ter overbrugging van de kloof tussen theoretische kennis en empirisch onderzoek werd voor dit proefschrift een processuele benadering gebruikt, waarin de relatie tussen forensgedrag en SWB als een tijdgebonden, onderling samenhangend proces wordt gezien (Whitehead, 1929; Schwanen, 2018). Voor de operationalisering van deze processuele benadering werden twee routes voor longitudinaal onderzoek voorgesteld: enerzijds het achterhalen van het 'upstreamproces' dat leidt tot veranderingen in forensgedrag en anderzijds de verrijking van de contextuele kennis over de relatie tussen forensgedrag en SWB. Het upstreamproces voor veranderingen in het woon-werkverkeer heeft betrekking op de redenen dat mensen hun forensgedrag al dan niet veranderen; de contextuele kennis betreft de tijd- en plaatsgebondenheid van de relatie tussen woon-werkverkeer en SWB. Om op basis van deze twee routes de relaties tussen woon-werkverkeer en SWB in de loop van de tijd te onderzoeken, werd in dit onderzoek voor de empirische analyse gebruikgemaakt van verschillende data van landelijke panels en longitudinale modelleermethoden. Het onderzoek had nadrukkelijk niet als doel een unidirectioneel causaal verband te vinden tussen woon-werkverkeer en SWB dat voor de gehele bevolking en in alle onderzoeksregio's geldt. Doel was het benoemen, operationaliseren en beter begrijpen van de onderling samenhangende relaties tussen forensgedrag en SWB, zoals die zich gedurende het leven van mensen en binnen de sociaal-ruimtelijke context van bepaalde plekken voordoen.

## 1 Longitudinale relaties tussen forensgedrag en subjectief welbevinden

Longitudinaal onderzoek, of panelonderzoek, is een onderzoeksontwerp waarbij eenzelfde onderzoeksobject in de loop van de tijd herhaaldelijk wordt geobserveerd (Ployhart en Vandenberg, 2010). Anders dan cross-sectioneel onderzoek, waarbij verschillende individuen op een bepaald moment in de tijd worden vergeleken, richt het longitudinale onderzoeksontwerp zich op gedragsvariaties en consequenties van gedragingen (zoals SWB), binnen een en hetzelfde individu in de loop van de

tijd. Dit ontwerp wordt dan ook als ‘een gouden standaard’ beschouwd voor het achterhalen van causale verbanden en directe beleidsontwerpen in kwantitatief onderzoek. Ondanks de methodologische vooruitgang die is geboekt op het gebied van longitudinale ontwerpen, levert het bestaande onderzoek naar de relatie tussen forensgedrag en SWB een inconsistent beeld op. In verschillende longitudinale onderzoeken leveren langere en meer gemotoriseerde forensroutes na verloop van tijd een negatief, niet-significant of zelfs positief effect op SWB op. Deze inconsistentie zou het gevolg kunnen zijn van een te grote nadruk op statistische significantie en methodologische “regulariteit in combinatie met de voorafgaande afhankelijke variabelen en onafhankelijke uitkomsten” (Schwanen, 2018). Aan de theoretische conceptualisering van de relatie tussen forensgedrag en SWB is echter weinig aandacht besteed. Ter overbrugging van de kloof tussen theoretische kennis en longitudinaal onderzoek gaat dit proefschrift uit van een processuele benadering; de relatie tussen forensgedrag en SWB wordt gezien als een proces (Whitehead, 1929). In dit proces hangen forensgedrag en SWB op lange termijn onderling met elkaar samen, en worden deze onderling samenhangende forensgedrag-SWB-relaties (opnieuw) vormgegeven door de eerdere ervaringen en situationele context van mensen.

Op basis van de processuele benadering is de eerste route het verkrijgen van inzicht in de redenen voor veranderingen in forensgedrag. Dit wordt het upstreamproces in forensgedragveranderingen genoemd. Op basis van de literatuur kom ik tot drie verschillende, onderling verband houdende processen die leiden tot veranderingen in forensgedrag en die het inzicht in de relatie tussen forensgedrag en SWB complex maken (Tao et al., 2022). Dit zijn veranderingen in de leefomgeving, informatie/participatie-interventies en verhuizingen. Deze upstreamprocessen hebben betrekking op de vraag of veranderingen in forensgedrag spontaan optreden wanneer de omstandigheden op het gebied van woon-werkverkeer veranderen, of dat er een interventie voor nodig is om informatie en sturing te bieden voor alternatieve forenskeuzes. Bovendien kan de reden voor het veranderen van forensgedrag los staan van de relatie tussen forensgedrag en SWB of er kan sprake zijn van een eigen selectieproces om een bestaande inconsistentie in gedrag-houding te adresseren. De tweede route die in dit proefschrift wordt voorgesteld is om de relatie tussen forensgedrag en SWB te bezien in relatie tot de levensloop en gelokaliseerde sociaal-ruimtelijke context van mensen. Dit wordt het contextuele begrip van de relatie tussen forensgedrag-SWB genoemd. Dit contextuele begrip gaat verder dan de regulariteit en stabiliteit waarvan wordt uitgegaan bij een unidirectioneel causaal verband tussen forensgedrag en SWB. In plaats daarvan worden de onderling samenhangende relaties tussen forensgedrag en SWB erkend als tijd- en plaatsgebonden. Wanneer de resultaten inconsistent blijken, zou er in het longitudinale onderzoek dan ook moeten worden gekeken naar de contextuele

karakteristieken van de relaties tussen forensgedrag en SWB, zoals de geografische omgeving, sociale atmosfeer, culturele normen en de geschiedenis van lokale regio's (Schwanen, 2018).

## 2 Onderzoeksdoel en -vragen

**Doel van dit promotieonderzoek is om meer inzicht te verkrijgen in de oorzaken van deze inconsistentie bij het onderzoeken van de relaties tussen forensgedrag en SWB op lange termijn.** Hiervoor werden in het kader van dit proefschrift drie centrale onderzoeksvragen beantwoord in vijf onderzoeken – een overzichtsstudie en vier longitudinale onderzoeken. De eerste onderzoeksvraag is hoe we de kloof tussen enerzijds de theoretische conceptualisering van de relatie tussen forensgedrag en SWB en anderzijds de uitkomsten van empirische longitudinale onderzoeken moeten begrijpen. Voor de beantwoording van deze vraag wordt in hoofdstuk 2 een literatuuroverzicht gegeven van twee gerelateerde onderzoeksgebieden die zich onafhankelijk van elkaar ontwikkelden – onderzoek naar de theorie/overzichtsstudies waarin de relatie tussen forensgedrag en SWB theoretische wordt geconceptualiseerd en longitudinaal onderzoek waarin deze relatie empirisch wordt onderzocht. De tweede vraag van dit proefschrift is hoe de relaties tussen forensgedrag en SWB op lange termijn verschilden wanneer rekening werd gehouden met verschillende upstreamprocessen voor forensgedragveranderingen. Het onderzoek naar deze vraag wordt in de hoofdstukken 3 tot en met 5 besproken op het niveau van het individu. In elk hoofdstuk wordt een specifiek proces besproken dat leidt tot individuele veranderingen in forensgedrag, in respectievelijk China, het Verenigd Koninkrijk en Nederland. Tot slot wordt in dit proefschrift ook gekeken naar het niveau van huishoudens, ter beantwoording van de derde onderzoeksvraag: hoe manifesteren de relaties tussen forensgedrag en SWB zich vanuit het perspectief van huishoudens (zie hoofdstuk 6)?

## 3 Data en methoden

Voor onderzoek naar veranderingen in forensgedrag en SWB op lange termijn voor een bepaald individu zijn longitudinale data nodig over zowel forensgedrag als SWB. Dergelijke longitudinale data, die de algemene forenspopulaties deugdelijk representeren, zijn slechts beperkt beschikbaar. Voor dit promotieonderzoek werden drie datasets (in plaats van één) gebruikt van landelijke panels uit China, het Verenigd Koninkrijk en Nederland, om de complexiteit van de relaties tussen forensgedrag en SWB te bestuderen in verschillende contextuele domeinen. Deze landelijke paneldatasets zijn afkomstig van respectievelijk de China Health and Nutrition Survey, de UK Household Longitudinal Study (ook wel Understanding

Society) en het Mobiliteitspanel Nederland. Het longitudinale onderzoek dat in de drie landen wordt gehouden is er niet op gericht om de resultaten op het gebied van de relatie tussen forensgedrag en SWB onderling te vergelijken. De contextuele bepaaldheid van deze relatie is nu juist het onderwerp van deze dissertatie. Zo werden in deze landen contextuele kenmerken onderzocht als de door de overheid gestuurde en grondgedreven stedelijke groei van de Chinese steden, het verplichte thuiswerken tijdens de COVID-19-pandemie in het Verenigd Koninkrijk en de grotere mogelijkheden voor het zelf kiezen van een woonplaats in Nederland (door polycentrische stedelijke regio's en de geavanceerde transportinfrastructuur).

Voor dit promotieonderzoek werden twee methodieken toegepast: een methode voor systematische reviews voor de overzichtsstudie en methoden voor het maken van longitudinale modellen voor het empirische onderzoek. Voor hoofdstuk 2 is de richtlijn voor Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 gevolgd voor het systematische verzamelen van bestaande longitudinale onderzoeken naar de relatie tussen forensgedrag en SWB. De verzamelde literatuur diende als bibliotheek voor de kritische overzichtsstudie. In de hoofdstukken 3 tot en met 6 werden kwantitatieve modelleermethoden toegepast om de relaties tussen forensgedrag en SWB te analyseren aan de hand van de voor elke longitudinale opzet geschikte methode. Meer specifiek werd voor hoofdstuk 3 gebruikgemaakt van multilevel-modellen met een difference-in-difference-ontwerp voor onderzoek naar het verband tussen veranderingen in forenskeuzen en psychologische stress voor inwoners van verschillende wijken. Voor hoofdstuk 4 werden fixed-effect-modellen toegepast om te ramen hoe individuele veranderingen in SWB na het thuiswerken samenhingen met het forensgedrag vóór de uitbraak van COVID-19. Gezien het complexe beslissingsproces dat ten grondslag ligt aan verhuizingen, werd voor hoofdstuk 5 de structural equation modelling-analyse toegepast om de directe en indirecte relaties te onderzoeken tussen gezins- en werkgerelateerde levensgebeurtenissen, veranderingen in bereikbaarheid en gebouwde omgeving, en veranderingen in forenskeuzen en voorkeuren voor en na verhuizing. In hoofdstuk 6 werden schijnbaar ongerelateerde regressiemodellen met random effecten ontwikkeld om zowel de individuele als de spillover effecten te onderzoeken van reistijden voor woon-werkverkeer op het levensgeluk van stellen.

## 4 Samenvatting van de onderzoeksresultaten

Voor het literatuuroverzicht in hoofdstuk 2 werden al bestaande longitudinale onderzoeken naar de relatie tussen forensgedrag en SWB op lange termijn geïnventariseerd. De resultaten van deze longitudinale onderzoeken waren geenszins consistent. Er bleven dan ook vragen bestaan over de mate waarin gemotoriseerd woon-werkverkeer over lange afstanden leidde tot lage scores voor SWB op

lange termijn. Als verklaring voor de inconsistente uitkomsten van longitudinale onderzoeken, werd in hoofdstuk 2 gesteld dat kennis over de relatie forensgedrag-SWB moet beginnen met de integratie van theorieën uit verschillende disciplines, zoals de 'utility equilibrium theory' uit de economie, theorieën over houding en gewoonten uit de sociale psychologie, en de benadering op basis van mobiliteitsbiografieën uit de transportgeografie. Aan de hand van de interdisciplinaire theorieën werd de relatie forensgedrag-SWB geconceptualiseerd als een tijdgebonden, onderling samenhangend proces, dat (opnieuw) wordt vormgegeven door eerdere ervaringen van mensen, de huidige omstandigheden en de verwachtingen voor de toekomst. Op basis daarvan zouden voor toekomstig longitudinaal onderzoek verschillende processen moeten worden onderscheiden die leiden tot veranderingen in forensgedrag, zoals veranderingen in de leefomgeving, informatie- of participatie-interventies en verhuizingen, samen met andere levensgebeurtenissen en levensprocessen over de lange termijn. De procesbenadering is een verrijking van de tijdsdimensie van longitudinaal onderzoek en draagt bij aan een beter begrip van de onderling samenhangende relaties tussen forensgedrag en SWB die zich voordoen in de levens van mensen en de bijbehorende sociaal-ruimtelijke context.

Op basis van de in hoofdstuk 2 geïntroduceerde procesbenadering is in dit proefschrift gekozen voor drie upstreamprocessen voor forensgedragveranderingen, die in de daaropvolgende drie hoofdstukken werden onderzocht. Hoofdstuk 3 richt zich op het proces van stedelijke groei in China. Dit is een exogeen proces als het gaat om forensgedrag-SWB-relaties, omdat individuen weinig invloed hebben op de door de overheid gestuurde stedelijke groei in China. Bovendien heeft die op korte termijn nauwelijks consequenties voor hun dagelijkse woon-werkverkeer. Hoofdstuk 3 is het verslag van een onderzoek naar de mate waarin mensen in de loop van de tijd vasthielden aan hun keuzes op het gebied van woon-werkverkeer, en of dit verband houdt met psychologische stress op lange termijn. Hiervoor werd gebruikgemaakt van de China Health and Nutrition Survey (2006-2015). Daarnaast werd ook een tijdsafhankelijke schaal – stedelijkheid – ingezet, om de mate uit uitgestrektheid van de stedelijke ruimte weer te geven en om de geografische variaties in de relatie forensgedrag-stress te onderzoeken. Hieruit bleek dat langdurig actief forensgedrag leidt tot verlichting van psychologische stress, terwijl langdurig gemotoriseerd woon-werkverkeer met de auto of het openbaar vervoer leidt tot een hoger stressniveau. Verrassend genoeg bleek er geen lineair verband tussen enerzijds stedelijke groei en anderzijds de toename van gemotoriseerd woon-werkverkeer en meer psychologische stress. Niet in de gebieden met een hoog niveau van stedelijkheid, maar in gebieden met een matig niveau van stedelijkheid was het risico op stress door woon-werkverkeer het hoogst, door de extreem lange duur van woon-werkverkeer via het openbaar vervoer. Door de focus op het exogene proces van stedelijke groei wordt in het hoofdstuk uiteindelijk geconcludeerd dat Chinese



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steden zich bij hun groei minder moeten richten op toename van de grond voor stedelijke ontwikkeling en meer op verbetering van de stedelijke voorzieningen en het welbevinden van stadsbewoners.

In hoofdstuk 4 lag de focus op een ander exogeen proces voor forensgedragveranderingen, namelijk het verplichte thuiswerken tijdens de COVID-19-pandemie, om te onderzoeken hoe mensen die thuis werkten terugkeken op hun forensgedrag voor de COVID-19-uitbraak. Vergeleken met het geleidelijke proces van stedelijke groei, draagt de exogene schok van de COVID-19-pandemie op twee manieren bij aan de bepaling van het effect van forensgedrag op SWB op de lange termijn. De eerste is dat de huizen- en arbeidsmarkt geen mogelijke compensatie konden vormen voor het netto-effect van het afgenomen of stopgezette woon-werkverkeer. De tweede is dat een groot deel van de werkende bevolking door de thuiswerkverplichting werd gedwongen om het gangbare forensgedrag te doorbreken en bewust moest nadenken over de gevolgen van hun forensgedrag op hun welbevinden ('commuting wellbeing') (Kroesen, 2022). Op basis van de Understanding Society-data uit het Verenigd Koninkrijk bleek dat de fixed-effect-modellen alleen onder forensen met een lang woon-werktraject (met een afstand van meer dan 30 Engelse mijl, oftewel een kleine 50 kilometer) een positief effect vonden van thuiswerken op het affectieve welbevinden. Forensen die daarvoor vaak naar het werk gingen lopen of fietsen rapporteerden daarentegen een afname van het affectieve welbevinden en levensgeluk nadat ze thuis gingen werken. Dit daadwerkelijk uitgevoerde experiment tijdens de COVID-19-pandemie ondersteunt de claim dat dagelijks woon-werkverkeer invloed heeft op SWB op lange termijn, en dat forenzen het prettig vinden om een korte wandeling of fietsrit naar en van het werk te maken.

In hoofdstuk 5 worden verhuizingen beschouwd als een belangrijke stimulans voor veranderingen in forenskeuzen en -voorkeuren. Vergeleken met exogene processen voor forensgedragveranderingen zijn beslissingen omtrent verhuizingen mogelijk zelfgestuurde processen, waardoor deze een endogeen proces voor forensgedragveranderingen kunnen worden genoemd. Meer specifiek zou inconsistentie tussen de vorm van woon-werkverkeer en de voorkeur voor een vorm kunnen leiden tot ontevredenheid, waaruit een keuze voor verhuizing en forensgedrag kan voortkomen (Cao et al., 2009). Bovendien kunnen veranderingen in forensgedrag na een verhuizing voortkomen uit veranderingen in de gebouwde leefomgeving en/of een aanpassing aan levensgebeurtenissen die op dat moment plaatsvinden (Coulter and van Ham, 2013). Om dit te onderzoeken wordt in het hoofdstuk gebruikgemaakt van data van het Mobiliteitspanel Nederland, om de longitudinale relaties te analyseren tussen veranderingen in de gebouwde leefomgeving, eventuele levensgebeurtenissen en wijzigingen in vormen van woon-werkverkeer, en voorkeuren voor en na een verhuizing. Nederland is interessant

vanwege de concurrerende forensalternatieven ten opzichte van auto's (denk aan de sterk ontwikkelde fietscultuur en openbaarvervoersystemen) en de polycentrische stedelijke regio's met de diverse huizenmarkten voor het zelf kiezen van een woonplaats. De resultaten van de longitudinale structural equation-modellen bleken een ondersteuning voor zelfgekozen woonplaatsen op basis van op voorhand bestaande voorkeuren voor autogebruik of openbaar vervoer; waarbij bewoners hun actieve forensgedragvoorkeur naar beneden bijstellen na een verhuizing naar een meer suburbane wijk die verder ligt van hun werk en het openbaar vervoer. Daarnaast vielen levensgebeurtenissen wat betreft samenstelling van het huishouden en op werkgebied, zoals geboorten en het krijgen van een andere baan, vaak samen met verhuizingen en vormen die aanleiding tot toegenomen behoefte aan autogebruik.

De hierboven omschreven drie hoofdstukken zijn gebaseerd op analyses op individueel niveau, waarbij voorbij wordt gegaan aan het feit dat beslissingen over forensgedrag vooral tot stand komen op het niveau van het huishouden, waarbij machtsrelaties op basis van gender een rol spelen in onderhandelingen met andere gezinsleden. Daarom wordt in hoofdstuk 6 een perspectief op het niveau van huishoudens toegepast om de relatie tussen forensgedrag en SWB voor getrouwde mannen en vrouwen te vergelijken in stedelijk China. Uit de resultaten van de panelversie van op het oog ongerelateerde regressiemodellen blijkt dat het levensgeluk van zowel getrouwde mannen als vrouwen gelijkelijk afnam naarmate hun woon-werkverkeer langer in beslag nam. Bovendien bleek dat er een overlappend effect is van woon-werkverkeer voor getrouwde mannen en vrouwen in verschillende stadia van het gezinsleven. De tijd die getrouwde vrouwen besteden aan hun woon-werkverkeer bleek een groter negatief effect te hebben op het levensgeluk van hun mannen dan andersom. De manier waarop getrouwde vrouwen hun woon-werkverkeer beleven hield meer verband met tijdsdruk vanwege de zorg voor nog niet naar schoolgaande kinderen en de sociale ondersteuning van overige familieleden (in dit onderzoek de grootouders van kinderen). Met name in een land waar veel belang wordt gehecht aan een patriarchale en collectieve gezinscultuur, zoals China, draagt het samenwonen met grootouders bij aan verlichting van het tijdsbeslag dat langdurig woon-werkverkeer voor jonge ouders met zich meebrengt, met name voor werkende moeders (Ta et al., 2019).

## 5 Synthese van de onderzoeksresultaten en geleerde lessen

Het overkoepelende doel van dit promotieonderzoek is om inzicht te krijgen in de vraag waarom bestaande onderzoeksuitkomsten inconsistent zijn wat betreft de relatie tussen forensgedrag en SWB op lange termijn. Door mensen in de loop van de tijd te volgen wordt in dit onderzoek geconcludeerd dat het dagelijkse woon-werkverkeer een belangrijke factor is voor het SWB van mensen op lange termijn.



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Dit betekent echter niet dat woon-werkverkeer over een grotere afstand altijd lineair leidt tot een afgenomen SWB, hoewel zo'n unidirectioneel causaal verband wel vaak wordt genoemd als reden waarom longitudinale onderzoeksontwerpen de voorkeur verdienen boven cross-sectioneel onderzoek (Suppes, 1970). Op basis van een procesbenadering wordt in dit proefschrift gesteld dat het redeneerproces voor longitudinale onderzoeken moet worden verbreed en dat de contextuele interpretatie moet worden verrijkt om te komen tot een beter begrip van de relatie tussen forensgedrag en SWB. De eerste route is in feite een stap achteruit, om het upstreamproces voor veranderingen in forensgedrag te achterhalen. De tweede route is erkennen dat de relatie tussen forensgedrag en SWB niet eenvoudig te generaliseren valt voor ruimte en tijd. Deze relatie is afhankelijk van de sociaal-ruimtelijke context die wordt bestudeerd, zoals de levensstadia waarin individuen en huishoudens zich bevinden en hun geografische en sociaal-culturele achtergrond. Het volgen van deze twee routes betekent niet dat er een uniform causaal verband bestaat tussen forensgedrag en SWB, maar dit draagt wel bij aan een beter begrip van de onderling samenhangende relatie tussen forensgedrag en SWB op lange termijn.

Theoretisch gezien is voor inzicht in de relatie tussen forensgedrag en SWB een integraal theoretisch perspectief nodig. Het economische raamwerk van een evenwicht voor individueel nut voldoet niet om de relatie forensgedrag-SWB te beschrijven. Uit de longitudinale analyse voor dit proefschrift bleek dat mensen minder gelukkig en tevreden waren met hun leven naarmate ze meer tijd besteedden aan woon-werkverkeer. Dit resultaat is strijdig met de theorie van nutsevenwicht, maar ondersteunt de forensgedragparadox: individuen ervaren geen compensatie op het gebied van huisvesting of werk die opweegt tegen het ongemak van langer woon-werkverkeer (Stutzer and Frey, 2008). Daarnaast werd voor deze dissertatie onderzocht of er een nutsevenwicht is op het niveau van het huishouden. Ook binnen huishoudens deed zich de forensgedragparadox voor; getrouwde mannen scoorden lager op SWB naarmate het woon-werkverkeer van hun vrouw meer tijd in beslag nam, en het levensgeluk van getrouwde vrouwen bleek afhankelijk van de tijdsduur van hun eigen woon-werkverkeer, waarbij de stadia van gezinsleven een rol speelden, wat netto een ongemak door woon-werkverkeer op het niveau van huishouden opleverde. Dit paradoxale fenomeen houdt echter niet in dat woon-werkverkeer moet worden tegengegaan om het SWB-niveau van mensen te verhogen. Dit blijkt uit de ervaring die werd opgedaan met thuiswerken tijdens de COVID-19-pandemie. Forenzen die eerder naar hun werk liepen of fietsten bleken lager te scoren op SWB nadat ze verplicht thuis moesten werken. Anders gezegd: mensen vinden het prettig om actief een korte afstand van en naar hun werk te overbruggen.

Op methodologisch vlak zijn voor deze dissertatie pilots gedaan met verschillende longitudinale onderzoeksontwerpen om de in de loop van de tijd de onderling samenhangende relatie tussen forensgedrag en SWB op lange termijn te

onderzoeken. Hoewel er steeds meer data van landelijke panels beschikbaar komt, is het ontwerp en de toepassing van deze longitudinale ontwerpen niet eenvoudig. Het is hiervoor niet alleen nodig om de verschillende upstreamprocessen voor forensgedragveranderingen van elkaar te onderscheiden, maar ook om de longitudinale analyses van de relatie tussen forensgedrag en SWB nauwkeurig te plaatsen in de sociaal-ruimtelijke context van een onderzoeksgebied. Daarnaast is het van belang dat de toegepaste modelleermethodes geschikt zijn voor longitudinaal onderzoek. Daarvoor wordt vaak zonder al te veel nadenken gebruikgemaakt van fixed-effectmodellen om onderzoek te doen naar de effecten van veranderend forensgedrag op SWB. Dat heeft als nadeel dat observaties van personen bij wie in een jaar geen of nauwelijks verandering in forensgedrag zijn opgetreden, impliciet buiten de longitudinale analyse vallen. Wat betreft de problemen en vooronderstellingen die invloed hebben op de verzameling en analyse van gegevens afkomstig van panels, zou voor longitudinaal gedragsonderzoek de onderzoeksgroep zorgvuldig moeten worden gescreend, geselecteerd en beschreven voordat geavanceerde modelanalyses worden toegepast.

Praktisch gezien leveren de resultaten uit het longitudinale onderzoek van dit promotieonderzoek implicaties op voor op mensen en plaatsen toegespitst beleid voor de beïnvloeding forensgedrag en het verbeteren van de SWB van forenzen. Wanneer we kijken naar plaatsen spelen initiatieven op het gebied van stadsplanning, zoals een uitgekiende stedelijke groei, transitie-georiënteerde stadsontwikkeling en beloopbare wijken een structurele rol in het sturen van vanuit milieu- en sociaal oogpunt wenselijke forenspatronen. Dergelijke op een plaats toegespitste initiatieven bleken effectief in het tegengaan van mismatches wat betreft woningen en banen en het stimuleren van duurzame transportmiddelen (Banister, 2008; Zhao and Li, 2017). Dit proefschrift biedt een nadere aanwijzing voor het potentieel van dergelijke initiatieven, gezien de voorkeur die bleek te bestaan voor actief forensgedrag over een korte afstand, wat positief bijdraagt aan de SWB-resultaten van forenzen. Naast deze op plaats gerichte planningsinitiatieven zijn situaties met flexibele werkplekken (bijvoorbeeld enkele dagen per week thuiswerken) en enkele nieuwe vervoersmiddelen (zoals de elektrische fiets) ook veelbelovend als het gaat om verlichting van de lasten van gemotoriseerd woon-werkverkeer over lange afstanden. Vanuit een op de persoon gericht perspectief zou sturing van de reisbehoefte kunnen worden toegespitst op sociale groepen met heterogene reisvragen en -voorkeuren. Zo zouden gedragsinterventies gericht op het tegengaan van woon-werkverkeer met de auto moeten worden toegespitst op buurten waar niet teveel autoliefhebbers wonen, en op mensen die op het punt staan een ingrijpende levensgebeurtenis mee te maken (zoals verhuizen naar een buitenwijk en het krijgen van een kind). Mogelijke interventiestrategieën zijn onder meer voorlichtings- en informatiecampagnes over milieubewustzijn, op de doelgroep afgestemde informatie



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over duurzame vervoersalternatieven voor gezinnen die op zoek zijn naar een woning en zorg dragen voor goed openbaar vervoer in de wijk.

## 6 Implicaties voor toekomstig onderzoek en op te stellen beleid

De procesbenadering is een veelbelovende richting voor toekomstig longitudinaal onderzoek voor meer inzicht in de relatie tussen forensgedrag en SWB. Voor dit promotieonderzoek is het forensgedrag en SWB van mensen theoretisch geconceptualiseerd als een onderling samenhangend proces dat zich op een bepaald moment gedurende de levensloop van mensen voordoet in een daarmee samenhangende sociaal-ruimtelijke context. Vanuit het levensloopperspectief is nader longitudinaal onderzoek nodig naar de manier waarop het woon-werkverkeer en andere levensdomeinen elkaar op de langere termijn beïnvloeden. Het is met name interessant om te onderzoeken hoe mensen hun forensgedrag aanpassen door te anticiperen, direct te reageren of pas later te reageren op levensgebeurtenissen, en hoe deze grote veranderingen in het leven gezamenlijk bijdragen aan de gezondheid en het SWB van mensen. Bovendien zijn het leerproces tijdens de jeugd en de navolging van oudere generaties ook mogelijke manieren om het forensgedrag van mensen te beïnvloeden en om hun houding ten opzichte van woon-werkverkeer te sturen. Voor meer inzicht in de relatie tussen forensgedrag en SWB zullen naar verwachting meer longitudinale analyses zich richten op het proces van het veranderen van forensgedrag en de dynamiek in de relatie tussen forensgedrag en SWB tijdens de levensloop.

De procesbenadering kan ook worden toegepast in gedragsgeoriënteerde interventie-experimenten en voor het maken van beleid op dit gebied. Bij interventie-experimenten worden deelnemers vaak uitgedaagd gedurende een korte tijd alternatieve forenskeuzen te onderzoeken (bijvoorbeeld over te stappen van forenzen met de auto naar fietsen naar het werk). Ter stimulering van de verwachte gedragsveranderingen is het nodig om niet alleen de veranderingen in forensgedrag te monitoren, maar ook de verandering in SWB-scores, zoals de tevredenheid met het woon-werkverkeer, in de loop van de tijd. Reden daarvoor is dat mensen hun forens-gerelateerde houding eerder aanpassen en eerder nieuwe forensroutines ontwikkelen als ze tevreden zijn over de alternatieve vorm van woon-werkverkeer (De Vos et al., 2022). Voor het in stand blijven van de gedragsveranderingen moet het forensgedrag en de SWB van deelnemers gedurende langere tijd worden gevolgd na de interventie. Dit maakt het noodzakelijk dat experimenten met tijdelijke interventies worden geïntegreerd in beleidsontwikkeling en -evaluatie op de lange termijn. Zo kunnen bijvoorbeeld in programma's voor woningontwikkeling op proef mobiliteitspakketten worden aangeboden aan onlangs verhuisde

bewoners, met een combinatie van gratis openbaar vervoer en deelfietsen, om zo te proberen het autogebruik te beperken. Daarnaast moeten, na het stopzetten van proefmobiliteitspakketten, doorlopend follow-ups worden opgenomen in de beoordeling van het programma, om ervoor te zorgen dat de gewenste forenspatronen en SWB-scores ook op lange termijn standhouden.

Op basis van de uitkomsten van dit promotieonderzoek zou door toekomstig longitudinaal onderzoek het procesmatige denken en het contextuele begrip kunnen worden ontwikkeld om inzicht te krijgen in de tijdgebonden, onderling samenhangende relatie tussen forensgedrag en SWB. Wanneer de resultaten van longitudinaal onderzoek naar de relatie tussen forensgedrag en SWB inconsistent zijn, moeten deze niet worden gezien als hindernis om te komen tot algemene onderzoeksconclusies, maar als aansporing voor onderzoekers om bestaande longitudinale onderzoeksresultaten behoedzaam toe te passen, om het longitudinale onderzoek zorgvuldig op te zetten en om de inconsistente resultaten van longitudinaal onderzoek nog kritischer te interpreteren. Daarnaast moeten de beleidsconsequenties van het aansturen van het proces van forensgedragveranderingen zorgvuldig worden afgewogen en moeten interventies goed aansluiten op verschillende plaatsen en sociale groepen, zodat dit uiteindelijk leidt tot een duurzame leefomgeving en sociaal welbevinden op lange termijn. Zoals uit dit promotie-onderzoek blijkt, is dagelijks forensgedrag van invloed op SWB op de lange termijn, maar om meer inzicht te krijgen in die relatie tussen forensgedrag en SWB moet longitudinaal onderzoek antwoord geven op de vraag waarom forensgedrag überhaupt al dan niet verandert en hoe de relatie forensgedrag-SWB er in een specifieke lokale, sociaal-ruimtelijke context uitziet.

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# 1 Introduction

Increasingly long and motorised commuting journeys are a striking feature of urban life and society. This unsustainable commuting pattern not only imposes great environmental and economic costs, but may also undermine public health and wellbeing in the long term. Research has been discussing the wellbeing aspect of commuting behaviours from a person-centred perspective, showing that commuters tend to report worse life satisfaction when they have long commuting trips. However, this contradicts what can be expected based on the utility equilibrium theory. This theory states that the wellbeing loss from long commute should have been compensated by job- or housing-related benefits, thereby contributing little to people's long-term happiness and life satisfaction. These inclusive findings warrant a better understanding of the mechanism underlying the commuting-wellbeing relationship.

Classic urban location theory understands individuals' commuting choices under the framework of utility equilibrium (Alonso, 1964; Mills, 1967; Muth, 1969). This equilibrium theory involves two basic hypotheses: Commuting comes from the long-term choices of residence and workplaces; and commuting itself comes with a cost, such as the time and money spent for the commuting journey, energy expenditure and psychological burdens (e.g., commuting stress). Based on these two hypotheses, individuals would only accept commuting-related costs if they could gain equivalent compensation from job and housing markets (e.g., a rewarding job and a big house). Otherwise, they would relocate the house close to the workplace or find another job around the residence to avoid unnecessary commuting costs. As a result, there is an equalised level of utility or wellbeing over all combinations of alternative job-housing relationships and commuting choices, or more simply put, any individuals bear no utility loss from their daily commuting journeys.

**In a direct test of the experienced utility of commuting, however, research evidence is inconsistent regarding the impact of daily commuting behaviours on long-term subjective wellbeing (SWB), including the affective evaluation (e.g., happiness) and cognitive assessment (e.g., satisfaction) of life domains and overall life.** Emerging longitudinal research focusing on the within-individual variations of commuting and SWB even finds that individuals systematically report lower levels of life satisfaction with the increase of commuting time or distance (e.g., Milner et al., 2017; Lorenz, 2018; Ingenfeld et al., 2019). This finding is well-known as the commuting paradox, given its inconsistency with the utility equilibrium that assumes negligible commuting-SWB relationships (Stutzer and Frey, 2008).



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**This thesis aims to better understand why this inconsistency occurs when examining the relationships between commuting behaviours and long-term SWB.** To achieve this aim, the thesis applies longitudinal research designs to investigate to what extent increasingly long and motorised commuting journeys are associated with worse SWB in the long term. The main contribution of this thesis is the conceptualisation of the commuting-SWB relationship as an interdependent and reciprocal process over time. This processual approach is organised around two ways forward in this thesis. **The first way forward is to differentiate the upstream process of (no) changes in commuting behaviours, regarding the reason for people to change or not to change their commuting behaviours in the first place. The second way forward is to acknowledge the contextual uncertainty in the commuting-SWB relationships, which can be specific to people at different life stages and different places.** Pursuing these ways forward requires panel datasets that contain both commuting and SWB information from different contextual areas. For this reason, nationwide multi-wave survey data from China, the United Kingdom (UK) and the Netherlands are used in this thesis to enrich the socio-spatially contextual understanding of the interdependent commuting-SWB relationships.

## 1.1 Longitudinal relationships between commuting behaviour and subjective wellbeing

Longitudinal research, or panel research, is a research design that repeatedly observes the same research object over a period of time (Ployhart and Vandenberg, 2010). Different from cross-sectional studies that compare different individuals at a single point of time, the longitudinal research design focuses on within-individual variations of behaviours and behavioural outcomes (e.g., SWB) over time. It is, therefore, regarded as "a golden standard" to infer causal relationships and direct policy designs in quantitative studies. Specific to the impact of commuting behaviours on SWB outcomes, longitudinal research satisfies three important preconditions for identifying this causal impact according to the probabilistic theory of causality (Suppes, 1973). First, longitudinal designs can meet the tendency requirement of causality by making explicit the time precedence between exposures and responses, i.e., changes in commuting behaviours precede changes in SWB outcomes in time. Second, the within-individual analysis excludes any unobserved

between-individual differences, such as the implicit personality constructs and intergenerational differences (i.e., the cohort effect), that confound the commuting-SWB causality. Third, the assessment of SWB is not biased toward the varied criteria among individuals by focusing on temporal variations of SWB for the same individual.

Despite the methodological advance of longitudinal designs, existing research on the commuting-SWB relationship is inconsistent; that is, increasingly long and motorised commuting journeys over time exert negative, insignificant, or even positive effects on long-term SWB outcomes in different longitudinal studies. This inconsistency could result from overemphasizing the statistical significance and methodological "regularity in conjunction between preceding dependent variables and independent outcomes" (Schwanen, 2018). However, theoretical conceptualisation of the commuting-SWB relationship is largely overlooked. To bridge the gap between theoretical understandings and longitudinal research, this thesis uses a processual approach to reframe the commuting-SWB relationship as a process (Whitehead, 1929). In this process, commuting behaviours are interdependent with SWB over time, and the interdependent commuting-SWB relationships are (re)shaped by people's past experiences and situational contexts.

Following the processual approach, the first way forward is to understand why commuting behaviours change or do not change in the first place, termed the upstream process of commuting changes. Based on the literature review, I summarise three different but interrelated processes that lead to changes in commuting behaviours and complicate the understanding of the commuting-SWB relationship (Tao et al., 2022). They are environmental changes, information/participatory interventions and the events of residential relocation. Specifically, environmental changes outline the variations in transportation infrastructure and physical environment over time. In such cases, people tend to repeat habitual commuting routines and do not deliberately think about their commuting wellbeing, especially when environmental changes are gradual and hard to be noticed in a short time. In contrast, behaviour interventions by information or participatory strategies reinforce people's intention to initiate commuting alternatives and proactively compare the experienced utility of available commuting choices. Different from the above two exogenous processes, residential relocation events are endogenous to the commuting-SWB relationship because relocation decision-making often involves a self-selection process. For example, dissatisfaction with daily commutes may constitute a reason for changing houses, and accordingly, for realising preferred commuting behaviours in the new place of residence. Notably, the analysis of the upstream process of commuting changes should not leave behind those individuals who do not change commuting behaviours over time. This is especially pertinent when examining the impact on long-term SWB outcomes because the benefit or threat of maintaining certain commuting behaviour may take time to appear.

The second way suggested by this thesis is to understand the commuting-SWB relationships appropriately situated in people's life courses and localised socio-spatial contexts, termed the contextual understanding of the commuting-SWB relationship. This contextual understanding goes beyond the regularity and stability assumed in the unidirectional commuting-SWB causality. Instead, it acknowledges the interdependent commuting-SWB relationships as time- and place-specific. Taking a life-course perspective, for example, residential relocation can be conceptualised as an adaptation to family- or job-related life events (e.g., suburban relocation after childbirth), along with the travel-related concern (e.g., a greater preference and demand for car use after childbirth and suburban relocation). It is open to question how the three of them (i.e., life events, residential relocation and commuting behaviours) are relationally situated in the life course and jointly influence people's SWB. In addition to the time-specific effect, the relationships between commuting behaviours and SWB may vary from place to place. This place-specific effect is not a nuisance that obstructs research from concluding a uniform commuting-SWB relationship across different areas, but a resource that contributes to understanding the contextual uncertainty in this relationship. Therefore, research should interpret the mixed findings for commuting-SWB relationships based on the contextual characteristics, including geographical environment, social atmosphere, cultural norms and past history, of local areas (Schwanen, 2018).

## 1.2 Research questions

To understand the longitudinal relationships between commuting behaviours and SWB, this thesis answers three main research questions in five studies – one review study and four empirical studies. The research framework is outlined in Figure 1.1.

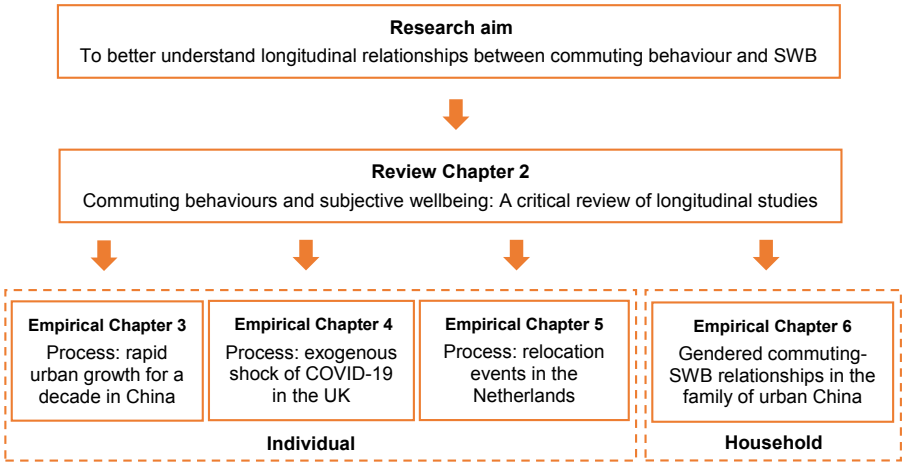


FIG. 1.1 Research framework

The first research question of this thesis is: **How to understand the gap between the theoretical conceptualisation of the commuting-SWB relationship and the outcome of empirical longitudinal studies?** To answer this question, Chapter 2 reports on a literature review to combine two areas of research that have been developing separately – theory/review research that theoretically conceptualises the commuting-SWB relationship and longitudinal research that empirically examines this relationship. The chapter develops from the theoretical understanding of commuting-SWB relationships from an interdisciplinary perspective. Based on the interdisciplinary theories, the processual approach is proposed to account for the mixed findings for commuting-SWB relationships in existing longitudinal studies. This approach suggests relevant longitudinal studies to differentiate upstream processes of commuting changes and to understand the contextual specificity of the commuting-SWB relationships.

The second research question is: **How do the relationships between commuting behaviours and long-term SWB vary after taking into account different upstream processes of commuting changes?** This question is investigated from Chapters 3 to 5 at the individual level. Each chapter discusses a specific process that leads to within-individual changes in commuting behaviours in China, the UK and the Netherlands, respectively. Chapter 3 focuses on a period of urban growth in China (2006-2015). During this decade, the process of Chinese urban growth is gradual so that people may hardly notice its impact on daily commutes and thus have weak intention to break commuting habits. For this consideration, the chapter pays particular attention to maintaining certain commuting mode over time and the



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associations with long-term psychological stress, a widely discussed indicator of affective wellbeing.

Chapter 4 uses working from home during the COVID-19 pandemic as a natural experiment to examine how reduced or cancelled commutes reshape homeworkers' SWB outcomes in the UK. Specifically, this chapter investigates the relationship between the transition to homeworking and SWB outcomes during the pandemic, and more importantly, to what extent this relationship depends on the pre-COVID-19 commuting distances and mode choices. In this case, the commuting-SWB causality can be better identified by studying the exogenous process of commuting changes experienced by a majority of the working population.

Chapter 5 analyses an endogenous process of commuting changes, i.e., residential relocation. According to the residential self-selection argument, the inconsistency between travel preferences and travel behaviours will cause dissatisfaction and lead the relocation decision-making. The observed commuting changes following residential relocation can thus be a realisation of pre-existing travel preferences rather than a result of changes in the residential environment pre-post relocation. Moreover, relocation is a long-term household decision involving a myriad of decision-making factors relevant to the wellbeing of other life domains (e.g., satisfaction with housing and neighbourhood school quality). If commuting-related residential self-selection is not the case, residents may adjust either their commuting behaviours or travel attitude after the relocation to achieve behaviour-attitude consistency. For these considerations, a pre-post event analysis is conducted in the Netherlands to understand the condition under which residential relocation results in changing not only commuting mode choices but also mode-specific preferences.

Chapters 3 to 5 focus on the individual-level analysis, while Chapter 6 turns to the household level by answering the following research question: **How do the commuting-SWB relationships manifest themselves from a household perspective?** The household-level analysis is required because working couples often decide on a common residential location and commute to their respective job locations. The allocation of job-housing relationships between couples may jointly shape their SWB outcomes. In Chapter 6, specifically, the longitudinal study in urban China examines whether commuting time is associated with life satisfaction for couples, and if so, whether and how the presence of children and grandparents influences the gendered commuting-SWB relationship. Here, the gendered commuting-SWB relationships concern not only the difference in the within-individual effect of commuting time but also the spill-overs of commuting utility between husbands and wives.

## 1.3 Data and methods

Longitudinal data including both commuting and SWB information are required to study changes in commuting behaviour and SWB for the same individual over time. This kind of longitudinal data with a good representation of general commuting populations is limited. In this thesis, not one but three nationwide panel datasets from China, the UK and the Netherlands are used to examine the complexity of commuting-SWB relationships in different contextual areas. These nationwide panel datasets are China Health and Nutrition Survey, the UK Household Longitudinal Study (or Understanding Society) and the Netherlands Mobility Panel, respectively. Longitudinal research conducted in three different countries does not aim at comparing the results of the commuting-SWB relationship between them. Instead, the contextual specificity for understanding this relationship is the interest of this thesis. For example, the contextual characteristics studied in these countries include the government-led and land-driven urban growth in urban China, the mandated working from home during the COVID-19 pandemic in the UK, and greater chances of residential self-selection in the Netherlands (due to polycentric urban regions and advanced transportation infrastructure).

Two types of methods are used in this thesis, i.e. the systematic review method for the review research and longitudinal modelling methods for the empirical research. Chapter 2 follows the guideline of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 to systematically collect existing longitudinal studies on commuting-SWB relationships. The collected literature serves as a library for the critical review research. Chapters 3-6 use quantitative modelling methods to analyse commuting-SWB relationships appropriate for each longitudinal design. Specifically, Chapter 3 employs the multilevel models with the difference-in-difference design to examine how changes in commuting mode choices are related to long-term psychological stress for residents from different neighbourhoods. Chapter 4 applies the fixed-effect models to estimate how within-individual changes in SWB after homeworking depend on the pre-COVID-19 commuting behaviours. Considering the complex decision-making process underlying residential relocation, Chapter 5 conducts the structural equation modelling analysis to explore the direct and indirect relationships between family- and job-related life events, changes in accessibility and neighbourhood built environment, and changes in commuting mode choices and preferences before and after residential relocation. In Chapter 6, seemingly unrelated regression models with random effects are developed to inspect the within-individual and spill-over effects of commuting time on life satisfaction for couples.

## 1.4 Thesis outline

After the Introduction Chapter, the remainder of this thesis is structured as follows. Chapter 2 critically reviews existing longitudinal research on commuting-SWB relationships. The processual approach put forward in Chapter 2 directs the following empirical Chapters 3-6. Specifically, Chapters 3, 4 and 5 investigate within-individual changes in commuting behaviours and SWB in China, the UK and the Netherlands, respectively. Each of the three chapters focuses on an upstream process of commuting changes specific to the contextual areas under study. Moreover, Chapter 6 examines the gendered commuting-SWB relationships in China from the household perspective. As a conclusion of this thesis, Chapter 7 finally synthesises the research findings, summarises the benefits and limitations of the panel data and longitudinal analytical methods used, and suggests how longitudinal research on commuting-SWB relationships and policy interventions on commuting behaviours can be further developed.

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# 2 Commuting behaviours and subjective wellbeing

## A critical review of longitudinal research

**Yinhua Tao, Ana Petrović & Maarten van Ham**

ABSTRACT The relationship between commuting behaviours and subjective wellbeing has been fascinating scholars of different disciplines. Especially in the last decade, longitudinal research designs have made great progress in identifying causality in the commuting-wellbeing relationship by focusing on within-individual variations over time. However, the results from longitudinal research are far from consistent and, therefore, questions remain unanswered regarding the association of motorised and long commuting journeys with subjective wellbeing in the long term. The aim of this literature review is to account for why these inconsistencies occur and to provide some avenues for future longitudinal research. We achieve this by developing theoretical conceptualisations of the commuting-wellbeing relationship from an interdisciplinary perspective, which drives the subsequent critical review of empirical longitudinal evidence based on nation/city-wide panel surveys, intervention experiments and relocation events. Our recommendation for future research is to distinguish and integrate different processes that lead to changes in commuting behaviours, including environmental changes, information or participatory interventions, and the event of residential relocation together with other life events and long-term processes in life. This processual thinking will enrich the temporal scope of longitudinal research and contribute to a better understanding of the interdependent relationship between daily commuting behaviours and long-term subjective wellbeing.

KEYWORDS Travel behaviour, well-being, causal relationships, mobility biographies, longitudinal designs, systematic review

## 2.1 Introduction

Transport and wellbeing have long been of interest to transport researchers and practitioners from the assertion that the ultimate goal of transportation planning and policies is public welfare and wellbeing (Kitamura et al., 1997; Ettema et al., 2010). According to the OECD (2013), subjective wellbeing (SWB) refers to "good mental states, including all of the various evaluations, positive and negative, that people make of their lives, and the affective reactions of people to their experiences". Commuting between home and workplaces, as routinely repeated travel behaviour and an unavoidable life domain for many working populations, may well exert an adverse effect on SWB in the long term. Cross-sectional studies have consistently concluded that there is a negative association of long commuting time and motorised commuting modes with overall life satisfaction and satisfaction with sub-domains of life (e.g., commuting satisfaction; Chatterjee et al., 2020). However, such cross-sectional findings contribute little to understanding the causality of the commuting-SWB relationship.

