# Changes in commuting mode and the relationship with psychological stress
## A quasi-longitudinal analysis in urbanizing China

Tao, Yinhua; van Ham, Maarten; Petrović, Ana

**DOI**
10.1016/j.tbs.2023.100667

**Publication date**
2024

**Document Version**
Final published version

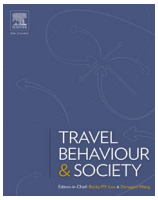
**Published in**
Travel Behaviour and Society

Travel Behaviour and Society 34 (2024) 100667

Contents lists available at ScienceDirect

Travel Behaviour and Society

journal homepage: www.elsevier.com/locate/tbs



# Changes in commuting mode and the relationship with psychological stress: A quasi-longitudinal analysis in urbanizing China

Yinhua Tao [a,b,*], Maarten van Ham [a], Ana Petrović [a]

[a] Faculty of Architecture and the Built Environment, Delft University of Technology, 2628 BL Delft, the Netherlands
[b] MRC Epidemiology Unit, University of Cambridge, CB2 0QQCambridge, the United Kingdom

ARTICLE INFO

*Keywords:*
Urban growth
Commuting behavior
Health
Subjective well-being
Longitudinal designs
Developing countries

ABSTRACT

Emerging longitudinal research on the relationship between commuting mode 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 relationship over time. The results show that maintaining car commuting and long-duration active commuting were associated with lower levels of psychological stress, while long-duration motorised commuting trips by car or public transport were predictive of higher stress levels. Moreover, high-urbanicity areas involved more active commuting trips and short motorised commuting trips, which were beneficial to long-term 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 in China, we recommend that urban governments should change the focus from expanding urban development land to improving urban amenities and urbanites' wellbeing.

## 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 distance and increasing motorised commuting trips. According to the commuting monitoring report of 44 cities of China (2022), 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 8.2 km and 36 min. Current public transport systems, however, only allow 45% of the Chinese urban population to access job locations within 45 min, so many commuters have to use private cars to commute. The over-reliance on cars and the lack of active commuting not only reduce the efficiency of urban transportation and energy use, but also pose 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, such as obesity, chronic diseases and all-cause mortality (e.g., Flint et al., 2016; Treff et al., 2017; Patterson et al., 2020). However, research evidence on the effects of commuting mode on psychological wellbeing focuses mostly on the momentary or short-term effects, such as the well-studied commuting stress (Novaco et al., 1979). There is no consensus regarding the commuting-wellbeing relationship in the longer term (see recent literature reviews by Chatterjee et al. 2020 and Tao et al. 2023a). In recent years, longitudinal studies in several developed countries (e.g., the UK and Germany) have explored whether changes in commuting mode choices induce psychological problems over time. Their results generally show that a switch to car commuting leads to worse psychological wellbeing in the long term, compared with maintaining commuting by public transport and active modes (e.g., Martin et al., 2014; Lorenz, 2018; Clark et al., 2020). In contrast, little evidence can be gained from developing countries, including urbanizing China, where rapid urban growth seems synchronous with urban commuting problems and urbanites' psychological disorders (Tao et al., 2023d).

* Corresponding author at: Faculty of Architecture and the Built Environment, Delft University of Technology, 2628 BL Delft, the Netherlands.
*E-mail address:* yh.tao@hotmail.com (Y. Tao).

https://doi.org/10.1016/j.tbs.2023.100667
Received 14 September 2021; Received in revised form 12 July 2023; Accepted 25 August 2023
Available online 30 August 2023

Moreover, people's commuting behaviours are varying at different stages of urban growth, so the analysis of the commuting-wellbeing relationship will benefit from considering geographic variances in commuting mode choices over time. Previous research has used urban population or land use density to measure urban growth