In the past decade, longitudinal studies examining the commuting-SWB relationship have been burgeoning due to increasing availability of panel datasets that follow people's behaviours and behavioural outcomes (e.g., SWB) over time. By virtue of the longitudinal design, these studies aim to answer the question of how changes in daily commuting journeys result in changes in long-term SWB. Compared with cross-sectional studies, longitudinal studies represent a big step forward in terms of uncovering the commuting-SWB causality for at least three reasons (Suppes, 1970). First, they control for any factors that are idiosyncratic to the individual and less likely to vary over time, such as personality, so the commuting-SWB relationship will not be confounded by unobserved between-individual differences. Second, SWB is specific to each individual's experience. It is not clear whether someone's report on SWB can be directly compared to that by someone else. In this respect, longitudinal designs have the advantage of focusing on within-individual variations in SWB over time. Third, some longitudinal designs, such as the intervention experiment that informs participants of available commuting choices or asks them to initiate alternative commuting choices, give insight in the temporal precedence between commuting behaviours and SWB outcomes. In such designs, a low level of SWB does

not constitute a reason for people to change commuting behaviours, which to some extent resolves the reverse causality issue.

Despite methodological advances in longitudinal studies, their results on the relationship between daily commuting journeys and long-term SWB are not consistent. Not all studies show that longer and motorised commuting journeys lead to worse SWB in the long term, indicating that extant cross-sectional evidence is not corroborated by longitudinal research. This inconsistency may come from an inadequate theoretical foundation of the commuting-SWB relationship and the variety of research designs and approaches that different longitudinal studies draw on. This presents a challenge when comparing different research designs, analysing the effect mechanisms, and critically evaluating findings on the commuting-SWB relationship.

Our study contributes to this emerging field by proposing a theory-driven conceptualisation of the commuting-SWB relationship and critically reviewing the longitudinal evidence on this relationship. We argue that longitudinal research should start with distinguishing and integrating different processes that lead to changes in commuting behaviours, including environmental changes, information/participatory interventions, and relocation events over the life course. Introducing this processual way of thinking will enrich the temporal scope of longitudinal research, and contribute to a better understanding of the interdependent relationship between commuting behaviours and subjective wellbeing appropriately situated in people's life courses and corresponding socio-spatial contexts.

We start our critical review by sketching the theoretical concepts and explanations of the relationship between commuting behaviours and SWB from an interdisciplinary perspective. The conceptual model that we derive from the interdisciplinary theories drives the following literature review of empirical longitudinal research. Finally, we outline an agenda and potential avenues for future longitudinal research with the aim of better understanding the commuting-SWB interdependency.

## 2.2 Conceptualisation of the commuting-wellbeing relationship

This section draws from an interdisciplinary perspective to conceptualise the dynamics in commuting behaviours and SWB over time, as well as the interdependent relationship between the two. Most of the relevant theories are not based on transportation research but originate from economics, psychology, sociology and geography. Given the intention to identify whether and how repetitive daily commutes have a lasting impact on SWB, we focus on the relationship between commuting behaviours and long-term SWB, including affective reactions (e.g., happiness) and cognitive judgement (e.g., satisfaction) of specific life domain and overall life (Diener et al., 2009). Our interest in the long-term effect is motivated by Chatterjee et al. (2020), which claims that "a consistent link between commuting and life satisfaction overall has not been established". Therefore, the synthesis of theories and longitudinal evidence is a viable way to clarify the mechanism underlying changes in commuting behaviours and to lend the causal inference on the commuting-SWB relationship.

### 2.2.1 Neo-classical and behavioural economics: The utility theory

Neo-classical economists understand commuting decisions within the framework of utility equilibrium. The precondition for utility equilibrium is that commuting acts as a source of disutility that demands the costs of, say, travel expenses, time loss and energy expenditure. Economically rational individuals would accept these commuting-related costs only if they could access more rewarding jobs or better living environments. The consequence is a spatial equilibrium in the job and housing market, where the disutility from commutes is fully compensated by job- and housing-related benefits (Alonso, 1964; Mills, 1967; Muth, 1969). Otherwise, individuals would search for long-term mobility strategies, such as job change and residential relocation, to leave the utility invariant among them.

However, decision utility inferred from observed choices is not always identical to the experienced outcome of choices (e.g., SWB), which contradicts the view of utility equilibrium. Neo-classical economists pay little attention to experienced utility even though it fits better with the original idea of utility, i.e., the experience of pleasure or pain (Bentham, 1789). Instead, behavioural economists account for the divergence

between decision utility and experienced utility by the iterative process of utility anticipation, experience and retrospection (Kahneman et al., 1997; Kahneman and Thaler, 2006). Specifically, individuals reach the commuting decision before the behaviour actually takes place. To reach the decision, they need to predict and compare the experienced outcomes of available choices by reflecting on their former experience (Ettema et al., 2016; De Vos et al., 2016). In most cases, the anticipation of experienced utility is not accurate due to socio-psychological mechanisms such as memory distortion (e.g., overstating the intensity and duration of negative past experiences; Wilson and Gilbert, 2003) and the focusing illusion (i.e., assessing an experience according to the most memorable moments, such as the most intense and recent moment, i.e., the peak-end rule; Kahneman and Krueger, 2006). Moreover, this inaccurate anticipation has roots in the hypothesis of individual rationality (Frey and Stutzer, 2014). In reality, however, individuals not only present heterogeneous preferences and assessments of choice outcomes but also reach commuting decisions under socio-spatial constraints or with limited mobile capability (e.g., unable to drive or cycle to work).

### 2.2.2 Social psychology: The attitude theory

Attitude, a core concept of social psychology, refers to the evaluative structure that predisposes individuals to respond to certain stimuli and behave in a certain way (Ajzen, 2001). When applied to the travel domain, attitude can be operationalised as the preference for means of travel, travel time or overall travel experience (Van Wee et al., 2019). In contrast to the economists' perspective that commuting is a source of disutility, psychologists believe that travel can bring happiness in its own right by providing, among others, transition time (e.g., shifts between different social roles; Jain and Lyons, 2008), an opportunity of time-out (e.g., the escape from obligations; Lyons and Chatterjee, 2008) and a form of physical activity (e.g., walking or cycling to work; Ory and Mokhtarian, 2005). Especially, the coincidence between commuting behaviours and travel attitude, such as commuters who value exercise can walk or cycle to work, will engender a positive evaluation on commuting journeys and may benefit overall SWB in the long term.

Travel attitude is originally framed as a stable construct in well-established psychological theories, such as the theories of reasoned action and planned behaviour. In these theories, attitude, together with the subjective norm and perceived behavioural control, forms the intention that drives behaviours (Fishbein and Ajzen, 1975; Ajzen, 1991). Habit derived from past behaviours and experience, however, mediates the effect of behavioural intention on the occurrence of

behaviours (Triandis, 1977; De Vos and Witlox, 2017). Under routine conditions, performing habitual behaviours is a more common way to reduce cognitive effort given that alternative commuting choices often involve high search costs and uncertain anticipated utility (Gärling and Axhausen, 2003; McInerney et al., 2013). In this case, individuals do not go through deliberate decision-making but repeat daily routines without seriously considering their attitude towards and satisfaction with commuting (De Vos et al., 2021a). Therefore, breaking travel habits often requires some events, such as temporary interventions on commuting behaviours and long-term relocation of residence or workplaces, to open up a window of opportunity for unfreezing habitual commuting routines (Van Acker et al., 2010).

Advances in attitude theories indicate that travel attitude is not entirely stable but varies under certain circumstances, which further complicates the relationship between travel attitude, behaviour and satisfaction (De Vos, 2022). De Vos et al. (2021a) describe this relationship as a cyclical process where travel mode choices not only condition but also are themselves conditioned by travel satisfaction through changes in travel attitude. Simply put, individuals who are satisfied with their commuting journeys will develop a preference and tend to follow this choice in the future. Van Wee et al. (2019) further summarise two theoretical explanations for changes in travel attitude. First, the learning theory underpins the cognitive process where individuals may shift their travel attitude at the time of exposing to a new travel environment or/and initiating a new travel choice (Bloom, 1956). Second, the cognitive dissonance theory concerns a mismatch between travel behaviour and attitude incurring discomfort (Festinger, 1957). As an adaptive strategy, individuals adjust either the attitude or the behaviour to restore the cognitive balance and return to the psychological "set point" (Brickman et al., 1978; Frederick and Loewenstein, 1999).

### 2.2.3 Social and transport geography: The relational perspective

Social and transport geography connect travel behaviours with multifaceted life domains and underlying socio-spatial contexts from a relational perspective (Müggenburg et al., 2015; Kwan and Schwanen, 2016). This relational perspective situates the temporal scope of the commuting-SWB relationship in everyday life and the life course, respectively. From the perspective of everyday life, commuting behaviours are not only interrelated with commuting satisfaction but also linked to SWB in other life domains. Possible mechanisms at play include the inter-domain transfer and the resource drain model (Chatterjee et al., 2020; Sun et al., 2021). In inter-domain transfers, stress and dissatisfaction generated from commuting

journeys spill over to negatively influence other life domains, such as job and family life (Calderwood and Mitropoulos, 2021). The resource drain model regards the resource, such as time and energy, allocated to different life domains to be limited. For example, an increase in commuting time indicates a corresponding decrease in time available for sleep, recreational exercise, social contact, et cetera, which are also significant contributors to long-term SWB (Delbosc, 2012).

From the perspective of the life course, mobility biographies are an instructive approach for linking changes in daily travel behaviours to life events along with changes in spatial context (Schoenduwe et al., 2015). Despite acknowledging travel behaviours as a routine practice, the mobility biographies approach has a particular interest in the dynamics of travel behaviours over the life course rather than extracting them from the context at a single time point (Müggenburg et al., 2015). In this approach, residential relocation acts as a key event linking life events in the family and job domains to changes in commuting behaviours. On the one hand, exposure to new residential environments evokes deliberate consideration for more desired commuting alternatives (Tao et al., 2021). On the other, people may proactively relocate to a neighbourhood that conforms to their travel attitude and preferences, which is termed (travel-related) residential self-selection (Cao et al., 2009). However, this self-selection process does not often take place because the decision-making of relocation involves a wide range of factors, such as dwelling quality, neighbourhood environment and social networks, over travel-related concerns (Chatman, 2009; Coulter et al., 2016; De Vos et al., 2021b). Besides, job-housing distances, limited budgets and transport opportunities, and varying preferences between family members constitute socio-spatial constraints that impede individuals' choices of preferred residential locations and commuting behaviours (De Vos et al., 2013; Cao and Ettema, 2014; Tao et al., 2022). As a result, individuals may end up having to commute in an undesired way and stay stuck in suboptimal SWB statuses.

### 2.2.4 A conceptual model for the commuting-wellbeing relationship

Figure 2.1 shows the conceptual model of commuting-SWB relationships. The model is developed based on the preceding theoretical conceptualisation and derives additional inputs from several review articles (Ettema et al., 2010, 2016; De Vos et al., 2013, 2021a; Mokhtarian, 2019; Chatterjee et al., 2020). These inputs are assembled in the right module "commuting-SWB relationships" of Figure 2.1, where three interdependent relationships are specified. First, not only does commuting behaviour and its consistency with travel attitude affect commuting wellbeing, but

also a positive commuting experience reinforces the commuting choice directly or through changing attitude towards the chosen commuting behaviour. Second, commuting behaviours are interrelated with other life domains (e.g., family and job domains) by emotional spill-overs and the allocation of time and energy resources, while changes in commuting behaviours often occur at the time of residential relocation or/and undergoing other life events. Third, the relationship between domain-specific and overall SWB involves a bottom-up effect where pleasures and pains gained from multiple life domains sum up to a global assessment of life satisfaction, as well as a top-down effect where overall satisfaction with life predisposes the way that people evaluate specific life domains.

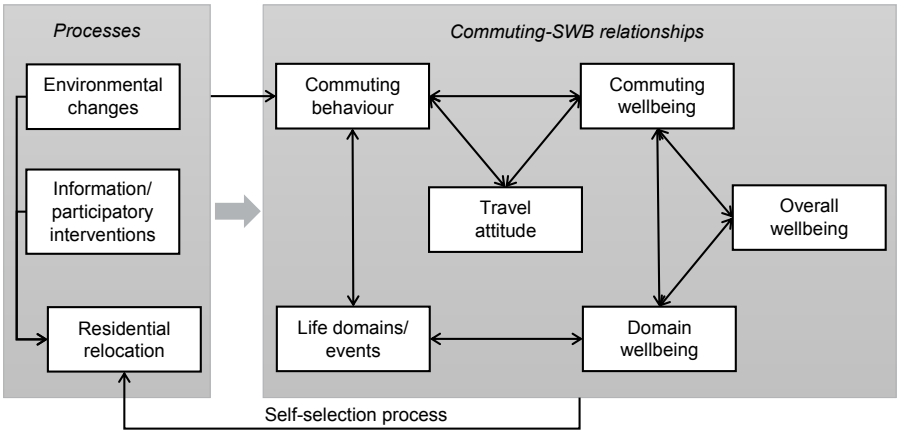


FIG. 2.1 A conceptual model for the commuting-SWB relationship

Our study contributes to the conceptual model by differentiating and integrating three upstream processes that lead to changes in commuting behaviours, i.e., environmental changes, information/participatory interventions, and relocation events over the life course. The first process, environmental changes, describes changes in built environment and transport systems over time. In this regard, environmental changes are exogenous to people's commuting choices so the unidirectional impact of commuting behaviour on SWB outcomes can be tentatively inferred. Note that environmental changes not only include gradual processes such as the evolution of land uses and traffic congestion over time, but also concern abrupt changes such as the operation or closure of transportation infrastructure and the changes caused by disruptive events (e.g., natural disasters and pandemics). In the former case, changes in the environment are often too subtle to be noticed so people tend to repeat habitual commuting routines and do not deliberately think



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about commuting wellbeing. Despite a significant environmental change in the latter case, anticipated commuting changes may not take place if people are not well-informed of environmental changes, regard environmental changes as a temporary stage, or are uncertain whether commuting changes will benefit SWB.

To simulate deliberate decision-making and unfreeze travel habits, information or participatory interventions are introduced as another exogenous source of commuting changes. Interventions on commuting behaviours are often designed as a temporary experiment. In the intervention experiment, informational strategies (e.g., tailored travel information on public transport routes and timetables) or participatory strategies (e.g., free tickets issued to new public transport users) are used to keep people informed of, or ask them to initiate, commuting alternatives. By doing so, people will reconsider habitual commuting routines and proactively compare the experienced utility of different commuting choices. Moreover, the original attitude towards the intervened commuting behaviour will be corrected by the information gained or by direct experience.

In addition to interventions, relocation and related life events also mark a clear cut for people to consciously rearrange daily activity-travel behaviours. Particularly, residential relocation, as the third process of our interest, is endogenous to the commuting-SWB relationship. Apart from a window of opportunity for exposing to new travel-related environments, residential relocation may involve a self-selection process for realising preferred commuting behaviours. That is to say, dissatisfaction with daily commutes drives the decision-making of relocation so that people can initiate desired commuting choices, indicating the reverse causality from SWB to commuting behaviours. Moreover, relocation events are embedded in the long-term process of life (Müggenburg et al., 2015). With increases in age or after undergoing major changes in life (e.g., the occurrence of life events), people may strive for long-term mobility (e.g., residential relocation) or/and daily mobility (e.g., changing commuting behaviours) to adapt to varying travel demands and preferences.

A final note is that the aforementioned three processes are not isolated but interrelated with each other, which further complicates the commuting-SWB relationship. For example, an intervention experiment may well achieve its potential at the time of abrupt environmental changes, such as issuing free tickets for a new public transport service. Residential relocation may take place when intervention and environmental changes discourage people's preferred commuting behaviours.

## 2.3 Review methodology

Based on the theoretical conceptualisation of the commuting-SWB relationship, we systematically collected empirical articles that repeatedly or retrospectively observe people's commuting behaviours and SWB to assess the methodologies used and the research findings, as well as to identify potential challenges for existing longitudinal studies. Our particular interest in these longitudinal studies is the extent to which they differentiate upstream processes of commuting changes and identify the interdependent commuting-SWB relationship as illustrated in the conceptual model (Figure 2.1). The selection of relevant articles followed the guideline of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020. The final search was conducted in July 2022, using the databases of the Web of Science, Scopus and Transportation Research International Documentation (TRID), and including peer-reviewed journal articles in English. The search strategy was based on a combination of three word strings: longitudinal designs (i.e., longitudinal, panel, prospective, retrospective, cohort, relocation, experiment and intervention), commuting behaviours (i.e., commuting, travel, mobility, trip, movement and transport), and SWB (wellbeing, life satisfaction, happiness, stress, health and quality of life).

The search strategy generated 7,214 raw records. After removing duplicate records across the three databases, screening by title and abstract, and full-text reading, there were 35 articles left. Six articles were further supplemented through forward and backward snowballing, resulting in a set of 41 longitudinal articles to be reviewed in our research. Figure 2.2 presents the PRISMA 2020 flow diagram of the article selection with detailed article exclusion criteria.

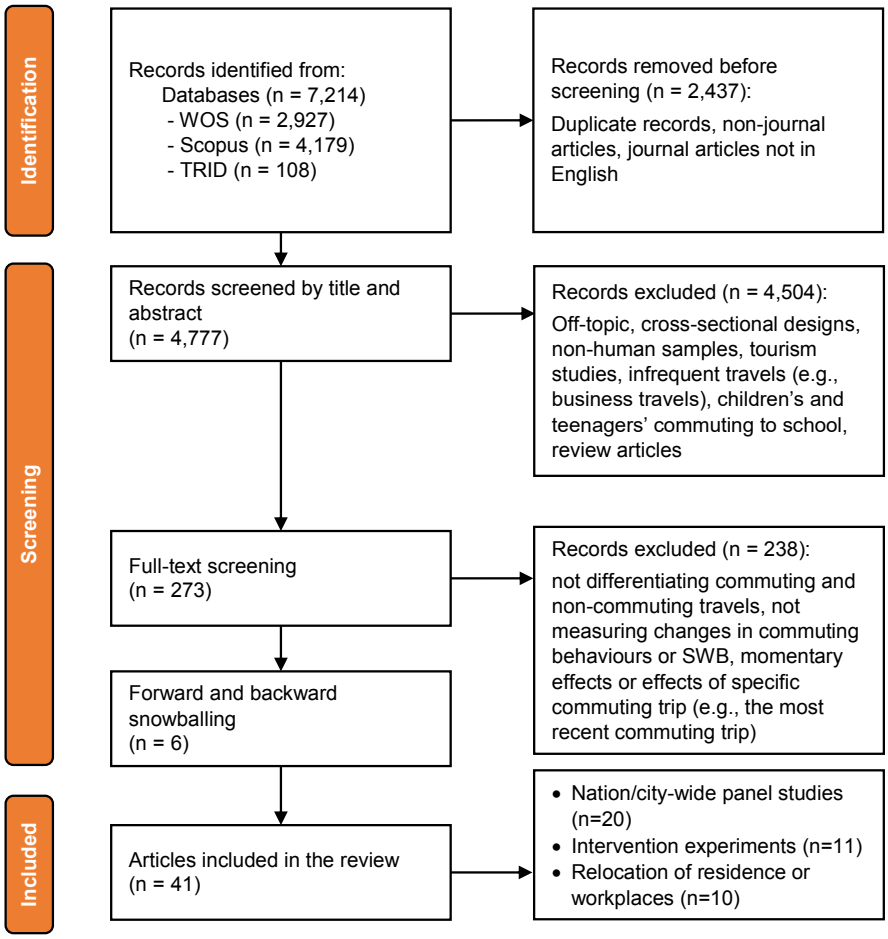


FIG. 2.2 PRISMA 2020 flow diagram of the article selection process



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## 2.4 Review results

The reviewed articles were classified into three categories, i.e., nation/city-wide panel studies, intervention experiments, and studies of relocation events. These three categories of longitudinal research vary in their research designs, including the studied geographical areas, sampling schemes, methods of analysis, and especially, the differentiation of upstream processes of commuting changes. For space reasons, we leave the overview of the reviewed longitudinal articles in the Appendix Tables 2.2-2.4 in the Appendix. Notably, all but three longitudinal articles were published between 2011 and 2022, and all articles concerning changes in commuting behaviours and SWB before and after the relocation event were published in the last five years (2017-2022; Table 2.1). In this section below, we will review research designs and findings for these three categories of longitudinal research in detail.

TABLE 2.1 Number of the reviewed articles by research designs and publication years

| Publication years | Nation/city-wide panel studies | Intervention experiments | Residential or workplace relocation |
|---|---|---|---|
| 2005 | 0 | 1 | 0 |
| 2008 | 1 | 1 | 0 |
| 2011 | 1 | 1 | 0 |
| 2012 | 0 | 2 | 0 |
| 2013 | 0 | 0 | 0 |
| 2014 | 5 | 0 | 0 |
| 2015 | 0 | 0 | 0 |
| 2016 | 2 | 1 | 0 |
| 2017 | 1 | 1 | 1 |
| 2018 | 1 | 1 | 2 |
| 2019 | 4 | 2 | 4 |
| 2020 | 1 | 1 | 1 |
| 2021 | 3 | 0 | 2 |
| 2022 | 1 | 0 | 0 |
| Total | 20 | 11 | 10 |



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### 2.4.1 Longitudinal research based on nation/city-wide panel surveys

There are twenty longitudinal studies drawing from nation- or city-wide panel surveys (Table 2.2). These panels follow a large number of people across the nation or the city by means of multi-wave surveys over a long time period. Representative panels include the UK Household Longitudinal Study (or Understanding Society, UKHLS) and the German Socio-Economic Panel (GSOEP), both of which have recorded yearly behavioural and wellbeing information for over 10,000 people over three decades. Compared with the cross-sectional design that analyses between-individual variations at a single time point, these longitudinal studies examine how within-individual changes in commuting behaviours are associated with corresponding changes in SWB outcomes by means of a fixed-effects model or a difference-in-difference approach.

The results from nation/city-wide longitudinal studies are not as consistent as the results from cross-sectional studies. Some of the longitudinal studies find that longer commuting time or distance does not result in worse overall SWB within the individual (Dickerson et al., 2014; Lorenz, 2018; Clark et al., 2020). This finding conforms to the framework of utility equilibrium, which means that individuals can obtain equivalent benefits in the job and housing market to compensate for increased commuting costs, thereby cancelling the negative effect of long commutes on SWB. However, some other longitudinal studies do observe similar results as cross-sectional studies. For example, Stutzer and Frey's research in Germany indicates that individuals' life satisfaction decreases as commuting time increases (Stutzer and Frey, 2008; Frey and Stutzer, 2014). Given the contradiction to the utility equilibrium, this result is termed the commuting paradox and explained by the theory of behavioural economics. The explanation is that individuals adapt more easily to extrinsic attributes (e.g., gains in labour income) than intrinsic ones (e.g., losses from commuting time), resulting in the negative effect of commuting time on overall SWB (Frey and Stutzer, 2014). Moreover, Milner et al. (2017) and Ingenfeld et al. (2019) identify a non-linear effect of long commutes on general psychological wellbeing in Australia and life satisfaction in Germany, with a much larger magnitude for extremely long commuting journeys (weekly commuting time > 6 hours in Australia and one-way commuting distance > 80 kilometres in Germany).

To specify the commuting-SWB relationship, several longitudinal studies investigate the spill-overs of commuting journeys to other life domains, and furthermore, analyse how the domain-specific SWB mediates the relationship between commuting behaviours and overall SWB. For example, analysis of UKHLS data shows that the longer the commuting time, the lower the satisfaction with jobs and leisure time,

and the higher the level of affective strain (Clark et al., 2020). By using the GSOEP data, Lorenz (2018) similarly indicates that longer commuting distance is linked to lower satisfaction with leisure time and family life, but less with affective SWB, such as frequent feelings of anger and worry. Based on the inter-domain spill-overs, Ingenfeld et al. (2019) account for the weak impact of long commutes on overall SWB by the fact that commuting journeys impose competing benefits and threats on different life domains. Specifically, longer commuting distance is related to higher satisfaction with work, income and housing on the one hand, and lower satisfaction with leisure time and health on the other, thereby causing the total effect on life satisfaction towards the null.

Commuting-SWB relationships also differ between social groups, with gender and occupational groups discussed the most by existing longitudinal studies. Five studies using the UKHLS data uniformly conclude that women experience greater disutility from increased commuting time than men, evidenced by worse general psychological wellbeing (Roberts et al., 2011; Feng and Boyle, 2014; Jacob et al., 2019), greater dissatisfaction with commuting time, leisure time (Wheatley, 2014) and social life (Nisic and Kley, 2019). The rationale includes women's dominant responsibility for household tasks and childcare, lower occupational status and wage rates in the job market, limited commuting mode choices, and involuntary residential relocation for male partners' occupational careers. In a household-level analysis, Hirte and Illmann (2019) demonstrate a cooperative commuting decision within the family, given that changes in couples' commuting distance do not influence their joint life satisfaction. Regarding occupational status, marginal dissatisfaction with longer commuting journeys comes from low job controls (Milner et al., 2017), fixed and long working hours (Wheatley, 2014), full-time jobs (Nisic and Kley, 2019), and thin labour markets (Roberts et al., 2011).

Apart from commuting time and distance, commuting mode choices exert an independent effect on SWB. Specifically, the switch to active mode (i.e., walking and cycling) is shown to be more beneficial to general psychological wellbeing compared with maintaining public transport or car use (Martin et al., 2014; Mytton et al., 2014; Jacob et al., 2021). In contrast to the benefits of active commuting, there is no consensus regarding the effect of switching between car and public transport on long-term SWB, partly due to various contextual exposures across research areas (Stutzer and Frey, 2008; Jacob et al., 2021; Wang et al., 2021). For example, research in Chinese cities shows that prevalent air pollutants to some extent aggravate the negative effect of long commuting time because of the prolonged exposure to air pollution, and mitigate the loss in life satisfaction for public transport commuters possibly due to lower risks of traffic accidents and fewer on-road air pollutants of commuting by underground compared with commuting by

car (Wang et al., 2021). Focusing on day-to-day variations of SWB outcomes in the car-dominant city of San Francisco, the US, Le and Carrel (2021) find that public transport commuting results in worse travel happiness than car commuting, while a happy public transport journey on the previous day is predictive of satisfaction with operational service quality on the following day. Also, evidence from Bristol, the UK shows that partial car commuters (who do not use cars on all workdays) are more likely to give up car use when they are satisfied with an alternative travel mode, suggesting the feedback effect of commuting satisfaction on mode choices.

Notably, most nation/city-wide longitudinal studies mix different upstream processes of commuting changes, including environmental changes, relocation events, or changes in age and life stages. To isolate the role of relocation and the self-selection for preferred commuting behaviours, some studies exclude observations of those who change housing or job locations between survey waves so that any changes in commuting behaviours come from the source exogenous to individual choices (Roberts et al., 2011; Martin et al., 2014; Jacobs et al., 2019, 2021). Instead, only a few studies focus on housing and job movers. Stutzer and Frey (2008) conduct a subgroup analysis of relocated residents whose commuting time is negatively related to life satisfaction in a smaller magnitude, suggesting the existence of residential self-selection. Lorenz (2018) differentiates between involuntary and voluntary job changes, and concludes that the negative effect of commuting distance on life satisfaction only applies to individuals who involuntarily change jobs. Besides the relocation event, these multi-year panel studies elaborate little on the results of other long-term processes in life, even though relevant time-varying confounders (e.g., age and age squared, and events of cohabitation and childbirth) are controlled for in their fixed-effect analyses of SWB outcomes. Only four studies have analysed the extent to which commuting-SWB relationships vary for people at different life stages. Specifically, Wheatley (2014) and Jacob et al. (2019) find that mothers are disproportionately influenced by longer commutes by showing worse leisure time satisfaction and general psychological wellbeing, respectively. By regressing the interaction term of commuting time and age groups on multiple SWB outcomes, Robert et al. (2011) and Clark et al. (2020) both show that age does not moderate the commuting-SWB relationship.

Another interesting study that makes clear the upstream process of commuting changes is based on the exogenous shock of the COVID-19 pandemic. Kroesen (2022) draws upon three-wave panel data in the Netherlands to examine how workers reflect on their previous commuting journeys after they are mandated to work from home during the COVID-19. The results show that the relationship between working from home and life satisfaction does depend on the pre-COVID-19 commuting time. Workers, especially female workers, who

commuted 1 hour or more to work report better life satisfaction after switching to homeworking. In addition, some recent studies indicate a declining uptake of public transport for commuting throughout the pandemic (Beck and Hensher, 2021; Hensher et al., 2022). However, longitudinal evidence is lacking to account for this decline by changes in attitude towards and satisfaction with public transport commuting. It is possible that people care more about social distancing and are reluctant to use public transport during, and even after the COVID-19 pandemic.

In summary, evidence from nation/city-wide longitudinal studies is robust because of large sample sizes, multi-wave follow-up observations, and representative geographic areas for study. However, findings for these longitudinal studies are not consistent, especially regarding the relationship between long commuting journeys and overall SWB in the long term. To account for this inconsistency, some studies have examined the inter-domain spill-overs and trade-offs, conducted subgroup analyses on gender and occupational groups, and differentiated the contextual exposure among travel modes. Even so, most of the nation/city-wide longitudinal studies mix the endogenous and exogenous sources of commuting changes, and especially overlook residential self-selection and the role of long-term processes in life, which may also constitute a reason for coming to inconsistent commuting-SWB relationships.

### 2.4.2 The intervention experiment

Our review contains eleven longitudinal studies that implement an intervention experiment to prompt participants to initiate commuting alternatives and observe resultant changes in SWB outcomes (Table 2.3). The experiments often employ soft interventions, including deliberation (e.g., imparting information on newly established bus routes), commitments (e.g., making commitments to commuting by public transport), and incentives (e.g., issuing pre-paid public transport tickets). According to the type of intervention strategies, deliberation is an informational strategy, while commitment and incentive strategies are participatory in nature and sometimes combined with each other. Despite the difference in intervention strategies, these studies are similar in research designs and methods. After stratifying intervention groups and controls groups who share similar modal choices at pre-intervention, the intervention experiment compares their changes in commuting mode and SWB pre-post intervention. Considering the small sample size and temporary intervention periods, the analysis of variance (ANOVA) is often used to compare within-individual differences in SWB pre-post intervention, as well as between-individual differences for intervention and control groups at post-intervention.

Intervention on the active mode, especially bicycle and e-bicycle, shows positive effects on commuting satisfaction and overall SWB. For example, company cycling programs conducted in Flanders and Germany similarly find that workers improve their general psychological wellbeing after they participate in the program and start cycling to work (De Geus et al., 2008; Synek and Koenigstorfer, 2019). Also, the benefit of e-bicycle use is manifested as greater commuting satisfaction in North-Brabant, the Netherlands, and better general psychological wellbeing in the UK (Page and Nilsson, 2017; De Kruijf et al., 2019). In particular, e-bicycle users' psychological wellbeing marginally increases when they commute with a longer duration (Page and Nilsson, 2017). There is only one intervention study comparing the wellbeing effect of different active modes (Neumeier et al., 2020). The results suggest that cycling to work is more beneficial to general psychological wellbeing than walking (from and to public transport stops) as part of the commuting journeys.

Public transport, as a potential alternative to cars for long-distance commuting journeys, is another focus of intervention studies. In effect, however, findings for public transport interventions are mixed across research contexts and designs. On the one hand, providing information on public transport routes or stations does not suffice to leverage a wider gain in SWB for populations from the neighbourhoods served. Wener et al. (2005) and Lionjanga and Venter (2018) both indicate that participants benefit from the opening of a new public transport service (e.g., by showing less job strain and greater satisfaction with free time) only after they actually switch to public transport for commuting. On the other hand, the commitment and incentive designs are more effective to improve commuting wellbeing but do not necessarily result in better overall SWB and new commuting habits. By combining pre-paid 1-month public transport tickets and the commitment to frequent public transport use, Pedersen et al. (2011) find that switching from cars to public transport leads to greater commuting satisfaction in a medium-sized city of Sweden. Abou-Zeid et al. (2012) and Abou-Zeid and Ben-Akiva (2012) conduct a comparable research design in three educational institutions, Switzerland and the Massachusetts Institute of Technology (MIT), the US, respectively. During the intervention period, participants from both studies show more positive attitude towards public transport and greater commuting satisfaction after switching to public transport. However, only in the US case, a certain amount of participants maintain public transport commuting and sustain high levels of commuting satisfaction several months after the intervention. This discrepancy is explained by the contextual difference between Switzerland and the US, such as higher parking permit costs and public transport subsidies in the US case (Abou-Zeid and Fujii, 2016).

Two notable concerns for intervention research are the validity of the sampling scheme and the time period for follow-up investigations. In the eleven intervention studies, four of them do not incorporate a control group, so the impact of commuting changes on SWB cannot be isolated from time-varying attributes (e.g., changes in traffic volume) other than the intervention itself. Moreover, sampling of the intervention group may be selective in the first place; that is, people who are stimulated by the intervention incentives or are open to the post-intervention change are more likely to accept the intervention. This selection bias is more of a concern if people who have already been unhappy with commutes are willing to participate in the intervention, thereby overstating the intervention effect on SWB outcomes. Therefore, it needs caution to extrapolate the results from an intervention experiment to the general population and to a different socio-spatial context.

Regarding the time period of intervention experiments, research participants are followed ranging from two weeks to one year in the eleven intervention studies, among which only five studies further compare changes in commuting behaviours and SWB at different post-intervention timestamps. The short time period for follow-up investigations restricts the scope for examining SWB outcomes from commuting satisfaction to overall SWB in the long term. In terms of e-bicycle interventions, De Geus et al. (2008) suggest that the positive effect of switching to e-bicycle on affective wellbeing lasts for six months and moderately weakens after one year. De Kruijf et al. (2019) come to a surprising finding that commuting satisfaction by e-bicycle is even higher six months later than one month after the intervention, possibly due to the monetary incentive design (i.e., cycling more and earning more). Regarding the temporal effect of public transport interventions, Pedersen et al. (2011) indicate that habitual car users significantly improve commuting satisfaction after switching to public transport, and two weeks later, their commuting satisfaction sustains. In contrast. Abou-Zeid et al. (2012) find that compared to the level at pre-intervention, participants rate higher levels of satisfaction with car commuting in the week following public transport use because they start to value the punctuality and flexibility of car use. Several months later, however, both the frequency of and satisfaction with car commuting return to the pre-intervention level.

In summary, intervention experiments are limited in sample size, geographical scale and time periods for study compared with nation/city-wide longitudinal research. Even so, the intervention design contributes to the commuting-SWB causality by reinforcing people's intention to break travel habits and clarifying the temporal precedence between changes in commuting behaviour and changes in SWB outcomes. Evidence from intervention experiments corroborates the wellbeing effect of switching to an active travel mode as found in nation/city-wide research, and further indicates the benefit of some emerging commuting practices, such

as e-bicycle use and the company-led program of active commuting to work, in improving commuting wellbeing. For public transport intervention, the participatory strategy seems more effective in increasing commuting satisfaction than the informational strategy, and in some cases, people who are satisfied with the alternative commuting mode will develop it as a new habitual routine.

### 2.4.3 The event of residential and workplace relocation

We finally reviewed ten longitudinal studies that focus on the effects of relocation events, including the relocation of residence and workplaces (Table 2.4). Most relocation studies retrospectively investigate participants' commuting behaviours and SWB before and after they move houses or change job locations, and then, use the difference-in-difference approach or ANOVA to examine the commuting-SWB relationship. Notably, relocation studies make explicit the geographical perspective by taking into account the spatial characteristics of relocation origins and destinations (e.g., urban-to-suburban relocation). Furthermore, residential relocation research incorporates the self-selection process; that is, relocating to match travel attitude and preferences.

Given that enterprise expansion and relocation are often beyond the control of individual employees, workplace relocation research views changes in job locations as an exogenous event. For workplace relocation from suburban to urban areas, specifically, von Behren et al. (2018) and Schneider and Willman (2019) similarly find that afterwards employees are more satisfied with commuting journeys because of shorter commuting time and a mode switch from car to other means of travel (e.g., bicycle). Conversely, suburban relocation of workplaces often involves longer commuting distances, but its influence on SWB depends on transportation infrastructure and traffic conditions in the suburb. For example, an involuntary workplace relocation to the suburbs of Beijing, China leads to greater commuting dissatisfaction and increased turnover intention for government staff (Qu et al. 2021). Moreover, longer commuting journeys to the suburbs not only lead to commuting dissatisfaction but also affect other life domains and cause lower attachment to workplaces and neighbourhoods, ultimately resulting in lower levels of overall SWB (Rau et al., 2019). Counterintuitively, a study in Montreal, Canada shows that workplace relocation to a peri-central location reduces employees' commuting time and improves their commuting satisfaction and workplace attachment (Gerber et al., 2020). Their justification is that the new workplace is located in a planned suburban centre integrated with an efficient transport system, including a regional rail station, a metro station and a highway interchange.

Similar to workplace relocation, residential relocation exposes people to a new travel-related environment that provides opportunities for, or imposes constraints on, initiating commuting alternatives. For example, a cluster analysis of relocated residents in Ghent, Belgium suggests that reduced commuting time and increased use of car alternatives lead to greater commuting satisfaction (De Vos et al., 2019). Nicholls et al. (2018) find that people who relocate to a newly built suburban residential estate report worse commuting satisfaction from increased commuting time and more congested traffic. Gerber et al. (2017) also indicate that longer commuting journeys by car are the least satisfying aspect of daily life after workers in Luxembourg relocate to a neighbouring country to live. However, the worsening commuting circumstance does not undermine satisfaction with the neighbourhood and overall life, because people attach more weight to housing conditions than to the commuting situation when estimating overall SWB (Gerber et al., 2017; Nicholls et al., 2018).

Residential relocation may also involve residents' self-selection for better housing, jobs, or even travel experiences. Specific to travel-related self-selection, changes in commuting behaviours following the relocation may derive more from a realisation of travel preferences and the intention to improve suboptimal SWB than vice versa. To date, however, there is limited longitudinal evidence in this regard. Kent et al. (2019) investigate how residents who move to a suburban greenfield estate psychologically react to changes in commuting time after isolating the role of travel attitude. The results show that even though the pro-car attitude and the disregard for travel time result in better SWB outcomes, changes in commuting duration and the departure time for commuting still exert an independent effect on anxiety and life satisfaction. De Vos et al. (2021b) contribute the only longitudinal evidence that explicitly examines travel-related self-selection and its influence on commuting wellbeing. By retrospectively investigating residents who relocate to urban and suburban areas, this study indicates that residents' commuting mode choices tend to accord with their mode-specific attitude after the relocation, and furthermore, the behaviour-attitude consistency results in greater commuting satisfaction.

Two noteworthy features of relocation research are the retrospective survey design and the individual-level event analysis. Except for Nicholls et al. (2018) and von Behren et al. (2018), eight out of ten relocation studies ask participants to retrospectively record their changes in commuting behaviours and SWB when participants have already settled down in the new residence or workplace, which inevitably introduces a recall bias and a consistency bias. Besides, the retrospective design regards travel attitude as stable over time, which neglects people's learning process and adaptability to new living environments not only by adjusting behaviours to match attitude but also by adjusting attitudes to match behaviours. If travel

attitude does change after the relocation, the retrospective questioning on travel attitude is not reliable to approximate the pre-relocation travel attitude and estimate the effect of residential self-selection.

Another issue is that the individual-level event analysis not only disregards the balancing and compromising between family members in reaching the relocation decision, but also disconnects the relocation event with other life events that jointly shape commuting choices (e.g., concurrent changes in job and housing locations, and childbirth as a common reason for suburban relocation and car use). There is limited, if any, household-level evidence from the perspective of trip chaining behaviours and the gender gap at different life stages. It shows that employees with shorter commutes incorporate more family-oriented trips (e.g., grocery shopping) into the commuting trips, which improves their satisfaction with family life (von Behren et al., 2018; Rau et al., 2019). Besides, after commuting distance increases, female employees and employees with school-aged children are under a greater threat of involuntary suburban relocation and report a higher intention to quit jobs (Qu et al., 2021).

In summary, compared with nation/city-wide studies and intervention experiments, relocation research refines the geographical perspective and leads to a better understanding of self-selection processes in the commuting-SWB relationship. Findings for involuntary workplace relocation are context-dependent. Relocation from suburban to urban areas stimulates shorter and less motorised commuting journeys that result in greater commuting satisfaction, whereas the wellbeing benefit for the reverse urban-to-suburban relocation depends on the supportive suburban environment with easy-access transport links to home locations. In contrast, the commuting-SWB relationship following residential relocation is more complicated, concerning not only the stimulus exercised by the new residential environment but also the self-selection for realising preferred commuting behaviours.

## 2.5 Agenda for future longitudinal research

Longitudinal research designs are important to validate the results from cross-sectional studies which consistently found that longer commutes lead to worse SWB outcomes. Our synthesis of existing longitudinal evidence, however, comes to inconsistent findings, especially for the impact of long commuting distance/time and switching between public transport and car on overall SWB in the long term. To address these inconsistencies, research has applied the utility equilibrium theory to substantiate the impact of longer commutes on worse commuting satisfaction and the inter-domain effects between commuting satisfaction and satisfaction with other life domains. To further bridge the gap between theoretical conceptualisations (Section 2.2) and longitudinal research (Section 2.4), in this section, we integrate theories from social psychology and transport geography to advocate a processual way of thinking on the nature of the commuting-SWB relationship. Specific avenues for future longitudinal designs and research are followed with the aim of better understanding the interdependent relationship between commuting behaviours and SWB.

### 2.5.1 A processual thinking for the commuting-wellbeing interdependency

Commuting-SWB relationships are manifested as a process where commuting and SWB are interdependent with each other over time and, at a certain point, individuals' wellbeing statuses are shaped by their past experiences and situational contexts (Whitehead, 1929; Schwanen, 2018). To apply this processual way of thinking, the first and foremost agenda for future longitudinal research is to differentiate and integrate different processes of commuting changes, whether they occur spontaneously as the travel-related environment evolves over time or require an intervention to inform or direct alternative commuting choices, and whether they are exogenous or endogenous to the commuting-SWB relationship. In our conceptual framework (Figure 2.1), we identify three different but interrelated processes. Among them, two processes are exogenous to the commuting-SWB relationship: Environmental changes outline temporal variations in transportation infrastructure and physical environment, which have the potential to break people's habitual travel routines. In contrast, information/participatory interventions target the behaviour itself and directly reinforce people's intention to initiate commuting alternatives. The third process, residential relocation events, is endogenous to the

commuting-SWB relationship since people may relocate to satisfy their desired commuting behaviours. In a nutshell, whilst processual thinking seems to take a step backwards in understanding the commuting-SWB relationship by retrieving the source of commuting changes, it actually makes a stride forwards by viewing the pathway to the occurrence of behaviours as equally important as behaviours and behavioural outcomes (e.g., SWB) themselves.

### 2.5.2 Avenues for future longitudinal designs and research

Based on the processual way of thinking, we suggest the first avenue for future longitudinal research to analyse how commuting-SWB relationships vary after taking into account different upstream processes of commuting changes. This recommendation concerns nation/city-wide longitudinal studies the most. As reviewed in Section 2.4.1, some nation/city-wide studies have isolated the process of exogenous environmental changes from residential self-selection by excluding workplace or residential movers. However, the analysis of non-movers introduces another selection issue; that is, relocation is not evenly distributed across the population. As a result, findings for the commuting-SWB relationship may be biased toward those who are not able to relocate when undesired environmental changes take place. Therefore, we recommend including and stratifying movers and non-movers in the longitudinal analysis to compare their differences in socio-economic characteristics, geographical distributions, and psychological reactions to environmental and commuting changes. In addition, other long-term processes in life deserve equal attention. Besides controlling for age effects and life events as time-varying confounders, future research can clarify the dynamics in commuting-SWB relationships by conducting subgroup analysis on people at different life stages, or path analysis on changes in life stages, commuting behaviours and SWB outcomes.

The second avenue is to refine the temporal aspect of the commuting-SWB relationship. This recommendation originates from the theory of travel attitude and habits, and concerns intervention experiments and nation/city-wide studies. Regarding the intervention experiments, the short time period for post-intervention investigations fails to track the long-term effect on SWB outcomes and the formation of new travel habits. Therefore, we suggest participants be followed for multiple waves over a longer time period after the intervention. These follow-up investigations can be realised by incorporating the information/participatory intervention into the appraisal of environment- and behaviour-oriented programs. For example, the long-term behavioural intervention after the operation of a new public transport service or a new residential estate can be promising in directing more sustainable

commuting patterns as well as improving public health and wellbeing. As for nation/city-wide longitudinal studies, it is problematic that commonly used modelling techniques, such as fixed-effect models and the difference-in-difference approach, implicitly drop those observations that have no change in commuting behaviours between survey waves. The benefit or threat of maintaining certain commuting behaviour may take time to appear. Besides, psychological adaptation may occur in anticipation of or lagging behind commuting changes. In this regard, maintaining analysis (e.g., the effect of maintaining commuting behaviours on changes in SWB from wave 1 to wave 2) and cross-lagged panel analysis (e.g., the effect of commuting behaviour at wave 1 on SWB at wave 2 after controlling for baseline SWB at wave 1) are recommended to recognise these cumulative and time-lagged effects. Besides changes in commuting behaviours, travel attitude is also subject to change in the long run (De Vos et al., 2021a; De Vos, 2022). For this, latent class transition analysis is a viable way to study how people adjust commuting behaviours versus travel attitude, especially when they are exposed to a new travel-related environment or/and undergo suboptimal SWB statuses caused by the behaviour-attitude inconsistency.

The third avenue, built on the relational perspective and the mobility biographies approach, is to investigate the commuting-SWB relationship over the life course in a household context. This recommendation directs at integrating insights from relocation studies that usually draw upon small-scale retrospective surveys into nation/city-wide multi-wave panel studies. Currently, these nation/city-wide studies are limited by using the snap-shots of longitudinal data that assume unobserved variables as stable between survey waves (Schoenduwe et al., 2015; Coulter et al., 2016). Future research will benefit from regarding relocation as an adaptation to other life events (e.g., suburban relocation after childbirth) along with the travel-related concern (e.g., a greater preference and demand for car use after childbirth and suburban relocation), and examining how the three of them are relationally situated in the life course and jointly shape SWB outcomes. Moreover, the individual-level analysis of commuting-SWB relationships ignores possible trade-offs of commuting utility between family members. There is evidence that compared with men, women fare worse in health and SWB outcomes from longer commutes and less say in family car use (Ta et al., 2019; Shen et al., 2021). However, it is not clear how this gendered pattern of commuting-SWB relationships is shaped by medium- and long-term mobility decisions (e.g., household car-use allocation and housing location choices) and reshaped after the occurrence of life events. It is also interesting to study whether females' SWB outcomes are more influenced by changes in male partners' commuting behaviours than vice versa by means of joint decision analysis (e.g., using intertemporal collective models; Chiappori and Mazzocco, 2017).

The final avenue we recommend for future longitudinal research is to scrutinize the commuting-SWB relationship rooted in local socio-spatial contexts. Longitudinal research tends to achieve a general conclusion on the unidirectional impact of commuting behaviour on SWB outcomes, termed the commuting-SWB causality. Existing longitudinal evidence, however, often comes to "surprising" findings. Some instances, as stated in Section 4, are that public transport commuters report better life satisfaction than car commuters in air-polluted Chinese cities (Wang et al., 2021), a workplace relocation to the suburb enhances employees' commuting satisfaction in Montreal, Canada (Gerber et al., 2020), and similar intervention strategies result in different levels of commuting satisfaction and mode switch in Switzerland and the US (Abou-Zeid et al., 2012; Abou-Zeid and Ben-Akiva, 2012). In this critical review, we further conceive the relationship between commuting behaviours and SWB as an interdependent and reciprocal process over time. To this end, more cross-country and cross-region comparisons that follow similar longitudinal research designs are welcome to identify this interdependency. When conflicting results arise, commuting-SWB relationships should be interpreted based on the contextual characteristics, including geographical environment, social atmosphere, cultural norms and past history, of local research areas (Schwanen, 2018).

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# Appendix

TABLE 2.2 Overview of the nation/city-wide panel studies

| Authors (Year) | Data | Measures of commuting behaviour | Measures of SWB | Methods of analysis | |
|---|---|---|---|---|---|
| Stutzer & Frey (2008) | German Socio-Economic Panel (GSOEP), 8 waves,1985-2003, N=19,088 | Commuting time | Life satisfaction, and satisfaction with life domains | Fixed-effect linear models | |
| Roberts et al. (2011) | UK Household Longitudinal Study (UKHLS), 14 waves, 1991-2004, N=15,077 | Commuting time, and commuting mode | General psychological wellbeing, measured by the General Health Questionnaire (GHQ) | Fixed-effect linear models | |
| Frey & Stutzer (2014) | GSOEP, 16 waves, 1998-2013, sample size not reported | Commuting time | Life satisfaction | Fixed-effect linear models | |
| Feng & Boyle (2014) | UKHLS, 18 waves, 1991-2008, N=5,216 | Commuting time, and commuting mode | General psychological wellbeing, measured by GHQ | Fixed-effect logit models | |
| Wheatley (2014) | UKHLS, 17 waves, 1993-2009, N=1,055 | Commuting time | Satisfaction with life domains | Ordered probit models | |
| Dickerson et al. (2014) | UKHLS, 13 waves, 1996-2008, N=9,330 | Commuting time | Life satisfaction, satisfaction with leisure time, and general psychological wellbeing (GHQ) | Pooled OLS models, fixed-effect ordered and linear models | |
| Martin et al. (2014) | UKHLS, 18 waves, 1991-2009, N=17,985 | Commuting mode, and commuting time | General psychological wellbeing, measured by GHQ | Fixed-effect linear models | |
| Chatterjee et al. (2016) | The North Bristol Commuter Panel (NBCP), 5 waves, 2014-2015, N=1,469 | Commuting mode | Commuting satisfaction | Multinomial logit models | |
| Mytton et al. (2016) | Commuting and Health of Cambridge Study, 4 waves, 2009-2012, N=801 | Active commuting by bicycle or walking | Mental wellbeing, measured by Mental Component Summary (MCS-8) | OLS models with the difference-in-difference approach | |
| Milner et al. (2017) | The Household, Income and Labour Dynamics, 13 waves, 2001-2013, N=16,805 | Commuting time | Mental wellbeing, measured by Mental Health Inventory (MHI-5) | Fixed-effect linear models | |

| | Main findings *(findings for the differentiation of upstream processes of commuting changes marked in bold and italic)* |
|---|---|
| | • Longer commuting time is associated with worse life satisfaction.<br>• ***Individuals who change jobs or residences reduce life satisfaction in a smaller magnitude if commuting time increases.***<br>• Within couples, someone's commuting time has a negative effect on the partner's life satisfaction. |
| | • Longer commuting time results in worse general psychological wellbeing for women but not for men. ***This result remains after excluding samples who change house, jobs or travel modes.***<br>• Gender differences in the commuting-SWB relationship are partly explained by women's greater responsibility for family tasks.<br>• Wives' disutility from longer commutes is not compensated by husbands' better psychological wellbeing.<br>• ***The effect of commuting time on SWB does not vary by age.*** |
| | • Individuals adapt more for labour income than commuting time, so longer commuting time results in worse life satisfaction. |
| | • Longer commuting time is associated with worse psychological wellbeing only for women, especially for mothers and female car commuters. |
| | • For men, long commuting time causes dissatisfaction with commuting time and the presence of children leads to greater dissatisfaction with leisure time.<br>• For women, both long and short commuting time produces dissatisfaction with leisure time.<br>• ***After childbirth, both short and long commutes cause dissatisfaction for mothers.***<br>• The negative effect of long commuting time is attenuated when the Flexible Working Regulations is implemented. |
| | • Pooled models find the negative effect of commuting time on life satisfaction, but no relationship is shown in fixed-effect models.<br>• Longer commuting time is associated with worse satisfaction with leisure time. |
| | • Switch from car travel to active travel is beneficial to general psychological wellbeing.<br>• Longer commuting time by walk leads to better psychological wellbeing, but the opposite is true for car commuting time.<br>• ***The above results remain after excluding house or job movers.*** |
| | • Partial car alone commuters are more likely to switch to non-car alone and less to car alone when they are satisfied with commutes.<br>• Commuting satisfaction exerts little effects on mode switch between extreme commuting groups, e.g., from car alone to non-car alone. |
| | • Maintaining cycling to work is associated with better mental wellbeing at follow-up, but changes in cycle commuting do not influence changes in mental wellbeing.<br>• Walking to work is not related to mental wellbeing. |
| | • Individuals who commute over 6 hours per week have worse mental wellbeing than those who commute 2 hours and less.<br>• Individuals with low job controls are marginally worse off in mental wellbeing as commuting time increases. |

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TABLE 2.2 Overview of the nation/city-wide panel studies

| Authors (Year) | Data | Measures of commuting behaviour | Measures of SWB | Methods of analysis | |
|---|---|---|---|---|---|
| Lorenz (2018) | GSOEP, 7 waves, 2007-2013, N=60,266 | Commuting distance | Life satisfaction, satisfaction with life domains, and affective emotions | Fixed-effect linear models | |
| Jacob et al. (2019) | UKHLS, 6 waves, 2009-2014, N=15,846 | Commuting time | General psychological wellbeing, measured by GHQ | Fixed-effect linear models | |
| Ingenfeld et al. (2019) | GSOEP, 16 waves, 1998-2013, N=25,422 | Commuting distance | Life satisfaction, satisfaction with life domains, and affective emotions | Fixed-effect linear models | |
| Nisic & Kley (2019) | UKHLS, 12 waves, 1997-2008, sample size not reported | Commuting time | Satisfaction with social life | Fixed-effect linear models | |
| Hirte & Illmann (2019) | GSOEP, 14 waves, 2000-2013, N=10,340 | Commuting distance | Life satisfaction | Fixed-effect ordered logit models | |
| Clark et al. (2020) | UKHLS, 6 waves, 2009-2014, N=26,551 | Commuting time, and commuting mode | Life satisfaction, satisfaction with life domains, and strain and mental health | Fixed-effect linear models | |
| Jacob et al. (2021) | UKHLS, 7 waves, 2009-2016, N=31,736 | Commuting mode | Satisfaction with health, and mental wellbeing measured by Mental Component Score (SF12-MCS) | OLS models with the difference-in-difference approach | |
| Wang et al. (2021) | China Labor-force Dynamics Survey (CLDS), 2 waves, 2014-2016, N=16,103 | Commuting time, and commuting mode | Life satisfaction | Multilevel logit models with the difference-in-difference approach | |
| Le & Carrel (2021) | San Francisco Travel Quality Study, 2 waves in 2013, N=623 | Commuting mode | Commuting satisfaction, and affective emotions | Fixed-effect linear models with time-lagged effects | |
| Kroesen (2022) | Longitudinal Internet Studies for the Social sciences (LISS), 3 waves, 2019-2020, N=1,912 | Pre-COVID-19 commuting time, and working from home during the COVID-19 | Life satisfaction | Fixed-effect linear models | |

| | Main findings *(findings for the differentiation of upstream processes of commuting changes marked in bold and italic)* |
|---|---|
| | • Commuting distance has stronger impacts on affective than cognitive wellbeing.<br>• Commuting distance is not associated with life satisfaction but relates to satisfaction with family life and leisure time.<br>• ***Involuntary job changes reduce life satisfaction if new jobs involve longer commutes, while commuting distance exerts little effect on life satisfaction for voluntary job hoppers and those who did not change jobs.*** |
| | • Longer commuting time leads to worse general psychological wellbeing for women but not for men.<br>• This commuting disutility is greater for married women with full-time jobs as managers or professionals and women in thin labour markets.<br>• ***Women who do not change jobs and houses for the past 5 years experience greater commuting disutility.***<br>• ***Mothers with children 0-4 years old are under the greatest impact by longer commuting time.*** |
| | • Commuting more than 80km is associated with worse life satisfaction.<br>• Longer commuting distance leads to greater satisfaction with work, income and housing, but worse satisfaction with leisure time and health. |
| | • Longer commuting time leads to worse satisfaction with social life for women, but the opposite is true for men.<br>• The increase of women's commuting time mainly derives from residential relocation to meet male partners' job prospect.<br>• High education and full-time jobs marginally reduce satisfaction with social life as commuting time increases, men and women alike. |
| | • Changes in commuting distance do not influence couples' joint life satisfaction.<br>• ***Results from couples either of whom change jobs or residences corroborate that the mover is compensated for longer commuting distance by better job and housing conditions.*** |
| | • Longer commuting time is not associated with life satisfaction, but relates to worse satisfaction with job and leisure time, increased strain, and worse mental health.<br>• ***Controlling for housing and job relocation decreases the effect size of commuting time on domain and overall SWB.***<br>• ***There is little difference in the association of commuting time with life satisfaction and leisure satisfaction by age.***<br>• Women's job satisfaction is more influenced by commuting time than men's.<br>• Walking to work is related to greater leisure time satisfaction and reduced strain, compared with car commuting.<br>• Working from home is associated with greater satisfaction with job and leisure time. |
| | • Compared with mode maintenance, switch from car to active mode improves mental wellbeing, while switch from active mode to public transport reduces satisfaction with health.<br>• ***After restricting samples to whom do not change job locations, the effects remain but are in a slighter higher magnitude.***<br>• The wellbeing effect of mode switch weakens with time. |
| | • Compared with car commuters, active commuters report better life satisfaction, and commuters by public transport have worse life satisfaction.<br>• Longer commuting time is related to worse life satisfaction.<br>• Air pollution mitigates the losses in life satisfaction for public transport commuters, but strengthens the negative effect of commuting time. |
| | • Compared with commuting by public transport, car commuting induces more positive emotions and fewer negative emotions.<br>• High levels of travel satisfaction on the previous day is predictive of worse travel satisfaction on the current day, while a positive emotion on the previous day is predictive of better travel satisfaction on the current day. |
| | • ***Workers, especially female workers, whose one-way commuting time was 1 hour or more report better life satisfaction after switching to working from home.*** |

TABLE 2.3 Overview of the intervention experiment studies

| Authors (Year) | Case area | Intervention strategy | Sampling | Measures of SWB | Methods of analysis | |
|---|---|---|---|---|---|---|
| Wener et al. (2005) | New Jersey, the US | Information on a new commuter rail line | Sample size not reported; 2-wave surveys pre-post the intervention | Perceived stress, and job strain | Analysis of Variance (ANOVA) | |
| De Geus et al. (2008) | Flanders, Belgium | A one-year cycling program where participants are committed to cycle to work | N=92; 3-wave surveys before, 1 month after, and 6 months after the intervention | Health-related quality of life, measured by the Short-Form-36 (SF-36) | Analysis of Variance (ANOVA) | |
| Pedersen et al. (2011) | A medium-sized city, Sweden | A prepaid 30-day public transport ticket and a signed contract | N=169; 4-wave surveys before, during, immediately after, and 2 weeks after the intervention | Commuting satisfaction | Analysis of Variance (ANOVA) | |
| Abou-Zeid et al. (2012) | Three institutions, Switzerland | A free public transport pass and the commitment to commuting by public transport | N=30; 3-wave surveys before, immediately after, and several months after the intervention; No control groups | Commuting satisfaction | Analysis of Variance (ANOVA) | |
| Abou-Zeid & Ben-Akiva (2012) | MIT, the US | A free public transport pass and the commitment to commuting by public transport | N=67; 3-wave surveys before, immediately after, and several months after the intervention; No control groups | Commuting satisfaction | Analysis of Variance (ANOVA) | |
| Abou-Zeid & Fuji (2016) | MIT, the US | A free public transport pass and the commitment to commuting by public transport | N=20; 3-wave surveys before, immediately after, and several months after the intervention; No control groups | Commuting satisfaction | Analysis of Variance (ANOVA) | |
| Page & Nilsson (2017) | A campus, the UK | 6-month free e-bicycle use | N=31; 2-wave surveys before and during the intervention | Affective emotions measured by the Flourishing scale, and General psychological wellbeing measured by GHQ | Analysis of Variance (ANOVA) | |

| | Main findings |
|---|---|
| | • Commuters report lower job strains after switching to the new train line.<br>• Mothers benefited more from the intervention with lower job strain, but there are no spill-overs of perceived stress or job strain to the spouse. |
| | • The cycling program improves the health-related quality of life in the first 6 months after the intervention.<br>• Particularly, vitality for the total group and physical functioning for women significantly increase. |
| | • Participants rate higher satisfaction with public transport after switching to it.<br>• Participants' initial prediction are lower than the reported satisfaction with public transport commuting.<br>• Car-use habit is responsible for the inaccurate prediction for commuting satisfaction. |
| | • A number of participants change their attitude towards car and public transport after the intervention.<br>• Compared with the pre-intervention level, participants report greater satisfaction with car commuting a week after the intervention, but the difference is non-significant 4-5 months later.<br>• Participants report greater satisfaction with public transport commuting after the intervention, but they only continue to use public transport occasionally. |
| | • Participants who have low satisfaction with car commuting tend to switch to public transport.<br>• Satisfaction with public transport is related to switching to public transport, through more positive attitude towards public transport. Besides, 30% of the participants switch to public transport after the intervention.<br>• All participants, whether switching to public transport or keeping car commuting, are happier with commuting journeys after the intervention. |
| | • Participants who switch to public transport report greater commuting satisfaction.<br>• The improvement in commuting satisfaction sustains in several months. |
| | • Participants report more positive affects after switching to e-bicycle commuting than maintaining non-active commuting.<br>• Active commuters with longer commuting distance report better general psychological wellbeing, while longer passive commutes result in worse general wellbeing. |

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TABLE 2.3 Overview of the intervention experiment studies

| Authors (Year) | Case area | Intervention strategy | Sampling | Measures of SWB | Methods of analysis | |
|---|---|---|---|---|---|---|
| Lionjanga & Venter (2018) | Johannesburg, South Africa | Information on the new Bus Rapid Transit (BRT) systems | N=423; 2-wave surveys before and after the BRT implementation | Life satisfaction, and satisfaction with free time | Ordered logit models with the difference-in-difference approach | |
| Synek & Koenigstorfer (2019) | 62 Companies, Germany | The company-bicycle leasing program | N=462; 2-wave surveys before and 40 days after the intervention; No control groups | Mental wellbeing, measured by Mental Component Summary (MCS-8) | OLS models with the difference-in-difference approach | |
| De Kruijf et al. (2019) | North-Brabant, Netherlands | An e-cycling incentive program | N=567; 3-wave surveys before, 1 mother after and 6 months after the intervention | Commuting satisfaction | OLS models with the difference-in-difference approach | |
| Neumeier et al. (2020) | University Clinic of Salzburg, Austria | A one-year commitment to active commuting by bicycle or walking | N=73; 2-wave surveys before and during the intervention | Health-related quality of life, measured by the Short-Form-36 (SF-36) | Analysis of Variance (ANOVA) | |

| | Main findings |
|---|---|
| | • The improved accessibility of public transport do not improve life satisfaction for residents of the BRT service areas.<br>• Actual BRT users have greater satisfaction with free time. |
| | • Switch to cycling to work increases the levels of mental wellbeing.<br>• Changes in time spent on bicycle commuting do not lead to changes in mental wellbeing. |
| | • Switch from car to e-bicycle increases commuting satisfaction.<br>• Commuting satisfaction with e-bicycle is even higher after 6 months than that after 1 month.<br>• There is little difference in satisfaction with e-bicycle commuting between previous car-only and multimodal commuters. |
| | • Switching to cycling and walk to public transport improves four subcomponents of the SF-36.<br>• Switching to cycling generates greater changes in health-related quality of life compared with switching to walk. |

TABLE 2.4 Overview of studies of residential and workplace relocation

| Authors (Year) | Study area | Relocation events | Sampling | Measures of SWB | Methods of analysis | |
|---|---|---|---|---|---|---|
| Gerber et al. (2017) | Luxembourg | Residential relocation to a bordering country | Retrospective surveys on relocated residents; N=1,298 | Life satisfaction, and satisfaction with life domains | Ordered logit models with the difference-in-difference approach | |
| Nicholls et al. (2018) | Selandra Rise estate, Melbourne | Residential relocation to a newly built suburban residential estates | Two-wave surveys before and after the relocation; N=433 | Commuting satisfaction, and satisfaction with the neighbourhood | Analysis of Variance (ANOVA) | |
| Von Behren et al. (2018) | Karlsruhe, Germany | Workplace relocation from the suburb to the inner city | Three-wave surveys before, immediately after, and 2 years after the relocation; N=39 | Commuting satisfaction | Analysis of Variance (ANOVA) | |
| Kent et al. (2019) | Sydney, Australia | Residential relocation to a newly constructed greenfield estate | Retrospective surveys on relocated residents; N=317 | Life satisfaction, affective emotions, and mental wellbeing measured by Mental Health Scale (MCS12) | OLS models with the difference-in-difference approach | |
| De Vos et al. (2019) | Ghent, Belgium | Residential relocation to a urban and a suburban neighbourhood | Retrospective surveys on relocated residents; N=1,650 | Commuting satisfaction | Cluster analysis and Analysis of Variance (ANOVA) | |
| Schneider & Willman (2019) | University of Wisconsin-Milwaukee, the US | Workplace relocation to the campus | Retrospective surveys on relocated staffs and university students; N=2,715 | Commuting satisfaction | Binary logit models with the difference-in-difference approach | |
| Rau et al. (2019) | Munich, Germany | Workplace relocation from the city centre to a greenfield site | Retrospective surveys on relocated employees; N=121 | Commuting satisfaction, and satisfaction with family and social life | Analysis of Variance (ANOVA) | |
| Gerber et al. (2020) | Montreal, Canada | Workplace relocation to a peri-central location with good transportation accessibility | Retrospective surveys on relocated employees; N=1,071 | Commuting satisfaction | Multinomial logit models with the difference-in-difference approach | |

| | Main findings |
|---|---|
| | • Residents are more likely to commuting by car after relocation.<br>• Commuting journeys after the relocation is the least satisfactory aspect of daily life but do not affect overall quality of life and life satisfaction. |
| | • Residents report more congested road and increased commuting time after relocation.<br>• Commuting time is negatively related to commuting satisfaction, but is not associated with satisfaction with the neighbourhood. |
| | • Employees are more satisfied with shorter commuting time after workplace relocation to the inner city.<br>• After two years, the switch from car to other travel modes (e.g., bicycle) is sustained, and employees take on more household tasks by combining shopping trips with commutes. |
| | • Increases in commuting time and changed commuting time of departure are associated with worse mental wellbeing, life satisfaction and anxiety.<br>• An appreciation of car use and disregards for public transport access are related to better SWB outcomes, while the resentment of travel time is related to worse SWB. |
| | • The cluster characterised by decreased commuting distance and duration and increased uses of car alternatives after relocation has higher levels of commuting satisfaction. |
| | • Participants are more satisfied with commutes if they have shorter commuting distance and shift from a motorised travel mode to walking or bicycle.<br>• The mode shift effect on commuting satisfaction is stronger for male participants. |
| | • Workplace relocation weakens social ties among employees and results in greater dissatisfaction with new commutes.<br>• Employees develop adaptations strategies as buying a car, and less common, moving house.<br>• Employees have fewer opportunities for trip chaining after the workplace relocation. |
| | • Reduced commuting time improves commuting satisfaction.<br>• Switch between car and other travel modes do not influence commuting satisfaction.<br>• Pro-train attitude decreases the commuting satisfaction while perceived reliability of public transport increases the commuting satisfaction.<br>• Commuting satisfaction is positively linked to workplace attachment. |

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TABLE 2.4 Overview of studies of residential and workplace relocation

| Authors (Year) | Study area | Relocation events | Sampling | Measures of SWB | Methods of analysis | |
|---|---|---|---|---|---|---|
| Qu et al. (2021) | Beijing, China | Workplace relocation from urban to suburban areas | Retrospective surveys on newly relocated employees and employees who do not move; N=1,005 | Commuting satisfaction | Ordered probit models with the difference-in-difference approach | |
| De Vos et al. (2021b) | Ghent, Belgium | Residential relocation to a urban and a suburban neighbourhood | Retrospective surveys on relocated residents; N=1,650 | Commuting satisfaction | Ordered logit models with the difference-in-difference approach | |

| | Main findings |
|---|---|
| | • Longer commuting distance after relocation leads to commuting dissatisfaction and increased turnover intention.<br>• The impact of commute satisfaction on turnover intention is significant only for female employees and married employees with children. |
| | • A decrease in travel duration, distance, car and public transport uses, as well as an increase in walking and cycling, leads to an increase in commuting satisfaction.<br>• Commuting satisfaction marginally turns better if commuting mode switch corresponds to travel mode attitude. |

TOC

# 3 Commuting mode shift and subjective wellbeing in urbanising China

**Yinhua Tao, Maarten van Ham & Ana Petrović**

ABSTRACT Emerging longitudinal research on the relationship between commuting behaviours and psychological wellbeing draws exclusively from cities in developed countries and the findings are not consistent. Our study contributes to the evidence base from urban China, where rapid urban growth has raised great concerns for urbanites' commuting problems and psychological stress risks. Drawing upon the China Health and Nutrition Survey (2006-2015), we followed a quasi-longitudinal design to examine changes in commuting mode and the associations with long-term psychological stress. Crucially, the neighbourhood-level urbanicity scale was incorporated to analyse geographic variations in the commuting-stress relationships over time. The results show that car use for commuting and long-duration active commuting were associated with lower stress levels, while long-duration motorised commuting trips were detrimental to psychological stress. Further, high-urbanicity areas involved more active commuting trips and short motorised commuting trips, which were beneficial to psychological wellbeing. In contrast, the commuting-related stress risks were noticeable in medium urbanicity areas, where the commuting duration by public transport was extremely high. Based on the socio-institutional context of urban growth and commuting-induced psychological issues in China, we recommend that urban governments should change the focus from expanding urban development land to improving urban amenities and urbanites' wellbeing.

KEYWORDS Urban growth, travel behaviour, health, well-being, neighbourhood effects, longitudinal designs

## 3.1 Introduction

Following the path of urban growth in the developed world, developing countries have been experiencing rapid expansions of urban space and increases in urban populations with multiple growth-led urban problems. In China, the proportion of urban populations has risen from 35.4% to 60.6% between 2000 and 2020, along with greater job-housing distances and increasing motorised commuting trips. According to the commuting monitoring report of 36 cities of China (2020), active commuting (i.e., walking and cycling to work) is losing its appeal considering that the average one-way commuting distance and duration are up to 8.1 kilometres and 36 minutes. Meanwhile, the current public transport system only gives 45% of the Chinese urban population access to job locations within 45 minutes, so many commuters have to resort to their private car to get to work. The over-reliance on motorised means of transport, such as cars and public transport, not only reduces the efficiency of urban transportation and energy use, but also poses a threat to public health and wellbeing.

Research on the relationship between commuting mode and health outcomes has paid much attention to the endpoint of physical health. An increasing body of longitudinal evidence has shown that everyday commuting on foot or by bike increases physical activity levels, reduces the number of fatal accidents, and thus lowers the risks of obesity, hypertension, and premature death (e.g., Flint et al., 2016; Mytton et al., 2016; Treff et al., 2017). On the contrary, long-term dependence on motorised means of transport increases the prevalence of chronic diseases and all-cause mortality due to the sedentary behaviour involved, the incidence of traffic accidents, and exposures to polluted and crowded traffic environments (e.g., Zijlema et al., 2018; Chatterjee et al., 2020).

Unlike the studies on physical health, studies investigating the effects of commuting mode on psychological wellbeing focus mostly on the momentary or short-term effects, such as the well-studied commuting stress (Novaco et al., 1979). There is no consensus from cross-sectional studies regarding the commuting-wellbeing relationship in the longer term (e.g., Hansson et al., 2011; Tajalli and Hajbabaie, 2017; Sun et al., 2020). In recent years, longitudinal studies in several developed countries (e.g., the UK and Germany) have explored whether commuting mode choices would induce psychological problems for urban populations. Their results generally show that car commuting leads to worse psychological wellbeing in the long term, compared with commuting by public transport and active modes (e.g., Martin et al., 2014; Knott et al., 2018; Lorenz, 2018). However, longitudinal

evidence of this kind is limited from developing countries, including urbanizing China where rapid urban growth seems synchronous with urban commuting problems and urbanites' psychological disorders.

Moreover, population commuting patterns are varying at different stages of urban growth, so the analysis of the commuting-wellbeing relationship will benefit from considering geographic variances, as well as temporal dynamics, in commuting mode choices across urban areas. Previous research has used urban population or land use density to measure urban growth and identified the variations of commuting behaviours over time (Adams, 1970; Sultana and Weber, 2014). Notably, this density-based measure simplifies the complexity of urban characteristics relevant to people's behaviours and wellbeing, and thus lends little support for explaining the long-term psychological outcome of commuting behaviours. Instead, the composite urbanicity scale incorporates a broad presence of urban features (e.g., economic activities, transport infrastructure, and environmental risks) representing the continuum from less urbanized to more urbanized areas (Vlahov and Galea, 2002; Cyril et al., 2013). Embracing this time-varying and neighbourhood-level urbanicity scale can not only identify temporal trends in using different commuting modes within the areas of similar levels of urbanicity, but also allow to compare commuting mode choices and their psychological effects among areas with different levels of urbanicity. This will ultimately result in a better understanding of how urban growth contributes to inequalities in commuting and wellbeing over space and time.

This study drew upon the China Health and Nutrition Survey (CHNS) dataset (2006-2015) and followed a quasi-longitudinal design to examine the relationship between commuting mode and psychological wellbeing in urbanizing China. To better understand changes in commuting behaviour, we firstly described temporal variations in commuting mode and commuting duration for each travel mode across urbanicity areas. Note that the research outcome, long-term psychological stress, was investigated only at the latest wave of the CHNS, which limited our ability to conduct a more stringent longitudinal design. Therefore, we then employ a before-and-after approach to examine whether changes in commuting mode and duration were related to long-term psychological stress at follow-up after controlling for the health and wellbeing status at baseline, and if so, how the relationships varied across urbanicity areas.

## 3.2 A review of urban commuting and psychological wellbeing

As early as the 1970s, the notion of commuting stress was put forward to describe the affective experience during the travel between home and workplaces (Novaco et al., 1979). Some earlier studies ascribe this stressful experience to the physical impedance of commuting trips, such as commuting distance and duration (Novaco et al., 1979; Novaco and Gonzalez, 2009). Based on this, Sposato et al. (2012) propose that perceived control is the pathway linking physical impedance and experienced stress. For example, having choices on different means of transport is associated with greater control on commuting variability and reduced commuting stress (Novaco and Gonzalez, 2009; Wener and Evans, 2011). Besides, walking and cycling are perceived as the most flexible and least stressful travel modes, while commuting by public transport and car usually involves higher levels of experienced stress (Legrain et al., 2015; Chatterjee et al., 2020).

Even though commuting is regarded as a daily episode with higher levels of negative affect than many other activity-travel behaviours (Kahneman et al., 2004), it is still ambiguous whether the everyday commute can exert an observable effect on long-term psychological wellbeing. A great deal of cross-sectional research has shown that certain commuting modes are associated with people's psychological outcomes in both directions. For example, car users tend to report their commuting trips as unpredictable and effortful, and thus are more likely to develop chronic stress symptoms than public transport commuters (Rissel et al., 2014; Tajalli and Hajbabaie, 2017). Oppositely, studies in urban China find that car commuting is related to better life satisfaction and general mental health than long commuting trips by public transport (Nie and Sousa-Poza, 2018; Zhu et al., 2019; Sun et al., 2020). Regarding the effects of active travel modes, walking or cycling to work is less connected with psychological wellbeing than with physical health. Several studies show that a significant psychological benefit of active commuting is only observed for long-duration trips and in large cities with accessible natural environments (Legrain et al., 2015; Zijlema et al., 2018). In addition, there are some studies suggesting negligible commuting-wellbeing associations irrespective of travel modes (Hansson et al., 2011; Dickerson et al., 2014; Higgins et al., 2018). The reason is that in the long term, commuters can well adapt to the daily hassle of commuting trips and return to a stable level of psychological state.

Given the aforementioned conflicting findings, an increasing number of transport and health geographers call for the use of longitudinal research designs to clarify the long-term psychological effects of everyday commuting trips. Compared with cross-sectional designs, longitudinal designs can not only control for the time-invariant factors confounding the exposure-outcome causality, but also account for the commuting-induced chronic psychological stress that cumulates over time within the individual. To date, however, the evidence drawn from longitudinal studies is quite weak and focuses exclusively on cities of developed countries. For example, Martin et al. (2014) draw upon the British Household Panel Survey (BHPS) and find that switching from a car to an active commuting mode, including walking, bicycle and public transport, greatly improves general psychological wellbeing in contrast with maintaining car use. Roberts et al., (2011) and Feng and Boyle (2014) also use the BHPS data, but conclude that long-duration commuting trips, especially those by car, increase the levels of psychological distress only for women. Drawing upon the German Socio-Economic Panel Survey, Lorenz (2018) and Ingenfeld et al. (2019) further discover that long commuting trips by motorised means of transport contribute to lower life satisfaction through reduced satisfaction with leisure time. Taken together, reasons for these mixed findings might include the differences in survey protocols and research contexts, treating public transport as active or non-active travel mode, adjusting in different ways for the confounders of other domains of daily lives (e.g., work, sleep and leisure time), etcetera.

Moreover, a longitudinal research design is crucial in understanding changes in commuting mode in combination with an uneven process of urban growth. This is of great concern in urbanizing China, where rapid urban expansion has induced greater job-housing distances and increasing motorised commuting trips for the past two decades (Wang and Chai, 2009; Zhao and Lu, 2011). To delineate the spatiotemporal dynamics in commuting patterns, previous research uses changes in population or land-use density to observe the associations with people's commuting behaviours over time. For example, Adams' growth waves posit that commuting transitions are manifested as increases in commuting duration and car dependency in newly-built sprawling areas, followed by reduced commuting duration and increased active commuting trips when populations and economic activities become more synchronized in time and space (Adams, 1970). The co-location mechanism corroborates the growth waves given that growth in populations and jobs follows each other with time so that commuting costs would decrease over a longer timescale (Vale, 2013). Sultana and Weber (2014) similarly state that sprawl is part of a continuum of urban growth and sooner or later increased density would provide advantages for commuting (e.g., reliable public transport infrastructure and accessible job locations within walking distance).

When extending to the psychological outcomes of commuting behaviours, research that relies solely on the density indicator to delineate urban areas does not sufficiently take into account the contextual exposure to multidimensional urban environments relevant to public health and wellbeing. This inevitably causes the misestimation of commuting-wellbeing relationship. Alternatively, urbanicity, defined as "the presence of urban features or the extent to which a place exhibits urban characteristics" (Vlahov and Galea, 2002), is a better proxy for exhibiting the spatiotemporal dynamics of multidimensional environmental characteristics. Specifically, the composite urbanicity scale often includes a variety of local factors, such as the intensity of economic activity, provision of transportation infrastructure and accessibility of amenities in residential areas, which are related to people's commuting mode choice and psychological outcomes (Vlahov and Galea, 2002; van Ham et al., 2012). Another advantage of the urbanicity scale is its sensitivity towards environmental changes over time (Jones-Smith and Popkin, 2010; Cyril et al., 2013). Therefore, employing this time-varying scale is helpful to compare the psychological effects of commuting mode among areas of different levels of urbanicity on the one hand, and on the other, examine how changes in commuting mode relate to long-term psychological outcomes within the areas with similar urbanicity levels. Ultimately, this will advance our understanding of the spatiotemporal dynamics in commuting behaviours and the impact on long-term psychological statuses.

## 3.3 Data and Methods

### 3.3.1 China Health and Nutrition Survey

The China Health and Nutrition Survey (CHNS) was designed for monitoring temporal changes in people's health-related behaviours and health outcomes in the evolving economic, institutional, and spatial transformation of Chinese society. The surveys were conducted every 2-5 years with a total of 10 waves between 1989 to 2015. The CHNS used a multistage random cluster sampling approach to collect data on individuals and households in nine provinces and three province-level municipalities with a good representation of urban, suburban, town, and rural areas in China (see for more detail Popkin et al., 2010). Ethical approval for the study was given by the Internal Review Board of the University of North Carolina at Chapel Hill and the Chinese Centre for Disease Control.

Our study used the last four waves of the CHNS data (i.e., 2006, 2009, 2011, and 2015 waves), collected in urban, suburban, and town areas, to explore the relationship between people's commuting mode and psychological stress for a decade of urbanization in China. The eligible samples for our study consist of 7,159 commuters who were 18-65 years old, worked outside the home, and participated in at least one wave of the surveys between 2006 and 2015. We further excluded 581 respondents who had missing commuting, wellbeing, or covariate information. This resulted in the 6,578 pooled samples with 11,289 person-year observations that were descriptively analysed in our study. In the pooled samples, 1,926 respondents who participated in at least two waves of the surveys including the last wave in 2015 constituted the longitudinal samples and were used in the modelling analysis. Table 3.4 shows the socioeconomic characteristics of the eligible samples, pooled samples, and longitudinal samples, respectively. Overall, the characteristics of the pooled samples are similar to those of the eligible samples, while the longitudinal samples were mildly underrepresented for older-aged (50-65 years old) and low-income (0-1,500 RMB/month) populations.

### 3.3.2 Variable settings

The outcome variable is psychological stress, one of the affective components of long-term psychological wellbeing. The psychological stress is measured by the well-established 14-item Perceived Stress Scale (PSS14; Katsarou et al., 2012; Ribeiro-Santiago et al., 2020). Specifically, respondents were asked 14 questions regarding the frequency of stress-related problems in the last month. Each answer was rated on a scale from 0 (never) to 4 (very often) and the total score of all answers represented the respondent's long-term psychological stress (range: 0-56). Note that PSS14 was only measured in the 2015 wave of the surveys (termed as the follow-up survey year in our study), which determined our study to be quasi-longitudinal in nature. Instead, we used one-item self-reported life satisfaction (range: 1-5) as a proxy for respondents' psychological wellbeing in 2006, 2009, and 2011 (termed as the baseline survey years in our study) following Wang and Wang (2016) and Clark et al. (2020). This design contributes to examining the effect of commuting changes on follow-up psychological stress after taking into account the starting state of psychological wellbeing.

The primary predictors of interest are changes in commuting mode and duration of different travel modes from baseline to follow-up. Specifically, the commuting mode was coded as active mode (walk or bicycle), public transport (bus or subway), and car in each wave of the surveys. Note that respondents could report more than one

travel mode for their two-way daily commuting trip. Following Flint et al. (2020)'s measurement on mode changes, we focused on maintaining each of the three travel modes (e.g., using active mode at baseline and follow-up), with the abandonment of baseline travel modes as the reference category (e.g., switching from active mode to public transport or car). The rationale for this maintaining analysis is that the long-term stress effect of commuting mode choices may take time to appear. Additionally, respondents reported the duration of using each commuting mode on a routine workday. The modelling analysis included both the log-transformed commuting duration at baseline (due to its right-skewed distribution) and changes in commuting duration from baseline to follow-up for each travel mode.

The dynamic urban environment along with rapid urban growth in China was measured by the urbanicity scale that was developed specially for the CHNS (Jones-Smith and Popkin, 2010). The urbanicity scale employed information on residential neighbourhoods in 12 domains, including population, economic activities, social services, transportation infrastructure, etcetera (see Table 3.5). In our study, the total score of 12 items represented the urbanicity levels for each surveyed neighbourhood (range: 0–120). According to Jones-Smith and Popkin (2010), we further categorized the continuous urbanicity levels into year-specific tertiles to analyse geographic variations in commuting behaviours and psychological wellbeing over time.

According to previous literature (e.g., Roberts et al., 2011; Martin et al., 2014; Lorenz, 2018), four subsets of covariates that might confound the commuting-wellbeing relationship were included, namely respondents' demographic information, housing and occupational characteristics, health-related lifestyles, and long-term health and wellbeing. The detailed variable settings are provided in Table 3.6. Note that the time-invariant demographics, housing characteristics, and long-term health status were controlled for only at baseline levels, while the time-varying occupational characteristics and health-related behaviours were adjusted for both at baseline levels and by changes between baseline and follow-up. The reason for treating housing characteristics as time-invariant factors is that the CHNS only followed respondents who did not change their residential addresses between survey waves.

### 3.3.3 Multilevel models

The descriptive analysis used the pooled samples to examine changes in commuting behaviours and psychological wellbeing, as well as the geographic variations in commuting mode and duration for areas of different urbanicity levels over time. In the modelling analysis, we drew from the longitudinal samples to explore the associations of psychological stress at follow-up with changes in commuting mode and duration from baseline to follow-up. Given the cluster sampling procedure, multilevel linear regression with random intercepts was employed to control for neighbourhood-level variances in psychological stress. Baseline years were also included to adjust for time fixed effects. All analyses were conducted in R 4.0.3.

Specifically, we constructed three series of multilevel models based on the baseline commuting mode (i.e., active mode, public transport and car). In each series of multilevel models, model 1 analysed the crude associations of follow-up psychological stress with changes in commuting mode and duration after adjusting for demographics and baseline years. Housing and occupation characteristics and health-related lifestyles were respectively included in model 2 and model 3. In model 4, long-term health and wellbeing were added. The fully adjusted model (model 5) incorporated the tertiles of urbanicity levels and the interactions terms with changes in commuting mode and duration to examine urbanicity-specific commuting-stress relationships. Note that the VIF values between explanatory variables were all below 4.0, suggesting a low probability of multicollinearity.

Several sensitivity analyses were performed to test for the robustness of the commuting-wellbeing relationship. First, we stratified respondents into two groups based on their life satisfaction levels at baseline and re-fitted the fully adjusted models. The two groups respectively represented respondents with (very) good life satisfaction and with moderate or (very) bad life satisfaction to address whether the commuting-stress relationship remained for people who had similar initial levels of psychological wellbeing. Second, we transformed the reference category of commuting mode choices to focus on specific types of mode transition (e.g., from active mode to public transport or to car). This transformation contributed to substantiating the stress effect of specific commuting modes. Third, we also examined gender differences in the commuting-stress relationship by separately fitting the fully adjusted models for men and women.

## 3.4 Results

### 3.4.1 Changes in commuting mode choices across urbanicity areas

Table 3.1 shows the descriptive statistics of the pooled samples, focusing on the temporal variations in commuting mode and duration as well as in psychological wellbeing. From 2006 to 2015, the proportion of active commuting decreased gradually from 68.0% to 51.2%. Accordingly, that of car commuting trips and, to a lesser extent, public transport commuting trips increased, either of them accounting for around one quarter of all commutes in 2015. The mean duration of a two-way commuting trip also rose from 32.6 minutes to 49.5 minutes in a day. Especially, commuting duration by public transport was as high as around 60 minutes/day between 2011 and 2015. Regarding the long-term psychological wellbeing, there were varying levels of commuters' life satisfaction with time. The mean score of psychological stress was 22.3 in 2015, similar to the results from cities of developed countries (Katsarou et al., 2012; Ribeiro-Santiago et al., 2020). Besides, the neighbourhood-level urbanicity levels increased steadily during the decade of our study, particularly in low and medium urbanicity areas.

In addition to the temporal trends, there were clear geographic patterns in commuting mode and duration for areas of different urbanicity levels from 2009 to 2015 (Figure 3.1). In low urbanicity areas, the mean duration of a two-way commuting trip stayed constant at around 35 minutes/day until 2011, and then drastically increased to 50 minutes/day in 2015, mainly because of the increasing commuting duration by car. Besides, the proportion of active commuting dramatically decreased over time, along with more public transport and car uses. Medium urbanicity areas had similar trends of changing proportions of active and car commuting trips. However, public transport remained a major part of people's everyday commutes given its increasingly long duration and share. In high urbanicity areas, the distribution of commute mode was relatively stable over time. A surprising finding is that commuting duration by public transport and car decreased to a great extent between 2011 and 2015, contributing to the decline in the mean duration of a two-way commuting trip from 52.55 to 48.60 minutes/day.

TABLE 3.1 Characteristics of pooled samples (N=6,578) and surveyed communities (N=169) over time[a]

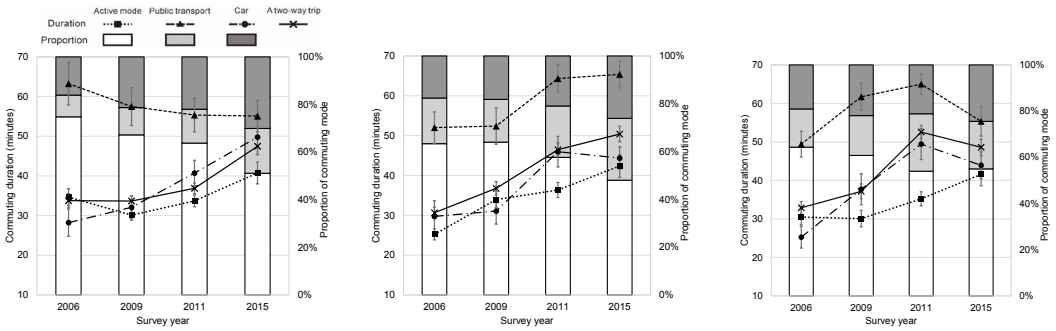
| | | 2006 | 2009 | 2011 | 2015 | Difference[b] |
|---|---|---|---|---|---|---|
| **Person-year observations** | Number | 2304 | 2400 | 3524 | 3061 | - |
| **Commuting mode** | | | | | | |
| Active mode | Proportion | 1566 (68.0) | 1541 (64.2) | 2056 (58.3) | 1567 (51.2) | ** |
| | Duration | 30.7 (44.6) | 31.3 (40.1) | 35.1 (46.5) | 41.6 (66.9) | ** |
| Public transport | Proportion | 335 (14.5) | 366 (15.3) | 717 (20.3) | 673 (22.0) | ** |
| | Duration | 53.7 (47.9) | 57.0 (54.8) | 63.9 (53.3) | 56.9 (56.7) | * |
| Car | Proportion | 403 (17.5) | 493 (20.5) | 751 (21.4) | 821 (26.8) | ** |
| | Duration | 27.6 (38.6) | 33.6 (43.0) | 45.5 (59.9) | 45.7 (61.8) | ** |
| **Commuting timec** | | 32.6 (45.8) | 35.3 (45.3) | 44.2 (55.0) | 49.5 (66.0) | ** |
| **Life satisfaction** | | | | | | |
| (Very) good | | 1569 (68.1) | 1248 (52.0) | 1938 (55.0) | 1935 (63.2) | ** |
| Moderate or (very) bad | | 735 (31.9) | 1152 (48.0) | 1586 (45.0) | 1126 (36.8) | ** |
| **Psychological stress** | | -[d] | - | - | 22.3 (6.2) | - |
| **Residential neighbourhoods** | Number | 110 | 110 | 161 | 159 | - |
| **Urbanicity** | | 79.5 (14.9) | 81.9 (13.7) | 83.8 (13.4) | 84.3 (12.5) | * |
| **Low** | Range | (38.4,76.6) | (37.9,81.9) | (38.4,82.9) | (41.1,82.6) | - |
| **Medium** | Range | (76.6,86.8) | (81.9,90.3) | (82.9,90.6) | (82.6,90.9) | - |
| **High** | Range | (86.8,101.6) | (90.3,106.5) | (90.6,100.9) | (90.9,104.4) | - |

*a. Data are shown in N (%) or mean (SD).*

*b. The differences in mean values and proportions are examined by t-tests and chi-squared tests, respectively. Results are shown as * p<0.05, ** p<0.01, or – not appliable.*

*c. Commuting time is the duration of a two-way commuting trip between home and workplace in a day.*

*d. – means do not apply*




(a) Low urbanicity areas (b) Medium urbanicity areas (c) High urbanicity areas

FIG. 3.1 Commuting mode and duration over time for low, medium and high urbanicity areas



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### 3.4.2 Relationships between commuting mode shift and psychological stress

Drawing from the longitudinal samples, the multilevel model results for the commuting-stress relationship are shown in Tables 3.2-3.3.

TABLE 3.2 Multilevel linear regression models for the independent effects of changes in commuting mode on follow-up psychological stress (N=1926)

| | Model 1[a] | Model 2[b] | Model 3[c] | Model 4[d] |
|---|---|---|---|---|
| | β (95% CI) | β (95% CI) | β (95% CI) | β (95% CI) |
| **Active commuting at baseline (N=1053)** | | | | |
| **Changes in active mode** | | | | |
| Abandoning active mode (N=336) | Reference | Reference | Reference | Reference |
| Maintaining active mode (N=717) | 0.30 (-0.21,0.81) | 0.34 (-0.19,0.87) | 0.31 (-0.19,0.80) | 0.39 (-0.20,0.98) |
| Active commuting duration at baseline | -0.35* (-0.62,-0.06) | -0.32* (-0.57,-0.07) | -0.30* (-0.54,-0.06) | -0.40** (-0.65,-0.15) |
| Changes in active commuting duration | -0.01 (-0.01,0.01) | -0.00 (-0.01,0.01) | -0.00 (-0.01,0.01) | -0.01 (-0.01,0.01) |
| **Public transport commuting at baseline (N=470)** | | | | |
| **Changes in public transport** | | | | |
| Abandoning public transport (N=209) | Reference | Reference | Reference | Reference |
| Maintaining public transport (N=261) | -0.65 (-1.90,0.60) | -0.64 (-1.82,0.54) | -0.66 (-1.83,0.52) | -0.58 (-1.85,0.69) |
| Commuting duration by public transport at baseline | 0.16 (-0.11,0.43) | 0.29 (-0.16,0.74) | 0.13 (-0.14,0.40) | 0.19 (-0.08,0.46) |
| Changes in commuting duration by public transport | -0.00 (-0.02,0.01) | -0.00 (-0.02,0.02) | -0.00 (-0.02,0.01) | -0.00 (-0.02,0.02) |
| **Car commuting at baseline (N=561)** | | | | |
| **Changes in car** | | | | |
| Abandoning car (N=202) | Reference | Reference | Reference | Reference |
| Maintaining car (N=359) | -1.47** (-2.64,-0.30) | -1.15** (-2.19,-0.12) | -1.16* (-2.25,-0.06) | -1.18* (-2.28,-0.08) |
| Commuting duration by car at baseline | 0.83* (0.07,1.59) | 0.77* (0.04,1.50) | 0.68 (-0.10,1.46) | 0.70 (-0.14,1.54) |
| Changes in commuting duration by car | 0.03* (0.01,0.05) | 0.02* (0.01,0.04) | 0.02* (0.01,0.03) | 0.02* (0.01,0.04) |

** p<0.05, ** p<0.01*

a. *Adjusted for baseline years and demographics.*
b. *As model 1, plus housing and occupational characteristics.*
c. *As model 2, plus health-related lifestyles.*
d. *As mode 3, plus life satisfaction and availability of physical diseases.*



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TABLE 3.3 Multilevel linear regression models for the interaction effects of urbanicity and changes in commuting mode on follow-up psychological stress (N=1926)

| | Model 5[a] | | |
|---|---|---|---|
| **Baseline commuting mode** | Active mode | Public transport | Car |
| | β (95% CI) | β (95% CI) | β (95% CI) |
| **Commuting mode** | | | |
| Abandoning baseline mode | Reference | Reference | Reference |
| Maintaining baseline mode | 0.33 (-0.20,0.86) | 0.28 (-0.21,0.77) | -0.67* (-1.29,-0.04) |
| **Commuting duration at baseline** | -0.16* (-0.27,-0.04) | 0.20 (-0.04,0.44) | 0.21 (-0.04,0.46) |
| **Changes in commuting duration** | -0.00 (-0.02,0.01) | 0.02 (-0.01,0.05) | 0.01 (-0.01,0.04) |
| **Urbanicity at baseline** | | | |
| Low urbanicity | Reference | Reference | Reference |
| Medium urbanicity | 2.04 (-0.90,4.98) | 1.88 (-1.06,4.82) | -0.79 (-1.77,0.19) |
| High urbanicity | -1.06* (-2.04,-0.08) | -0.93 (-2.50,0.64) | -1.22* (-2.33,-0.09) |
| **Urbanicity * Commuting mode** | | | |
| Low urbanicity * Maintaining baseline mode | Reference | Reference | Reference |
| Medium urbanicity * Maintaining baseline mode | 0.19 (-0.39,0.78) | 0.69 (-0.23,1.61) | -0.56 (-1.26,0.15) |
| High urbanicity * Maintaining baseline mode | -0.08 (-0.60,0.45) | -0.53 (-1.51,0.45) | -0.70 (-1.80,0.40) |
| **Urbanicity* Commuting duration at baseline** | | | |
| Low urbanicity * Baseline commuting duration | Reference | Reference | Reference |
| Medium urbanicity * Baseline commuting duration | -0.26* (-0.45,-0.06) | 1.22** (0.16,2.28) | 1.29** (0.15,2.43) |
| High urbanicity * Baseline commuting duration | -0.51** (-0.84,-0.18) | -0.69 (-2.45,1.07) | -0.20 (-0.59,0.20) |
| **Urbanicity* Changes in commuting duration** | | | |
| Low urbanicity * Commuting duration change | Reference | Reference | Reference |
| Medium urbanicity * Commuting duration change | -0.00 (-0.03,0.02) | 0.06* (0.02,0.10) | 0.03* (0.01,0.06) |
| High urbanicity * Commuting duration change | -0.02* (-0.05,0.00) | 0.00 (-0.05,0.05) | 0.01 (-0.02,0.04) |

** p<0.05, ** p<0.01*

a. *Adjusted for baseline years, demographics, housing and occupational characteristics, health-related lifestyles and health status.*

Table 3.2 reports the associations of changes in commuting mode and duration with psychological stress at follow-up, stratified by baseline commuting mode. Table 3.3 further presents the geographical variances in the commuting-stress relationship across urbanicity areas. In the series of models for each baseline commuting mode, the neighbourhood-level variances accounted for 19%-25% of random variances in psychological stress, indicative of a valid multilevel structure.

For baseline active commuters, those who maintained or abandoned the active mode showed an insignificant difference in long-term psychological stress at follow-up (see Table 3.1, Model 1). However, active commuting with a longer duration was associated with lower levels of psychological stress (Model 1). After adjusting for baseline health and wellbeing, the effect size of active commuting duration was even larger (Model 4), indicating that the commuting-stress relationship to some extent depended on the initial level of psychological wellbeing. Compared with active commuting in low urbanicity areas, a longer active commuting duration in medium, and especially, high urbanicity areas was predictive of marginally lower levels of psychological stress (see Table 3.3).

For baseline public transport commuters, neither maintaining public transport use nor changes in commuting duration by public transport was associated with follow-up psychological stress, after controlling for baseline health and wellbeing (Model 4). Notably, public transport commuters had significantly higher levels of psychological stress in medium urbanicity areas, where the absolute commuting duration by public transport was the highest among urbanicity areas (Model 5). In medium urbanicity areas, specifically, a longer duration of public transport commuting at baseline was related to higher levels of psychological stress at follow-up. Further, a prolonging commuting duration by public transport from baseline to follow-up was marginally linked to higher follow-up stress levels.

For baseline car commuters, maintaining car commuting had a significant influence on lowering follow-up psychological stress (Model 1), and this effect to some extent attenuated but stayed significant after adjusting for occupational and housing characteristics (Model 2). However, car commuters who had a longer commuting duration at baseline and increased their commuting duration from baseline to follow up were related to higher levels of psychological stress at follow-up (Model 1). Note that the magnitude of baseline commuting duration attenuated when controlling for housing and occupation and its significance disappeared after adjusting for health-related lifestyles (Model 3), suggesting the trade-offs between time spent on car commuting and other health-related behaviours. Similar to findings for public transport commuters, longer baseline commuting duration and prolonging commuting duration by car (Model 5) were marginally associated with higher stress levels in medium urbanicity areas.

Regarding the relationships between covariates and psychological stress, baseline life satisfaction was strongly and significantly associated with follow-up psychological stress, suggesting the necessity of taking into account psychological wellbeing at baseline in our quasi-longitudinal study. Besides, urban populations, people older than 50 years, people employed by governments or state-owned

enterprises, and housing owners had lower stress levels than rural-to-urban migrants, young people (18–30 years old), self-employed people or farmers, and housing renters, respectively. The gender difference in psychological stress was only significant for baseline car commuters, with female car users showing higher levels of psychological stress. Monthly wages at baseline did not predict follow-up psychological stress, but an increase in monthly wages from baseline to follow-up was associated with lower stress levels. Frequent exercisers also had lower levels of psychological stress and the transition from more frequent to less frequent exercises was related to higher stress levels. There were no systematic associations of psychological stress with (changes in) working hours, (changes in) sleep time, drinking and smoking habits, chronic physical diseases and baseline years.

### 3.4.3 Sensitivity analyses

Results of several sensitivity analyses are shown in Tables 3.7–3.9. First, we lent some support to the commuting-wellbeing causality after stratifying respondents based on their life satisfaction at baseline (Table 3.7). Specifically, baseline active commuters reported lower levels of follow-up psychological stress as their commuting duration increased, and the magnitude was greater for people who rated their baseline life satisfaction as (very) good. In contrast, a longer commuting duration by non-active travel mode (i.e., public transport or car) at baseline was predictive of higher follow-up stress levels in medium urbanicity areas, and the magnitude was greater for people who rated their baseline life satisfaction as moderate or (very) bad. Second, we corroborated the psychological benefit of car commuting. Commuters who switched from active mode or public transport to car reported lower stress levels at follow-up compared with those who maintained the active mode or public transport (Table 3.8). In high urbanicity areas, however, switching from car to active commuting was marginally associated with lower levels of psychological stress. Third, men and women showed little difference in the commuting-stress relationship, except that women were psychologically more stressed with longer non-active commuting duration while men were less stressed with the increase of active commuting duration (Table 3.9).

## 3.5 Discussion and Conclusions

### 3.5.1 Interpretation of main findings

Our study examined the associations of commuting mode with long-term psychological stress and the role of urbanicity in the commuting-stress relationship in rapidly urbanizing China. The main findings are that the car was the means of transport that imposed the least stress burden on urban commuters in China. In contrast, longer-duration commuting trips by motorised means of transport, including public transport or car, were predictive of worse psychological stress, while active commuting for a longer duration was conducive to relieving the stress. Crucially, there were great geographic variations in commuting mode choices and resultant psychological outcomes among different urbanicity areas. Compared with low urbanicity areas, high urbanicity areas involved more active commuting trips and shorter non-active commuting trips that contributed to lower stress levels. Oppositely, more prominent stress problems related to everyday commuting trips occurred in medium urbanicity areas, where the commuting duration by public transport was extremely high.

The psychological benefits of car commuting were observed in two ways. First, people who maintained car commuting showed lower levels of follow-up psychological stress than those who abandoned car use. Second, switching from public transport or active mode to the car was associated with lower stress levels compared with maintaining public transport or active mode. This finding is inconsistent with some longitudinal evidence in cities of developed countries (Wener et al., 2003; Roberts et al., 2011; Martin et al., 2014). Their findings indicate that compared with the car, public transport as the primary commuting mode was associated with better psychological wellbeing because of the physical activity and social contact involved. In this study, we used detailed records on commuting mode choices to exclude the active parts (e.g., walking to bus stops) of a commuting trip undertaken mainly by public transport. Our results corroborated psychological benefits of car uses as evidenced by cross-sectional studies in urban China (Nie and Sousa-Poza, 2018; Zhu et al., 2019; Sun et al., 2020). We further examined the mechanism underlying that income might be a confounder relating to both lower stress levels and more car uses. The model results, however, show that the inclusion of baseline wage levels and wage changes only modestly influenced the effect size of maintaining car commuting. In this regard, possible pathways accounting for the

psychological benefits of car commuting, such as socio-psychological (e.g., a visible sign of affluence and great controls over the commuting trip) and contextual factors (e.g., driving comfort and less exposure to environmental hazards), still warrant further examination in urban China.

Despite the psychological benefits of maintaining car use for commuting, we found that a longer commuting duration by car was predictive of higher levels of psychological stress. Aside from the attention fatigue and congestion experience for long-duration car commuting trips, it is likely that long commuting duration restricts disposable time for health-related activities, such as leisure and sleep. Consistent with the findings from American and European cities (Kün-Nelen, 2016; Morris and Zhou, 2018), our study preliminarily demonstrated this stress-mediated process by which the stress effect of long-duration car commuting trips turned insignificant after taking into account the stress-relieving effect of recreational exercises. In other words, spending much time on car commuting discouraged frequent participation in recreational exercises and increased the likelihood of giving up exercises, thereby contributing to psychological stress issues in the long term.

The relationship between active commuting and psychological stress to a great extent rested with the commuting duration and presented geographic variations across urbanicity areas. Notably, long active commuting trips at baseline were associated with lower levels of follow-up psychological stress, especially for people who had good life satisfaction at baseline. The reason is illustrated by previous studies that walking or cycling to work for a longer time involves the higher intensity of physical activity with positive moods and is more likely to meet the required dose of generating long-term psychological benefits (Clemes et al., 2014; Martin et al., 2014). In addition, high urbanicity areas facilitated a relaxing active commuting experience, considering that people in these areas had marginally lower levels of psychological stress as the active commuting duration prolonged or the transition from car to active mode occurred. The reason lies in that high urbanicity areas are often featured as better job-housing balance, diversified urban spaces and improved transportation infrastructure, which give active commuters a feeling of comfort and safety from traffic and help them recover from the stress of daily hassles (Martin et al., 2014; Legrain et al., 2015).

On the contrary, chronic stress problems were remarkable for long-duration public transport commuters in medium urbanicity areas. Here, rapid urban growth gives rise to great job-housing mismatch and crowded traffic environment. At the same time, the construction of efficient public transportation systems always lags behind the urban land expansion. As shown in our study, public transport commuters in medium urbanicity areas had to endure more than 1 hour for everyday commuting trips. This

not only causes great opportunity costs for participating in health-related activities, but also implies the inflexibility and the loss of control for commuting trips due to unpredictable delays and multiple transfers (Hansson et al., 2011; Chatterjee et al., 2020). This finding adds to the claim that growth-induced commuting and stress problems have transferred from highly urbanized areas to less urbanized areas with medium urbanicity levels, and might further extend to low urbanicity areas where rapid urban growth is about to take place.

### 3.5.2 Implications for urban growth in China

Urban growth does not necessarily result in an increasing number of motorised commuting trips with long duration and the loss of commuting-induced psychological wellbeing. Our study extended Adams' growth waves and the commuting transition hypothesis by examining the geographic patterns of commuting behaviours over time through the neighbourhood-level urbanicity scale. We showed that the later stage of urban growth with high urbanicity levels made for the reduced commuting duration by motorised travel mode and increased active commuting trips, which further resulted in better psychological wellbeing. Urban growth is, therefore, not only a spatial phenomenon involving the complexity of multidimensional environmental characteristics, but also a temporal process exhibiting dynamics in the urban environment and urbanites' commuting behaviours. In its initial stage, urban growth characterised as the low-density sprawling pattern may cause the explosion of long motorised commuting trips even though it has advantages in providing affordable housing, decentralizing employment opportunities, and favouring freer residential and job relocation (Zhao and Lu, 2011; Sultana and Weber, 2014). In the long term, the aggregation of economic activities, residential amenities and transportation infrastructure in initially sprawling areas will support a compact, self-contained and high-urbanicity environment to reduce commuting time, encourage active commuting, and thus benefit psychological wellbeing.

In the context of urbanizing China, however, rapid urban growth might not spontaneously create high urbanicity areas conducive to people's commuting experience and psychological wellbeing. This relates to the urban growth path of Chinese cities that pays much attention to urban land expansion rather than urbanites' daily lives and wellbeing. Wu (2015) ascribed this unique path to the Chinese land-driven growth machine. Since the introduction of the land market and economic decentralization in the 1980s, the local governments in Chinese cities have taken the responsibility to drive economic growth and finance public services from the state (Wang and Chai, 2009; Fan et al., 2014). To secure fiscal revenue

and stimulate the local economy, urban governments progressively expand the urban development land by encroaching adjacent rural areas, and then lease the newly-developed land to commercial and residential markets as a way of earning the differential rural-urban land rent. One remarkable downside of the land-driven urban growth is the widespread sprawling pattern in Chinese cities, where the low-density residential populations at the city fringes have difficulties in accessing satisfactory job opportunities and public transportation infrastructure (Zhao and Lu, 2011; Ta et al., 2017). As a result, an increasing number of commuters turn to motorised means of transport, especially private cars, to cover the long commuting distance. Notably, this trend is expected to be intensified in urbanizing China given the absolute low proportion of car commuters and the psychological benefits of maintaining and switching to car commuting as evidenced in our study.

### 3.5.3 Limitations and conclusions

Our study has several limitations and suggestions for future studies. First, the CHNS only investigated the perceived stress scale in 2015, which limited our ability to control for all time-invariant idiosyncratic effects by using fixed-effect models. Alternatively, we followed a before-and-after approach to analyse the relationship between maintaining certain commuting mode from baseline to follow up and long-term psychological stress at follow up, after controlling for baseline health and wellbeing status and separating the time-varying and time-invariant covariates. Further, we conducted the sensitivity analysis by stratifying respondents based on their baseline life satisfaction, but it should be noted that life satisfaction and psychological stress represent different dimensions of long-term psychological wellbeing. For this reason, we are cautious to conclude the commuting-wellbeing causality. Second, our research samples were restricted to those who worked out of home. It would be interesting to examine the psychological effect of working from home and commuting outside the rush hours, especially in the era of post-COVID-19 urban societies. Third, our study did not expound the pathways linking commuting mode and psychological stress. We recommend for future studies to examine more detailed socio-psychological and contextual mediators in explaining the commuting-stress relationship.

This is one of the first quasi-longitudinal studies that analysed the relationship between commuting mode and psychological wellbeing in urban China. We found evidence for the psychological benefits of commuting by car and long-duration active commuting, as well as the stress burden of long-duration motorised commuting trips. We further disclosed that commuting-related stress risks were prominent the

most in rapidly urbanizing areas with medium urbanicity levels, while high-urbanicity areas were supportive of commuting by active mode and motorised commuting trips with short duration, thereby benefiting people's long-term psychological wellbeing. In order to cope with the growth-induced commuting and wellbeing issues in urbanizing China, we urge researchers and policymakers to refocus the urban growth path from urban space expansion to urbanicity and urban lives.

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# Appendix

TABLE 3.4 Socio-economic characteristics of the eligible samples, pooled samples and longitudinal samples[a]

| | Eligible samples (N=7,159) | Pooled samples (N=6,578) | Longitudinal samples (N=1,926) |
|---|---|---|---|
| **Gender** | | | |
| Male | 3,995 (55.8) | 3,697 (56.2) | 1,104 (57.3) |
| Female | 3,164 (44.2) | 2,881 (43.8) | 822 (42.7) |
| **Age** | | | |
| 18-29 | 966 (13.5) | 954 (14.5) | 297 (15.4) |
| 30-49 | 4,210 (58.8) | 4,085 (62.1) | 1,317 (68.4) |
| 50-65 | 1,983 (27.7) | 1,539 (23.4) | 312 (16.2) |
| **Marital status** | | | |
| Married | 6,171 (86.2) | 5,697 (86.6) | 1,703 (88.4) |
| Unmarried or other | 988 (13.8) | 881 (13.4) | 223 (11.6) |
| **Registered residence status** | | | |
| Urban residents | 5,233 (73.1) | 4,802 (73.0) | 1,420 (73.7) |
| Rural-to-urban migrants | 1,926 (26.9) | 1,706 (27.0) | 506 (26.3) |
| **Occupational types** | | | |
| Governments or state-owned enterprises | 2,899 (40.5) | 2,671 (40.6) | 788 (40.9) |
| Private enterprises, foreign enterprises, or joint ventures | 3,150 (44.0) | 2,947 (44.8) | 857 (44.5) |
| Neighbourhood committees or social organizations | 480 (6.7) | 460 (7.0) | 143 (7.4) |
| The self-employed or farmers | 630 (8.8) | 500 (7.6) | 138 (7.2) |
| **Monthly wages** | | | |
| 0-1,500 RMB[b] | 3,214 (44.9) | 2,605 (39.6) | 574 (29.8) |
| 1,500-3,000 RMB | 2,842 (39.7) | 2,802 (42.6) | 1,107 (57.5) |
| 3,000-5,000 RMB | 802 (11.2) | 691 (10.5) | 160 (8.3) |
| >5,000 RMB | 293 (4.1) | 480 (7.3) | 85 (4.4) |
| **Housing tenure** | | | |
| Self-owners | 6,336 (88.5) | 5,854 (89.0) | 1,720 (89.3) |
| Renters or others | 823 (11.5) | 724 (11.0) | 206 (10.7) |

*a. Data are shown in N (%).*

*b. Monthly wages are uniformly inflated to the 2006 level and RMB (renminbi) is the official currency of People's Republic of China.*

TABLE 3.5 Twelve items of the urbanicity scale for the CHNS[a]

| Items | Description |
|---|---|
| Population density | Total population of the community divided by community area, from official records. |
| Economic activity | Daily wage for ordinary male worker (reported by community official) and percent of the population engaged in non-agricultural work. |
| Traditional markets | Distance to the market three categories; (1) within the boundaries of the community, (2) within the city but not in this community, or (3) not within the city/village/ town); number of days of operation for eight different types of market (including food and fuel markets). |
| Modern markets | Number of supermarkets, cafes, internet cafes, indoor restaurants, outdoor fixed and mobile eateries, bakeries, ice cream parlors, fast food restaurants, fruit and vegetable stands, bars within the community boundaries. |
| Transportation infrastructure | Most common type of road, distance to bus stop, and distance to train stop. (Distance is categorized as (1) within community, (2) <¼ 1 km from community, and (3) >¼ 1 km from community). |
| Sanitation | Proportion of households with treated water and prevalence of households without excreta present outside the home. |
| Communica-tions | Availability (within community boundaries) of a cinema, newspaper, postal service, telephone service; and percent of households with a computer, percent of households with a television, and percent of households with a cell phone. |
| Housing | Average number of days a week that electricity is available to the community, percent of community with indoor tap water, percent of community with flush toilets, and percent of community that cooks with gas. |
| Education | Average education level among adults >21 years old. |
| Diversity | Variation in community education level and variation in community income level. |
| Health infrastructure | Number and type of health facilities in or nearby (12 km) the community and number of pharmacies in community. |
| Social services | Provision of preschool for children under 3 years old, availability of (offered in community) commercial medical insurance, free medical insurance, and/or insurance for women and children. |

a. *Source: Jones-Smith and Popkin (2010)*

TABLE 3.6 Variable settings

| Category | Variable | Description | Levels |
|---|---|---|---|
| Psychological stress | Perceived stress | 14-item Perceived Stress Scale (PSS14) measured (range: 0-56) | Follow-up |
| Commuting mode | Mode transition | 1=maintaining specific travel mode (i.e., active mode, public transport, or the car) from baseline to follow-up,<br>0=abandoning certain travel mode (reference) | Changes |
| | Mode duration | Log-transformed commuting duration for each travel mode | Baseline |
| | Changes in duration | Changes in commuting duration for each travel mode from baseline to follow up | Changes |
| Urbanicity | Urbanicity | Year-specific tertiles of 12-item community-level urbanicity scale (range: 0-120) | Baseline |
| Demographics | Gender | 1=men, 0=women (reference) | Baseline |
| | Age | 1=18-29 years old (reference), 2=30-49 years old, 3=50-65 years old | Baseline |
| | Marital status | 1=married, 0=other (reference) | Baseline |
| | Registered residence status | 1=urban residents, 0=rural-to-urban migrants (reference) | Baseline |
| Housing and occupations | Housing tenure | 1=the self-owned, 0=renters or others (reference) | Baseline |
| | Housing area | Housing areas per capita in the household | Baseline |
| | Occupational type | 1=governments or state-owned enterprises, 2=private enterprises, foreign enterprises (reference), or joint ventures, 3=neighbourhood committees or social organizations, 4=the self-employed or farmers | Baseline |
| | Job changes | 1=changing jobs from baseline to follow-up, 0=not changing jobs (reference) | Changes |
| | Work time | Routine work time in a week | Baseline |
| | Changes in work time | 1=increase, 2=stable (reference), 3=decrease | Changes |
| | Monthly wages | 1=0-1500 RMB (reference), 2=1500-3000 RMB, 3=3000-5000 RMB, 4= 5,000 RMB or more | Baseline |
| | Changes in monthly wages | 1=increase, 2=stable (reference), 3=decrease | Changes |
| Health-related lifestyles | Sleep time | Hours spent on sleep on a routine weekday | Baseline |
| | Changes in sleep time | 1=increase, 2=stable (reference), 3=decrease | Changes |
| | Recreational exercises | 1=taking recreational exercises frequently (reference), 0=not taking exercises frequently (reference) | Baseline |
| | Changes in exercises | 1=increase, 2=stable (reference), 3=decrease | Changes |
| | Smoking habit | 1=smokers, 0=non-smokers (reference) | Baseline |
| | Drinking habit | 1=alcohol users, 0=non-alcohol users (reference) | Baseline |
| Long-term health and wellbeing | Physical diseases | 1=having any diagnosed physical diseases, including hypertension, diabetes, myocardial infarction, apoplexy, asthma, stroke or any cancers, 0=not having any diagnosed physical diseases (reference) | Baseline |
| | Life satisfaction | Self-reported life satisfaction levels (range:1-5) | Baseline |

TABLE 3.7 Sensitivity modelling analyses according to life satisfaction at baseline

| | Model S1[a] | Model S2[a] |
|---|---|---|
| Baseline life satisfaction | (Very) good | Moderate or (very) bad |
| | β (95% CI) | β (95% CI) |
| Active commuting at baseline | | |
| **Active mode** | | |
| Abandoning active mode | Reference | Reference |
| Maintaining active mode | 0.28 (-0.11,0.67) | 0.46 (-0.20,1.11) |
| **Active commuting duration at baseline** | -0.23** (-0.39,-0.07) | -0.12* (-0.23,-0.02) |
| **Changes in active commuting duration** | -0.02 (-0.04,0.01) | -0.01 (-0.03,0.02) |
| **Urbanicity at baseline** | | |
| Low urbanicity | Reference | Reference |
| Medium urbanicity | 1.68 (-0.28,3.64) | 2.16 (-0.39,4.70) |
| High urbanicity | -1.81* (-3.47,-0.14) | 0.87 (-0.70,2.44) |
| **Urbanicity * Active mode** | | |
| Low urbanicity * Maintaining active mode | Reference | Reference |
| Medium urbanicity * Maintaining active mode | 0.18 (-0.12,0.47) | 0.30 (-0.09,0.69) |
| High urbanicity * Maintaining active mode | -0.17 (-0.42,0.09) | 0.43 (-0.10,1.96) |
| **Urbanicity* Active commuting duration at baseline** | | |
| Low urbanicity * Baseline commuting duration | Reference | Reference |
| Medium urbanicity * Baseline commuting duration | -0.16 (-0.18,0.06) | -0.39* (-0.74,-0.04) |
| High urbanicity * Baseline commuting duration | -0.53** (-0.92,-0.14) | -0.46** (-0.78,-0.09) |
| **Urbanicity* Changes in active commuting duration** | | |
| Low urbanicity * Commuting duration change | Reference | Reference |
| Medium urbanicity * Commuting duration change | 0.00 (-0.02,0.02) | -0.01 (-0.04,0.02) |
| High urbanicity * Commuting duration change | -0.02* (-0.04,-0.01) | -0.01 (-0.03,0.02) |
| Non-active commuting at baseline | | |
| **Non-active mode (public transport or the car)** | | |
| Abandoning non-active mode | Reference | Reference |
| Maintaining non-active mode | -0.43 (-1.02,0.16) | -0.35 (-0.96,0.25) |
| **Non-active commuting duration at baseline** | 0.21 (-0.03,0.45) | 0.19 (-0.08,0.46) |
| **Changes in non-active commuting duration** | 0.02 (0.00,0.04) | -0.01 (-0.03,0.01) |
| **Urbanicity at baseline** | | |
| Low urbanicity | Reference | Reference |
| Medium urbanicity | -0.85 (-1.81,0.11) | 0.41 (-0.37,1.19) |
| High urbanicity | -1.74** (-3.26,-0.21) | 1.31 (-0.69,3.30) |
| **Urbanicity * Non-active mode** | | |
| Low urbanicity * Maintaining non-active mode | Reference | Reference |
| Medium urbanicity * Maintaining non-active mode | -0.20 (-0.78,0.39) | -0.47 (-1.25,0.31) |
| High urbanicity * Maintaining non-active mode | -0.55 (-1.17,0.07) | -0.79 (-1.58,0.01) |

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TABLE 3.7 Sensitivity modelling analyses according to life satisfaction at baseline

| | Model S1[a] | Model S2[a] |
|---|---|---|
| **Urbanicity* Non-active commuting duration at baseline** | | |
| Low urbanicity * Baseline commuting duration | Reference | Reference |
| Medium urbanicity * Baseline commuting duration | 0.94* (0.07,1.80) | 1.50** (0.32,2.67) |
| High urbanicity * Baseline commuting duration | -0.65 (-1.43,0.13) | -0.43 (-1.21,0.35) |
| **Urbanicity* Changes in non-active commuting duration** | | |
| Low urbanicity * Commuting duration change | Reference | Reference |
| Medium urbanicity * Commuting duration change | 0.02* (0.00,0.05) | 0.02 (-0.01,0.05) |
| High urbanicity * Commuting duration change | -0.02 (-0.05,0.02) | 0.02 (-0.02,0.04) |

** p<0.05, ** p<0.01*

a. *Adjusted for baseline years, demographics, housing and occupational characteristics, health-related lifestyles and health status.*

TABLE 3.8 Sensitivity modelling analyses for commuting mode transition

| | Model S3[a] | | |
|---|---|---|---|
| **Baseline commuting mode** | Active mode | Public transport | Car |
| | β (95% CI) | β (95% CI) | β (95% CI) |
| **Commuting mode transition** | | | |
| Maintaining baseline mode | Reference | Reference | Reference |
| Switch to active mode | -[b] | -0.22 (-0.51,0.08) | 0.25 (-1.06,1.56) |
| Switch to public transport | -0.34 (-1.48,0.80) | - | -0.64 (-2.46,1.18) |
| Switch to the car | -0.82** (-1.51,-0.13) | -0.40* (-0.77,-0.03) | - |
| **Commuting duration at baseline** | -0.17* (-0.30,-0.03) | 0.20* (0.02,0.38) | 0.18 (-0.02,0.37) |
| **Changes in commuting duration** | -0.00 (-0.02,0.01) | 0.04 (-0.02,0.07) | 0.01 (-0.01,0.03) |
| **Urbanicity at baseline** | | | |
| Low urbanicity | Reference | Reference | Reference |
| Medium urbanicity | 1.99 (-0.56,4.54) | 1.88 (-0.86,4.62) | -0.75 (-1.73,0.23) |
| High urbanicity | -1.10* (-2.14,-0.06) | -0.90 (-2.47,0.67) | -1.23* (-2.40,-0.05) |
| **Urbanicity * Commuting mode** | | | |
| Low urbanicity * Switch to active mode | - | Reference | Reference |
| Medium urbanicity * Switch to active mode | - | -0.52 (-1.10,0.07) | 0.48 (-0.54,1.50) |
| High urbanicity * Switch to active mode | - | -0.92 (-1.86,0.02) | -1.07* (-2.09,0.05) |
| Low urbanicity * Switch to public transport | Reference | - | Reference |
| Medium urbanicity * Switch to public transport | 0.20 (-0.02,0.41) | - | 0.87 (-1.09,2.83) |
| High urbanicity * Switch to public transport | -0.08 (-0.28,0.12) | - | 0.59 (-1.18,2.35) |
| Low urbanicity * Switch to automobile | Reference | Reference | - |
| Medium urbanicity * Switch to the car | -0.17* (-0.31,-0.03) | -1.98* (-3.92,-0.04) | - |
| High urbanicity * Switch to the car | 0.06 (-0.04,0.16) | -1.15 (-2.52,0.22) | - |
| **Urbanicity* Commuting duration at baseline** | | | |
| Low urbanicity * Baseline commuting duration | Reference | Reference | Reference |
| Medium urbanicity * Baseline commuting duration | -0.17* (-0.30,-0.03) | 1.05** (0.17,1.93) | 1.11** (0.19,2.03) |
| High urbanicity * Baseline commuting duration | -0.38** (-0.760,-0.16) | -0.75 (-2.12,0.62) | -0.15 (-0.48,0.18) |
| **Urbanicity* Changes in commuting duration** | | | |
| Low urbanicity * Commuting duration change | Reference | Reference | Reference |
| Medium urbanicity * Commuting duration change | -0.00 (-0.03,0.02) | 0.03 (-0.02,0.07) | 0.02* (0.00,0.05) |
| High urbanicity * Commuting duration change | -0.01 (-0.02,0.01) | 0.00 (-0.04,0.03) | 0.01 (-0.02,0.04) |

** p<0.05, ** p<0.01*

*a. Adjusted for baseline years, demographics, housing and occupational characteristics, health-related lifestyles and health status.*

*b. – means do not apply.*

TABLE 3.9 Sensitivity modelling analyses for men and women

| | Model S4[a] | Model S5[a] |
|---|---|---|
| Gender | Men | Women |
| | β (95% CI) | β (95% CI) |
| **Active commuting at baseline** | | |
| **Active mode** | | |
| Abandoning active mode | Reference | Reference |
| Maintaining active mode | -0.07 (-0.19,0.05) | 0.41 (-0.21,1.03) |
| Active commuting duration at baseline | -0.29* (-0.54,-0.04) | -0.15 (-0.28,-0.01) |
| Changes in active commuting duration | -0.01 (-0.02,0.01) | -0.00 (-0.01,0.01) |
| **Urbanicity at baseline** | | |
| Low urbanicity | Reference | Reference |
| Medium urbanicity | 1.75 (-0.95,4.46) | 2.27 (-0.85,5.39) |
| High urbanicity | -1.20* (-2.32,-0.09) | -0.86* (-1.68,-0.04) |
| **Urbanicity * Active mode** | | |
| Low urbanicity * Maintaining active mode | Reference | Reference |
| Medium urbanicity * Maintaining active mode | -0.58 (-1.36,0.20) | 0.74 (-0.24,1.72) |
| High urbanicity * Maintaining active mode | -0.06 (-0.27,0.16) | -0.15 (-0.36,0.07) |
| **Urbanicity* Active commuting duration at baseline** | | |
| Low urbanicity * Baseline commuting duration | Reference | Reference |
| Medium urbanicity * Baseline commuting duration | -0.28* (-0.55,-0.04) | -0.22* (-0.41,-0.04) |
| High urbanicity * Baseline commuting duration | -0.57** (-0.96,-0.18) | -0.34* (-0.64,-0.06) |
| **Urbanicity* Changes in active commuting duration** | | |
| Low urbanicity * Commuting duration change | Reference | Reference |
| Medium urbanicity * Commuting duration change | -0.01 (-0.02,0.01) | -0.03 (-0.05,0.01) |
| High urbanicity * Commuting duration change | -0.02 (-0.06,-0.00) | -0.00 (-0.04,0.03) |
| **Non-active commuting at baseline** | | |
| **Non-active mode (public transport or the car)** | | |
| Abandoning non-active mode | Reference | Reference |
| Maintaining non-active mode | -0.36 (-0.94,0.23) | -0.27 (-0.88,0.34) |
| Non-active commuting duration at baseline | 0.08 (-0.14,0.19) | 0.32* (0.05,0.60) |
| Changes in non-active commuting duration | -0.00 (-0.02,0.01) | 0.01 (-0.01,0.03) |
| **Urbanicity at baseline** | | |
| Low urbanicity | Reference | Reference |
| Medium urbanicity | 0.87 (-0.70,2.43) | 1.06 (-0.70,2.82) |
| High urbanicity | -1.30* (-2.55,-0.05) | -0.94 (-2.11,0.24) |
| **Urbanicity * Non-active mode** | | |
| Low urbanicity * Maintaining non-active mode | Reference | Reference |
| Medium urbanicity * Maintaining non-active mode | -0.36 (-0.95,0.23) | 0.42 (-0.36,1.20) |
| High urbanicity * Maintaining non-active mode | -0.74 (-1.72,0.24) | -0.56 (-1.34,0.22) |

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TABLE 3.9 Sensitivity modelling analyses for men and women

| | Model S4[a] | Model S5[a] |
|---|---|---|
| **Urbanicity* Non-active commuting duration at baseline** | | |
| Low urbanicity * Baseline commuting duration | Reference | Reference |
| Medium urbanicity * Baseline commuting duration | 0.85** (0.26,1.44) | 1.33** (0.19,2.47) |
| High urbanicity * Baseline commuting duration | -0.54 (-1.24,0.16) | -0.37 (-0.91,0.18) |
| **Urbanicity* Changes in non-active commuting duration** | | |
| Low urbanicity * Commuting duration change | Reference | Reference |
| Medium urbanicity * Commuting duration change | 0.04* (0.00,0.07) | 0.03 (-0.01,0.07) |
| High urbanicity * Commuting duration change | 0.00 (-0.02,0.02) | -0.00 (-0.02,0.01) |

** p<0.05, ** p<0.01*

a. *Adjusted for baseline years, demographics, housing and occupational characteristics, health-related lifestyles and health status.*

# 4 Working from home and subjective wellbeing in the United Kingdom

## A natural experiment of the COVID-19 pandemic

**Yinhua Tao, Ana Petrović & Maarten van Ham**

ABSTRACT Despite the social and economic losses that have resulted from the COVID-19 crisis, the prevalence of working from home (WFH) has alleviated unsustainable commuting patterns and is expected to continue in post-COVID-19 society. By taking a person-centred perspective and using a longitudinal COVID-19 survey from the UK, this study investigates the relationship between WFH and subjective wellbeing (SWB). Our particular interest is the extent to which this relationship depends on homeworkers' commuting behaviours prior to the COVID-19 outbreak. Results from the pooled modelling analysis and fixed-effect modelling analysis show that the transition to WFH was conducive to affective wellbeing in the short term and not predictive of life satisfaction. However, this positive effect on affective wellbeing became insignificant after we took specific experiences of WFH into account. Positive homeworking experiences were more of a result of strong social support, healthy daily lifestyles and stable financial circumstances during the pandemic. Even so, the WFH-SWB relationship does depend on homeworkers' pre-COVID-19 commuting behaviour. Long-distance commuters (one-way commuting distance > 30 miles) reported better affective wellbeing when they could work from home, while commuters who had frequently walked or cycled to work reported worse SWB outcomes after switching to WFH.

KEYWORDS Well-being, travel behaviours, work from home, coronavirus, longitudinal designs, the UK

## 4.1 Introduction

Working from home (WFH) is not a new concept. It emerged in the 1970s when telecommuting technologies allowed workers to complete job tasks remotely and reduce regular travel between their homes and workplaces (Nilles, 1976). Since the outbreak of the COVID-19 crisis, WFH has become a common practice as governments around the world encourage or enforce homeworking as a way of suppressing the spread of coronavirus and ensuring the continuity of economic activities. In the UK, for example, around half of the working population carried out some work at home during the COVID-19 pandemic; by comparison, only 5.1% of the working population were routine homeworkers prior to the pandemic (Cameron, 2020). Leaving aside the heavy social, economic and health losses caused by the COVID-19 crisis, WFH is regarded as a beneficial practice by transportation researchers because it curtails the operational costs of enterprises, decreases the volume of traffic at rush hours, and contributes to a more sustainable mobility system (Beck and Hensher, 2020; 2021).

From a person-centred perspective, it is important to understand how people evaluate their "workplace" wellbeing and reconsider their commuting experience when they make the change to homeworking. In doing so, homeworkers will learn the ways to maintain good mental states and subjective wellbeing (SWB) during the pandemic. Moreover, the experience of homeworking reveals the preference for work locations and will inform more supportive workplace arrangements in post-COVID-19 society. An increasing body of evidence has shown that people generally perceive WFH as a positive experience during COVID-19 lockdowns, even though lockdowns themselves have a negative effect on public health and wellbeing (Davillas and Jones, 2020; Brodeur et al., 2021). The reason for this is that employees attach great importance to the flexibility of their workplace and the autonomy of their work-life schedule, which can be better fulfilled by working at home than at the official workplace. A majority of homeworkers even state that they are reluctant to resume daily commuting to work when the coronavirus pandemic subsides (Beck et al., 2020). From the employers' viewpoint, they are also willing to establish WFH as a norm because there is little evidence of the decrease in labour productivity (Barrero et al., 2021).

Debates around this issue claim that specific stay-at-home experiences account for homeworkers' SWB during the pandemic. Drawing upon the job demands-resources model, occupational health research shows that workplace wellbeing concerns the balance between the demands of remote work and the resources available to

offset losses in SWB (Galanti et al., 2021; Meyer et al., 2021; Wood et al., 2021). On the demand side, work-family conflicts, such as the imbalance between pervasive workloads and demanding household chores, become salient after the sudden transition to WFH, thereby causing psychological stress and burnout. On the resource side, social support from the family and colleagues helps to combat loneliness and sustain wellbeing status during the pandemic. In addition, appropriate home workspaces and financially secure jobs also constitute resources for the maintenance of productivity and happiness. Alongside the occupational health research, evidence from lifestyle research indicates that teleworking is conducive to SWB because of its flexibility in space and time and the absence of commuting journeys. Compared with regular commuters, homeworkers are left with more time and energy to prepare healthy foods, take frequent exercise and get enough sleep (Giovanis and Ozdamar, 2021; Fukumura et al., 2021).

However, less is known about the extent to which homeworking experiences during the pandemic vary by the pre-pandemic commuting patterns. The answer to this question will contribute to a better understanding of the causal relationship between commuting behaviours and SWB outcomes, or simply put, the impact of long and motorised commutes on affective happiness and cognitive satisfaction. To date, evidence on commuting-SWB causality is rather mixed despite an increasing number of longitudinal studies on this topic (Chatterjee et al., 2020; Tao et al., 2022). The mixed evidence includes findings that: individuals with increasingly long commutes have worse SWB because they experience the disutility of commuting journeys and the spill-overs from commuting to other life domains (e.g., family and work life); or, they do not systematically show worse SWB because of the job- and housing-related benefits they receive as a compensation for commuting (e.g., a well-paid job or a big house); or, they appreciate the intrinsic value of travel experiences (e.g., physical activity when commuting by bicycle or walking). In our study, governmental directives on WFH during the pandemic provide a real-world experiment which can be used to examine how reduced or cancelled commutes reshape people's SWB outcomes. Based on this exogenous workplace transition experienced by a majority of the working population, we assume that if commutes do exert a significant effect on SWB, pre-COVID-19 commuters who travelled long distances to work would become better off after switching to WFH, while those who cycled or walked to work would miss the benefits of active commuting by experiencing reduced levels of SWB.

Our study drew from a multi-wave COVID-19 survey in the UK to analyse the relationship between the transition to WFH and SWB outcomes during the pandemic, and the extent to which this relationship depends on pre-COVID-19 commuting distances and mode choices. The remainder of this paper is organised as follows. Section 2 presents a brief review of the mixed longitudinal evidence on the

commuting-SWB relationship. Section 3 introduces the data source, sample selection and modelling methods used in this study, followed by the model results of pooled analyses and fixed-effect analyses in Section 4. In Section 5, we finally discuss the main findings of this study and the implications for commuting and workplace arrangements in post-COVID-19 society.

## 4.2 Longitudinal evidence on the commuting-wellbeing relationship

The notion that travel is wasteful in itself is embedded in transportation research and planning: the only goal of, for example, travelling to work is to reach the workplace and perform job tasks. According to this notion, job seekers strive to minimise commuting time by using motorised means of transport on the one hand, and to expand job choices by reaching more distant workplaces on the other (Banister, 2011). The result has been a prevalence of long-distance and motorised commuting journeys over the last few decades. Evidence has shown that this commuting pattern is environmentally unsustainable given the challenges of massive carbon emissions, intensified energy consumption and heavy traffic congestion (Horner, 2004; Banister, 2008). However, whether and how it affects social sustainability and wellbeing is less clear.

In recent years, a growing body of longitudinal studies have investigated whether longer commuting journeys are causally related to SWB by controlling for unobserved time-invariant factors between individuals and analysing within-individual changes in commuting and SWB over time. However, results from these longitudinal studies are rather mixed (see the reviews by Chatterjee et al., 2020 and Tao et al., 2022). Some panel studies find that individuals whose commuting journeys grow longer become worse off in terms of SWB outcomes, because they underestimate the emotional spill-overs (e.g., commuting stress leaking into work and family life) and resource constraints (e.g., little time available for exercise, sleeping, and other daily activities after long commuting journeys) which can result from daily commutes (Stutzer and Frey, 2008; Wheatley, 2014; Ingenfeld et al, 2019). Other longitudinal studies do not observe a systematic commuting-SWB relationship and ascribe this result to the utility equilibrium. It means that individuals will accept longer commutes only if they are compensated by a better job or housing, resulting in equivalent levels of SWB between individuals (Dickerson et

al., 2014; Lorenz, 2018; Clark et al., 2020). Alongside the role of commuting time and distance, commuting mode choices also exert an independent effect on SWB, and especially that the transition to cycling or walking leads to greater psychological health and life satisfaction (Martin et al., 2014; Jacob et al., 2021).

In addition to the instrumental role of commuting to access the workplace, commuting can be valued in its own right. Jain and Lyons (2008) consider travel as a gift because it provides a transition opportunity (the experience of distance when switching roles between family and work life) and an opportunity for 'time out' (the escape from family and job obligations). More specifically, Ory and Mokhtarian (2005) summarise the positive utility of daily commutes as adventure- and variety-seeking, a sign of independence and freedom, a symbol of status and control, a form of escape and a transitional buffer, and a way of exercise and environmental exposure. Active commuting mode, such as cycling or walking to work, can easily integrate physical activity into daily routines and expose people to environmental and social amenities. This may explain why active commuters report better SWB outcomes in previous longitudinal studies. During the COVID-19 pandemic, people who follow the work-at-home mandate are found to undertake more undirected leisure travel by cycling and walking (De Vos, 2020), which lends further support to the positive utility derived from the active travel experience.

Governmental directives on WFH during the pandemic establish a natural experiment in which homeworkers are given the opportunity to reflect on the experienced utility of their reduced or cancelled commuting journeys (Kroesen, 2022). Compared with prior longitudinal designs that focus on within-individual analysis, this experimental design helps to uncover the commuting-SWB causality for another two important reasons. First, the governmental stay-at-home order is an exogenous event. Commuters who switch to WFH are less likely to face losses in the job and housing markets compensating for the benefits of not commuting. Therefore, a net effect of (not) commuting on SWB can be observed. Besides, the exogenous intervention in workplaces precedes changes in SWB outcomes. This reduces the bias from reverse causality, that is, unhealthy and unhappy people are more likely to avoid commuting during the pandemic. Second, mandatory WFH creates an unstable context in which previous commuters have to break their habitual commuting routines. In normal situations before the pandemic, changes in traffic environment (e.g., increased traffic volume) and associated commuting journeys (e.g., increased commuting time) were often mild and difficult to notice. In this stable context, people tend to cease affective responses to repeated commuting routines, which may constitute a reason why previous within-individual analyses have shown a negligible commuting-SWB relationship (Abou-Zeid et al., 2012). When a stay-at-home order is imposed during the pandemic, however, a majority of workers abandon commuting to work

(CTW) and initiate WFH. This triggers a reflective evaluation of SWB as homeworkers consciously compare the pros and cons of WFH and CTW. When WFH is experienced as satisfactory, people are likely to develop it into a new habitual routine and decide not to go back to daily commuting, ultimately resulting in structural changes in commuting patterns and workplace arrangements in the post-COVID-19 era.

## 4.3 Data and Methods

### 4.3.1 1970 British Cohort Study

Our study drew from a specially designed COVID-19 survey in the 1970 British Cohort Study (BCS70) that has been following the lives of people who were born in 1970 in the UK since their childhoods. The COVID-19 survey aims to understand how the coronavirus crisis alters people's everyday life, health and SWB. The survey consists of three waves, with each wave corresponding to specific contexts of the COVID-19 prevalence and lockdown policies in the UK (Figure 4.1). Wave 1 took place in May 2020, a month after the government announced the first national lockdown and introduced the stay-at-home order in reaction to the initial peak of COVID-19 cases. Wave 2 took place from September to October 2020 when the lockdown restrictions were eased and people were allowed to return to the workplace. Wave 3 took place between February and March 2021, just after the UK entered the third national lockdown and new confirmed COVID-19 cases escalated to over 50,000 per day. To retrieve the baseline measures of socio-economic characteristics, commuting behaviours and SWB before the COVID-19 outbreak, we linked the COVID-19 survey to the latest BCS70 survey wave that was conducted between 2017 and 2019 (denoted as 'the pre-COVID-19 wave' in our study).

Given our interest in the impact of switching from CTW to WFH, our study selected 2,800 participants from the COVID-19 survey according to the following criteria: participants always commuted to work before the pandemic, stay employed and did not change jobs during the pandemic, had no missing values in research variables, and completed at least two waves of the COVID-19 survey. That is to say, our study sample was composed of an unbalanced panel of participants, with 1,452 (51.9%) appearing in all three waves and 1,348 (48.1%) in two waves, to reduce the attribution bias from longitudinal sampling.

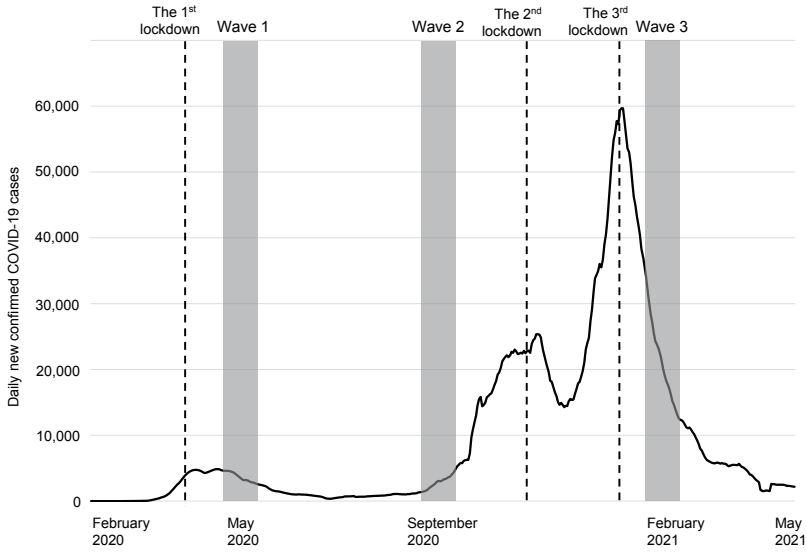


FIG. 4.1 Timeline of the COVID-19 survey and national lockdown restrictions with the number of daily new confirmed COVID-19 cases in the UK

Here, we make two justifications for the sample selection process and leave possible selection biases to be further discussed in the Limitations. First, participants who worked from home before the pandemic were dropped from the analysis because their workplace changed little following the COVID-19 outbreak, and because they only represented a small proportion of the working population (7.6% participants in the pre-COVID-19 wave of BCS70 were frequent homeworkers). Second, we excluded participants who stopped work after the COVID-19 outbreak. Compared with participants who continued to work, unemployed workers tended to be self-employed and work in service, trades or elementary operations (Appendix Table 4.5). Their occupational characteristics, such as weak resistance to the crisis and the on-site operations required, mean that in most cases WFH is out of the question for them, so we cannot examine its impact on SWB. Moreover, we also compared the pre-COVID-19 commuting behaviours of participants who continued to work versus those who stopped work after the COVID-19 outbreak (Table 4.5). There is little evidence that long-distance or public transport commuters tended to stop work during the COVID-19 pandemic. Therefore, analysis of how WFH-SWB relationships depend on pre-COVID-19 commuting behaviours is less likely to be biased if unemployed workers are excluded.



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Table 4.1 shows the socioeconomic characteristics of all research participants and participants who had experience of WFH during the three-wave COVID-19 survey. Generally, research participants are socioeconomically representative of the cohort of the 1970s, except women are mildly overrepresented (55.4% female versus 44.6% male). Most of the participants are married, do not have school-aged children, own a house with more than one room per person, and reside in urban areas. Compared with all research participants, WFH participants are more likely to be well-educated, have a high income, and work as managers or professionals, indicating that our findings on the effect of WFH on SWB are specific to those who are able to work from home during the pandemic.

TABLE 4.1 Participants' socio-economic characteristics at the pre-COVID-19 wave (N=2,800)

| | | All participants (%) | WFH participants (%) |
|---|---|---|---|
| Gender | Men | 44.6 | 43.4 |
| | Women | 55.4 | 56.6 |
| Qualification | GCSE | 49.1 | 36.8 |
| | Intermed | 16.5 | 17.1 |
| | Degree+ | 34.4 | 46.1 |
| Occupation | Managers or professionals | 53.2 | 68.3 |
| | Service workers or operatives | 46.8 | 31.1 |
| Income (GBP/week) | ≤ 500 | 25.0 | 20.7 |
| | 501-1,000 | 43.0 | 39.7 |
| | > 1,000 | 32.0 | 39.6 |
| Marital status | Married | 67.5 | 69.3 |
| | Other | 32.5 | 30.7 |
| Presence of school-aged children | ≥ 1 child aged 6-12 | 18.3 | 21.0 |
| | No child aged 6-12 | 81.7 | 79.0 |
| Housing tenure | Self-owned | 85.5 | 89.2 |
| | Other | 14.5 | 10.8 |
| Housing condition | > 1 room/person | 84.9 | 85.2 |
| | ≤ 1 room/person | 15.1 | 14.8 |
| Residential area | Urban | 85.1 | 84.1 |
| | Rural | 14.9 | 15.9 |

### 4.3.2 Variable settings

The outcome variable is subjective wellbeing (SWB), including both affective and cognitive evaluations of SWB for each wave of the survey. The indicator of affective wellbeing was derived from the nine-item Malaise inventory, a well-documented measure of psychological distress and depression in general population studies (Arias-de la Torre et al., 2021). The Malaise inventory incorporates nine dichotomous items (i.e., yes or no questions) to assess the prevalence of affective symptoms (i.e., feeling tired, depressed, worried, violent, scared, upset, jittery, nervous or angry) in participants' daily lives. In our study, the 0 or 1 score of each item was aggregated and then reversed to 0-9 so that higher scores refer to greater affective wellbeing (or fewer affective symptoms). Cognitive wellbeing was measured by the single life satisfaction item. Participants were asked by the question: "Overall, how satisfied are you with your life nowadays?". The answer was rated from 0 to 10, with higher scores representing greater cognitive wellbeing (or higher levels of life satisfaction).

The key explanatory variables are workplaces during the pandemic on the one hand, and commuting behaviours (i.e., commuting distances and mode choices) before the pandemic on the other. The workplace variable was taken from the three-wave COVID-19 survey and was dichotomised as switching to working from home (WFH; completely working from home or working some days at home and some days at employers' premises), and maintaining commuting to work (CTW; working at employers' premises). The commuting behaviour variables were taken from the pre-COVID-19 wave of BCS70 and were collated by asking participants whether they had changed their commuting behaviours between the pre-COVID-19 wave and the COVID-19 survey. Specifically, one-way commuting distance was categorised as ≤ 5, 6–15, 16–30, or > 30 miles. According to Lorenz (2018) and Ingenfeld et al. (2019), this categorisation scheme performs well in removing the outliers in distance records and examining the non-linear impact of commuting distance on SWB. Commuting mode choice was measured by the frequency of using the following means of transport to travel to work: car, public transport, bicycle and walking. The answer to each commuting mode was dichotomised as frequent mode use (e.g., always or usually commuting by car) or infrequent mode use (e.g., occasionally or never commuting by car).

Covariates fall into two groups, time-invariant and time-varying variables. Time-invariant variables consist of participants' socio-economic characteristics (gender, income, employment type, occupation, presence of a partner, and presence of school-aged children), level of potential risk from COVID-19 (chronic diseases and risk awareness), and pre-COVID-19 SWB, which were regarded as independent contributors to SWB besides workplace and commuting variables. Time-varying

variables are composed of homeworking status and environment (financial status, working hours and the number of rooms per person), social support (satisfaction with partner relationships and support from other people), lifestyles (frequency of exercise, healthy eating habits and sleeping hours) during the pandemic, which might mediate the association between WFH and SWB. Area- and time-fixed effects were also taken into account by including the urban/rural dichotomy and three survey waves, respectively. The detailed variable settings are provided in Table 4.6.

### 4.3.3 Pooled models and fixed-effect panel models

Both pooled analyses and panel analyses were undertaken to examine the WFH-SWB relationship, as well as the moderating role of pre-COVID-19 commuting behaviours. Pooled analyses used the wave-specific observations to predict between-individual variances in SWB. Specifically, ordinal logistic regression models were constructed to explore how the transition from CTW (before the pandemic) to WFH was associated with SWB outcomes after the onset of the pandemic. Robust standard errors were clustered at the individual level due to repeated sampling between survey waves. The models followed a step-by-step design. Specifically, model 1 analysed the crude association of changes in workplaces (i.e., switching to WFH versus maintaining CTW) with SWB outcomes, after adjusting for the confounders of socioeconomics, COVID-19 risks, pre-COVID-19 SWB, and area- and time-fixed effects. Model 2 incorporated the variables of homeworking status and environment, social support, and lifestyles to recognise under which conditions WFH is associated with SWB. Model 3 further built the interaction terms between WFH and the variables of commuting behaviours to investigate whether and how the effect of WFH on SWB depends on pre-COVID-19 commuting distance and mode choices.

Panel analyses used the fixed-effect ordinal logistic models to probe how within-individual changes in workplaces resulted in corresponding changes in SWB outcomes between the three waves of the COVID-19 survey. The fixed-effect models perform better in inferring causal relationship because any unobserved time-invariant characteristics between individuals are taken into account. By focusing on within-individual changes in SWB after the COVID-19 outbreak, we can also isolate the shock of coronavirus itself abruptly undermining SWB, and thus attribute changes in workplaces to exogenous lockdown restrictions rather than self-selective WFH for fear of coronavirus. In panel analyses, we incorporated the same variables as we had in Model 3, with the exception that time-invariant covariates were automatically dropped out of the fixed-effect models that were built at the within-individual level. Before fitting the above models, we calculated the variance inflation

factor (VIF) values between explanatory variables to assess multi-collinearity. The results were all below 4.0 except between self-employment and poor financial status (VIF = 9.2), so we excluded the employment type variable in the models. All modelling analyses were conducted in STATA 17.

## 4.4 Results

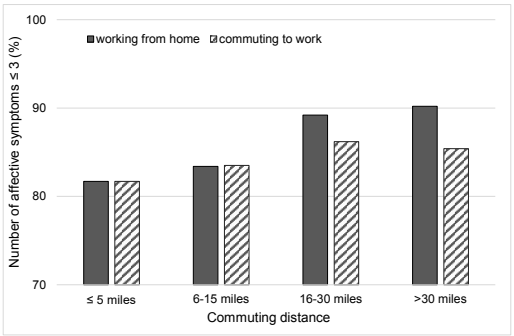
### 4.4.1 Changes in subjective wellbeing from commuting to homeworking

Table 4.2 shows the distribution of commuting behaviours, work locations and SWB before and after the COVID-19 outbreak. Among the cohort of the 1970s, around three-quarters of the participants travelled no more than 15 miles to work prior to the pandemic, while 10.1% of them had to commute over 30 miles to their workplaces. Despite the short commuting distance for most workers, 79.9% of the participants frequently commuted by car. In contrast, frequent public transport users, cyclists, and pedestrians accounted for 12.0%, 4.1%, and 12.8% of the participants, respectively. Considering the small number of cyclists, we grouped cyclists and pedestrians into active mode users in the following analysis. After the COVID-19 outbreak and subsequent lockdown measures, WFH became the new routine for roughly half of the 1970s cohort. Despite commuting to work on a daily basis before the pandemic, 59.3% of the participants occasionally or always worked from home when the first national lockdown was enforced at Wave 1. After the lockdown was eased at Wave 2, the WFH proportion decreased to 46.7%, but quickly rebounded to 54.3% after the government reintroduced the stay-at-home order at Wave 3. In terms of temporal variances in SWB, participants' affective wellbeing and life satisfaction both declined throughout the pandemic. Comparing SWB at the pre-COVID-19 wave and one year after the COVID-19 outbreak at Wave 3, we can see that the proportion of participants with the number of affective symptoms $\leq 3$ and the level of life satisfaction $\geq 7$ decreased from 86.4% to 83.4% and from 91.3% to 80.3%, respectively. In addition, participants reported mildly fewer affective symptoms when they worked at home rather than at workplaces.

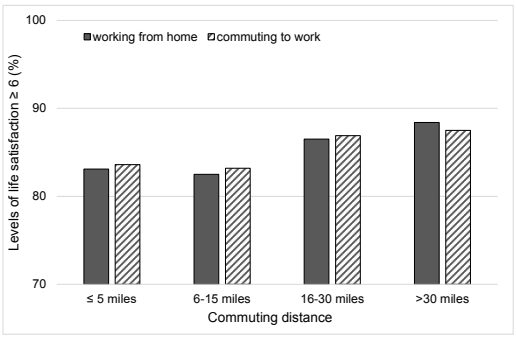
TABLE 4.2 Descriptive statistics of commuting behaviours, work locations and subjective wellbeing

| Variables | Types | Pre-COVID-19 wave (%) | Wave 1 (%) | Wave 2 (%) | Wave 3 (%) |
|---|---|---|---|---|---|
| Commuting distance | ≤ 5 miles | 41.9 | | | |
| | 6-15 miles | 32.7 | | | |
| | 16-30 miles | 15.4 | | | |
| | > 30 miles | 10.1 | | | |
| Commuting mode | Car users | 79.9 | | | |
| | PT users | 12.0 | | | |
| | Active mode users | 16.3 | | | |
| | Cyclists | 4.1 | | | |
| | Pedestrians | 12.8 | | | |
| Work locations | Working from home, WFH | | 59.3 | 46.7 | 54.3 |
| | Commuting to work, CTW | | 40.7 | 53.3 | 45.7 |
| Subjective wellbeing | Affective symptoms (≤3) | 86.4 | 87.7 | 82.3 | 83.4 |
| | WFH | | 88.7 | 82.9 | 83.6 |
| | CTW | | 86.4 | 81.8 | 83.1 |
| | Life satisfaction (≥7) | 91.3 | 86.6 | 86.2 | 80.3 |
| | WFH | | 87.0 | 86.2 | 80.0 |
| | CTW | | 85.9 | 86.2 | 80.7 |

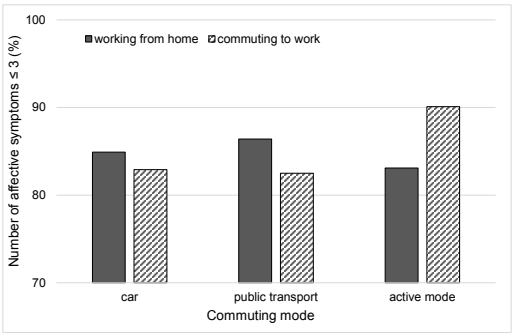
After stratifying participants by their pre-COVID-19 commuting distance and mode choices, we observed more clear patterns of the WFH-SWB relationship (Figure 4.2). For long-distance commuters (one-way commuting distance > 15 miles), the transition to WFH was beneficial to their affective wellbeing, as indicated by the higher percentage of experiencing few affective symptoms (≤ 3) among WFH participants compared to those who still commuted to work. For the short-distance commuters (one-way commuting distance ≤ 15 miles), however, there were negligible differences in affective wellbeing and life satisfaction whether they switched to WFH or maintained CTW. It is striking that pre-COVID-19 active commuters fare worse in SWB after the transition to WFH, by experiencing a greater number of affective symptoms and lower levels of life satisfaction. Conversely, the affective wellbeing of non-active commuters, especially public transport users, to some extent improved after WFH.



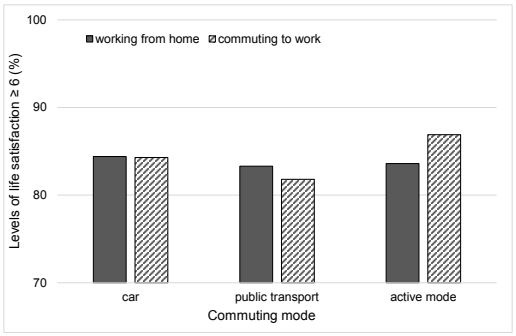

(a) WFH – affective wellbeing, by commuting distance




(b) WFH – life satisfaction, by commuting distance




(c) WFH – affective wellbeing, by commuting mode




(d) WFH – life satisfaction, by commuting mode

FIG. 4.2 The two-way relationship between work locations and subjective wellbeing, stratified by pre-COVID-19 commuting distance and travel mode

### 4.4.2 Relationships between the transition to homeworking and subjective wellbeing

Table 4.3 presents the pooled modelling results to predict between-individual variances in SWB. Model 1 shows that after controlling for the confounders, the transition to WFH was associated with better affective wellbeing, but not related to higher levels of life satisfaction at the default significance level of $p<0.05$. Compared with participants who maintained CTW, those who switched to WFH had an odds ratio (OR) of reporting fewer affective symptoms by 13%. To observe the long-term effect of WFH, we re-fitted Model 1 based on the subsample of those participants who had completed all the three-wave surveys and always worked from home across the survey waves. The results, however, show that WFH was not significantly associated



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with the two SWB outcomes (affective wellbeing: OR=1.13, p=0.15; life satisfaction: OR=1.10, p=0.21). After taking specific stay-at-home experiences into account, Model 2 indicates that the effect of WFH on affective wellbeing became insignificant and decreased in magnitude, suggesting the mediating role of homeworking conditions. Specifically, a satisfied relationship with the partner, strong social support from others and adequate time for sleep were indicative of greater affective and cognitive wellbeing, while declined financial situations were predictive of worse SWB outcomes. Besides this, participants who exercised more frequently reported higher levels of life satisfaction during the pandemic.

To examine the moderating role of commuting behaviours in the WFH-SWB relationship, in model 3, we incorporated the interaction terms of WFH with pre-COVID-19 commuting distance on the one hand, and with pre-COVID-19 commuting mode on the other, . Conforming to the descriptive results, the model results support that pre-COVID-19 long-distance commuters benefited from WFH with better affective wellbeing, whereas previous active mode users valued their commuting journeys and reported worse affective wellbeing as homeworkers during the pandemic. Specifically, when participants switched to WFH after the COVID-19 outbreak, the OR of reporting fewer affective symptoms was 1.32 times higher for the pre-COVID-19 long-distance commuters (> 30 miles) than for their short-distance counterparts (≤ 5 miles). In contrast, the OR of reporting better affective wellbeing decreased by 13% among pre-COVID-19 active commuters after the transition to WFH. Note that the fully adjusted model (Model 3) had a moderate model fit, with pseudo R-square 0.17 and 0.12 for affective and cognitive wellbeing, respectively.

TABLE 4.3 Ordinal logistic models for predicting between-individual variances in SWB

| | Model 1 | | | | Model 2 | | | | Model 3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Affective wellbeing | | Life satisfaction | | Affective wellbeing | | Life satisfaction | | Affective wellbeing | | Life satisfaction | |
| | OR | P | OR | P | OR | P | OR | P | OR | P | OR | P |
| **Work locations** | | | | | | | | | | | | |
| WFH (ref. CTW) | 1.13* | 0.04 | 0.97 | 0.53 | 1.05 | 0.43 | 0.93 | 0.21 | 1.55 | 0.10 | 1.03 | 0.79 |
| **Homework status and environment** | | | | | | | | | | | | |
| Worse financial status (ref. about the same) | | | | | 0.80** | 0.00 | 0.72** | 0.00 | 0.82** | 0.00 | 0.72** | 0.00 |
| Better financial status (ref. about the same) | | | | | 1.12 | 0.06 | 1.16** | 0.01 | 1.12* | 0.05 | 1.17** | 0.01 |
| Working hours | | | | | 0.99 | 0.11 | 0.99 | 0.46 | 0.99 | 0.09 | 0.99 | 0.51 |
| > 1 room per person | | | | | 1.16 | 0.08 | 0.90 | 0.18 | 1.27 | 0.07 | 0.90 | 0.17 |
| *Social support* | | | | | | | | | | | | |
| Satisfaction with partner relationships | | | | | 1.07** | 0.00 | 1.36** | 0.00 | 1.07** | 0.00 | 1.36** | 0.00 |
| Support from other people | | | | | 1.12** | 0.00 | 1.20** | 0.00 | 1.12** | 0.00 | 1.20** | 0.00 |
| *Lifestyles* | | | | | | | | | | | | |
| Frequency of exercises | | | | | 1.01 | 0.51 | 1.03** | 0.01 | 1.02 | 0.22 | 1.03** | 0.01 |
| Healthy eating habit | | | | | 1.01 | 0.26 | 1.01 | 0.36 | 1.00 | 0.96 | 1.01 | 0.32 |
| Sleeping hours | | | | | 1.35** | 0.00 | 1.19** | 0.00 | 1.35** | 0.00 | 1.19** | 0.00 |
| **WFH × Commuting distance (CD) (ref. WFH × CD ≤ 5 miles)** | | | | | | | | | | | | |
| WFH × CD 6-15 miles | | | | | | | | | 0.95 | 0.64 | 0.86 | 0.10 |
| WFH × CD 16-30 miles | | | | | | | | | 1.02 | 0.85 | 0.82 | 0.09 |
| WFH × CD > 30 miles | | | | | | | | | 1.32** | 0.04 | 0.96 | 0.72 |
| *WFH × Commuting mode* | | | | | | | | | | | | |
| WFH × Car | | | | | | | | | 1.05 | 0.62 | 1.02 | 0.82 |
| WFH × Public transport | | | | | | | | | 1.08 | 0.58 | 1.02 | 0.89 |
| WFH × Active mode | | | | | | | | | 0.87** | 0.03 | 0.88 | 0.27 |
| **Socio-demographics** | | | | | | | | | | | | |
| Men (ref. women) | 1.71** | 0.00 | 1.12 | 0.06 | 1.88** | 0.00 | 1.17** | 0.01 | 1.52 | 0.08 | 1.18** | 0.01 |
| Income 501-1,000 (ref. ≤ 500) | 1.07 | 0.35 | 0.85** | 0.02 | 1.04 | 0.60 | 0.81** | 0.00 | 1.07 | 0.35 | 0.81** | 0.00 |
| Income > 1,000 (ref. ≤ 500) | 1.25** | 0.01 | 0.91 | 0.25 | 1.21** | 0.03 | 0.89 | 0.14 | 1.22** | 0.02 | 0.90 | 0.18 |
| Manager or professionals | 0.93 | 0.23 | 0.77** | 0.00 | 0.89 | 0.08 | 0.73** | 0.00 | 0.93 | 0.26 | 0.73** | 0.00 |
| Living with the partner | 0.82** | 0.02 | 1.37** | 0.00 | 0.55** | 0.00 | 0.34** | 0.00 | 0.58** | 0.00 | 0.34** | 0.00 |
| Living with the school-aged children | 1.03 | 0.71 | 0.94 | 0.43 | 1.04 | 0.60 | 0.98 | 0.79 | 1.09 | 0.30 | 0.98 | 0.81 |

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TABLE 4.3 Ordinal logistic models for predicting between-individual variances in SWB

| | Model 1 | | | | Model 2 | | | | Model 3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Affective wellbeing | | Life satisfaction | | Affective wellbeing | | Life satisfaction | | Affective wellbeing | | Life satisfaction | |
| | OR | P | OR | P | OR | P | OR | P | OR | P | OR | P |
| **COVID risks and pre-COVID-19 SWB** | | | | | | | | | | | | |
| Chronic physical diseases | 0.70** | 0.00 | 0.85** | 0.00 | 0.70** | 0.00 | 0.87** | 0.01 | 0.72** | 0.00 | 0.87** | 0.01 |
| Risk awareness towards COVID-19 | 1.09** | 0.00 | 1.12** | 0.00 | 1.09** | 0.00 | 1.12** | 0.00 | 1.11** | 0.00 | 1.12** | 0.00 |
| Pre-COVID-19 affective wellbeing | 1.97** | 0.00 | 1.12** | 0.00 | 1.93** | 0.00 | 1.09** | 0.00 | 1.95** | 0.00 | 1.09** | 0.00 |
| Pre-COVID-19 life satisfaction | 1.14** | 0.00 | 1.64** | 0.00 | 1.09** | 0.00 | 1.52** | 0.00 | 1.07** | 0.00 | 1.52** | 0.00 |
| **Area- and time-fixed effect** | | | | | | | | | | | | |
| Urban areas (ref. rural areas) | 0.85* | 0.04 | 0.97 | 0.68 | 0.86* | 0.05 | 0.97 | 0.73 | 0.88 | 0.14 | 0.97 | 0.66 |
| Wave 2 (ref. Wave 1) | 0.68** | 0.00 | 0.84** | 0.00 | 0.72** | 0.00 | 0.92 | 0.11 | 0.70** | 0.00 | 0.93 | 0.13 |
| Wave 3 (ref. Wave 1) | 0.80** | 0.00 | 0.56** | 0.00 | 0.83** | 0.00 | 0.59** | 0.00 | 0.81** | 0.00 | 0.59** | 0.00 |
| Pseudo R-square | 0.14 | | 0.07 | | 0.16 | | 0.12 | | 0.17 | | 0.12 | |

* *p<0.05, ** p<0.01*

Table 4.4 presents the results of fixed-effect models for predicting within-individual variances in SWB. The within-individual analysis to a great extent improved the model fit [p(LR test) = 0.00] and corroborated the results from the between-individual analysis — i.e., the mediation of specific stay-at-home experiences in the WFH-SWB relationship, better affective wellbeing for the pre-COVID-19 long-distance commuters who switched to WFH, and worse affective wellbeing for pre-COVID-19 active commuters after the transition to WFH. Notably, two differences in the fixed-effect models further indicate the significant role of pre-COVID-19 commuting behaviours in moderating the WFH-SWB relationship. First, compared with short-distance commuters (≤ 5 miles), long-distance commuters (> 30 miles) were 2.31 times more likely (1.32 times in the pooled analysis) to report better affective wellbeing when they switched from CTW to WFH between easing and enforcing lockdown restrictions during the pandemic. Second, the pre-COVID-19 active commuters performed worse in not only affective wellbeing but also life satisfaction after turning to work from home. For those previous active commuters, specifically, the transition to WFH marginally decreased the ORs of reporting better affective wellbeing and life satisfaction by 18% and 37%, respectively.

TABLE 4.4 Fixed-effect ordinal logistic models for predicting within-individual variances in SWB

| | Model 4 | | | | Model 5: Men | | | | Model 6: Women | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Affective wellbeing | | Life satisfaction | | Affective wellbeing | | Life satisfaction | | Affective wellbeing | | Life satisfaction | |
| | OR | P | OR | P | OR | P | OR | P | OR | P | OR | P |
| **Work locations** | | | | | | | | | | | | |
| WFH (ref. CTW) | 1.91 | 0.09 | 1.03 | 0.83 | 2.06 | 0.11 | 1.01 | 0.96 | 1.89 | 0.20 | 1.07 | 0.69 |
| **Homework status and environment** | | | | | | | | | | | | |
| Worse financial status (ref. about the same) | 0.82** | 0.04 | 0.67** | 0.00 | 0.98 | 0.92 | 0.64** | 0.00 | 0.74** | 0.01 | 0.70** | 0.00 |
| Better financial status (ref. about the same) | 1.19** | 0.04 | 1.04 | 0.56 | 1.46** | 0.00 | 1.11 | 0.35 | 1.10 | 0.36 | 1.04 | 0.65 |
| Working hours | 0.99 | 0.21 | 0.99 | 0.43 | 0.98** | 0.02 | 1.00 | 0.34 | 0.99 | 0.35 | 0.99 | 0.10 |
| > 1 room per person | 1.99** | 0.00 | 1.04 | 0.73 | 1.60** | 0.05 | 0.85 | 0.41 | 2.15** | 0.00 | 1.22 | 0.21 |
| **Social support** | | | | | | | | | | | | |
| Satisfaction with partner relationships | 1.19** | 0.00 | 1.46** | 0.00 | 1.21** | 0.00 | 1.55** | 0.00 | 1.16** | 0.00 | 1.40** | 0.00 |
| Support from other people | 1.26** | 0.00 | 1.31** | 0.00 | 1.18** | 0.00 | 1.30** | 0.00 | 1.33** | 0.00 | 1.32** | 0.00 |
| **Lifestyles** | | | | | | | | | | | | |
| Frequency of exercises | 1.09** | 0.00 | 1.10** | 0.00 | 1.07** | 0.02 | 1.09** | 0.00 | 1.08** | 0.00 | 1.09** | 0.00 |
| Healthy eating habit | 1.01 | 0.42 | 1.03 | 0.09 | 1.04 | 0.08 | 1.04* | 0.04 | 1.01 | 0.64 | 1.01 | 0.46 |
| Sleeping hours | 1.61** | 0.00 | 1.29** | 0.00 | 1.45** | 0.00 | 1.28** | 0.00 | 1.60** | 0.00 | 1.20** | 0.00 |
| **WFH × Commuting distance (CD) (ref. WFH × CD ≤ 5 miles)** | | | | | | | | | | | | |
| WFH × CD 6-15 miles | 1.02 | 0.91 | 0.79 | 0.09 | 0.90 | 0.73 | 0.99 | 0.98 | 1.13 | 0.58 | 0.77 | 0.12 |
| WFH × CD 16-30 miles | 1.48 | 0.09 | 0.83 | 0.27 | 1.44 | 0.07 | 0.88 | 0.61 | 1.12 | 0.70 | 0.86 | 0.49 |
| WFH × CD > 30 miles | 2.31** | 0.00 | 1.02 | 0.92 | 1.58 | 0.09 | 1.08 | 0.75 | 2.09** | 0.02 | 1.05 | 0.89 |
| **WFH × Commuting mode** | | | | | | | | | | | | |
| WFH × Car | 1.03 | 0.90 | 0.91 | 0.51 | 1.19 | 0.54 | 0.95 | 0.81 | 1.07 | 0.79 | 0.92 | 0.63 |
| WFH × Public transport | 0.99 | 0.88 | 1.10 | 0.63 | 0.96 | 0.78 | 1.05 | 0.88 | 1.02 | 0.84 | 1.04 | 0.88 |
| WFH × Active mode | 0.82** | 0.04 | 0.63** | 0.03 | 0.82 | 0.10 | 0.62** | 0.04 | 0.81* | 0.05 | 0.64 | 0.13 |
| LR test | | 0.00 | | 0.00 | | 0.00 | | 0.00 | | 0.00 | | 0.00 |

** p<0.05, ** p<0.01*

The pooled modelling results show that women reported worse SWB outcomes than men, so we additionally fitted the fixed-effect models for the subsamples of male and female participants to analyse whether previous commuting situations and the transition to WFH account for the gender difference in SWB during the pandemic. The results show that long-distance female commuters (> 30 miles) were 2.09 times more likely to report greater affective wellbeing after switching to WFH. In contrast, the effect size for male counterparts was somewhat lower at 1.58 times, and the result only reached the significance p<0.10.

# 4.5 Discussion and Conclusions

## 4.5.1 Discussion of main findings

Transportation research claims that WFH may be the only structural change in people's daily activities and travel behaviours that will last in post-pandemic society (Beck et al., 2020; Beck and Hensher, 2021), highlighting the importance of understanding the implications of WFH for travel demand management, environmental sustainability and social wellbeing. Focusing on the social indicator of people's subjective wellbeing (SWB), our study drew upon a longitudinal COVID-19 survey dataset in the UK to investigate the relationship between commuting behaviours, work locations and SWB outcomes. Our main findings are that: WFH contributed little to improving life satisfaction but significantly alleviated affective symptoms in the short term during the pandemic. The positive effect of WFH on affective wellbeing can largely be accounted for by specific stay-at-home experiences, including social support, healthy lifestyles and changes in financial circumstances. Notably, it is homeworkers' commuting behaviours prior to the COVID-19 outbreak that moderated the WFH-SWB relationship during the pandemic. Homeworkers whose pre-COVID-19 commuting journeys covered more than 30 miles reported greater affective wellbeing, while pre-COVID-19 commuters who frequently walked or cycled to work were worse off in terms of SWB outcomes after switching to WFH.

In response to some recent evidence that WFH is a generally positive experience (Davillas and Jones, 2020; Brodeur et al., 2021), our results further indicate that the wellbeing benefits of WFH are determined by its interference with work and family lives, and only appear in the short term. First, the impact of WFH on affective wellbeing became insignificant after stay-at-home experiences were accounted for. Conforming to the evidence from occupational health and lifestyle research, the sudden transition to WFH during the pandemic requires homeworkers to reconcile their home and work domains (Fukumura et al., 2021; Meyer et al., 2021). Lack of social support and financial resources to a great extent threaten homeworkers' SWB, while reduced commutes and flexible work schedules increase the time and energy available to develop a healthier lifestyle with adequate sleep and frequent exercises. Second, the impact of WFH on life satisfaction, as well as on affective wellbeing for people who worked at home throughout the three-wave survey, did not reach significance, indicating the uncertainty of homeworking experiences in the long term.

To justify the long-term benefit of WFH, further research is recommended to continue monitoring changes in workplace choices and SWB outcomes, especially after the pandemic subsides.

Despite the uncertainty of the independent effect of WFH on SWB, pre-COVID-19 long-distance commuters were better off after switching to WFH. Specifically, homeworkers showed greater affective wellbeing when their regular commuting journeys that stretched over 30 miles were entirely or partly cancelled by the lockdown restrictions. Our finding that commuting distance moderates the commuting-SWB relationship is complementary to recent evidence that focuses on commuting time in the Netherlands (Kroesen, 2022). In this study, commuters, especially female commuters, whose journey to work took over one hour reported better life satisfaction after switching to WFH. Notably, distance or proximity to workplaces is less involved in previous travel-related SWB research based on the notion that job seekers desire to move quickly and access more job options. The result is an increasing job-housing mismatch and motorised commuting pattern (Banister, 2011). The COVID-19 outbreak and the subsequent lockdown policies provide a window of opportunity to experiment with an alternative workplace arrangement, WFH, which has great potential for reducing long-distance commuting journeys and enhancing people's affective wellbeing.

Regarding the role of commuting mode, commuters who had frequently walked or cycled to work were worse off in terms of SWB outcomes when they worked from home during the pandemic. This result was established after we accounted for the short-distance characteristic of most active commuting journeys, which corroborates the positive utility derived from the experience of walking or cycling to work (Ory and Mokhtarian, 2005; Jain and Lyons, 2008). It is inspiring to observe that people miss the benefit from active commuting during the lockdown period, which means that they value the active mode itself and may reconsider it as their mode choices after they return to the workplace. If this is the case, reducing job-housing distances should be made a priority in post-COVID-19 society to alleviate spatial barriers for active commuting. Hopefully, it will increase the take-up of active modes that have drastically declined in the UK over the last decade (Flint et al., 2016). Counterintuitively, our model results show little evidence that motorised mode users, especially public transport commuters, had better SWB after homeworking, even though commuting by public transport was found to be more dissatisfying than any other travel modes prior to the pandemic (De Vos et al., 2016). This can be explained by the fact that pre-COVID-19 public transport commuters switch to other travel modes for social distancing during the pandemic, thereby mixing the reference group and misestimating the effect of public transport use on SWB.

Another interesting finding is that female long-distance commuters benefited from WFH more than their male counterparts in terms of affective wellbeing. This is not to say that the gender gap in SWB decreases because women still reported worse affective wellbeing and life satisfaction during the pandemic. Our tentative evidence suggests that when women are free from regular long commutes, they are psychologically more relieved by being able to better manage work and family responsibilities (Giovanis and Ozdamar, 2021). Even so, the gendered commuting-SWB relationship may still remain because women are more likely to stop work or serve as front-line key workers in the midst of COVID-19, and less likely to have been long-distance commuters before the COVID-19 outbreak, which determines their possibility of WFH and the chance to benefit from WFH in the first place (Wielgoszewska et al., 2020). In addition, we also analysed whether mothers who lived with school-aged children felt worse when both groups were mandated to work or study at home. The results are not shown in the models because the interaction between WFH and the presence of children did not exert a significant effect on mothers' SWB outcomes. The reason could be that most of the participants, i.e., the cohort of 1970s, have passed the life stage of nurturing school-aged children.

### 4.5.2 Implications for future workplace arrangements

Our study has some implications for workplace arrangements in post-COVID-19 society. We suggest an ideal way to improve workplace wellbeing as the combination of WFH on some days of the week and active commuting to nearby workplaces on the others. Admittedly, remote work at home is not always possible in some occupations that require face-to-face communications or on-site operations. However, it is still possible to apportion parts of the workload to be completed at home if workers desire to do so. Besides, supportive family and social relationships, stable financial circumstances and healthy lifestyle behaviours are also important preconditions for a positive homeworking experience. Moreover, under the influence of COVID-19, commuters started to value their active travel experiences, which can be treated as a window of opportunity to encourage a sustainable commuting pattern with more short-distance and non-motorised trips. Possible planning strategies include developing safe and attractive active transport networks, and encouraging high-density and mixed-use neighbourhoods to mitigate the job-housing mismatch and diversify localised activity destinations. According to Beck and Hensher (2020; 2021), another viable strategy is to introduce satellite offices or neighbourhood business hubs to support working close to home, which will deliver the benefits of avoiding stressful long commutes and potential burdens of WFH (e.g., social isolation and work-family conflicts) at the same time.

### 4.5.3 Limitations and conclusions

Our study is methodologically sound in identifying the commuting-SWB causality by integrating the pooled analysis pre-post the COVID-19 outbreak and the fixed-effect analysis between enforcing and easing lockdown restrictions during the COVID-19 pandemic. The reasons are that changes in people's commuting behaviours are not only exogenous to changes in SWB outcomes and compensation from job and housing markets, but also significant for a large number of previously commuting populations who consciously reconsider their habitual commuting routines versus homeworking experiences by changing baseline levels of SWB. Even so, there are still some caveats to note when interpreting our results.

First, our study selected the participants who always commuted to work before the pandemic and remained employed during the pandemic to examine how previous commuting populations evaluated their WFH experiences after the COVID-19 outbreak. We believe that excluding pre-COVID-19 homeworkers did not introduce a serious bias in our results given the small number of these participants. However, a fair proportion of workers indeed stopped work during the pandemic (30% of the BCS70 participants by May 2020; Wielgoszewska et al., 2020), and these unemployed workers may suffer from the greatest decline in SWB. In our study, we estimated the SWB effect of switching to WFH by using the maintenance of CTW as a reference, leaving the participants who stopped work out of consideration. For this reason, our results should be regarded as a conservative estimation of positive WFH experiences. In addition, results from the cohort of the 1970s may not be generalised to other birth cohorts, and especially to young couples who lived with their children when kindergartens and schools were closed during the lockdown.

Second, the impact of WFH on people's SWB and sustainable travel patterns is uncertain in the long term. Our results are based on the three-wave COVID-19 survey ranging from May 2020 to March 2021, which is, to our knowledge, one of the richest longitudinal data sources including the information of people's workplaces and SWB during the COVID-19 pandemic. However, caution should be taken when directly extrapolating from our results to the long term, and especially to the post-COVID-19 era. Over time, people may well adapt to WFH experiences and show little difference in SWB outcomes whether to work at home or in an office. They may also change their attitudes towards WFH once they regain the freedom to choose their place of work after the crisis ends. In a much longer term, routine homeworkers may even adjust their residential locations because proximity to workplaces plays a weaker role in the choice of residence. With fewer days for commuting, they may also conduct more non-commuting trips, but it is not clear whether or not these non-commuting trips are in short distance and by active travel mode. Taking all these

considerations into account, we acknowledge that research on this topic is still at a nascent stage. It may be too early to draw definite conclusions about the complex interactions between commuting travels, non-commuting travels and long-term decisions on residential and work locations, as well as their combined effects on SWB outcomes in post-COVID-19 society.

Governmental directives on WFH during the COVID-19 crisis provides a natural experiment to uncover the causal relationship between (not) commuting and SWB outcomes. The results from our study indicate that the transition from commuting to WFH leads to better affective wellbeing for pre-COVID-19 long-distance commuters, but results in worse affective wellbeing and life satisfaction for people who frequently walked or cycled to work before the pandemic. These findings lead us to recommend a mix of WFH and active commuting over short distances in post-COVID-19 society. Despite the barriers to homeworking in some occupations and the uncertainty of homeworking experiences in the long term, this hybrid workplace arrangement deserves due consideration for its co-benefits of easing traffic congestion, promoting environmental sustainability, and enhancing public health and wellbeing.

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# Appendix

TABLE 4.5 Comparisons of occupational and commuting characteristics for participants who continued to work versus stopped work after the COVID-19 outbreak

| | | Employed workers (N=2,800, %) | Unemployed workers (N=533, %) |
|---|---|---|---|
| Employment types | Self-employers | 10.6 | 64.8 |
| | Employees or employers | 89.4 | 35.2 |
| Standard occupational classification 2010 (SOC2010) | Managers, directors and senior officials | 14.4 | 9.8 |
| | Professional occupations | 28.2 | 11.7 |
| | Associate professional and technical occupations | 16.8 | 18.7 |
| | Administrative and secretarial occupations | 13.5 | 5.5 |
| | Skilled trades occupations | 7.1 | 19.5 |
| | Caring, leisure and other service occupations | 8.3 | 15.6 |
| | Sales and customer service occupations | 3.8 | 3.8 |
| | Process, plant and machine operatives | 4.3 | 7.6 |
| | Elementary occupations | 3.6 | 7.8 |
| Commuting distance | ≤ 5 miles | 41.9 | 58.9 |
| | 6-15 miles | 32.7 | 20.5 |
| | 16-30 miles | 15.4 | 8.8 |
| | > 30 miles | 10.1 | 11.8 |
| Commuting mode | Car users | 79.9 | 76.0 |
| | PT users | 12.0 | 8.9 |
| | Cyclists | 4.1 | 3.1 |
| | Pedestrians | 12.8 | 12.5 |

TABLE 4.6 Variable settings

| Category | Variable | Description |
|---|---|---|
| Subjective wellbeing | Affective wellbeing | Self-reported prevalence of affective symptoms (range: 0 the lowest affective wellbeing – 9 the highest) |
| | Life satisfaction | Self-rated levels of overall life satisfaction (range: 0 the lowest life satisfaction – 9 the highest) |
| Work locations | Working from home, WFH | Completely working from home or working some days at home and some days at employers' premises |
| | Commuting to work, CTW | Working at employers' premises |
| Pre-COVID-19 commuting behaviours | Commuting distance | ≤ 5 miles, 6-15 miles, 16-30 miles, > 30 miles |
| | Commuting mode | Car users, public transport users, active mode users |
| Socio-economic characteristics | Sex | Men, women |
| | Employment types (excluded from the models for the multi-collinearity) | Self-employers, employees or employers |
| | Occupation | Managers or professionals, service or skilled workers |
| | Income | ≤ 500 GBP/week, 501-1000 GBP/week, > 1000 GBP/week |
| | Presence of the partner | Living with the partner, or not |
| | Presence of children | Living with ≥ 1 child aged 6-12, no child aged 6-12 |
| COVID risks and pre-COVID-19 SWB | Chronic physical diseases | Having any chronic physical diseases (including cancer, heart diseases, pulmonary diseases, diabetes, asthma, etc.), or not |
| | Risk awareness | Willingness to take risks (0 the lowest – 10 the highest) |
| | Pre-COVID-19 affective wellbeing | Self-reported prevalence of affective symptoms (range: 0 the lowest affective wellbeing – 9 the highest) |
| | Pre-COVID-19 life satisfaction | Self-rated levels of overall life satisfaction (range: 0 the lowest life satisfaction – 9 the highest) |
| Area- and time-fixed effect | Residential areas | Urban areas, rural areas |
| | Survey waves | Wave 1, wave 2, wave 3 |
| Homework status and environment | Financial status | Worse financial status, about the same financial status, better financial status |
| | Working hours | Hours of work on a typical week |
| | Housing condition | > 1 room per person, ≤ 1 room per person |
| Social support | Satisfaction with partner relationships | Self-rated levels of satisfaction with partner relationships (0 the lowest – 6 the highest) |
| | Support from other people | Self-rated levels of being able to get help from or be listened by others (0 the lowest – 6 the highest) |
| Lifestyles | Exercises | Days of exercises 30 minutes or more in a typical week |
| | Eating | Portions of fresh fruit and vegetables in a typical day |
| | Sleeping | Sleeping hours at night in a typical day |

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# 5 Changes in commuting mode choices and preferences in the Netherlands

## A pre-post event analysis of residential relocation

**Yinhua Tao, Ana Petrović, Maarten van Ham & Xingxing Fu**

ABSTRACT Residential self-selection studies argue that pre-existing travel-related attitude overshadows the role of changes in residential built environment in (re)shaping travel behaviours. Our study contributes to this self-selection argument by including family- and job-related life events as another self-selection source, and accounting for the reverse causality from built environment to travel attitude as opposed to the attitude-induced self-selection. We used a two-wave sample of 1,038 Dutch residents before and after the relocation. Structural equation models were developed to investigate longitudinal relationships between changes in residential built environment and job-housing distances, the occurrence of life events, and changes in commuting mode choices and preferences pre-post relocation. Results supported residential self-selection from pre-existing preferences for car and public transport commuting, while residents lowered the active commuting preference after moving to a more suburban neighbourhood. Life events concurrent with residential relocation, such as childbirth and job changes, also underlay greater demand for car use.

KEYWORDS Built environment, travel behaviour, residential self-selection, mobility biographies, longitudinal designs, Netherlands

# 5.1 Introduction

Recognising the triggers of changes in population travel patterns is a prerequisite for managing travel demand and promoting sustainable ways of travelling (e.g., using public transport or active travel modes such as bicycle and walking). Travel behaviours, especially repetitive choices of commuting modes, are often the result of habitual routines in which people do not go through deliberate consideration every time they make travel-related decisions (Scheiner, 2007). According to the habit-discontinuity hypothesis, changes in the context will make behaviour-relevant information salient and stimulate people to reconsider their travel routines. Here the context encompasses the physical environment and infrastructure where behaviours take place, as well as relevant time and social cues such as the transition in social roles over the life course (Verplanken et al. 2008). Residential relocation represents such an abrupt change in spatial contexts, including changes in the residential built environment and job-housing relationships. For this reason, relocation and subsequent spatial changes may act as a trigger for the commuting mode shift.

The literature has been discussing whether the observed commuting mode shift following residential relocation is a result of changes in spatial contexts pre-post relocation or just a manifestation of the pre-relocation travel attitude and socio-economic status of an individual. This widely-discussed debate is termed residential self-selection, or residential sorting phenomenon (Mokhtarian and Cao, 2008; Cao et al., 2009; van Ham et al., 2012). For example, the coincidence between suburban living and car commuting may not be attributed to the suburban environment with poor access to the job centre and public transport systems, but rather results from residents' prior selection into the suburban neighbourhood depending on their high income or/and preferences for car use. From the perspective of residential self-selection, therefore, pre-existing travel attitude to a great extent drives the commuting mode shift, while changes in spatial contexts pre-post relocation do not play an important role as long as people can freely relocate their houses to satisfy residential and travel preferences (Næss, 2009; Ettema and Nieuwenhuis, 2017).

In this study, we argue that context changes along with residential relocation still matter for commuting mode choices and preferences in two ways. First, residential relocation not only brings about a change in spatial contexts but also takes place because of the transition in personal and family life, which jointly lead to the commuting mode shift. According to the mobility biographies approach, the relocation event can be an adaptation to other events embedded in people's immediate social contexts, especially life events in the employment and household

domains (Scheiner, 2014; Müggenburg et al., 2015). A case in point is that after a child is born, parents may simultaneously increase the demand for car use and a large living space in the car-dominant suburb (Oakil et al., 2016; Whittle et al., 2022). In this case, life events (e.g., childbirth) underlie a common reason for residential location choices and commuting mode choices, and thus, act as the third source of residential self-selection besides socio-economics and travel attitude (Zhang, 2014). Second, changes in socio-spatial contexts following residential relocation result in not only changes in commuting mode choices but also changes in commuting mode preferences. This contradicts the assumption of residential self-selection studies, i.e., travel-related attitude is stable over time (Ajzen, 1991). According to the learning process and the cognitive dissonance theory, however, people would adapt to the new place of residence not only by changing travel behaviours but also by adjusting travel attitude (Van Wee et al., 2019; Tao et al., 2022). If so, travel attitude measured at post-relocation should not be regarded as a source of residential self-selection but rather a result of context changes pre-post relocation (Ewing et al., 2016). This is evidenced by a recent longitudinal study in Beijing, China, where the effect of residential self-selection is limited due to constrained housing markets but residents' attitude toward active travel modes significantly improves after they move to a more urbanised neighbourhood (Wang and Lin, 2019).

As a contribution to the residential self-selection argument, our study takes a nuanced socio-spatial perspective to understand the condition under which residential relocation results in changing not only the choice of but also the preference for commuting modes. Using the Netherlands Mobility Panel, a longitudinal research design pre-post the relocation event was developed to answer the following two questions: (1) how do changes in spatial contexts (i.e., changes in residential built environment and job-housing distances) and the transition in personal and family life (i.e., the occurrence of family- and job-related life events) influence the commuting mode shift pre-post residential relocation, and (2) how do these context changes and resultant commuting mode shift further influence the commuting mode preference at post-relocation, after taking into account the effect of residential self-selection arising from residents' socio-economic status and commuting mode preference at pre-relocation.

The remainder of this paper is structured as follows. Section 5.2 presents an overview of the relocation research evidence on changes in commuting modes and travel attitude, followed by a conceptual framework in Section 5.3. Section 5.4 introduces the Netherlands Mobility Panel data and longitudinal structural equation modelling methods used in our study. Section 5.5 exhibits and explains the model results, and finally, Section 5.6 discusses the main research findings and provides some policy implications for travel demand management and sustainable transportation planning.

## 5.2 Literature review

### 5.2.1 Changes in commuting modes pre-post residential relocation

Urban and transport geographers have studied the relationship between built environment and travel behaviours for decades (see the review articles by Ewing and Cervero, 2010, and Guan et al., 2020). A large body of cross-sectional evidence has documented that a compact and mixed-use neighbourhood with easy access to diverse transport facilities is correspondent with more trips by active mode and public transport there, while residents from a low-density neighbourhood with limited activity destinations and transportation infrastructure tend to own cars and use them for daily long-distance trips (e.g., Handy et al., 2005; Schwanen and Mokhtarian 2005; van Acker and Witlox, 2010; Tao et al., 2022). To further identify the environment-travel causality, recent studies focus on the event of residential relocation to compare within-individual changes in travel behaviours pre-post relocation (e.g., Cervero and Day, 2008; Scheiner and Holz-Rau, 2013; Zhao and Zhang, 2018; De Vos et al., 2021). Their rationale for better causal inference is that changes in environmental exposures precede changes in behavioural responses in time, and any between-individual idiosyncratic confounders (e.g., travel-related attitude) are controlled for by the within-individual analysis.

Relocation-based travel behaviour studies are especially interested in investigating changes in commuting mode choices. The reasons are that repetitive commuting behaviours not only constitute one of the key factors for residential location choices, but also will be deliberately reconsidered after abrupt changes in job-housing relationships (Tao et al., 2022). However, research evidence is still mixed in concluding the impact of changes in built environment characteristics on changes in commuting mode choices. Analysis of the regional-scale built environment shows that relocating to the suburb will induce a switch to the car for commuting, while moving closer to the city centre leads to more frequent use of public transport and active modes (Scheiner and Holz-Rau, 2013; Beige and Axhausen, 2017). In contrast, some other studies claim that the impact of general relocation direction is negligible (Oakil et al., 2016), or depends on the urban structure under study (Næss, 2011). For example, a cross-city study in Norway finds that shorter distances to the city centre, rather than to the second-order centre, decrease the propensity of commuting by car, which supports the compact city strategy in Scandinavian cities (Engebretsen et al., 2018). Oppositely, evidence from the polycentric Greater Oporto areas suggests that compared with



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the distance to the main city centre, the distance to the closest retail centre exerts a stronger effect on the likelihood of owning and using cars (Næss, 2015). Compared with the effect of regional built environment, commuting mode shift is more directly linked to changes in job-housing distances and local built environment at residence. There is consistent evidence that the longer the commuting distance is following the relocation, the higher the probability that people acquire additional cars and switch to the car for commuting (Clark et al. 2016; Yang et al., 2017; Zhao and Zhang, 2018; Whittle et al, 2022). In addition, moving to a neighbourhood accessible to frequently-running and high-quality transit lines makes public transport a competitive alternative to the car for long-distance commuting trips. As a result, commuters' car ownership and use are likely to decline, or at least remain at the former levels, after the relocation (Cervero and Day, 2008; Cao et al. 2019; Ibraeva et al., 2022).

The mixed findings for the causal relationship between built environment and commuting modes may lie in the residential self-selection (or residential sorting phenomenon). Its basic idea is that people select the place of residence for matching their travel demand, abilities and preferences (see Mokhtarian and Cao, 2008 for a review of research methodologies and Cao et al., 2009 for a review of empirical findings). Simply put, people may decide on the residential location in advance of the actual move based on their socio-economic status and preferred means of transport. Regarding the self-selection from socio-economics, a well-documented example is that socio-economically deprived groups (e.g., low-income households and racial minorities) choose to live in urban areas to enable public transport use or access adjacent job markets (Cao et al., 2009). Besides, baseline car ownership at pre-relocation is also an important factor of relocation decision-making. Available cars in the household expand people's choice set of residential locations considering the ability of travelling longer distances within a certain commuting time (Næss, 2009; van Acker and Witlox, 2010; Scheiner, 2014).

Another source of residential self-selection is the preference for residential locations and travel behaviours. Regarding the mode-specific preference, a mismatch between the commuting mode choice and preference would cause dissatisfaction and thus constitute a reason for moving home. In this regard, previous self-selection studies often follow a retrospective survey design to collect attitudinal information after respondents have changed their houses. This post-hoc measure of travel attitude is then used to infer the self-selection process that occurred at an earlier time (e.g., Handy et al., 2005; Cao et al., 2007; De Vos et al. 2018; Zhao and Zhang, 2018; Guan and Wang, 2020). Their study results have come to a general consensus that travel-related self-selection is at play because most of the respondents move to a neighbourhood that allows the use of their preferred means of transport; However, residential built environment and job-housing distances still exert an independent

effect on commuting mode choices over and above the effect of residents' travel preferences.

Notably, residential self-selection studies have argued much on the role of changes in spatial contexts (i.e., residential built environment and job-housing distances) for commuting mode shift following the relocation, but overlook the fact that daily commuting behaviours are subject to habitual routines and embedded in social life. In this regard, life-oriented travel behaviour studies and the mobility biographies approach have provided solid theoretical justification for the stability and changes in travel behaviours over the life course. Life-oriented travel behaviour studies propose that people's past experiences gradually accumulate to shape current travel demand and preferences. However, a sequence of events in life evoke the transition in social roles and statuses, which has the potential to reshape travel behaviours (Beige and Axhausen, 2017; Zhang, 2014; Zhang and van Acker, 2017). Echoing this, the mobility biographies approach specifies the reasons for daily mobility changes (i.e., changes in travel behaviours and mobility tool availability, such as car ownership) by the events in three life domains: changes in household composition in the household domain (e.g., childbirth, moving out of or into the household), job-related events in the employment domain (e.g., job changes and retirement), residential relocation and corresponding changes in accessibility and built environment in the residential domain (Lanzendorf, 2003; Scheiner, 2007). It has to be emphasised that these events are not isolated but interrelated with each other in life, which jointly influence people's daily mobility (Müggenburg et al., 2015; Tao et al., 2022).

Based on the mobility biographies, residential relocation can be conceptualised as an adaptation to events in the household and employment domains, because the relocation event is often coincided, or even induced, by other family- and job-related life events (Müggenburg et al., 2015). In the household domain, relocation is likely to take place when people give birth to a child, start and stop cohabitating with the partner, or undergo other changes in household composition (Scheiner and Holz-Rau, 2013; Clark et a., 2016; Guan and Wang, 2020). Each of these family-related life events conveys a specific form and meaning of residential relocation, and thus, evokes the reconsideration of former travel habits. Likewise, in the employment domain, the co-location hypothesis claims that individuals adjust their housing locations closer to job locations, or vice versa, as a way to temper commuting changes (Gordon et al., 1991; Cervero and Day, 2008; van Ham et al., 2012). Recent longitudinal evidence, however, does not always support the job-housing co-location. Guan and Wang (2020) indicate that residents who live in urban areas also tend to work there since they desire to commute in short distances or use easy-access public transport. Oppositely, Prillwitz et al. (2007) and Beige and Axhausen (2017) find that people who alter both housing and job locations do not decrease

the commuting distance but significantly increase the number of family cars and their use for commuting.

### 5.2.2 Changes in travel attitude pre-post residential relocation

Attitude is broadly defined as a favourable or unfavourable inclination toward the evaluated object (e.g., travel) based on people's needs, values and tastes (Ajzen and Fishbein, 1977). In residential self-selection studies, travel-related attitude, or more specifically the preference for certain travel modes, is regarded as an antecedent to the choice of residential locations and travel behaviours. This claim on the exogenous nature of attitude in relocation decision-making originates from socio-psychological theories. In the well-known theory of planned behaviour, for example, the intention and occurrence of behaviours are incurred by the time-invariant attitude, along with subjective norms and perceived behaviour control (Ajzen, 1991). This makes explicit the causal direction running from attitude to behaviour, and lends support to the retrospectively residential self-selection studies. If travel attitude does not vary over time, these self-selection studies should not be blamed much for using travel attitude measured at post-relocation to infer the preceding housing selection process.

However, travel attitude is not a stable construct but subject to change under certain circumstances, suggesting the endogeneity of travel attitude in the environment-travel causality. Recent critical reviews by van Wee et al. (2019) and Guan et al. (2020) have argued that travel attitude can be reshaped by changes in travel demand (e.g., car dependence after childbirth), environmental opportunities (e.g., limited public transport services at residence), and mobility cultures (e.g., programs of cycling to work in the company). Following this string of thinking, the reverse effect from built environment to travel attitude makes more sense in the retrospectively residential self-selection studies, because residents may have adjusted their travel attitude after living a while in the new place of residence (Ewing et al., 2016). Empirically, there is little evidence regarding the attitudinal changes due to limited longitudinal data that repeatedly sample the same respondents in the long term. Drawing upon available panel datasets, emerging longitudinal studies have been investigating the relationship between changes in travel behaviours and attitude in a stable context where people do not change their houses and workplaces. The results show that travel mode choices and mode-specific preferences mutually influence each other over time, and in some cases, people are more likely to change the preference for a travel mode than the use of that mode (Kroesen et al., 2017; Olde Kalter et al., 2020; McCarthy et al., 2021).

Changes in travel attitude are more likely to be the case when the context is unstable, e.g., following residential relocation. As Lin et al. (2017) have evidenced, the exposure to a new spatial context after the relocation exerts a significant impact on travel attitude especially when travel-related residential self-selection does not take place; that is, people do not choose residential locations based on their pre-existing travel attitude. In this case, there are two possible pathways underlying changes in travel attitude. The first pathway, the adjustment to cognitive dissonance, takes effect when people face constraints to move into the neighbourhood in line with their desired way of travelling. The inconsistency (or dissonance) between travel behaviours and attitude would arouse a feeling of discomfort, which motivates people to adjust travel attitude to better match their behaviours and improve their travel satisfaction (Festinger, 1957; De Vos and Singleton, 2020). The second pathway, the learning process, occurs when people do not take travel-related factors into serious consideration for relocation decision-making. After the relocation, they will immerse in a different spatial setting and mobility culture, consciously search for travel-related information, and alter their stance toward available travel choices (Bohte et al., 2009). In addition, direct travel experiences are a more active form of learning. After using the alternative travel mode stimulated by the new place of residence, people may also correct and adapt their pre-existing preference for that mode (Næss, 2009; van Wee et al., 2019).

The impact of built environment or travel behaviours on travel attitude is termed the reverse causality, as opposed to the residential self-selection where travel attitude predisposes the choice of residential locations and travel behaviours (van de Coevering et al., 2018; van Wee et al., 2019). While increasing studies have examined the bi-directional relationships between built environment and travel attitude (e.g., Ewing et al., 2016; Lin et al., 2017; van de Coevering et al., 2016, 2018; Kroesen, 2019), there is limited evidence drawing upon the real panel data pre-post the event of residential relocation. Following a quasi-longitudinal research design, De Vos et al. (2021a, b) request relocated residents in the city of Ghent, Belgium to retrospect their changes in residential locations (measured by self-reported changes in the urbanised levels of the neighbourhood), travel mode use and mode-specific attitude pre-post relocation. The results show that residents develop more positive attitude toward public transport and active modes after moving to a more urbanised neighbourhood. However, these quasi-longitudinal studies fail to take into account the baseline status at pre-relocation, especially the residential self-selection from pre-existing travel attitude, given only the information on changes investigated. To our best knowledge, Wang and Lin (2019) provide the only longitudinal evidence that simultaneously tests the residential self-selection and reverse causality hypotheses. Their study draws upon a two-wave panel survey on 229 respondents before and after their residential relocation in Beijing, China.

Results from the structural equation models suggest little evidence of residential self-selection on the one hand, because travel mode preferences at pre-relocation do not predict the choices of residential built environment and the commuting distance at post-relocation. On the other hand, the reverse causality is established because residents state a preference for active travel modes after moving to a densely populated and easily accessible neighbourhood.

Moreover, life events occurring at the time of residential relocation may also engender a transition in travel attitude. This attitudinal transition involves several causal mechanisms, including spurring a deliberation process, changing travel demand, and altering social roles and norms (Clark et al., 2016; Janke and Handy, 2019). Longitudinal studies of this kind have examined the independent effects of different life events on attitudinal changes. For example, young parents tend to appreciate car use after giving birth to a child because of more tight time schedules and constraints of coordination (Kroesen, 2019; Whittle et al., 2022). However, less studied is how travel attitude varies as a result of interrelated life choices, especially the residential relocation that often corresponds with job changes and changes in household composition. To this end, a socio-spatially contextual perspective that marries the relocation event with other family- or job-related events is warranted to account for not only changes in travel behaviours but also changes in travel attitude.

## 5.3 Conceptual model

According to the literature review, residential self-selection is still an area of debate concerning the reverse causality issue and the self-selection resulting from family- or job-related life events. These debates reflect three different but interrelated perspectives on how residential relocation and associated context changes influence, or are influenced by, people's travel behaviours and attitude: First, relocation may be induced by travel-related self-selection where prepositioned travel attitude drives the choice of residential locations and travel behaviours. Second, relocation may be an adaptation to other life events, such as childbirth and job changes, along with varying travel demands and preferences. Third, relocation itself may be a key event in changing travel behaviours and attitude through the exposure to new spatial contexts and the intention to break travel habits.

Based on these considerations, our study constructed the conceptual model in Figure 5.1 to jointly analyse the relationships between changes in residential built environment and job-housing distances (i.e., spatial contexts), the occurrence of life events, and changes in commuting mode choices and preferences before and after residential relocation. Specifically, changes in spatial contexts pre-post relocation are assumed to result in not only changes in commuting mode choices, but also changes in commuting mode preferences. Regarding the interrelations between travel behaviours and attitude, we focused more on the path from changes in commuting mode choices to changes in commuting mode preferences (the solid line in Figure 5.1) than the opposite path (the dashed line in Figure 5.1). This is because people tend to gradually adjust the commuting mode preference as they live in the new place of residence or experience the alternative commuting mode for a while (van de Coevering et al., 2016; De Vos et al., 2018). In contrast, changes in commuting mode choices are a more immediate response to the new spatial context as long as people can access the required mobility tools, especially the car (van Acker and Witlox, 2010; Scheiner, 2014; Wang and Lin, 2019). For this reason, we introduced changes in household car ownership as a mediator to account for the indirect effect of changes in spatial contexts on changes in commuting mode choices and preferences. Moreover, three possible sources of residential self-selection were taken into account, i.e., individual and household socio-economic characteristics, pre-relocation commuting mode preferences, and family- and job-related life events concurrent with the relocation event. Among the three self-selection factors, the inconsistency between commutiing mode choices and preferences at pre-relocation may induce a low level of commuting-related wellbeing (e.g., commuting dissatisfaction), which motivates people to relocate to a new place of residence and realise the preferred way of commuting. Besides, we also included the spatial contexts, household car ownership and commuting mode choices at pre-location to control for the influence of preceding living experiences and travel habits.

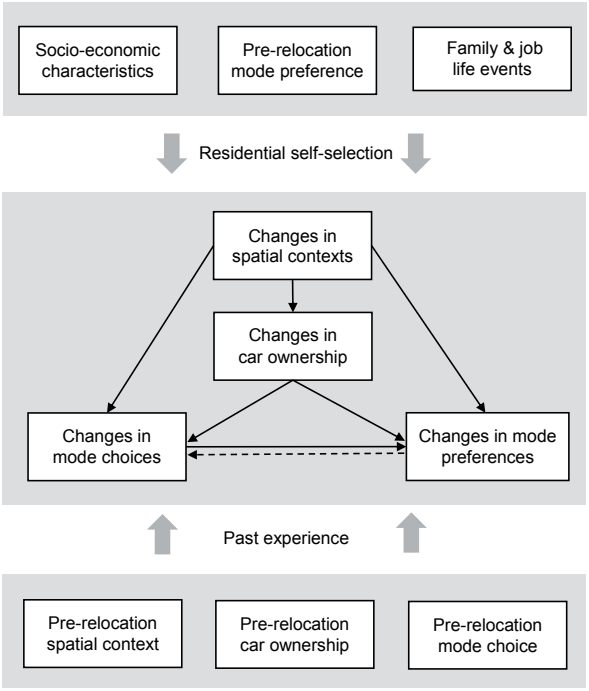


FIG. 5.1 A conceptual model for the interrelations between spatial contexts, commuting mode choices and mode-specific preferences

It is worth highlighting that our study employed a longitudinal research design to compare changes in commuting mode choices and preferences pre-post residential relocation. This pre-post event analysis is recommended as an appropriate way to examine the causal relationship between built environment and travel behaviours, and to identify the transition in travel attitude after major changes in life (Mokhtarian and Cao, 2008; Naess, 2009; Guan et al., 2020; Tao et al., 2022). Compared with previous cross-sectional or quasi-longitudinal research, our longitudinal design makes methodological advances, other than avoiding the recall and consistency biases from the retrospective survey, in four aspects. First and foremost, we assessed residential self-selection by using the commuting mode preference measured at pre-relocation. In addition, we took into account past residential and travel experiences before the relocation, which are left aside by (quasi-)longitudinal studies focusing solely on changes. Moreover, we followed a contextually sensitive approach to examine the joint role of changes in spatial contexts and the occurrence of life events. Last but not least, we examined the reverse causality by analysing the influence of context changes and commuting mode shift on the mode-specific preference at post-relocation.

## 5.4 Data and methods

### 5.4.1 Netherlands Mobility Panel

Our study drew upon the Netherlands Mobility Panel (Mobiliteitspanel Nederland in Dutch, MPN) data. MPN is a nationwide panel survey in which over 7,000 respondents aged 12 and above have been asked to complete an online questionnaire every year since 2013. For detailed sampling and survey procedures see Hoogendoorn-Lanser et al. (2015). In each wave of the surveys, respondents recorded their daily travel behaviours and current travel attitude. They also reported major changes in life between survey waves, including changes in household composition, residential locations, car ownership and work conditions. This unique combination of longitudinal information on travel behaviours and life events enables us to study changes in commuting mode choices and preferences of the Dutch population over time.

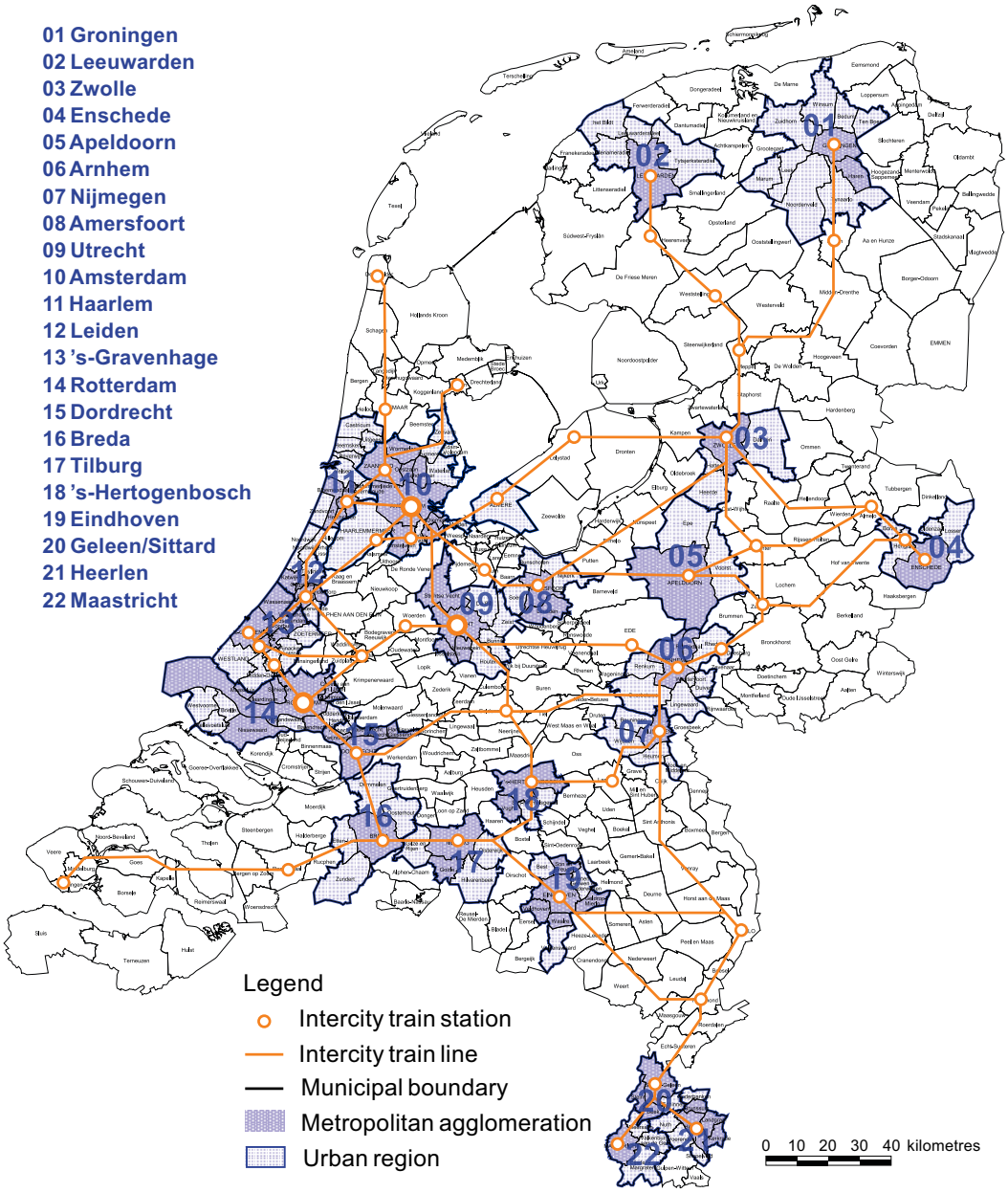


FIG. 5.2 Urban regions and intercity train networks in the Netherlands

*Source: modified by the Statistics Netherlands (2015) and the NS rail map (2020)*



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We chose the Netherlands as the case area to examine commuting-related residential self-selection for two reasons. First, compared with the US and some Asian countries (e.g., China), the Netherlands is characterised as more compact urban forms with mixed land uses and accessible job (sub)centres. Figure 5.2 shows that in the Netherlands, there are 22 functional urban regions where most of the populations from surrounding areas commute to work and conduct routine activities. These polycentric urban regions provide commuting populations with more options to choose job-housing relationships and greater chances to meet travel preferences. Second, there are competitive alternatives to cars given the good quality of public transport networks and cycling infrastructure in the Netherlands. Even so, there is still room for expanding bicycle use, especially for the commuting purpose, given that over half of the car commuting trips are currently within the cycling distance (<7.5 kilometres; Rijksoverheid, 2018).

Our study selected the respondents who regularly commuted to work and had experienced residential relocation between the survey waves of 2013 and 2019. Note that our studied respondents are longitudinal in nature because each of them had a continuous two-year record, one year before and the other year after the relocation event. Table 5.1 shows baseline socio-economic characteristics and residential areas of the commuting respondents who had relocated their houses, with those of all commuting respondents as a comparison. It is expected that compared with the general commuting population, relocated commuting respondents were younger, better educated, and more likely to be singles from low-income carless households and highly urbanised areas. We excluded those non-movers from the analysis because they had little variation in residential built environment over the survey waves. More importantly, residential self-selection only applied to people who actually exercised the housing choices.

TABLE 5.1 Baseline socio-economic and residential characteristics of the relocated commuting respondents and all commuting respondents in the MPN dataset

| | | Relocated respondents[a] (N=1,038) | MPN respondents[a] (N=7,113) |
|---|---|---|---|
| Gender | Men | 49.9 | 49.6 |
| | Women | 50.1 | 50.4 |
| Age | 18-29 | 16.8 | 16.8 |
| | 30-39 | 27.4 | 22.1 |
| | 40-49 | 30.4 | 27.0 |
| | 50-69 | 20.3 | 34.1 |
| Education | Elementary or secondary education | 12.4 | 22.5 |
| | Vocational education | 34.3 | 42.1 |
| | University or higher education | 53.3 | 35.4 |
| Household type | Single, no children | 37.2 | 18.6 |
| | Single parent | 5.9 | 6.2 |
| | Couple, no children | 22.7 | 24.1 |
| | Couple with children | 32.6 | 48.9 |
| | Others | 1.6 | 2.2 |
| Household income levels | Low income (< 26,200 euros/year) | 27.0 | 17.5 |
| | Middle-low income (26,200-38,800 euros/year) | 24.5 | 22.1 |
| | Middle-high income (38,800-65,000 euros/year) | 27.3 | 37.1 |
| | High income (>65,000 euros/year) | 21.2 | 23.3 |
| Household car ownership levels | No car | 19.7 | 10.2 |
| | 1 car | 52.1 | 48.7 |
| | 2 or more cars | 29.2 | 41.1 |
| Residential location | High-urbanised areas (>1,500 inhabitants/km$^2$) | 62.8 | 49.4 |
| | Moderate-urbanised areas (1,000-1500 inhabitants/km$^2$) | 15.0 | 20.8 |
| | Low- or non-urbanised (<1,000 inhabitants/km$^{2)}$ | 22.2 | 29.8 |

*a. Results are show in %.*

### 5.4.2 Variable settings

There are five subsets of the variables, including travel behaviours and attitude, residential built environment and job-housing relationships, life events, household car ownership, and socio-economic characteristics. Notably, all variables, except life events and time-invariant socio-demographics (i.e., gender, age and educational attainment), were included in the modelling analysis by the baseline value before the relocation and the difference in value (i.e., changes) pre-post relocation. These variables of interest are described in Table 5.2 and explained in detail below.

Travel behaviours and attitude were respectively operationalised as the travel mode choice and mode-specific preference for commuting trips pre-post residential relocation. To accurately estimate the behaviour-attitude interrelations, these two measures were uniformly specific to the dimension of travel modes and the purpose of commuting to work (Bohte et al., 2009; Kroesen et al., 2017). In the MPN survey, respondents were required to name the means of transport that they used most frequently and preferred to use to commute. Their answers were coded as car, public transport (PT), walking and bicycle (use or preferences). Considering the small number of walking as the most frequently used and the preferred commuting mode, we combined walking and bicycle into the active mode (AM) for the modelling analysis.

Job-housing distances and residential built environment attributes relevant to the commuting trips defined the spatial contexts before and after the relocation. These environmental attributes were measured at different scales, ranging from the regional scale to the neighbourhood scale. Specifically, the distance (from the residence measured at the 6-digit zip code) to the nearest urban region centre described the residential location at the regional scale, while its changes pre-post relocation outlined the general relocation direction, i.e., moving closer to or away from the urban region. Besides, the distance to the workplace (i.e., commuting distance) and its changes measured the job-housing relationships over space, while the distance to the nearest intercity train station and its changes evaluated how easy commuters could access high-quality public transport infrastructure at residence.

TABLE 5.2 Description of research variables

| Category | Description | Variable | Pre-relocation[a] | (Post-) relocation[a] | Difference[b] |
|---|---|---|---|---|---|
| Commuting mode choice | Main means of transport used for commuting trips | Car | 53.4 | 56.7 | ** |
| | | Public transport | 14.7 | 16.4 | |
| | | Active mode | 31.9 | 26.9 | |
| | | Bicycle | 28.0 | 23.8 | |
| | | Walk | 3.9 | 3.1 | |
| Commuting mode preference | Preferred means of transport for commuting trips | Car | 49.6 | 46.0 | ** |
| | | Public transport | 10.5 | 12.1 | |
| | | Active mode | 39.9 | 41.9 | |
| | | Bicycle | 35.7 | 33.9 | |
| | | Walk | 4.2 | 8.0 | |
| Spatial context | Built environment characteristics and job-housing relationships | Distance to the urban region centre | 11.95 | 12.93 | ** |
| | | Distance to the job location | 22.56 | 24.90 | * |
| | | Distance to the intercity train station | 8.64 | 9.60 | ** |
| Social context | Family- and job-related life events occurred in the same year of residential relocation | Childbirth | —[c] | 9.5 | — |
| | | Cohabitation | — | 13.6 | — |
| | | Separation | — | 6.3 | — |
| | | Job change | — | 32.3 | — |
| Household car ownership | The number of cars in the household | Number of cars | 1.14 | 1.16 | |
| | | No car | 19.7 | 19.6 | ** |
| | | 1 car | 52.1 | 51.2 | |
| | | 2+ cars | 28.2 | 30.3 | |
| Socio-economic characteristics | Socio-economic characteristics at baseline, except household income with baseline values at pre-relocation and change values pre-post relocation included | Income: low | 27.0 | 22.1 | ** |
| | | Income: middle-low | 24.5 | 22.5 | |
| | | Income: middle-high | 27.3 | 30.8 | |
| | | Income: high | 21.2 | 24.6 | |
| | | Gender: men | 49.9 | — | — |
| | | Gender: women | 50.1 | — | — |
| | | Age: 18-29 | 16.8 | — | — |
| | | Age: 30-39 | 27.4 | — | — |
| | | Age: 40-49 | 30.4 | — | — |
| | | Age: 50-69 | 20.3 | — | — |
| | | Education: elementary or secondary | 12.4 | — | — |
| | | Education: vocational | 34.3 | — | — |
| | | Education: university or higher | 53.3 | — | — |

*a. Results are show in % or means.*

*b. Differences in mean values and proportions were examined by t-tests and chi-squared tests, respectively. Results are shown as * $p<0.05$ and ** $p<0.01$.*

*c. — represents not applicable.*



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Life events in the household and employment domains were included to identify the transition in personal and family life at the time of residential relocation. In the household domain, we chose childbirth, cohabitation and separation to describe major changes in family life. When these family-related life events occurred in the same year of relocation, they respectively captured moving houses for childrearing, moving in together with the partner, and living apart from the partner. In the employment domain, we used changes in the workplace, together with residential relocation, to examine the co-location pattern of job and housing locations. Besides, changes in household income were included to adjust for the income effects along with job changes. Notably, when respondents changed their houses, around one-third of them experienced a change in either household or employment domains in the same year, which entails the consideration of life events for relocation decision-making (Table 5.2).

Household car ownership was introduced as an intermediating pathway linking residential relocation to changes in commuting mode choices and preferences. Specifically, car ownership levels were measured by the number of cars in the household before and after the relocation. In addition, socio-economic characteristics included were composed of gender, age, educational attainment and annual household income at pre-relocation.

### 5.4.3 Structural equation models

Our study used the longitudinal structural equation modelling method to empirically examine the conceptual model in Figure 5.1. Unlike the multivariate regression that estimates a single outcome by a series of indicators, structural equation models (SEMs) allow the analysis of multi-stage interdependencies between endogenous variables (i.e., variables are simultaneously treated as the outcome in a set of relationships and as the indicator of the outcome in other relationships), after taking into account the influence of exogenous indicators on endogenous outcomes. In the past two decades, SEMs have been increasingly applied in travel behaviour research to understand the complex process of travel-related decision-making (e.g., Mokhtarian and Cao, 2008; van Acker and Witlox, 2010; Wang and Lin, 2019; De Vos et al., 2021a, b). For these considerations, it is suitable for our study to employ longitudinal SEMs to investigate the endogenous relationships between changes in spatial contexts, car ownership levels, and commuting mode choices and preferences pre-post residential relocation, as well as to account for exogenous impacts, especially, of family- and job-related life events.

SEMs were specifically constructed as follows. We firstly divided the respondents based on their baseline commuting modes at pre-relocation (i.e., non-car users, non-PT users and non-AM users), and then, fitted three SEMs to explain the process of switching to each commuting mode of interest (i.e., switching to car, switching to PT and switching to AM) with the reference of maintaining the commuting mode pre-post relocation. The rationales for dividing these mode-specific commuting groups are threefold: First, to analyse the switch to a certain commuting mode, it is methodologically sound to keep the baseline commuting mode to be similar (e.g., maintaining non-car use versus switching from non-car use to car use). Second, commuting-related residential self-selection can be better estimated after controlling for the baseline commuting mode (e.g., the impact of pre-relocation car commuting preference on residential location choices specifically for people who did not commute by car before the relocation). Third, the reverse causality can be further examined by including the commuting mode preference at post-relocation as the outcome (e.g., the impact of switching to car use on post-relocation car commuting preference after controlling for the car commuting preference at pre-relocation).

We used the weighted least square mean and variance adjusted (WLSMV) estimators to fit the SEMs. Compared with the maximum likelihood (ML) estimator, WLSMV estimators perform better in reducing the possibility of type I errors and estimating the variables that are not normally distributed (Kline, 2016), which is particularly the case for our binary measures on changes in commuting mode choices and preferences. We also took into account the time fixed effects by adjusting for the calendar year at pre-relocation. The SEM analysis was undertaken using the program Mplus.

# 5.5 Results

## 5.5.1 Changes in commuting mode choices and preferences pre-post relocation

Table 5.3 describes the within-individual variations in commuting mode choices and preferences before and after residential relocation. Regarding changes in commuting mode choices, car use was more stable than public transport (PT) and active mode (AM) use. Nearly 80% of the pre-relocation car commuters maintained their car use at post-relocation, while around half of PT and AM users switched to other commuting modes. Especially for pre-relocation active commuters, one-third of them switched to car use after the relocation, possibly because of the increased distance to the workplace and the urban region (as shown in Table 5.2). Similar to the results for commuting mode shift, commuting mode preferences were subject to great changes following the relocation. This adds to the argument that retrospectively residential self-selection research should have regarded travel attitude measured at post-relocation as more of a result than a reason for residential location choices (Ewing et al., 2016). Interestingly, only 40% of the respondents who preferred PT commuting at pre-relocation maintained this preference afterwards, while more than 60% of the respondents repeatedly stated car or AM as the preferred commuting mode pre-post relocation. Taken together with the results for commuting mode shift, it is possible that some former active commuters had to give up the AM use after the relocation even though they still desired to use that mode.

TABLE 5.3 Changes in commuting mode choices and preferences before and after residential relocation[a]

| | | | The post-relocation year | | |
|---|---|---|---|---|---|
| | | | Commuting mode choice | | |
| | | | Car | PT | AM |
| The pre-relocation year | Commuting mode choice | Car | 79.8 | 6.9 | 13.3 |
| | | PT | 24.8 | 51.0 | 24.2 |
| | | AM | 32.9 | 16.3 | 50.8 |
| | | | Commuting mode preference | | |
| | | | Car | PT | AM |
| | Commuting mode preference | Car | 68.2 | 7.0 | 24.8 |
| | | PT | 22.4 | 40.8 | 36.8 |
| | | AM | 26.1 | 13.8 | 60.1 |

*a. Results are show in %.*



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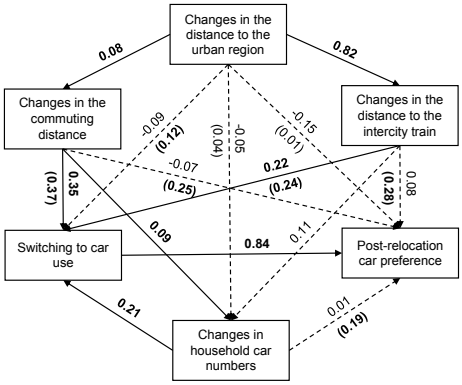
### 5.5.2 Interrelations between residential built environment, commuting mode choices and preferences pre-post relocation

Three SEMs were further fitted to understand the mechanism underlying each mode switch behaviour (i.e., switching to car, PT and AM) and the impact on post-relocation mode preference. In the raw SEMs that linked all the paths between variables, the goodness-of-fit indices of the models just met the recommended values. This is not surprising because raw SEMs were saturated with limited degrees of freedom (d.f.). Besides, most of the baseline socio-demographic characteristics at pre-relocation did not show significant effects on endogenous variables that were measured by changes in value. To improve the mode fit, we removed those insignificant paths (at $p < 0.10$) between socio-demographics and endogenous variables, following Wang and Lin (2017) and De Vos et al. (2021a, b). After the path removal, results for other variables hardly changed, and the adjusted SEMs fitted the data quite well as indicated by the numbers of free parameters (84-90) and the commonly-used goodness-of-fit indices (Chi-square/d.f. = 0.57-0.92, CFI = 1.00-1.00, TLI = 1.01-1.04, RMSEA = 0.00-0.01, SRMR = 0.02-0.03; Table 5.4).

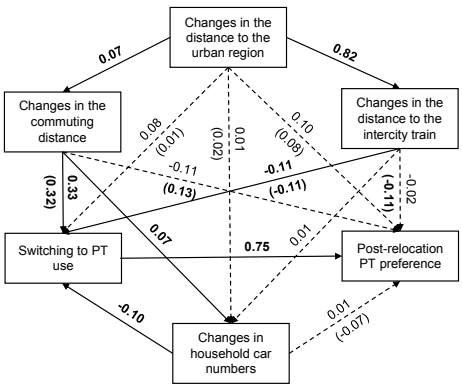
TABLE 5.4 Goodness-of-fit indices for three SEM models

| | Recommended values | Switching to car model (N=484) | Switching to PT model (N=885) | Switching to AM model (N=707) |
|---|---|---|---|---|
| Number of free parameters | >15 | 84 | 90 | 88 |
| Chi-square /degrees of freedom, d.f. | <5 | 0.73 | 0.92 | 0.57 |
| CFI: Comparative fit index | >0.95 | 1.00 | 1.00 | 1.00 |
| TLI: Tucker-Lewis index | >0.95 | 1.03 | 1.01 | 1.04 |
| RMSEA: Root mean square error of approximation | <0.05 | 0.01 | 0.00 | 0.00 |
| SRMR: Standardized root mean square residual | <0.05 | 0.02 | 0.03 | 0.02 |

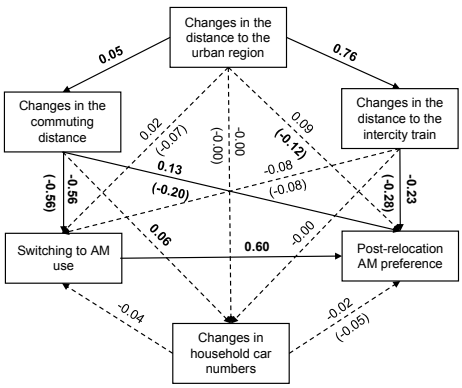
Results from the adjusted SEMs are shown in Figure 5.3 and Tables 5.5-5.7. Figure 5.3 illustrates the relationships between endogenous variables for respondents who respectively switched to car, PT and AM for commuting after the relocation. A notable finding is that in all three models, switching to a commuting mode pre-post relocation had a strong and significant impact on the preference for that mode at post-relocation. This impact was established after adjusting for the pre-relocation mode preference; that is, a fresh experience of commuting by car, PT or AM after the relocation helped to develop a positive stance toward the chosen mode. Here, the effect of commuting mode choices on mode-specific preferences could be interpreted as the cause-impact relationship, because the individual switched the commuting mode at an earlier time than the stated mode preference at post-relocation.




(a) Switching to car model




(b) Switching to PT model




(c) Switching to AM model

FIG. 5.3 SEM results for the standardised direct effects and total effects (in parentheses) between endogenous variables

*Note. Numbers in bold refer to significant direct effects and indirect effects (in parentheses) at p<0.05. Solid lines represent significant direct effects while dashed lines represent insignificant direct effects.*

Regarding the role of spatial contexts, regional built environment did not directly influence commuting mode shift, but it did exert indirect effects through changes in job-housing distances and public transport accessibility at residence. Given the polycentric urban regions in the Netherlands, relocation within an increased distance to the centre of an urban region was associated with corresponding increases in the commuting distance and the distance to an intercity train station. On this basis, respondents who commuted longer distances were more likely to start using cars or PT for commuting and less likely to switch to AM use. Also, worse accessibility to intercity trains was related to a lower likelihood of switching to PT use and a greater likelihood of switching to car use. Hence, previous research findings for the limited role of residential relocation in travel mode shift can be misleading, because they disregard the spatial context of the relocation (e.g., using the occurrence of relocation events) or rely on a coarse measure of it (e.g., general relocation direction within the city; Scheiner and Holz-Rau, 2013; Clark et al., 2016; McCarthy et al., 2021).

Besides the effects on commuting mode shift, spatial contexts also mattered for commuting mode preferences. This is especially the case for the active commuting preference, given the significant direct effects of changes in residential built environment and job-housing distances on the preference for active commuting at post-relocation. Specifically, as respondents relocated farther away from the intercity train station, they were less likely to prefer walking or cycling for (part of the) commuting trips. On the contrary, respondents would miss the benefit of short-distance active commuting and exhibit a greater preference for AM use with the increase of commuting distances. Even so, the total effect of increased commuting distances on the post-relocation AM preference was negative because the indirect effect through discouraging a switch to AM was much larger in magnitude. Taken together, a suburban relocation away from the urban region negatively predicted the active commuting preference in the total effect. This echoes our descriptive results and the cognitive dissonance theory (Festinger, 1957; De Vos and Singleton, 2020). When relocated residents could not walk or cycle to work within acceptable distances, they would abandon their preference for active commuting to alleviate the behaviour-attitude inconsistency. Regarding the results for car and PT commuting preferences, there were insignificant direct effects of changes in residential built environment and job-housing distances on post-relocation mode preferences, while the total effects, especially the indirect effects through commuting mode shift, were significant in expected directions.

In line with previous research evidence (e.g., van Acker and Witlox, 2010; Wang and Lin, 2019; Whittle et al., 2022), changes in household car numbers acted as a mediator between changes in commuting distances and switching to car or PT

use. Specifically, when respondents moved away from their job locations, they would acquire more cars and start using them for commuting trips. Instead, longer commuting distances would marginally impede the mode switch to PT if respondents increased household car numbers following the relocation.

Results for the commuting mode preference at pre-relocation substantiated residential self-selection arising from the pre-existing preferences for car and PT commuting. This is inconsistent with the longitudinal evidence from Beijing, China where residents' housing choices are constrained due to institutional factors and housing affordability (Wang and Lin, 2019). In our study, a predilection for car commuting at pre-relocation stimulated a move to the place away from the urban region and the job location, which further increased the number of family cars and their use for commuting. Similarly, respondents who had regarded PT as the preferred commuting mode chose to relocate closer to the intercity train station. However, commuting-related self-selection did not apply to respondents who preferred active commuting before the relocation. This means that walking and cycling enthusiasts might not find a suitable house close to the workplace, or they did not even consider satisfying the commuting preference through residential relocation. Despite this, the commuting mode preference at pre-relocation is a strong indicator of the commuting mode choice and preference at post-relocation, for the three studied means of transport alike. This result aligns with other studies indicating that prepositioned travel attitude has an autonomous impact on subsequent travel behaviours, but does not always translate into the long-term decision on residential locations (Ettema and Nieuwenhuis, 2017; Wang and Lin, 2019).

Life events concurrent with residential relocation also predicted the commuting mode choices and preferences at post-relocation, especially through changes in household car numbers. In such cases, residential relocation is an adaptation consequent to the occurrence of another life event, and after these structural transitions in life, people's travel demand and preferences vary from the situation before (Müggenburg et al., 2015). In the household domain, specifically, respondents would acquire additional cars when relocation and childbirth events happened in the same year. Afterwards, they tended to start car commuting and not to switch to PT. Besides, the cohabitation event was related to increased commuting distances, because respondents were required to negotiate a common housing location with their partners at the cost of the proximity to their own workplaces (Wang et al., 2020). In contrast, the separation event decreased household car numbers, possibly as a result of the financial loss and the moving out from the former car-owning households (Scheiner, 2007). However, the decrease in car numbers might not lead to a decline in car use in the long term, considering that respondents showed a greater preference for car commuting after the separation.

In the employment domain, the coincidence between housing and job changes did not shorten the commuting distance in all three SEM models. Inconsistent with the co-location hypothesis, this result indicates that the studied respondents did not treat residential relocation as a way to approach the workplace, or vice versa (similar longitudinal evidence provided by Prillwitz et al., 2007 and Beige and Axhausen, 2017). Moreover, simultaneous changes in housing and job locations prompted a switch to car use and AM use. Starting car commuting could arise from more income gained and extra cars purchased after job changes (Table 5.5). In contrast, the switch to active commuting might relate to the gender difference, because female respondents commuted shorter distances than male respondents following the relocation (Table 5.7). To test this, we constructed the interaction terms between gender and the event of job changes in Tables 5.5 and 5.7. The results support that when housing and job changes took place in the same year, women were marginally more likely to switch to AM and less likely to switch to car for commuting (only at the significance p between 0.10 and 0.20), suggesting their tendency of working closer to home and active commuting to work.

Changes in household car ownership and spatial contexts pre-post relocation also depended on their baseline statuses at pre-relocation. This state dependence is hardly considered by quasi-longitudinal relocation studies that simply investigate environmental and behavioural changes (e.g., Scheiner and Holz-Rau, 2013; De Vos et al., 2021a, b). As for the results of baseline car ownership, respondents from car-owned households tended to move away from the urban region and the train station. Accordingly, they were inclined to switch to car for commuting but less likely to start PT use after the relocation. It suggests that car availability undermines the importance of residential built environment for relocation decision-making, which contributes to greater car dependence in the household. In line with the evidence from other longitudinal studies (Scheiner and Holz-Rau, 2013; van de Coevering et al., 2016), the baseline values of built environment characteristics and the commuting distance were negatively associated with their respective change values pre-post residential relocation. For example, a long distance to the centre of an urban region at pre-relocation was predictive of a decline in that distance following the relocation. The only counterintuitive finding is that respondents who had lived away from the urban region would increase the distance to the train station after changing their houses. This could result from the fact that residents who enjoy suburban living do not consider PT as an alternative to the car for commuting in the first place, so they are less motivated to move closer to the train station.

Besides the significant results of gender and household income as stated before, there were two age groups with the potential of increased car use, suggesting the long-term process in life at play. Compared with the respondents aged

below 30, those aged 30–39 were more likely to increase household car numbers, prefer not to commute by PT, and avoid switching to active commuting after residential relocation. Despite expressing an aversion to car use, respondents aged between 50 and 69 tended to move farther from the urban region and acquire more cars in the household, which entailed and enabled the long-distance car commuting trips.

TABLE 5.5 Standardised direct effects between exogenous and endogenous variables in the SEM model for switching to car use

| | Post-relocation car preference | Switching to car use | Changes in household car numbers | Changes in the distance to the urban region centre | Changes in the commuting distance | Changes in the distance to the intercity train station |
|---|---|---|---|---|---|---|
| Car preference at pre-relocation | 0.31** | 0.60** | 0.25* | 0.26* | 0.26** | -0.03 |
| Childbirth | -0.13 | -0.13 | 0.52** | 0.21 | -0.02 | -0.21 |
| Cohabitation | -0.02 | 0.12 | 0.02 | 0.24 | 0.21* | 0.06 |
| Separation | 0.27* | 0.23 | -0.35* | 0.04 | -0.16 | 0.04 |
| Job changes | 0.01 | 0.20* | 0.28** | 0.03 | 0.09 | -0.05 |
| Income changes | 0.07 | -0.04 | 0.14** | -0.06 | 0.00 | -0.01 |
| Household car ownership at pre-relocation | -0.10 | 0.86** | -0.69** | 0.17 | 0.06 | 0.16* |
| Distance to the urban region centre at pre-relocation | 0.05 | -0.16 | -0.01 | -0.32** | -0.04 | 0.29** |
| Commuting distance at pre-relocation | 0.09 | 0.09 | 0.06 | 0.05 | -0.56** | -0.06 |
| Distance to the intercity train station at pre-relocation | -0.06 | 0.26* | 0.05 | -0.10* | 0.09 | -0.32** |
| Household income at pre-relocation | 0.07 | -0.03 | 0.11* | -0.06 | 0.04 | -0.04 |
| Men (ref. women) | — | — | — | — | 0.10 | — |
| Age: 30-39 (ref. <30) | — | — | 0.13 | — | — | — |
| Age: 40-49 | — | — | — | — | — | 0.40 |
| Age: 50-69 | -0.33* | — | 0.41** | — | — | — |
| Education: Vocational (ref. elementary or secondary) | — | — | — | — | — | — |
| Education: University or higher | — | — | — | — | — | — |

** p<0.05, ** p<0.01. — represents the insignificant paths (p>0.10) excluded from the SEM.*

TABLE 5.6 Standardised direct effects between exogenous and endogenous variables in the SEM model for switching to PT use

| | Post-relocation PT preference | Switching to PT use | Changes in household car numbers | Changes in the distance to the urban region centre | Changes in the commuting distance | Changes in the distance to the intercity train station |
|---|---|---|---|---|---|---|
| PT preference at pre-relocation | 0.48** | 0.86** | -0.00 | -0.12 | 0.14 | -0.18* |
| Childbirth | -0.06 | -0.41* | 0.02 | 0.07 | -0.03 | 0.05 |
| Cohabitation | 0.09 | 0.08 | 0.14 | 0.04 | 0.16* | -0.01 |
| Separation | 0.32 | -0.40 | -0.25* | 0.07 | -0.08 | -0.10 |
| Job changes | -0.12 | 0.11 | 0.13* | -0.01 | 0.03 | 0.01 |
| Income changes | -0.05 | -0.01 | 0.14** | 0.00 | -0.02 | -0.07 |
| Household car ownership at pre-relocation | 0.09 | -0.63** | -0.53** | 0.19 | -0.00 | 0.12 |
| Distance to the urban region centre at pre-relocation | 0.04 | -0.10 | 0.12 | -0.41* | 0.04 | 0.37** |
| Commuting distance at pre-relocation | 0.01 | 0.13* | 0.05 | 0.04 | -0.55* | -0.02 |
| Distance to the intercity train station at pre-relocation | 0.00 | -0.05 | -0.09 | 0.06 | 0.03 | -0.42** |
| Household income at pre-relocation | -0.06 | 0.08 | 0.05 | -0.07* | -0.03 | -0.04 |
| Men (ref. women) | — | — | — | — | 0.14* | — |
| Age: 30-39 (ref. <30) | -0.32* | — | 0.26** | — | — | — |
| Age: 40-49 | — | -0.42* | — | — | — | — |
| Age: 50-69 | — | -0.30 | — | 0.19* | — | — |
| Education: Vocational (ref. elementary or secondary) | — | — | 0.19 | — | — | — |
| Education: University or higher | — | — | 0.18 | — | — | 0.18 |

** p<0.05, ** p<0.01. — represents the insignificant paths (p>0.10) excluded from the SEM.*

TABLE 5.7 Standardised direct effects between exogenous and endogenous variables in the SEM model for switching to AM use

| | Post-relocation AM preference | Switching to AM use | Changes in household car numbers | Changes in the distance to the urban region centre | Changes in the commuting distance | Changes in the distance to the intercity train station |
|---|---|---|---|---|---|---|
| AM preference at pre-relocation | 0.52** | 0.64** | -0.01 | -0.06 | -0.07 | -0.01 |
| Childbirth | -0.18 | -0.13 | 0.02 | 0.15 | -0.09 | -0.08 |
| Cohabitation | -0.08 | 0.06 | 0.27* | 0.07 | 0.08 | -0.02 |
| Separation | 0.15 | 0.20 | -0.29** | 0.16 | 0.07 | 0.02 |
| Job changes | -0.01 | 0.23* | 0.14 | 0.02 | 0.01 | -0.02 |
| Income changes | 0.00 | 0.06 | -0.13 | 0.00 | -0.09 | -0.03 |
| Household car ownership at pre-relocation | -0.13 | -0.12 | -0.68** | 0.26* | 0.13 | 0.10 |
| Distance to the urban region centre at pre-relocation | 0.08 | 0.12 | 0.08 | -0.38** | -0.05 | 0.33** |
| Commuting distance at pre-relocation | 0.10 | -0.35** | 0.06 | 0.01 | -0.48** | -0.02 |
| Distance to the intercity train station at pre-relocation | -0.17* | -0.26** | 0.04- | 0.05 | 0.08 | -0.40** |
| Household income at pre-relocation | -0.02 | -0.09 | 0.14 | 0.04 | 0.06 | 0.01 |
| Men (ref. women) | — | — | — | — | 0.29** | — |
| Age: 30-39 (ref. <30) | — | -0.09 | 0.18* | — | 0.15* | — |
| Age: 40-49 | — | — | — | — | — | — |
| Age: 50-69 | — | — | — | 0.20* | — | 0.11 |
| Education: Vocational (ref. elementary or secondary) | — | -0.15 | 0.22* | — | — | — |
| Education: University or higher | 0.21 | — | 0.25* | — | — | — |

** p<0.05, ** p<0.01. — represents the insignificant paths (p>0.10) excluded from the SEM.*

## 5.6 Discussion and conclusions

Residential self-selection research has been arguing for the role of changes in built environment versus pre-existing travel attitude in (re)shaping travel behaviours. Our study contributes to this self-selection argument by integrating it into a wider scope of the interrelation with life events and recognising the temporal variations in travel attitude pre-post residential relocation. Following a longitudinal research design and a socio-spatial contextual approach, we have investigated how commuting mode choices and preferences are causally influenced by residential built environment and job-housing relationships on the one hand, and by the coincidence between relocation events and other family- or job-related life events on the other hand. Our findings substantiated residential self-selection specifically for people who preferred commuting by motorised travel modes, especially by car, before the relocation. Also, the reverse causality was established considering the impact of changes in spatial contexts and commuting modes on post-relocation mode preferences, especially on the active commuting preference. Moreover, family- and job-related life events (e.g., childbirth and job changes) often coincided with the relocation event and predisposed the choices of residential locations, which jointly contributed to greater demand for car use and imposed additional barriers for promoting sustainable commuting behaviours.

Given that travel attitude is time-varying pre-post residential relocation, our study found not only residential self-selection but also reverse causality at play in the relationships between built environment, commuting mode choices and mode-specific preferences. The only longitudinal evidence that takes into account these two effects in an integrated framework is from Beijing, China, where the housing market is tight and residents have little say in housing choices (i.e., limited residential self-selection; Wang and Lin, 2019). Their study also acknowledges that the results were likely to be biased due a small sample size, with the cost of simplifying the measures of spatial contexts and the sources of residential self-selection. Drawing upon large-scale panel samples in the Netherlands, our study shows that the extent to which residential self-selection and reverse causality played a role was specific to the commuting mode of interest. For the active commuting preference, there was little residential self-selection but clear evidence of reverse causality. In other words, active commuting lovers were incapable of or did not think about changing houses to satisfy their travel preferences. However, once they moved away from the urban region with increased commuting distances and worse accessibility to high-quality public transport, they would adjust downwards their favourable stance toward active commuting. In contrast, we did find the self-selection for people who appreciated

using motorised means of transport for commuting. Particularly, car lovers were inclined to move to more suburban areas and acquire additional cars to cover longer-distance commuting trips, while public transport lovers would relocate to a place with an easier access to the intercity train. For car and public transport alike, the reverse causality from spatial contexts to mode-specific preferences only appeared after commuters had actually switched to that travel mode.

The second important contribution of our study is introducing life events in the household and employment domains to better understand the relationships between changes in built environment and changes in commuting behaviours. These life events are closely relevant to the relocation decision-making and jointly reshape people's commuting mode choices and preferences. This adds claim to the residential self-selection that relocation decision-making involves a myriad of factors related to the wellbeing of other life domains beyond the commuting-related wellbeing in daily life. As proposed by the mobility biographies approach, the interrelated decisions on where to live and how to travel are embedded in changes in the social context along one's life course (Scheiner, 2014). Using family- and job-related life events as a surrogate for people's immediate social contexts in personal and family life, our results support that three concurrent life events in the household domain were related to greater car use or preferences. Specifically, childbirth increased car numbers in the household and stimulated car use for commuting. Cohabitating with the partner led to longer commuting distances that entailed car use, while separating with the partner would develop a preference for car commuting. In addition, evidence on the co-location between housing and job locations was less clear and the resultant commuting mode shift is likely to present gender differences. Another intriguing finding is that two age groups, namely those in their thirties and fifties or sixties, had the potential of switching to more car-oriented commuting patterns regardless of the occurrence of life events.

Based on these main findings, our study offers policy implications for urban transportation planning and travel demand management aimed at spreading sustainable commuting patterns among a wider range of working populations. Our pre-post analysis of the relocation event lends support to the structural role of spatial contexts in (re)shaping people's commuting mode choices and preferences above their prepositioned socio-economics and travel attitude. As such, policy initiatives, such as the transport-oriented development, walkable neighbourhoods and smart urban growth, deserve to be advocated for allowing the self-selection into the neighbourhood friendly to transit/active transportation, as well as encouraging the preference transition to these sustainable travel modes and enhancing their future use. Specific to each commuting mode under study, a number of people could not find a suitable house to walk or cycle to work even though they desired to do

so. Apart from alleviating the job-housing mismatch within the urban region, flexible workplace settings (e.g., working closer to home at satellite offices or neighbourhood business hubs; Beck and Hensher, 2021) and widespread e-bicycle use are also promising ways to reduce spatial barriers for active commuting. Considering the strong residential self-selection to satisfy the car commuting preference, we suggest policy initiatives target those carless households and neighbourhoods with fewer car lovers. A viable way is by making alternative commuting modes more attractive. As shown by our results, an easy-access and high-quality public transport system around the neighbourhood is a countermeasure for extended commuting distances and increased car use following the relocation. Furthermore, weakening people's preference for car commuting, such as through educational campaigns on environmental awareness and company-led programs of active/transit commuting to work, is helpful to discourage car use in everyday life and influence the long-term decision on residential locations.

Notably, the policy implications abovementioned should not leave behind the social context of residential relocation and heterogeneous travel demand and preferences for people at different life stages. To promote sustainable means of transport, we recommend policy designs targeting and being tailored to those potential car users before their major changes in life. Two age groups of particular interest are commuters in their early adulthood who are undergoing frequent changes in family circumstances and job-housing relationships, and those middle-aged commuters who relocate away from the urban region prior to their retirement. Given their tendency to start car use or enhance car preferences after the relocation, additional intervention strategies, such as targeted information on sustainable travel alternatives for housing-seeking families and trial mobility packages combining free public transport tickets and bike sharing offers, are required to postpone or even reverse their motorised commuting patterns in the near future.

There are also some limitations in our study and relevant suggestions for future research. First, we relied on a two-wave panel dataset to investigate changes in commuting mode choices and mode-specific preferences pre-post residential relocation. To further analyse the temporality of these changes, we suggest a multi-wave prospective survey including at least three waves respectively before the relocation, immediately after the relocation, and a period of time after the relocation. This multi-wave design can evaluate the anticipated or time-lagged responses to life events by adjusting long-term and daily mobility (e.g., residential relocation and travel mode shift). It can also help in assessing the time it takes to adapt to the new place of residence by changing the travel behaviour or attitude, as well as in examining the reciprocal relationships between the two over time (Guan et al., 2020; Tao et al., 2022). Second, extrapolating our findings for travel mode

switch (e.g., switching to car use) to the situation of travel mode disposal (e.g., giving up car use) should be done with caution. Especially, changes in car use are likely to be asymmetrical; that is, once the car-use habit is established, it is difficult to roll back (Scheiner, 2007; Clark et al. 2016). If so, our study on the mode switch behaviour is of particular importance, because it is relevant to discouraging car use in the first place. Third, our research evidence on gender differences in commuting behaviours is tentative. For drawing more robust conclusions, we recommend using matched panel samples of husbands and wives to study how couples allocate their job-housing relationships and commuting mode choices at the time of relocation decision-making, and how these gender differences are varying across different life stages.

As one of the very few studies using real panel data pre-post residential relocation, our study provides additional insights into the longitudinal relationship between changes in socio-spatial contexts, travel behaviours and travel-related attitude. Echoing the habit-discontinuity hypothesis, residential relocation triggers people to deliberately think about their habitual commuting behaviours and pre-existing travel preferences. However, the magnitude and direction of changes in commuting mode choices and preferences depend on the socio-spatial contexts of residential relocation and are specific to the commuting mode of interest. To better understand the relocation decision-making and resultant travel-related changes, residential relocation should be conceived as a process in the household context where the interrelated decisions on residential locations and travel behaviours are embedded in the long-term process of individual and family lives.

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# 6 A household perspective on the commuting paradox in China

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ABSTRACT Research on the experienced utility of commuting time is dominated by an individualistic view of choice concerning the trade-offs between long commutes and job- or housing-related benefits. The widely discussed phenomenon of the commuting paradox shows that individuals systematically report worse subjective wellbeing as commuting time increases over time, indicating the incomplete trade-offs and net disutility for long commutes at the individual level. This paper takes a household perspective and conducts one of the first longitudinal studies on the gendered relationship between commuting time and subjective wellbeing in China. Drawing upon the China Health and Nutrition Survey between 2006 and 2015, we used seemingly unrelated regression models and fixed-effect models not only to compare the within-individual effect but also to investigate the spill-over effect of commuting time on life satisfaction between matched samples of husbands and wives. We additionally focused on the role of preschool-aged children and co-residence with grandparents in the gendered commuting-wellbeing relationship. The results supported the individual-level commuting paradox, considering that both partners had lower levels of life satisfaction with the increase of their own commuting time. Interestingly, husbands' life satisfaction was more negatively affected by wives' commuting time than vice versa, while wives' commuting utility was more related to the great time pressure from childcare and the social support from extended family members (i.e., grandparents). Our research findings have implications for urban planning and governance policies which aim at mitigating job-housing mismatch, delivering accessible childcare services and transforming gendered social norms.

KEYWORDS Travel behaviour, well-being, gender, family, causality, developing countries

## 6.1 Introduction

Long commuting journeys are considered a daily burden for many people and families. According to the commuting monitoring report of 44 cities in China (2022), the average one-way commuting time was up to 36 minutes, and 24% of the commuters travelled more than 45-minutes between home to job locations. Over the past decade, there has been a growing body of longitudinal evidence concerning the within-individual relationship between the increase of commuting time and the loss in subjective wellbeing (e.g., Wheatley, 2014; Lorenz, 2018; Ingenfeld et al., 2019; Jacob et al., 2019; Clark et al., 2020). Notably, this body of work dominantly regards individuals as the agent to analyse the commuting-wellbeing relationship, neglecting that individuals' commuting decisions may be reached in a household context with gendered power relations and the negotiation with other family members involved (Coulter et al., 2016; Chiappori and Mazzocco, 2017). Taking into account the linked lives between family members is important to understand the nuanced relationship between commuting time and subjective wellbeing from the household perspective.

Spatial economists disregard the commuting-related utility cost. They believe that there is always an equilibrium for the decision utility of commuting time (e.g., momentary costs); Otherwise, individuals will adjust job or housing locations to avoid the utility loss from long commutes (Chatterjee et al., 2020). In the classic monocentric urban model where job locations are concentrated in the city centre and residents live in the peripheral areas, the working residents would search for an equilibrium between long commuting journeys and low house prices or a satisfactory living environment away from the city centre (Alonso, 1964; Mills, 1967; Muth, 1969; Ma and Banister, 2006). In contrast, labour economists generally treat housing locations as a given. They propose a job search model in which workers are willing to pay high commuting costs to access financially or intrinsically rewarding jobs (Manning, 2003; Robert et al., 2011; Jacob et al., 2019). In either way of thinking, the disutility from long commutes is fully compensated for by better housing or job conditions, contributing to the equalized decision utility between individuals.

The individual-level utility equilibrium idea may not hold if the focus shifts from the decision utility derived from observed choices to the experienced utility manifested by commuters' subjective wellbeing (SWB; Ettema et al., 2010). Influential research by Stutzer and Frey (2008) shows that longer commuting time is systematically linked to worse SWB outcomes. This finding is summarised as the commuting paradox; that is, individuals' long commuting journeys are not fully justified by the compensation from the housing and job markets, thereby leading to net experienced

disutility. However, the phenomenon of the individual commuting paradox has not been supported by some recent longitudinal evidence, which observes negligible effects of within-individual changes in commuting time on corresponding changes in SWB outcomes (e.g., Lorenz, 2018; Morris and Zhou, 2018; Clark et al., 2020). Our study proposes that the commuting paradox can be better understood from the household perspective. According to traditional gender role models, females often take on the role of the primary caregiver and the secondary earner in a household (Bielby and Bielby, 1992; Rapino and Cooke, 2011; Chidambaram and Scheiner, 2020). For this reason, they may face higher opportunity costs of commuting time and bear greater psychological burdens from increased commutes than their male partners. Moreover, households are often the unit where commuting decisions are made for multiple family members. This suggests that commuting-SWB relationships may not only depend on the household structure, such as the presence of children, but also manifest themselves as the utility spill-overs between male and female partners. For example, the increase of a female's commuting time may matter not only for the SWB outcome of her own, but also for that of her male partner.

Our study drew from the longitudinal China Health and Nutrition Survey (CHNS) data to analyse whether commuting time is associated with SWB outcomes for couples, and if so, whether and how the presence of children and grandparents influences the gendered commuting-SWB relationship. The answer to these questions will contribute to better understandings of the commuting paradox in three ways. First, we explore the commuting-SWB relationship for matched samples of husbands and wives. Our concerns include not only the difference in the within-individual effect of commuting time but also the spill-overs of commuting utility between husbands and wives. Second, we go beyond the individual-level analysis to study the role of other family members in the gendered commuting-SWB relationship from the household perspective. Third, we enlarge the geographical scope of the international literature by providing one of the first longitudinal studies from China, where socialist market-oriented reforms have greatly reshaped household gender-role divisions over the past few decades (Jarvis et al., 2009; Sun et al., 2019). The contextual specificity of Chinese societies, i.e., intergenerational co-residence, is taken into account given that co-residence with the elder generation is a traditional form of living, as well as a realistic strategy for young couples to reduce housing costs, share childcare responsibility, and thus relieve work-commuting-family conflicts in China (Ta et al., 2019).

## 6.2 Literature review

### 6.2.1 The relationship between commuting time and subjective wellbeing

The seminal study by Stutzer and Frey (2008) draws from German Socio-Economic Panel Study (GSOEP, 1985-2003) data to examine the experienced utility of commuting time. They find that individuals systematically report lower levels of life satisfaction as their commuting time increases over time. Given the contradiction with the equilibrium location theory, this finding is termed the commuting paradox, indicating that long commutes do not obtain full compensation from the housing and job markets and thus bring net disutility. To account for the commuting paradox, Stutzer and Frey (2008) propose three possible explanations, including the equilibrium for the dual-earner couples (without differentiating the gender), incomplete trade-offs between dissatisfaction with increased commuting time and better housing or job satisfaction, and the existence of moving costs in the housing and job markets. However, their empirical results fail to validate these explanations. In their follow-up research, Frey and Stutzer (2014) turn to seek explanations from behavioural economics. The main argument involved is that individuals tend to underestimate the future utility of intrinsic attributes (e.g., the opportunity cost of time), but overvalue the extrinsic needs (e.g., well-paid jobs and low housing costs) at the time of making commuting-related decisions. The result is that individuals accept overlong commuting time that contributes to their net experienced disutility.

Stutzer and Frey's works set a benchmark for a great deal of follow-up research that examines commuters' experienced utility by investigating the relationship between commuting time and SWB outcomes. As yet, however, the findings based on different research designs and contexts are rather mixed (See reviews by De Vos et al., 2013, Chatterjee et al., 2020 and Tao et al., 2022). Cross-sectional studies from Sweden (Friman et al. 2017), Spain (Simón et al., 2020), the United States (Choi et al. 2013), and China (Tao et al., 2022) consistently find that commuting time is inversely associated with life satisfaction or general psychological wellbeing, suggesting that "stress does not pay" (Stutzer and Frey, 2008). In China, specifically, Nie and Sousa-Poza (2018) conduct a cross-sectional mediation analysis showing that longer commuting time is associated with worse happiness and life satisfaction, partly through less time available for sleep. Zhu et al. (2019) pool the samples from China Labour-Force Dynamics Survey (CLDS). The results

indicate that people who commute a longer time have higher levels of work stress and lower levels of job and family life satisfaction, which undermines their overall life satisfaction. Particularly, people who reside in less urbanised areas are under a greater threat of long commutes. Similarly, Sun et al. (2021) draw from the CLDS data and find that the negative association of long commuting time with overall SWB is accounted for by job satisfaction, self-reported health status and social support from neighbours.

However, longitudinal studies, which are mostly conducted in cities of developed countries, fail to validate the individual commuting paradox. Even though some of these longitudinal studies show similar results as the cross-section research (e.g., Stutzer and Frey, 2008; Wheatley, 2014; Milner et al., 2017), there is longitudinal evidence observing a negligible and insignificant impact of commuting time on SWB within the individual. For example, Morris and Zhou (2018) find that longer commuting time results in higher wages and homeownership in the United States, which might justify the weak relationship between commuting time and life satisfaction. Drawing from the same GSOEP data (2007-2013) as Stutzer and Frey (2008), Lorenz (2018)'s fixed-effect modelling analysis suggests that increasingly long commuting journeys are not related to worse life satisfaction for the same individual, even though longer commutes do lead to greater dissatisfaction with specific life domains (e.g., family life and leisure time). Clark et al. (2020) also use the fixed-effect models and substantiate the insignificant impact of commuting time on general psychological wellbeing and life satisfaction in the United Kingdom. Generally, longitudinal evidence on the negligible commuting-SWB relationship seems to support the utility equilibrium theory; that is, individuals are "successful in balancing the negative aspects of commuting against the wider benefits, e.g. access to employment, earnings and housing" (Clark et al., 2020).

Moreover, it is problematic that the commuting paradox implicitly assumes commuting itself as a source of disutility. In the field of transport geography, several review papers have elaborated that people not only travel to meet instrumental needs (e.g., accessing job locations), but also value travel in its own right (e.g., travel as an enjoyable activity; Ettema et al., 2010; De Vos et al., 2013; Mokhtarian, 2019). One remarkable benefit of commuting is the transition opportunity to get away from the hassles of work affairs and family chores so that commuters can do something pleasant or simply enjoy the time alone (Jain and Lyons, 2008). In addition, the positive utility of commuting time may be related to the travel mode choice. Evidence shows that compared with commuting by car or public transport, active commuting (e.g., walking and cycling to work) for a certain amount of time would meet required physical activity levels and improve individual health and SWB (Martin et al., 2014; Clark et al., 2020; Jacob et al., 2021; Tao et al. 2022).

### 6.2.2 Gender differences in the commuting-wellbeing relationship in the household

An important argument for the individual-level commuting paradox is that someone's commuting time involves negotiating and balancing with other family members. This means that the utility equilibrium is likely to be reached at the household level. It is economically sound that couples develop a cooperative strategy to maximize their collective utility (Chiappori and Mazzocco, 2017; Hirte and Illmann, 2019). Simply put, someone's utility losses from long commutes are compensated by the partner's utility gains, thereby resulting in a roughly zero net utility in the household. In Stutzer and Frey (2008)'s empirical analysis, however, the hypothesis of household-level equilibrium is also rejected. Instead, an individual would report worse life satisfaction as the partner's commuting time increases, indicating that long commutes bring negative externalities to other family members.

The household-level commuting paradox can be attributed to the asymmetrical position and bargaining power between male and female partners. Although the past decades have witnessed great advances in women's economic and social lives (e.g., the normalisation of dual-earner couples and narrowing gender gaps in the commuting distance; Cooke, 2013; Thomas et al., 2017), it is still too early to conclude that "the end of patriarchy was on the immediate horizon" (Perrons, 2003). Even in the dual-earner household, working women are found to face more role conflicts as the primary caregiver and the secondary income earner than working men (Bielby and Bielby, 1992; Chidambaram and Scheiner, 2020). Based on this gendered division of household labour, there is emerging longitudinal evidence showing that compared with men, women performed worse in SWB outcomes with the increase of commuting time or distance (e.g., Roberts et al., 2011; Feng and Boyle, 2014; Wheatley, 2014; Jacob et al., 2019). This disproportionate commuting disutility for women may arise from the domains of job and family lives. In the job domain, married women tend to accept under-qualified and less-rewarding jobs in the local labour market for their male partners' job careers (Rapino and Cooke, 2011). This limits women's chances of trading-off longer commutes with better job benefits (e.g., higher wages). In the family domain, women often undertake the main responsibility for domestic tasks, which imposes strict time constraints and increases their psychological sensitivity toward the increase of commuting time (Crane, 2007). As such, striking a balance between household responsibility and professional aspiration may restrict women's spatial mobility, induce higher opportunity costs of commuting time, and result in greater utility losses from long commutes.

Apart from not differentiating the gender role, previous literature is limited in examining the spill-over effects of someone's commuting time on the partner's SWB outcomes. This issue cannot be overlooked because family members' lives are linked and interdependent (Coulter et al., 2016; Thomas et al., 2017). Recent research in China has identified a collaborative decision-making where working couples allocate their job-housing distances more fairly after residential relocation (Yao and Wang, 2021). However, changes in the built environment pre-post residential relocation still show opposite effects on mode-specific travel time between male and female partners. These environmental changes further influence one's daily travels through the partner's travel mode attitude and choices, ultimately shaping both partners' SWB outcomes in an interactive way (Guan and Wang, 2019; Mao and Wang, 2020; Wang et al., 2020). Following this way of thinking, we assume that if long commutes impose stress or time burdens on someone, his or her partner could either enjoy the positive utility from this person's job benefits that compensate for long commuting time, or bear the utility loss of less support for family chores. This situation is more complex if gender differences are considered. There is, even if little, evidence stating that males' satisfaction with family life is more influenced by female partners' commuting journeys than vice versa because in this case, males are less likely to count on their partners to perform household tasks (Brömmelhaus et al., 2020).

Moreover, gendered commuting-SWB relationships may vary according to the household structure, especially the presence of children and their grandparents in the household. Childcare, on the one hand, may impose different impacts on fathers' and mothers' commuting utility. For instance, Rapino and Cooke (2011) find that having children significantly decreases mothers' – but not fathers' – commuting time. Carta and De Philippis (2018) provide an explanation that market services are not a perfect substitute for childcare. As a result, mothers are more likely to reduce commuting and working hours, or even quit the labour market, in exchange for childcare time when fathers' commuting time increases. Feng and Boyle (2014), Wheatley (2014), and Jacob et al. (2019) further extend the discussion to the experienced utility of mothers' commuting time. Their consistent findings are that mothers report worse SWB outcomes as their commuting journeys prolong due to the competing time use for childcare.

Assistance from the elder generation (i.e., children's grandparents), on the other hand, may play a positive role in changing gendered commuting patterns and utilities by shifting the division of labour within the household. Especially in a nation putting much weight on the patriarchal and collective culture of the family, such as China, intergenerational co-residence is a tradition and also becoming a common household strategy for young parents to cope with high housing prices and seek social support for childcare (Wang and Qin, 2017; Ta et al., 2019). Meanwhile, the

burgeoning market economy in China is still incapable of providing adequate and affordable pre-school facilities, so the childcare provided by grandparents may contribute to relieving work-life conflicts for young parents, especially for mothers (Sun et al., 2019). Taken together, there is a need to pay due attention to the gender issue and household perspective when examining the experienced utility of commuting time, and especially, the longitudinal evidence of this kind is limited from the developing world such as China.

## 6.3 Data and methods

### 6.3.1 China Health and Nutrition Survey

Our study used the data from the China Health and Nutrition Survey (CHNS). CHNS is a household-level longitudinal survey conducted every 2-5 years from 1989 to 2015 in 15 provinces and municipal cities of China. In each of the provinces and municipal cities, a multistage and random cluster process was followed to recruit a sample of around 30,000 individuals from 7,200 households. Within the household, every family member aged 6 and above was invited to fill in a questionnaire including information on demographics, daily activity and travel behaviours, health and SWB (see Popkin et al., 2010 for the detailed sampling procedure). Ethical approval for the survey was acquired from the Internal Review Board of the University of North Carolina at Chapel Hill and the Chinese Centre for Disease Control.

We chose the longitudinal couple samples from the survey waves of 2006, 2009, 2011 and 2015 for study because only the latest four waves contain the SWB information (i.e., a one-item measure of overall life satisfaction). Within the studied ten years, cities in China have experienced rapid urban population and land expansions, along with increasing job-housing mismatch and associated public health and wellbeing issues. The specific criteria for selecting eligible couple samples include that: (1) Husbands and wives aged 20-65 years old were followed no fewer than 2 continuous waves; (2) They stay married and at least one of the partners commuted to work; and (3) They had no missing information on the variables of interest. This selection procedure resulted in 2,435 couple samples

(i.e., 4,870 individual samples) with 13,484 person-year observations analysed in our study. Table 6.3 presents the baseline socioeconomic characteristics of the studied samples, which are similar to those of initially recruited samples and thus representative of the general population with a range of socio-economics in China.

### 6.3.2 Variable settings

The outcome variable is life satisfaction, representing the cognitive aspect of SWB. This global measure of life circumstances derives from reflective reasoning and is regarded as a satisfactory approximation of experienced utility by economists and transport geographers (e.g., Stutzer and Frey, 2008; De Vos et al., 2013; Morris and Zhou, 2018). In our study, life satisfaction was investigated at each wave of the survey by asking husbands and wives the question: "How satisfied are you with your life as a whole?". Their answers ranged from 1 (very unsatisfied) to 5 (very satisfied). Given the small number of answers on being very unsatisfied and being unsatisfied (i.e., levels 1 and 2, collectively accounting for 4.9% of all person-year observations), we combined these two answers to obtain a four-level life satisfaction scale.

The key explanatory variable is commuting time. The reason for choosing commuting time to predict experienced utility is its greater relevance to the opportunity cost of commuting (e.g., time available for other life domains) compared with commuting distance (Robert et al., 2011; Gutiérrez-i-Puigarnau and Van Ommeren, 2015). Specifically, husbands and wives who were employed at each wave of the survey were required to record their two-way commuting time on a regular working day. Besides, they also reported the travel modes that were used for commuting and the duration that they commuted by each travel mode. The commuting mode was coded as active mode (walk or bicycle), public transport (bus or subway), and car.

According to prior literature (e.g., Roberts et al., 2011; Feng and Boyle, 2014; Wheatley, 2014; Jacob et al., 2019; Mao and Wang, 2020), five subsets of covariates that might confound the gendered commuting-SWB relationship were taken into account. They are demographic characteristics, housing and employment conditions, health status, household structure, and the place of residence, among which household structure is the concern to examine the commuting-SWB relationship for couples at different family life stages. Specifically, the household structure was measured by whether couples lived together with preschool-aged children (<6 years old) and their grandparents. The detailed settings for variables of interest could be found in Table 6.4.

### 6.3.3 Seemingly unrelated regression and fixed-effect models

The modelling analysis was performed in three stages. In the first stage, we developed a panel version of seemingly unrelated regression (SUR) models to investigate the effect of commuting time on life satisfaction for matched husbands and wives. In travel behaviour and wellbeing studies, SUR models have been applied to regress the interrelated dependent variables, such as individual travel mode share (Cao et al., 2009), gendered commuting behaviours (Kwon and Akar, 2021), and couples' SWB outcomes (Mao and Wang, 2020). In our study, we estimated husbands' and wives' life satisfaction simultaneously by allowing for their error terms to be correlated. Following Biørn (2004) and Nguyen and Nguyen (2010), a one-way random effect estimation was employed given the panel nature of our data. In the SUR models, the Generalised Least Squares (GLS) are the estimators that we used for estimating the life satisfaction outcome.

Regarding the inclusion of explanatory variables, SUR models followed a step-by-step approach to examine the commuting paradox at the household level. Model 1 included the commuting time of one's own to estimate the variances in life satisfaction with the change of commuting time (e.g., associations of husbands' commuting time with husbands' life satisfaction), after adjusting for the covariates excluding housing- and employment-related variables. Following Clark et al. (2020), we also introduced the within-individual averaged commuting time across survey waves to remove its cross-sectional variations, but the results showed little difference in the effect of commuting time on life satisfaction for both partners. Model 2 took into account possible compensating factors from housing and job markets to control for the market imperfection and to assess the net utility of commuting time. Partner's commuting time was further added in model 3 to study whether someone's life satisfaction was influenced by the partner's commuting journeys (e.g., associations of husbands' commuting time with wives' life satisfaction). To analyse the role of household structure on the gendered commuting-SWB relationship, model 4 included the interaction terms between (partner's) commuting time and the presence of preschool-aged children in the household, and model 5 further added the interaction terms with co-residence with grandparents. Given the GLS estimators used, all explanatory variables had gone through the multi-collinearity test before fitting the SUR models. The variance inflation factor (VIF) values between them were all below 4.0, indicating no serious multi-collinearity problems.

In the second stage, fixed-effect (FE) ordered logit models were employed to analyse the within-individual variances of life satisfaction between survey waves for husbands and wives, respectively (models 6 and 7). According to Stutzer and



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Frey (2008), the FE model contributes to better understandings of the commuting-SWB causality because it removes any endogeneity derived from time-invariant idiosyncratic characteristics. For example, personality traits may predispose the way that individuals choose job-housing relationships and psychologically react to changes in commuting time, suggesting a spurious commuting-SWB relationship if those unobserved time-invariant variables are left uncontrolled. In addition, compared with the SUR models using the GLS estimators, the FE ordered logit models using the Blow-up and Cluster (BUC) estimators are more suitable to predict the life satisfaction outcome that was measured by an ordinal scale (Dickerson et al., 2014; Clark et al., 2020). Note that the FE models shared the same explanatory variables with the fully-adjusted SUR models (i.e., model 5).

Another challenge in identifying the commuting-SWB causality is the sample selection bias. This selection bias comes from the fact that commuting time can only be observed for people who were employed at the time of the survey. Excluding those person-year observations that reported unemployed or arbitrarily setting their commuting time to zero may misestimate the commuting disutility. This is particularly the case for wives because they have a higher likelihood of leaving the labour market as commuting time increases (Robert et al., 2011; Carta and De Philippis, 2018). Therefore, we applied the Heckman approach to correct for the bias of selecting into the labour market before fitting the SUR and FE models. Specifically, we estimated a random effect probit model on whether or not the participant was in employment for each wave of the survey. Following Rapino and Cooke (2011) and Roberts et al. (2011), the explanatory variables of employment status included the aforementioned covariates, plus the partner's working hours and monthly wages acting as over-identifying instruments. Finally, the inverse Mills ratio (i.e., the Mills term) generated from the probit model was additionally included in the models for predicting couples' life satisfaction.

In the third stage, several sensitivity analyses based on the SUR models were performed to test for the robustness of gendered commuting-SWB relationships. First, we examined the mode-specific effect of commuting time on life satisfaction because the commuting utility might depend on the travel mode used (Martin et al., 2014; Clark et al., 2020; Jacob et al., 2021). Second, we grouped the two-way commuting time into 5 categories (<30, 30-60, 60-90, 90-120 and >120 minutes) because the negative wellbeing effect of commuting time might be negligible, or even reversed, below certain time thresholds, indicating a non-linear relationship (Dickerson et al., 2014; Ingenfeld et al., 2019). Third, we investigated geographical variations in the gendered commuting-SWB relationship by including the interaction terms between commuting time and the type of geographic area for the place of residence. This is of our interest because, in urbanising China, commuting time has increased more rapidly

in large cities than in small cities, towns and rural areas (Zhu et al., 2019). However, it is not clear to what extent the effect of commuting time on SWB outcomes varies over space. Fourth, we restricted couple samples to those who did not change commuting modes, job and housing locations between survey waves. As such, any variations in commuting time were induced by exogenous shocks (e.g., changes in traffic infrastructure or congestion), rather than the reverse causality from low levels of life satisfaction to proactively adjusting commuting time (e.g., by relocation or changing travel modes; Gutiérrez-i-Puigarnau and van Ommeren, 2015; Jacob et al., 2019). Fifth, we focused on the subgroup of dual-earner couples that both partners were employed along the survey waves. The reason is that more intra-couple negotiations on job-housing relationships might be required to relieve the work-family conflicts in these households (Chidambaram and Scheiner, 2020; Yao and Wang, 2021).

## 6.4 Results

### 6.4.1 Couples' commuting behaviours and life satisfaction

Table 6.1 shows the distribution of life satisfaction, commuting time and employment status for husbands and wives, respectively. Even though husbands and wives presented little difference in life satisfaction, their working and commuting situations varied from each other. Specifically, around 40 percent of person-year observations (43.0% for husbands and 44.1% for wives) rated their overall life satisfaction as moderate or bad. Although both partners experienced an increase of commuting time, the gender gap in commuting time became increasingly large along the survey waves. From 2006 to 2015, the daily average commuting time for husbands went up from 33.9 to 47.0 minutes, while that for wives increased from 32.2 to 41.2 minutes. Notably, household structure matters for the gendered commuting behaviours. Average two-way commuting time showed a significant difference between fathers and mothers, but the significance disappeared when parents lived together with their children's grandparents. In addition, compared with wives, husbands were more likely to commute by car (34.4% versus 14.8%) but less likely to walk or cycle to work (62.8% versus 79.2%). Regarding employment status, husbands worked longer hours, earned more wages, and had a higher proportion of being in employment (92.3% versus 75.2%) than wives.



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TABLE 6.1 Life satisfaction, commuting and employment information for husbands and wives[a]

| | | Husbands[b,c] | Wives[b,c] | Difference[d] |
|---|---|---|---|---|
| **Life satisfaction** | | | | |
| **Very bad or bad** | | 4.8 | 5.0 | |
| **Moderate** | | 38.2 | 39.1 | |
| **Good** | | 39.4 | 39.0 | |
| **Very good** | | 17.6 | 16.9 | |
| **Commuting time** | | 39.7 (46.2) | 38.2 (45.2) | |
| **2006** | | 33.9 (35.1) | 32.2 (34.3) | |
| **2009** | | 35.2 (39.3) | 34.3 (38.2) | |
| **2011** | | 39.1 (42.7) | 35.2 (39.3) | * |
| **2015** | | 47.0 (46.4) | 41.2 (44.6) | * |
| **Couples living with children (<6 years old)** | | 42.4 (50.5) | 39.5 (45.8) | * |
| **Couples living with children and grandparents** | | 44.0 (51.0) | 42.5 (50.0) | |
| **Commuting mode** | | | | |
| **Car** | Percentage | 33.4 | 14.8 | ** |
| | Time | 39.3 (48.9) | 35.4 (39.7) | * |
| **Public transport** | Percentage | 9.0 | 10.3 | * |
| | Time | 59.9 (54.1) | 53.6 (47.0) | * |
| **Active mode** | Percentage | 62.8 | 79.2 | ** |
| | Time | 34.5 (40.9) | 34.1 (42.8) | |
| **Employment information** | | | | |
| **Employment status** | | | | ** |
| Being employed | | 92.3 | 75.2 | |
| Being unemployed | | 7.7 | 24.8 | |
| **Primary wage earner** | | 74.9 | 25.1 | ** |
| **Monthly wages[c]** | | 2326.3 (3157.2) | 1757.8 (2400.6) | ** |
| **Weekly working hours** | | 43.6 (17.3) | 40.8 (17.9) | ** |

*a. N=4,870 individual samples and 13,484 person-year observations*

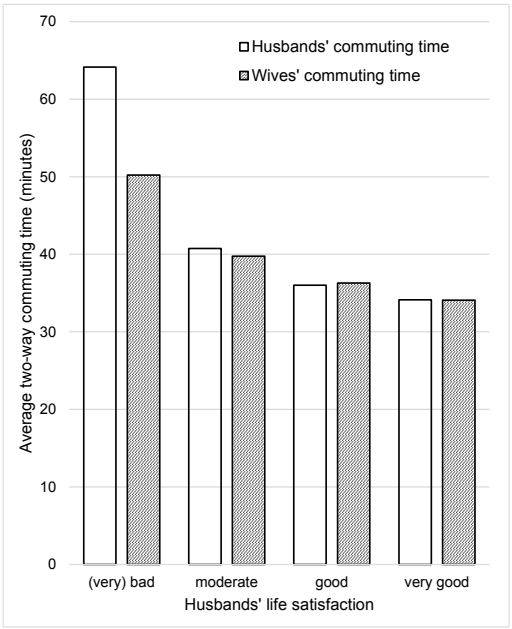
*b. Results are show in % or means (standard deviations).*

*c. Differences in mean values and proportions were examined by t-tests and chi-squared tests, respectively. Results are shown as * p<0.05 and ** p<0.01.*

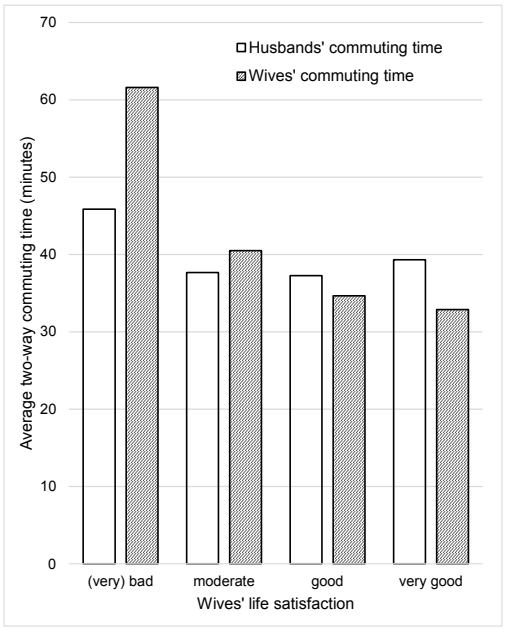
*d. Monthly wages were uniformly inflated to the 2006 level, and RMB (renminbi) is the official currency of People's Republic of China.*

Figure 6.1 shows the two-way relationship between commuting time and life satisfaction for matched husbands and wives. Interestingly, a husband's life satisfaction was patterned by not only his own but also his wife's commuting time (Figure 6.1a). Specifically, husbands reported lower levels of life satisfaction when both partners spent a longer time on daily commuting journeys. In contrast, a wife's life satisfaction was only negatively associated with the commuting time of her own (Figure 6.1b). There was no clear pattern between husbands' commuting time and wives' life satisfaction. Although providing an initial insight into the

relationship between commuting time and life satisfaction, Figure 6.1 represents the results for pooled couples across survey waves. Also, the results were not adjusted for other time-varying characteristics, especially possible job- and housing-related compensations for longer commutes. For these considerations, we carried out the following SUR and FE modelling analysis to further identify the within-individual variations of life satisfaction over time with the increase of both partners' commuting time.




(a) Husbands' life satisfaction




(b) Wives' life satisfaction

FIG. 6.1 The two-way relationship between commuting time and life satisfaction for husbands and wives



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### 6.4.2 Independent and spill-over effects of commuting time on life satisfaction for couples

The SUR and FE model results for matched husbands' and wives' life satisfaction are presented in Table 6.2. Specifically, Models 1–5 show the results of SUR models, and models 6–7 show the results of FE models.

Model 1 substantiated the independent effect of someone's commuting time on his or her own life satisfaction after controlling for the covariates and the correlated life satisfaction outcomes for couples. When commuting time increased, husbands and wives decreased their life satisfaction levels by a similar magnitude. After considering the possible job and housing compensation in model 2, the effect size of commuting time on life satisfaction increased for both partners but still stay relatively small. Besides, gaining home ownership and having a larger living space were significantly associated with higher levels of life satisfaction, indicating partial compensation for greater commuting costs from the housing market. However, neither longer working hours nor higher wages (including absolute wages and wage differences between partners) significantly predicted life satisfaction outcomes for husbands and wives.

The partner's commuting time was included in model 3. It is interesting to find that husbands' life satisfaction was more negatively influenced by wives' commuting time than vice versa. Specifically, when a wife increased the commuting time, her husband's life satisfaction significantly decreased. In contrast, increases in a husband's commuting time mildly improved his wife's life satisfaction, but this effect is only significant at $p<0.10$. After controlling for the husband's commuting time, the negative influence of a wife's commuting time on her own life satisfaction became stronger in magnitude, suggesting a greater commuting disutility for working wives than for working husbands in the household.

In models 4 and 5, we further took into account the presence of preschool-aged children and their grandparents, respectively. Generally, the commuting utility for mothers was more related to the household structure than that for fathers. Model 4 shows that mothers marginally lowered life satisfaction levels with the increase of their own commuting time, but this effect was not significant for fathers. In addition, fathers' life satisfaction became worse as mothers' commuting time increased, while mothers' life satisfaction surprisingly became better with the increase of fathers' commuting time. Model 5 finds that co-residence with grandparents significantly alleviated parents' commuting and childcare burdens. When grandparents were available at home, not only were both parents psychologically relieved from longer commuting time by rating marginally higher levels of life satisfaction, but also mothers' life satisfaction turned much better resulting from fathers' longer commuting time.

TABLE 6.2 Seemingly unrelated regression and fixed-effect model results for husbands and wives

| Life satisfaction[a] | Model 1: SUR | | Model 2: SUR | | Model 3: SUR | | Model 4: SUR | | Model 5: SUR | | Model 6: FE | Model 7: FE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Husbands | Wives | Husbands | Wives | Husbands | Wives | Husbands | Wives | Husbands | Wives | Husbands | Wives |
| Age | 0.11** (0.00) | 0.11** (0.00) | 0.10** (0.00) | 0.10** (0.00) | 0.10** (0.00) | 0.10** (0.00) | 0.10** (0.00) | 0.10** (0.00) | 0.10** (0.00) | 0.10** (0.00) | —[f] | — |
| Age square | -0.00** (0.00) | -0.00** (0.00) | -0.00** (0.00) | -0.00** (0.00) | -0.00** (0.00) | -0.00** (0.00) | -0.00** (0.00) | -0.00** (0.00) | -0.00** (0.00) | -0.00** (0.00) | — | — |
| Education: Middle school or below | Reference | | Reference | | Reference | | Reference | | Reference | | — | — |
| High school or college | 0.01 (0.02) | 0.08* (0.03) | 0.01 (0.02) | 0.08** (0.02) | 0.01 (0.02) | 0.08** (0.02) | 0.01 (0.02) | 0.08** (0.02) | 0.01 (0.02) | 0.07** (0.02) | — | — |
| University or above | 0.14** (0.04) | 0.19** (0.05) | 0.13** (0.04) | 0.19** (0.05) | 0.13** (0.04) | 0.19** (0.05) | 0.13** (0.04) | 0.19** (0.05) | 0.13** (0.04) | 0.19** (0.05) | — | — |
| *Hukou*[b]: rural-to-urban migrants or rural residents | Reference | | Reference | | Reference | | Reference | | Reference | | Reference | |
| Urban residents | 0.01 (0.02) | 0.01 (0.02) | 0.02 (0.02) | 0.02 (0.02) | 0.02 (0.02) | 0.02 (0.02) | 0.02 (0.02) | 0.02 (0.02) | 0.02 (0.02) | 0.02 (0.02) | 0.19 (0.23) | 0.09 (0.20) |
| Presence of children | 0.05* (0.02) | 0.10** (0.02) | 0.04* (0.02) | 0.08** (0.02) | 0.03 (0.02) | 0.08** (0.02) | 0.01 (0.04) | 0.00 (0.04) | 0.01 (0.04) | 0.01 (0.04) | 0.15* (0.07) | 0.19 (0.12) |
| Presence of grandparents | 0.12** (0.03) | 0.12** (0.03) | 0.11** (0.03) | 0.10** (0.03) | 0.11** (0.03) | 0.10** (0.03) | 0.11** (0.03) | 0.10** (0.03) | 0.06* (0.03) | 0.01 (0.03) | 0.20* (0.11) | 0.09 (0.05) |
| Chronic diseases | -0.14** (0.02) | -0.09** (0.03) | -0.14** (0.02) | -0.09** (0.03) | -0.14** (0.02) | -0.09** (0.03) | -0.14** (0.02) | -0.09** (0.03) | -0.14** (0.02) | -0.09** (0.03) | -0.27* (0.11) | -0.13 (0.10) |
| Place of residence: town or rural areas | Reference | | Reference | | Reference | | Reference | | Reference | | — | — |
| Megacities | 0.14** (0.04) | 0.19** (0.06) | 0.15** (0.04) | 0.20** (0.07) | 0.16* (0.04) | 0.21** (0.07) | 0.16** (0.04) | 0.21** (0.07) | 0.16** (0.05) | 0.21** (0.07) | — | — |
| Other cities | -0.06 (0.05) | -0.04 (0.03) | -0.05 (0.03) | -0.03 (0.03) | -0.04 (0.03) | -0.03 (0.03) | -0.04 (0.03) | -0.03 (0.03) | -0.04 (0.03) | -0.03 (0.03) | — | — |
| The Mills term[c] | -0.09** (0.01) | -0.06** (0.01) | -0.09** (0.02) | -0.04** (0.01) | -0.09** (0.02) | -0.04** (0.01) | -0.09** (0.02) | -0.04** (0.01) | -0.09** (0.02) | -0.04** (0.01) | -0.26** (0.07) | -0.26** (0.08) |
| Commuting time[d] | -0.09** (0.01) | -0.10** (0.01) | -0.11** (0.01) | -0.13** (0.01) | -0.08** (0.01) | -0.13** (0.02) | -0.08** (0.02) | -0.11** (0.02) | -0.09** (0.02) | -0.11** (0.02) | -0.31** (0.06) | -0.32** (0.07) |
| Primary wage earner | | | 0.03 (0.02) | -0.02 (0.03) | 0.02 (0.02) | -0.01 (0.03) | 0.02 (0.02) | -0.01 (0.03) | 0.02 (0.02) | -0.00 (0.03) | -0.04 (0.10) | -0.09 (0.12) |
| Monthly wages[e] | | | 0.01 (0.01) | 0.01 (0.01) | 0.01 (0.00) | 0.01 (0.01) | 0.01 (0.00) | 0.01 (0.01) | 0.01 (0.00) | 0.01 (0.01) | 0.01 (0.01) | 0.01 (0.01) |
| Woking hours | | | -0.00 (0.00) | 0.00 (0.00) | -0.00 (0.00) | 0.00 (0.00) | -0.00 (0.00) | 0.00 (0.00) | -0.00 (0.00) | 0.00 (0.00) | -0.00 (0.00) | 0.00 (0.00) |
| Housing tenure | | | 0.24** (0.05) | 0.22** (0.05) | 0.25** (0.05) | 0.22** (0.05) | 0.25** (0.05) | 0.22** (0.05) | 0.24** (0.05) | 0.21** (0.05) | 0.45** (0.18) | 0.43** (0.18) |

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TABLE 6.2 Seemingly unrelated regression and fixed-effect model results for husbands and wives

| Life satisfaction[a] | Model 1: SUR | | Model 2: SUR | | Model 3: SUR | | Model 4: SUR | | Model 5: SUR | | Model 6: FE | Model 7: FE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Husbands | Wives | Husbands | Wives | Husbands | Wives | Husbands | Wives | Husbands | Wives | Husbands | Wives |
| Housing area | | | 0.01** (0.00) | 0.01** (0.00) | 0.01** (0.00) | 0.01** (0.00) | 0.01** (0.00) | 0.01** (0.00) | 0.01** (0.00) | 0.01** (0.00) | 0.01** (0.00) | 0.01** (0.00) |
| Partner's commuting time[c] | | | | | -0.04** (0.01) | 0.02 (0.01) | -0.03 (0.02) | 0.01 (0.02) | -0.03 (0.02) | 0.01 (0.02) | -0.15* (0.07) | -0.00 (0.05) |
| Commuting time × Children | | | | | | | 0.02 (0.01) | -0.04** (0.01) | 0.01 (0.01) | -0.05 (0.04) | -0.03 (0.05) | -0.08* (0.05) |
| Partner's Commuting time × Children | | | | | | | -0.03* (0.01) | 0.04* (0.02) | -0.05 (0.04) | 0.02 (0.01) | 0.01 (0.12) | -0.05 (0.05) |
| Commuting time × Children × Grandparents | | | | | | | | | 0.03* (0.01) | 0.04* (0.02) | 0.08 (0.08) | 0.07* (0.03) |
| Partner's commuting time × Children × Grandparents | | | | | | | | | 0.04 (0.05) | 0.06** (0.02) | 0.16 (0.14) | 0.21** (0.08) |
| (Pseudo) $R^2$ | 0.04 | 0.03 | 0.05 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.05 |
| Correlation residuals | 0.58 | | 0.57 | | 0.57 | | 0.57 | | 0.57 | | — | |

*a. Results are shown as unstandardised coefficients with significance (robust standard errors). Significance: * p<0.05, ** p<0.01*

*b. Hukou specifies the dual household registration system in China, which divides residents into urban residents and rural residents or rural-to-urban migrants.*

*c. The Mills term represents the inverse Mills ratio generated from the probit model on the probability of being in employment.*

*d. Commuting time was transformed to the unit of hours for easy interpretation.*

*e. Monthly wages were uniformly inflated to the 2006 level and transformed to the unit of a thousand RMB (renminbi, the official currency of People's Republic of China).*

*f. — represents not applicable.*

The effect of covariates on life satisfaction showed little difference between husbands and wives. Results from age and age square exhibited a non-linear change in life satisfaction: With increases in age, both partners were firstly more satisfied with overall life before their life satisfaction worsened at an elder age. Besides, better-educated people, people who lived together with children and grandparents, and people who resided in the megacity rated higher levels of life satisfaction, while chronic physical diseases constituted a significant threat to overall life satisfaction, for husbands and wives alike. Regarding the results of correlated error terms, the residual correlation in life satisfaction was moderate-to-high between matched husbands and wives, indicating the existence of other factors commonly influencing couples' SWB outcomes and the validity of using SUR models in our study.

To better understand the commuting-SWB causality, we further employed the FE ordered logit models to focus solely on the within-individual variations of life satisfaction for husbands and wives, respectively (models 6 and 7). Note that some demographic variables and the variable of the place of residence were automatically excluded from the FE models, because they were largely time invariant (e.g., educational attainment and the city size) or varying to the same degree (e.g., age) for the same individual between survey waves. The results from FE models to a great extent corroborated those from SUR models: Both partners uniformly reported worse satisfaction with the increase of their own commuting time; Husbands' life satisfaction was negatively impacted by wives' commuting time; Mothers were more dissatisfied with life as the commuting time of their own increased, while co-residing with grandparents reduced this commuting disutility for mothers.

A final note of the modelling analysis is that the results of the inverse Mills ratio identified the selection bias from excluding the unemployed observations or simply regarding their commuting time as zero. In all models, the Mills term was predictive of worse life satisfaction, suggesting that neglecting selective employment would overestimate the effect of commuting time on life satisfaction. Even so, it should be kept in mind that the R2 of all models were low, which is consistent with some longitudinal studies on commuting-SWB relationships (Robert et al., 2011; Lorenz, 2018; Morris and Zhou, 2018). The low R2 suggests that life satisfaction is a broad measure involving people's subjective assessment on various aspects of life and long commuting time does act as one of the daily hassles.

### 6.4.3 Sensitivity analyses

In the sensitivity analysis based on the SUR models, the commuting-SWB relationship for husbands and wives was examined by classifying commuting time and focusing on certain subgroups of interest (Figure 6.2). After differentiating the mode-specific commuting time, panel A finds that longer commuting time was predictive of worse life satisfaction regardless of the travel modes used. Results from panel B identified a non-linear commuting-SWB association, considering that the negative effect of commuting time on both partners' life satisfaction was only significant for daily commuting journeys lasting more than 60 minutes. Especially for wives, commuting over 60 minutes a day worsened their life satisfaction in a much larger magnitude than for husbands. In panel C, commuting-SWB relationships showed geographic variations based on the population size of the city where couples resided. Compared with couples from town or rural areas, those residing in the megacity decreased much less in levels of life satisfaction as their commuting time increased, possibly due to greater job and housing opportunities in a larger search area in the megacity.

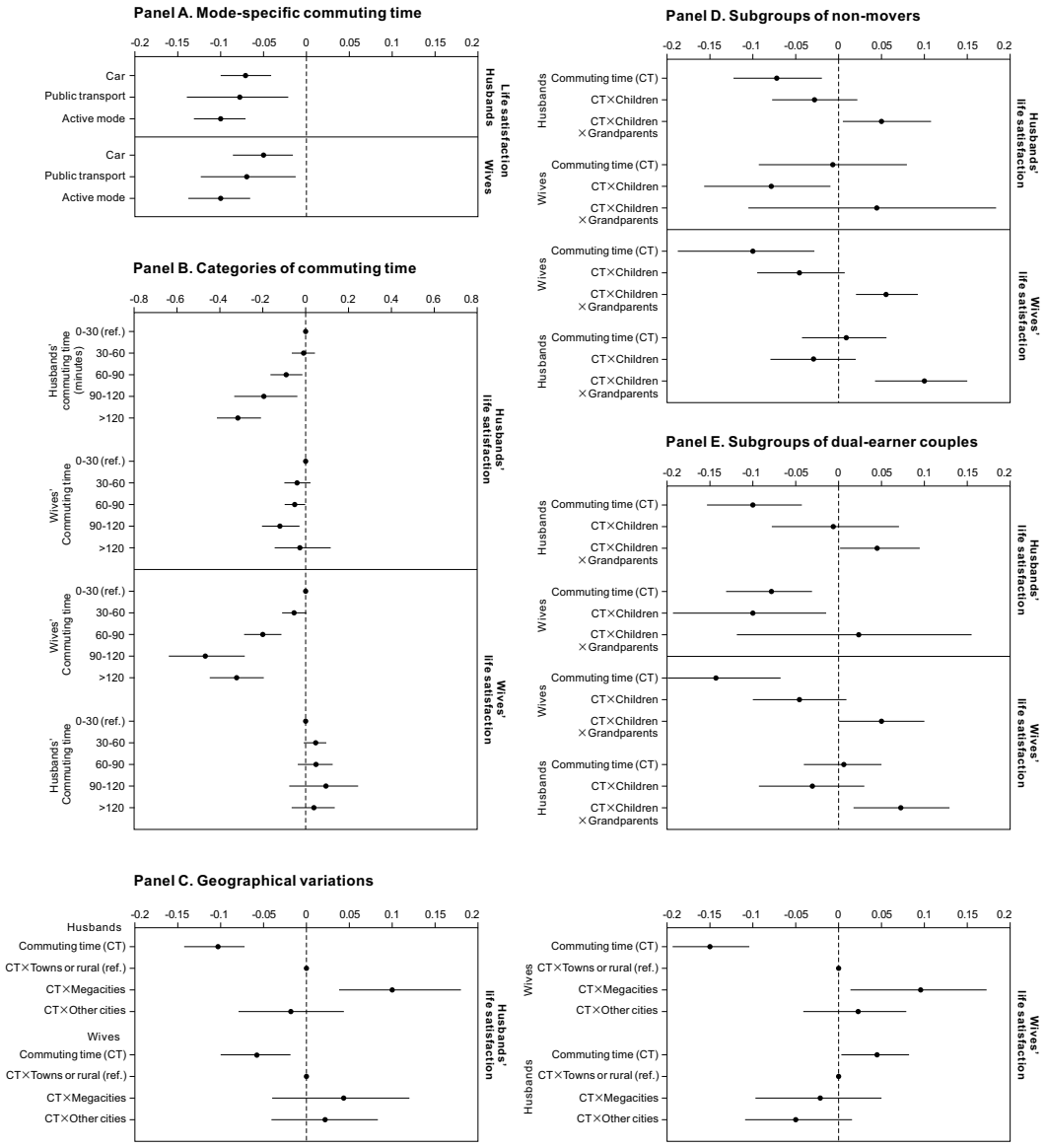


FIG. 6.2 Sensitivity analysis results of the relationship between commuting time and life satisfaction for husbands and wives based on the SUR models[a,b]

*a. Results are shown as unstandardized coefficients with 95% confidence intervals.*

*b. The covariates were controlled for in the SUR models for sensitivity analyses and their results were not shown in the figure.*



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After excluding couple samples who moved houses, changed jobs or commuting modes in panel D, we obtained similar results as in the SUR and FE models, i.e., the commuting disutility for both partners, the spill-overs from mothers' longer commuting time to fathers' worse life satisfaction and from fathers' longer commuting time to mothers' better life satisfaction, as well as the role of grandparents in alleviating mothers' commuting disutility. In panel E, we selected two-worker households and refitted the SUR models after excluding the Mills term. The results show that the work-life conflicts and related commuting disutility were more prominent for dual-earner couples. Compared with the results for all couples, working couples' life satisfaction was more influenced by their own commuting time given the larger effect size. Besides, working husbands or fathers reported much worse life satisfaction when their female partners increased the commuting time.

## 6.5 Discussion and Conclusions

### 6.5.1 Discussion of main findings

Research on the experienced utility of commuting time used to assume an individualistic view of choice concerning the trade-offs between long commutes and job- or housing-related benefits. Our study contributes to the international evidence base by longitudinally examining the relationship between commuting time and life satisfaction for matched samples of husbands and wives from the household perspective in China. The main findings are that husbands and wives similarly reported worse life satisfaction as their own commuting time increased over time. Furthermore, husbands' life satisfaction was more negatively influenced by wives' commuting time than vice versa, while the commuting utility for wives was more related to the household structure (i.e., the presence of children and their grandparents in the household) than that for husbands. These findings lend credence to the commuting-SWB causality, because we followed a stringent longitudinal research design and corrected for the biases from reverse causality and selective employment.

Echoing the work by Stutzer and Frey (2008), our study corroborated the commuting paradox at the individual level. To husbands and wives themselves, there

were additional costs of long commutes that were not paid off from the housing and job markets, and especially, this experienced disutility was noticeable for the commuting journeys over 60 minutes a day. By focusing on the within-individual variations of life satisfaction, our fixed-effect analysis contributes to the causal inference, demonstrating that longer commuting time does constitute a reason for worse overall SWB. This causality can hardly be drawn from the aggregated national statistics and cross-sectional research evidence where the coincidence between commuting time/distance and SWB might derive from the heterogeneous tastes of residential and travel choices for different people. A case in point is that high-income people who choose to reside in suburban large houses tend to drive long to work and show a positive outlook on life. In this case, the income confounder counteracts the negative impact of commuting journeys on SWB outcomes.

Regarding the gender difference in commuting-SWB relationships, our study finds that husbands and wives similarly showed worse life satisfaction when the commuting time of their own increased. This finding is discordant with some longitudinal studies from developed countries where women are shown under a greater burden of commuting disutility than men (Robert et al., 2011; Feng and Boyle, 2014; Brömmelhaus et al., 2020). Their explanation is that as the secondary income earner in the family, women often cannot justify their increasing commuting time by the wage rate offered. In our study, the uniform commuting disutility for both partners might exemplify the moving costs in the housing market given that couples shared the same residential location. The model results also suggest that housing area and tenure, rather than wages and working hours, constituted a part of the compensating factors for longer commutes. In other words, couples were willing to accept longer commuting time to access a bigger house or get home ownership. However, improving the housing condition is not always feasible in Chinese cities as indicated by the increasing housing price and stabilising residential mobility in recent years (Sun et al., 2019; Zhu et al., 2019). According to behavioural economics, people in such tight housing market are also likely to overestimate the future utility of housing-related benefits and underestimate the psychological burden imposed by daily commuting journeys (i.e., the inconsistency between decision utility and experienced utility; Frey and Stutzer, 2014). Because of the utility misestimation and restrained housing choices, couples will ultimately be in a disequilibrium state where they have to bear the experienced disutility arising from increased commuting time.

Moreover, our study observed the intra-couple spill-overs of commuting utility but not in a way that completely supported the household-level utility equilibrium. On the one hand, the increase of a wife's commuting time worsened not only her own but also her husband's life satisfaction. It is possible that wives' longer commutes are not out of choice for better job benefits, so husbands still need to

work the same to sustain the family (Jacob et al., 2019). Meanwhile, husbands gain less support for family chores when wives commute for a longer time, resulting in husbands' greater dissatisfaction with life (Brömmelhaus et al., 2020). On the other hand, a wife's life satisfaction surprisingly turned better with the increase of her husband's commuting time, and this is especially the case when they became parents and lived together with their children's grandparents. The reason could lie in that fathers are compensated for the increased commutes with more income. This economic compensation is shared by female partners and is essential to raising a child. Another important mechanism underlying the intra-couple utility spill-overs is the traditional gender role in the historically patriarchal society of China. This prevailing gender belief regards that women should place more on household responsibility than occupational aspiration, which not only legitimates the discomfort that husbands felt from wives' longer commuting time, but also explains why wives were psychologically relieved when husbands commuted a longer time for better job careers.

Regarding the role of household structure, the commuting disutility is closely tied with the parental status. Our results show that mothers who had preschool-aged children marginally reported worse life satisfaction with the increase of their commuting time, and this effect on mothers was much greater if both parents were employed. This finding conforms to the hypothesis of "a second shift at home" for females (Hochschild and Machung, 2012). Influenced by the culturally prescribed gender role, working mothers have to combine paid employment with the overwhelming majority of childcare tasks (Feng and Boyle, 2014; Jacob et al., 2019). When everyday work and commuting journeys call for increasing time costs, mothers are more likely to suffer from work-family conflicts and experience disproportionate commuting disutility. The source of this disutility can be great time pressure from not only taking care of children after commuting home, but also chauffeuring preschool-aged children to childcare facilities that are often not located on their way to the workplace (Kwan, 1999; Rapino and Cooke, 2011; Chidambaram and Scheiner, 2020).

It is reassuring, however, that co-residence with grandparents to a great extent alleviated mothers' commuting disutility. Unlike the popularity of shrinking family sizes and nuclear family structures in developed countries (Jarvis et al., 2009), intergenerational co-residence is still a common form of living in China. Particularly, co-residence with extended family members is widely recognised as a way for young couples to balance the intra-couple division of household duties (Ta et al., 2019). Our study adds to the evidence that this extended family structure matters for mothers' commuting utility. The childcare provided by grandparents not only decreased the utility loss arising from mothers' longer commuting time but also

generated utility spill-overs from fathers' longer commuting time to mothers' better life satisfaction. There are two possible reasons to account for this result. First, market services are not a reliable source of childcare in the burgeoning market economy of China because they are not geographically accessible in many areas or economically affordable for many households. Drawing from the same dataset as our study, Sun et al. (2019) find that "more than 60% of the women had never used any kind of childcare service provided by a nonhousehold member". Second, market services are not a perfect substitute for the childcare provided by family members. When young parents commute for a long time, they, especially mothers, would feel at ease if grandparents are available to look after their grandchildren because of the kinship ties between them.

### 6.5.2 Policy implications for urban planning and travel demand management

Our research findings provide important policy implications for travel demand management, urban planning and social governance. Considering the commuting disutility for both genders, our study lends support to urban planning initiatives in mitigating local job-housing mismatch, such as decentralising job locations and developing rapid transit links between residential and job (sub)centres (Ma and Banister, 2006; Ibraeva et al., 2020). In the context of urban China, the implementation of affordable housing projects with easy access to residents' workplaces is another task posed to governments and real estate developers. In addition, flexible workplace arrangements, such as working from home on some days of the week, are also a viable way to alleviate commuting disutility, especially at the time of the post-COVID-19 era when telecommunication technologies and home offices are well set to cope with the requirement of remote work.

Given the great time pressure from commuting and childcare for working parents, we recommend that adequate and reliable childcare facilities are equipped not only in residential neighbourhoods but also around parents' workplaces. In this way, the responsibility for providing childcare services can be partially transferred to the enterprises. Working parents can also combine commuting trips with chauffeuring trips more easily. Besides the physical facility planning, policy designs should play a role in transforming gender role ideologies and thus reshaping the gendered commuting-SWB relationship. This does not mean that men and women should commute or work the same, but rather they deserve more freedom to arrange their job-housing relationships as desired. For example, the paternity and parental leave policies conducted in some European counties (e.g., the Netherlands and Germany)

grant husbands and wives similar rights to temporally leave the job after having a child. This contributes to not only sharing the childcare responsibility between both partners but also fostering a gender-neutral social norm among the public.

### 6.5.3 Research limitations and conclusions

There are several limitations of our study and suggestions for future research. First, even if there was a negative effect of commuting time on life satisfaction, we would not like to overstate this influence because of the moderate-to-small effect size. According to De Vos et al. (2013) and Mokhtarian (2019), the modest influence of commuting time may be the reason for individuals to stay in a disequilibrium state but not to change their job-housing relationships. Second, our study focused exclusively on the married heterosexual couples that are in the great majority in Chinese societies. It will be interesting to validate the gendered commuting-SWB relationships for homosexual couples, single persons and parents, among others, because traditional gender role is more likely to be compromised in these families. Besides, the survey did not follow the divorced couples after at least one of the partners moved out of their former residences. This might underestimate the commuting disutility because couples who had commuted for a long time were more likely to have conflicts and get divorced. Third, SWB outcomes were measured by a single item of overall life satisfaction, which is, to our knowledge, the only longitudinal and nationwide data source access to the public in China. Considering that commuting does constitute a threat to people's long-term life satisfaction as found in our study, we advocate for more refined measures of life satisfaction (e.g., the Satisfaction with Life Scale; Diener et al., 1985) and satisfaction with life domains (e.g., housing and job satisfaction). This will be helpful to identify nuanced mechanisms underlying the gendered commuting-SWB relationships. Fourth, our study drew from the 4-wave CHNS surveys from 2006 to 2015 when rapid urbanisation and increasing job-housing mismatch took place in China. We recommend future research using updated survey waves to validate our findings, especially regarding the extent to which commuting behaviours evolve and resultant commuting-SWB relationships change after the COVID-19 outbreak.

Our study revisited the commuting paradox from the household perspective to propose that gender, housing and household structure are fundamental to understanding the commuting utility in the context of Chinese societies. Drawing on Jarvis et al. (2009)'s view that the household "stretches through communities, social and kin networks and a multiplicity of formal and informal economic opportunities", we come to a conclusion that the experienced utility of commuting time cannot only

be conceived as an outcome of individual travel choices but involves the influence of traditional gender role in the household and the interaction with other family members. In the socialist market system of China, women's economic and social statuses are on the rise but the gender equality issue is still an ongoing debate. A remarkable aspect of the gendered commuting-SWB relationships, as discussed in our study, is that the commuting utility for men depends on both partners' commuting time, while that for women is largely shaped by the motherhood and a traditional form of household structure, i.e., intergenerational co-residence.

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# Appendix

TABLE 6.3 Socio-economic characteristics of the studied samples and recruited samples

| | Studied samples[a] | Recruited samples[a] |
|---|---|---|
| | (N=4,870) | (N= 6,760) |
| **Gender** | | |
| Men | 2,435 (50.0%) | 3,380 (50.0%) |
| Women | 2,435 (50.0%) | 3,380 (50.0%) |
| **Age** | | |
| 18-29 | 522 (10.7%) | 744 (11.0%) |
| 30-40 | 1,516 (31.1%) | 1,959 (29.0%) |
| 40-50 | 1,810 (37.2%) | 2,411 (35.7%) |
| 50-65 | 1,022 (21.0%) | 1,646 (24.3%) |
| **Educational attainment** | | |
| Middle school or below | 3,009 (61.5%) | 4,184 (61.9%) |
| High school or college | 1,311 (26.9%) | 1,771 (26.2%) |
| University or above | 550 (11.3%) | 805 (11.9%) |
| **Household registration status, hukou** | | |
| Urban residents | 2,853 (58.6%) | 4,039 (59.8%) |
| Rural-to-urban migrants or rural residents | 2,017 (41.4%) | 2,720 (40.2%) |
| **Employment status** | | |
| Being employed | 3,976 (81.6%) | 5,534 (81.9%) |
| Being unemployed | 894 (18.4%) | 1,226 (18.1%) |
| Monthly wages[b] | 2083.12 (2871.75) | 1953.65 (2168.28) |
| Weekly working hours | 42.31 (17.62) | 42.73 (17.89%) |
| **Housing tenure** | | |
| Self-owners | 4,250 (87.3%) | 5,734 (84.8%) |
| Renters or others | 620 (12.7%) | 1,026 (15.2%) |
| Housing area per capita | 41.61 (25.70) | 41.36 (23.76) |
| **Household structure** | | |
| Dual-earner couples | 3,674 (75.9%) | 4,788 (70.8%) |
| Single-earner couples | 1,166 (24.1%) | 1,972 (29.2%) |
| Couples living with preschool-aged children (<6) | 1,923 (39.5%) | 2,568 (38.0%) |
| Couples living with children and grandparents | 677 (35.2%) | 896 (34.9%) |
| **Place of residence** | | |
| Megacities | 672 (13.8%) | 1,070 (15.8%) |
| Other cities | 1,635 (33.6%) | 2,073 (30.7%) |
| Towns or rural areas | 2,563 (52.6%) | 3,617 (53.5%) |

*a. Data are shown in N(%) or mean (s.d.).*

*b. Monthly wages were uniformly inflated to the 2006 level and RMB (renminbi) is the official currency of People's Republic of China.*

TABLE 6.4 Variable settings

| Category | Variable | Type | Description |
|---|---|---|---|
| Subjective wellbeing | Life satisfaction | Ordinal | One-item overall life satisfaction level [range: 1 (very) unsatisfied – 4 very satisfied] |
| Commuting time | Commuting time | Continuous | Two-way commuting time in hours |
| Demographic characteristics | Age | Continuous | Age ranging from 20 to 65 years old |
| | Age square | Continuous | The squared value of age |
| | Educational attainment | Categorical | 1=middle school or below, 2=high school or college, 3=university or above |
| | Household registration *(hukou)* status | Binary | 1=urban residents, 0= rural-to-urban migrants or rural residents |
| Housing and employment | Primary wage earner | Binary | 1=primary wage earner, 0=not the primary wage earner |
| | Monthly wages[a] | Continuous | Wages (in thousand RMB) from the primary job per month |
| | Working hours | Continuous | Working hours per week |
| | Housing tenure | Continuous | 1=self-owners, 0=renters or others |
| | Housing area | Continuous | Housing areas per capita in the household |
| Health status | Physical diseases | Binary | 1=having any diagnosed chronic physical diseases, including hypertension, diabetes, myocardial infarction, apoplexy, asthma, stroke or any cancers, 0=not having any diagnosed chronic physical diseases |
| Household structure | The presence of children | Binary | 1=having preschool-aged children under 6 years old, 0=not having preschool-aged children |
| | Co-residence with grandparents | Binary | 1=co-residing with preschool-aged children and grandparents; 0=not co-residing with preschool-aged children and grandparents |
| Geographic context | The place of residence | Categorical | 1=megacities (with a population over 10 million, including Beijing, Shanghai or Chongqing), 2=other cities, 3= town or rural areas |

a. *Monthly wages were uniformly inflated to the 2006 level and RMB (renminbi) is the official currency of People's Republic of China.*

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# 7 Discussion and conclusions

This thesis has investigated the relationship between daily commuting behaviours and long-term SWB from a longitudinal perspective. The underlying problem that motivated the thesis is the inconsistent research evidence on the commuting-SWB relationship, and more importantly, the insufficient theoretical conceptualisation of this relationship. As a response to the gap between theoretical understandings and empirical research, this thesis used a processual approach to frame the commuting-SWB relationship as an interdependent process over time (Whitehead, 1929; Schwanen, 2018). To operationalise this processual approach, two ways forward were proposed for longitudinal research, namely retrieving the upstream process that leads to changes in commuting behaviours and enriching the contextual understanding of commuting-SWB relationships. The upstream process of commuting changes pertains to the reason for people to (not) change their commuting behaviours, while the contextual understanding relates to the commuting-SWB relationship as time- and place-specific. Following these two ways forward, the empirical analysis of this thesis drew upon different nationwide panel data and longitudinal modelling methods to investigate the relationships between commuting behaviours and SWB over time. To reiterate, the aim of this thesis was not to identify a unidirectional commuting-SWB causality uniform to the general population and across research areas, but to acknowledge, operationalise and better understand the interdependent commuting-SWB relationships situated in the life courses of people and the socio-spatial contexts of places.

To achieve this aim, this thesis addressed three research questions in five studies. These five studies respectively contain a published paper or a paper manuscript, using nationwide panel data from China, the UK and the Netherlands. The thesis started with a review of longitudinal research to critically discuss the gap between theoretical conceptualisation and longitudinal analysis of the commuting-SWB relationship. In this critical review, the processual approach was introduced to explain inconsistent longitudinal findings and to direct the following empirical research. Next, the longitudinal analysis of this thesis investigated how the commuting-SWB relationships varied after considering different upstream processes of commuting changes. Three upstream processes that led to within-individual



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variations of commuting behaviours were respectively studied in respective contextual areas, i.e., rapid urban growth in China, mandatory working from home during the COVID-19 pandemic in the UK, and the events of residential relocation in the Netherlands. Finally, this thesis proceeded from the individual-level analysis to examine the commuting-SWB relationships from a household perspective. The household-level research in urban China compared the commuting-SWB relationships between husbands and wives and analysed the role of family life stages in the gendered commuting-SWB relationships.

## 7.1 Summary of research results

The literature review in Chapter 2 collected existing longitudinal studies that investigated the relationship between commuting behaviours and SWB over time. Results from these longitudinal studies were far from consistent. Therefore, questions remained unanswered regarding the extent to which motorised and long commuting journeys resulted in low levels of SWB in the long term. To account for inconsistent longitudinal findings, Chapter 2 postulated that understanding commuting-SWB relationships should start from integrating theories from different disciplines, including the utility equilibrium theory from economics, habit and attitude theories from social psychology, and the mobility biographies approach from transport geography. Based on the interdisciplinary theories, the commuting-SWB relationship was conceptualised as an interdependent process over time, (re)shaped by people's past experiences, present circumstances, and future expectations. This directs future longitudinal research to distinguish different processes that lead to changes in commuting behaviours, including environmental changes, information or participatory interventions, and the events of residential relocation together with other life events and long-term processes in life. The processual approach enriches the temporal scope of longitudinal research and contributes to a better understanding of the interdependent commuting-SWB relationships situated in people's life courses and corresponding socio-spatial contexts.

Based on the processual approach as introduced in Chapter 2, this thesis selected three upstream processes of commuting changes for research in the following three chapters. Specifically, Chapter 3 focused on the process of urban growth in China. This process is exogenous to the commuting-SWB relationships, because individuals have little control of government-led urban growth in China and hardly notice its

impact on daily commutes in the short term. In this regard, Chapter 3 examined to what extent people maintained commuting mode choices over time and whether this was associated with long-term psychological stress, using data from the China Health and Nutrition Survey (2006-2015). A time-varying composite scale – urbanicity – was also included to characterise the expansion of urban space and to investigate geographic variations in commuting-stress relationships. The results show that long-duration active commuting relieved psychological stress, while long-duration motorised commuting trips by car or public transport led to higher stress levels. Surprisingly, urban growth did not induce more motorised commuting trips and greater psychological stress in a linear fashion. In medium-level urbanicity areas, rather than high-level ones, the commuting-related stress risks were noticeable the most because of the extremely high duration of commuting by public transport. By focusing on the exogenous process of urban growth, the chapter finally suggested that Chinese cities should change the growth path from expanding urban development land to improving urban amenities and urbanites' wellbeing (Wu, 2015).

Chapter 4 shifted the focus to another exogenous process of commuting changes, mandatory working from home during the COVID-19 pandemic, to analyse how homeworkers reflected on their pre-COVID-19 commuting behaviours. Compared to the gradual process of urban growth, the exogenous shock of COVID-19 contributes to estimating the effect of commuting behaviours on long-term SWB for two reasons. The first reason is the exclusion of any possible compensations from housing and job markets to observe the net impact of reduced or cancelled commuting journeys, and the second reason is that mandatory homeworking regulations enforced a large number of working populations to break habitual commuting routines and deliberately reconsider their commuting wellbeing (Kroesen, 2022). Using the Understanding Society data from the UK, the results from the fixed-effect models only found a positive effect of working from home on affective wellbeing for long-distance commuters (one-way commuting distance > 30 miles). In contrast, commuters who had frequently walked or cycled to work reported worse affective wellbeing and life satisfaction after switching to homeworking. This real-world experiment during the COVID-19 pandemic adds to a stronger claim that daily commutes do influence long-term SWB, and what commuters really appreciate is walking or cycling to work over short distances.

In Chapter 5, residential relocation was regarded as a key event in stimulating changes in commuting mode choices and preferences. Compared to the exogenous process of commuting changes, relocation decision-making might involve a self-selection process, or termed an endogenous process of commuting changes. Specifically, the inconsistency between commuting modes and mode-specific preferences would cause dissatisfaction, which prompted the choices of residential

locations and commuting behaviours (Cao et al., 2009). Moreover, changes in commuting behaviours following the relocation could be a result of changes in residential built environment or/and an adaptation to concurrent life events (Coulter and van Ham, 2013). To examine this, the chapter used the Netherlands Mobility Panel data to analyse the longitudinal relationships between changes in residential built environment, the occurrence of life events, and changes in commuting mode choices and preferences pre-post residential relocation. Netherlands is an interesting case to study because of competitive commuting alternatives to cars (e.g., prevalent cycling culture and well-developed public transport systems) and the polycentric urban regions with diverse housing markets for residential self-selection. The results from the longitudinal structural equation models supported residential self-selection from pre-existing preferences for car and public transport use, while residents would adjust downwards the active commuting preference after moving to a more suburban neighbourhood with longer distances to the job locations and public transport stations. Besides, life events in the household and employment domains, such as childbirth and job changes, often coincided with the relocation event and underlay greater demand for car use.

The above three chapters are based on the individual-level analysis, ignoring that commuting decisions are often reached at the household level, involving gendered power relations in negotiations with other family members. To this end, Chapter 6 took a household perspective to compare gendered commuting-SWB relationships between husbands and wives in urban China. The results from the panel version of seemingly unrelated regression models indicate that husbands and wives similarly had worse life satisfaction as the commuting time of their own increased. Moreover, the results demonstrate the spill-over effects of commuting utility between husbands and wives at different family life stages. Specifically, husbands' life satisfaction was more negatively affected by wives' commuting time than vice versa, while wives' commuting utility was more related to the time pressure from caring for preschool-aged children and the social support from extended family members (i.e., children's grandparents in this study). Especially in a nation putting much weight on the patriarchal and collective culture of the family as China, co-residing with the grandparents contributes to alleviating the utility loss from long commutes for young parents, especially for working mothers (Ta et al., 2019).

## 7.2 Synthesis of research results

The overarching aim of this thesis was to understand why existing research evidence comes to inconsistent findings regarding the relationships between commuting behaviours and long-term SWB. By following people through time, this thesis concludes that commuting journeys in daily life constitute an important component of people's SWB in the long term. However, this does not imply that longer commuting journeys always result in worse SWB outcomes in a linear fashion, even though this unidirectional causal inference is often claimed for favouring longitudinal research designs over the cross-sectional ones (Suppes, 1970). Learning from the processual approach, the thesis posits that longitudinal studies should expand the reasoning process and enrich the contextual interpretation for better understanding the commuting-SWB relationships. The first way forward is actually a step backwards to retrieve the upstream process of commuting changes. It should be investigated whether changes in commuting behaviours occur spontaneously as the travel-related environment evolves over time, or require an intervention to inform and direct alternative commuting choices. Besides, the reason for changing commuting behaviours should be differentiated, namely whether it is exogenous to the commuting-SWB relationship, or it involves a self-selection process to address the pre-existing behaviour-attitude inconsistency. The second way forward is to acknowledge the fact that the commuting-SWB relationship cannot be easily generalised over space and time. Instead, it is sensitive to the socio-spatial contexts under study, including the individual and family life stages of people and the geographic and socio-cultural backgrounds of places. Following these two ways forward does not mean that there is a uniform commuting-SWB causality, but it does contribute to better understanding the interdependent commuting-SWB relationships over time. In what follows, both ways forward are reframed and summarised from theoretical, methodological and practical standpoints.

Theoretically, understanding the commuting-SWB relationship requires an integrative theoretical perspective. The economic framework of individual utility equilibrium alone does not suffice to encapsulate the commuting-SWB relationship. The longitudinal analysis of this thesis shows that people were less happy and satisfied with overall life as their commuting journeys prolonged over time. This result contradicts the utility equilibrium but corroborates the phenomenon of the commuting paradox; that is, individuals do not gain equivalent housing- and job-related compensations to balance off the disutility from longer commutes (Stutzer and Frey, 2008). Furthermore, the thesis has examined whether there is a household-level utility equilibrium. Again, the phenomenon of the commuting



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paradox appeared in the household – husbands were worse off in SWB outcomes as their wife's commuting time increased, while a wife's life satisfaction was related to her own commuting time and moderated by family life stages, resulting in a net commuting disutility at the household level. However, this paradoxical phenomenon does not mean that commuting journeys should be cancelled for improving people's SWB outcomes. This is evidenced by the homeworking experience during the COVID-19 pandemic. Those former commuters missed the benefit of walking or cycling to work by showing worse SWB outcomes when they were mandated to work from home, or put it in another way, people appreciated active commuting over short distances. The positive commuting utility can seek explanations from the attitude theory, claiming that commuting can bring benefits in its own right by involving physical activity into commuting trips, providing the transition opportunity between home and workplaces, and meeting people's innate needs of movement in daily life (Lyons and Chatterjee, 2008).

Methodologically, this thesis has piloted different longitudinal research designs to examine the interdependent relationships between commuting behaviours and long-term SWB over time. Despite increasing availability of nationwide panel data, designing and implementing such longitudinal designs is not easy. It does not only require isolating different upstream processes of commuting changes, but it also requires caution to situate the longitudinal analysis of commuting-SWB relationships appropriately in the socio-spatial contexts of research areas. In either case, there is a risk to simplify the interdependent commuting-SWB relationships. Taking examples from this thesis, people tend to repeat their commuting routines in the gradual process of urban growth (see Chapter 3). Under such stable circumstances, the longitudinal analysis focusing on commuting changes may be biased because a majority of the commuting population keeps their travel habits or does not notice the influence of subtle commuting changes (e.g., increasing commuting time) on SWB. Some exogenous shock, as evidenced by the COVID-19 pandemic in Chapter 4, provides a real-world experiment to examine how people psychologically react to the absence of commuting journeys.

Equally important, appropriate longitudinal modelling methods should be matched with the research designs. In longitudinal studies, fixed-effect modelling analysis is widely used to investigate the impact of changes in commuting behaviours on changes in SWB outcomes without serious consideration. The cost is that those person-year observations with no or little change in commuting behaviours are implicitly dropped out of the longitudinal analysis. For this, the maintaining analysis has been conducted in Chapter 3 and can be furthered by using some advanced panel models (e.g., cross-lagged panel models; Olde Kalter et al., 2021). Other longitudinal studies in this thesis show that structural equation models combined

with the difference-in-difference method perform well in establishing the reciprocal associations and mediating pathways between commuting behaviours and SWB (see Chapter 5), while random-effect seemingly unrelated models can address the spill-over effects of someone's commuting behaviours on the SWB outcomes of another related person (see Chapter 6).

Practically, the longitudinal findings of this thesis provide implications for place-based and people-based policy-makings in intervening commuting behaviours and improving commuters' SWB. From a place-based perspective, urban planning initiatives, such as smart urban growth, transit-oriented development and walkable neighbourhoods, play a structural role in steering environmentally and socially desirable commuting patterns. These place-based initiatives have shown effectiveness in reducing local job-housing mismatch and encouraging the uptake of sustainable means of transport, such as public transport, bicycles and waking (Banister, 2008; Zhao and Li, 2017). This thesis further indicates their potential in satisfying the preference for active commuting over short distances and thus enhancing the SWB outcomes of the commuting population. Besides these place-based planning initiatives, flexible workplace settings (e.g., working from home on some days of the week or working closer to home at satellite offices) and some novel travel modes (e.g., e-bicycle) are also promising to alleviate the burden from long-distance motorised commuting. From a person-centred perspective, travel demand management should be tailored to social groups with heterogeneous travel demands and preferences. To reduce car commuting trips, for example, behaviour interventions should target those neighbourhoods with fewer car lovers and those people who are about to experience major changes in life (e.g., relocating to a suburban housing and giving birth to a child). Possible intervention strategies include educational and information campaigns on environmental awareness, targeted information on sustainable travel alternatives for housing-seeking families and equipping accessible public transport stations around the neighbourhood.

## 7.3 Research limitations and directions for future research

Following the processual way of thinking, this thesis has examined two upstream processes of commuting changes independently (i.e., subtle or abrupt environmental changes and relocation events), which leaves the third upstream process, information/participatory interventions, undiscussed. Different from the studied two processes, information/participatory interventions use soft strategies, such as spreading tailored information about cycling routes and issuing free public transport tickets, to encourage participants to initiate more desirable commuting alternatives (Abou-Zeid and Ben-Akiva, 2012). It thus can be a viable practice to increase the use of sustainable travel modes and the levels of commuters' SWB at the same time. Besides, Chapters 3-5 respectively focused on a specific upstream process of commuting changes. In some cases, however, these upstream processes are not isolated but interrelated with each other, which complicates the understanding of commuting-SWB relationships. For example, people may take the initiative to move out of their former houses when unpleasant environmental changes occur at the residence. It is also unclear if the intervention following major changes in life (e.g., residential relocation) or abrupt environmental changes (e.g., the operation of a new transit line) can better leverage the window of opportunity to promote the commuting patterns that are environmentally sustainable and socially desirable.

Furthermore, a life-course perspective is required to expand the temporal scope for the longitudinal analysis of commuting-SWB relationships. Drawing upon the nationwide multi-wave surveys from three different countries, longitudinal research in this thesis has analysed changes in commuting behaviours and SWB for some years (4 waves in a decade of urban growth in China, 3 waves during the COVID-19 pandemic in the UK, and 2 waves pre-post residential relocation in the Netherlands). This multi-wave analysis can be developed by investigating how travel behaviours evolve over the life course. In this regard, mobility biographies provide an instructive approach for linking the stability and changes in daily travel behaviours to family- and work-related life events, together with other long-term processes in life (e.g., age effects and the learning process; Müggenburg et al., 2015). These interrelated life domains further shape and are reshaped by domain-specific and overall SWB (e.g., satisfaction with daily travel and overall life). This thesis has taken one of the first steps to examine changes in commuting mode choices pre-post the event of residential relocation and the gendered commuting-SWB relationships at

different family life stages. Less understood is how daily travel behaviours, long-term residential mobility, and other life domains are relationally situated in the life course and interrelated with SWB in the long term.

This thesis also has some reflections on longitudinal data collection and analysis. First, the detailed information on travel behaviours and SWB are rarely contained in the nationwide panel surveys. This is why this thesis focused on the longitudinal relationships between commuting behaviours and satisfaction with overall life. The interrelations between commuting travels and non-commuting travels, as well as the pathways linking travel behaviours to overall SWB (e.g., through the mediation of domain-specific SWB), are out of the scope of this thesis. Second, longitudinal data collection often contains a bias from panel attrition. This attrition bias comes from the non-random drop-outs of recruited panel samples in the second or subsequent survey waves (Goodman and Blum, 1996). A possible way to reduce the attribution bias, as conducted in this thesis, is by comparing the studied samples with initially recruited samples regarding their socio-economic characteristics, and then, a weighing scheme can be extracted and applied to the studied samples. Third, another related but different bias in longitudinal research is the sample selection. The selection bias occurs when researchers select a certain group of panel samples to study and generalise the study results to other groups or the general population (Heckman, 1979). In the longitudinal analysis of commuting-SWB relationships, a common practice is removing the panel samples who do not have commuting records in some (but not all) survey waves. As such, a selection bias is implicitly introduced because the selected samples are not representative of the general commuting population intended to be analysed. The Heckman approach used in Chapter 6 can well address this selection bias. Concerning the problems and biases involved in panel data collection and analysis, longitudinal behaviour research should be more cautious in sample screening, selection and description before diving into sophisticated modelling analysis.

## 7.4 Research implications

The processual approach is a promising direction for future longitudinal research to enrich the understanding of commuting-SWB relationships. This thesis theoretically conceptualises people's commuting behaviours and SWB as an interdependent process situated in people's life courses and corresponding socio-spatial contexts. From a life-course perspective, future longitudinal research is warranted to investigate how the travel domain and other life domains interact with each other in the long term. Particularly, it is interesting to study how people adjust commuting behaviours by anticipating, immediately responding to, or lagging behind the occurrence of life events, and how these major changes in life jointly contribute to long-term health status and SWB. Moreover, the learning process during childhood and the succession from the older generation are also possible pathways for shaping people's commuting habits and predisposing their travel-related attitudes. To further the understanding of commuting-SWB relationships, therefore, more longitudinal analyses are expected to expound the process of commuting changes and the dynamics in commuting-SWB relationships over the life course.

The processual approach can also be exercised in behaviour-oriented intervention experiments and relevant policy-makings. In the intervention experiments, participants are often directed to pilot alternative commuting choices (e.g. switching from commuting by car to cycling to work) for a short period of time. To stimulate expected behaviour changes, it is necessary to monitor not only changes in commuting behaviours but also changes in SWB outcomes, such as commuting satisfaction, over time. This is because people are more likely to adjust their travel-related attitudes and develop new travel routines if they find the commuting alternative satisfactory (De Vos et al., 2022). To sustain the behaviour changes, participants' commuting behaviours and SWB should be followed over a longer time period after the intervention. This necessitates the integration of temporary intervention experiments into long-term policy development and evaluation. In the programs of residential estate, for example, trial mobility packages combining free public transport tickets and bike sharing offers can be issued to the newly relocated residents to impede prevalent car use. Furthermore, the ongoing follow-ups after the end of trial mobility packages should be incorporated into the program assessment to ensure that desirable commuting patterns and SWB outcomes are sustained in the long term.

Based on the findings of this thesis, future longitudinal research could develop the processual way of thinking and the contextual way of understanding to investigate the interdependent commuting-SWB relationships over time. When the longitudinal

findings for commuting-SWB relationships are inconsistent with each other, they should not be regarded as a barrier for research to reach a general conclusion, but as a prompt for researchers to use existing longitudinal evidence more cautiously, to design the longitudinal research more carefully, and to interpret inconsistent longitudinal findings more critically. Accordingly, policy implications should carefully consider ways to steer the process of commuting changes and to conduct the intervention tailored for different places and social groups, with the ultimate goal of promoting environmental sustainability and social wellbeing in the long term. As this thesis demonstrated, daily commuting behaviours matter for long-term SWB, but to better understand the commuting-SWB relationships, longitudinal research needs to answer why commuting behaviours change or do not change in the first place and how the commuting-SWB relationships manifest themselves specific to local socio-spatial contexts.

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# Curriculum Vitae

## Yinhua Tao (陶印华)

Yinhua Tao was born in 1995 in Wuhu, and finished high school in Ma'anshan, China. He received his bachelor's degree in Human Geography and Urban-Rual Planning from East China Normal University, China, and the master's degree in Human Geography from Peking University, China. In November 2020, he joined the Urban Studies section at the Faculty of Architecture and the Built Environment, Delft University of Technology, where he continued the health geography and longitudinal behaviour research. His PhD thesis theoretically conceptualises and longitudinally investigates the relationships between commuting behaviours and subjective wellbeing in urban life.

Yinhua has participated in two research programmes, namely the Mobility-based Environmental Exposures and Stress Responses during his master's study, and the Longitudinal Analysis of Commuting behaviours and Subjective wellbeing as his PhD research. He presented his research outputs at the international conferences – the 3rd International Time Geography Conference in Lund (Sweden), the Association of American Geographers (AAG) Annual Meeting in Washinton DC (USA), China's New Urban Agenda: An International Dialogue on Sustainable Development in Manchester (UK), Current Perspectives on Spatial Mobilities at the Institute for Employment Research in Nuremberg (Germany). His research work is published in the Transport Reviews, Transportation Research Part A, Social Science & Medicine, Health & Place, Applied Geography, Annals of the American Association of Geographers, and so on. After obtaining his doctoral degree, Yinhua will continue the longitudinal research in health-related behaviours as a postdoc researcher at the MRC Epidemiology Unit, University of Cambridge.

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# Publications

## Peer-reviewed journal articles

Tao, Y.*(corresponding author), Petrović, A., van Ham, M., & Fu, X. (2023). Residential relocation as a key event in commuting mode shift. *Transportation Research Part D: Transport and Environment*, 119. https://doi.org/10.1016/j.trd.2023.103772.

Tao, Y.*, van Ham, M., Petrović, A., & Ta, N. (2023). A household perspective on the commuting paradox: Longitudinal relationships between commuting time and subjective wellbeing for couples in China. *Transportation Research Part A: Policy and Practice*, 170. https://doi.org/10.1016/j.tra.2023.103640.

Tao, Y.*, Petrović, A., & van Ham, M. (2022). Commuting behaviours and subjective wellbeing: A critical review of longitudinal research. *Transport Reviews*, https://doi.org/10.1080/01441647.2022.2145386.

## Other publications

Tao, Y., Ma, J.*, Shen, Y., & Chai, Y. (2022). Neighborhood effects on health: A multilevel analysis of neighborhood environment, physical activity and public health in suburban Shanghai. *Cities*, 129, 103847.

Shen, Y., & Tao, Y.* (2022). Associations between spatial access to medical facilities and health-seeking behaviors: A mixed geographically weighted regression analysis in Shanghai, China. *Applied Geography*, 139, 102644.

Tao, Y., Kou, L., Chai, Y.*, & Kwan, M. P. (2021). Associations of co-exposures to air pollution and noise with psychological stress in space and time: A case study in Beijing, China. *Environmental Research*, 196, 110399.

Tao, Y., Chai, Y., Zhang, X.*, Yang, J., & Kwan, M. P. (2021). Mobility-based environmental justice: Understanding housing disparity in real-time exposure to air pollution and momentary psychological stress in Beijing, China. *Social Science & Medicine*, 287, 114372.

Tao, Y., Chai, Y., Kou, L.*, & Kwan, M. P. (2020). Understanding noise exposure, noise annoyance, and psychological stress: Incorporating individual mobility and the temporality of the exposure-effect relationship. *Applied Geography*, 125, 102283.

Tao, Y., Yang, J., & Chai, Y.* (2020). The anatomy of health-supportive neighborhoods: A multilevel analysis of built environment, perceived disorder, social interaction and mental health in Beijing. *International Journal of Environmental Research and Public Health*, 17(1), 13-31.

Kou, L., Tao, Y.*, Kwan, M. P., & Chai, Y. (2020). Understanding the relationships among individual-based momentary measured noise, perceived noise, and psychological stress: A geographic ecological momentary assessment (GEMA) approach. *Health & Place*, 64, 102285.

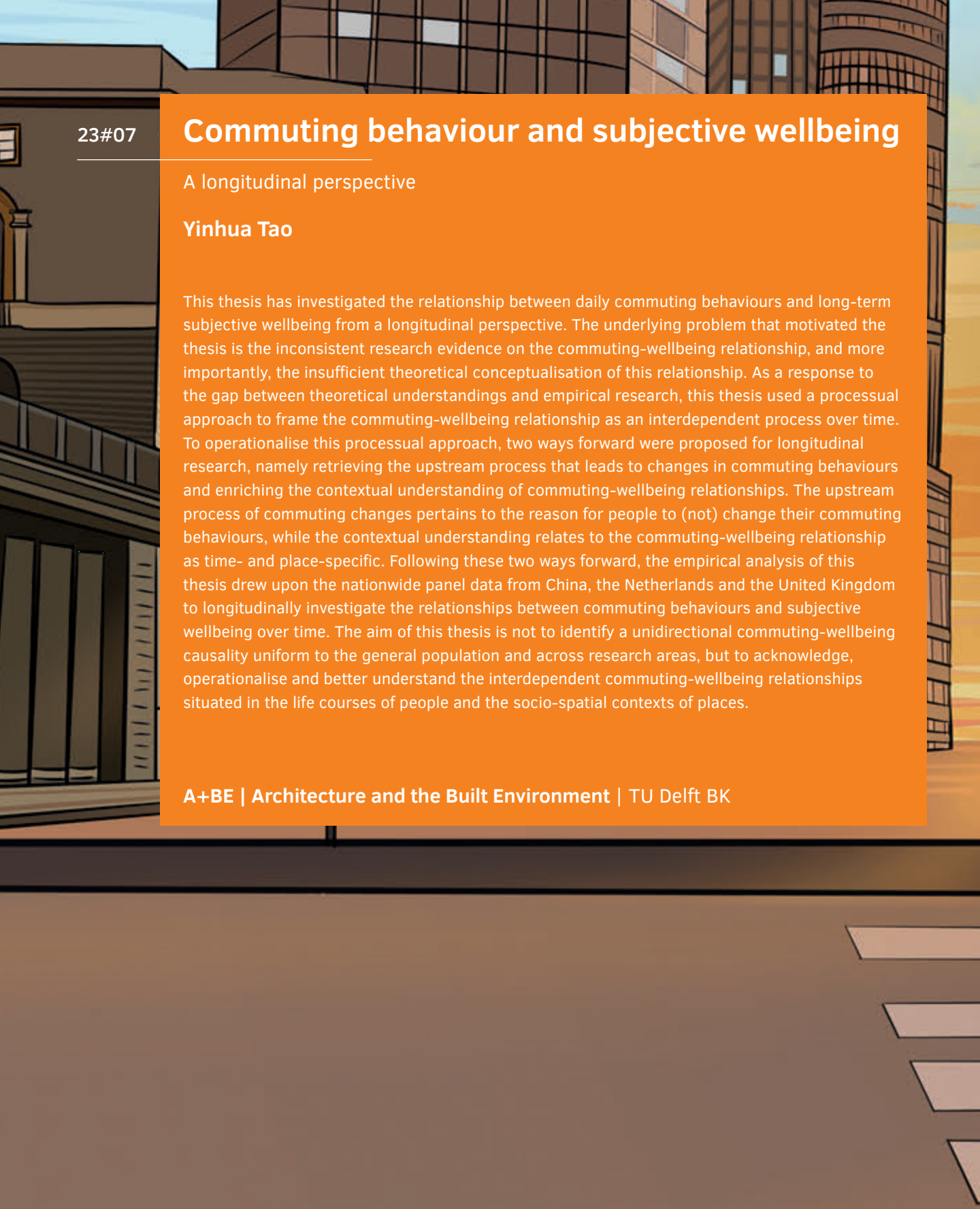
Ma, J., Tao, Y., Kwan, M. P.*, & Chai, Y. (2020). Assessing mobility-based real-time air pollution exposure in space and time using smart sensors and GPS trajectories in Beijing. *Annals of the American Association of Geographers*, 110(2), 434-448.

## Submitted papers

Tao, Y.*, Petrović, A., & van Ham, M. *(submitted to a peer-reviewed journal)*. Working from home and subjective wellbeing during the COVID-19 pandemic in the United Kingdom: The role of pre-COVID-19 commuting distance and mode choices.

Tao, Y.*, *(submitted to a peer-reviewed journal)*. Linking residential mobility with daily mobility: A three-wave cross-lagged panel analysis of travel mode choices and preferences pre-post residential relocation in the Netherlands.

Tao, Y.*, van Ham, M., & Petrović, A. *(submitted to a peer-reviewed journal)*. Changes in commuting mode and the relationship with psychological stress: A quasi-longitudinal analysis in urbanizing China.



23#07

# Commuting behaviour and subjective wellbeing

## A longitudinal perspective

**Yinhua Tao**

This thesis has investigated the relationship between daily commuting behaviours and long-term subjective wellbeing from a longitudinal perspective. The underlying problem that motivated the thesis is the inconsistent research evidence on the commuting-wellbeing relationship, and more importantly, the insufficient theoretical conceptualisation of this relationship. As a response to the gap between theoretical understandings and empirical research, this thesis used a processual approach to frame the commuting-wellbeing relationship as an interdependent process over time. To operationalise this processual approach, two ways forward were proposed for longitudinal research, namely retrieving the upstream process that leads to changes in commuting behaviours and enriching the contextual understanding of commuting-wellbeing relationships. The upstream process of commuting changes pertains to the reason for people to (not) change their commuting behaviours, while the contextual understanding relates to the commuting-wellbeing relationship as time- and place-specific. Following these two ways forward, the empirical analysis of this thesis drew upon the nationwide panel data from China, the Netherlands and the United Kingdom to longitudinally investigate the relationships between commuting behaviours and subjective wellbeing over time. The aim of this thesis is not to identify a unidirectional commuting-wellbeing causality uniform to the general population and across research areas, but to acknowledge, operationalise and better understand the interdependent commuting-wellbeing relationships situated in the life courses of people and the socio-spatial contexts of places.

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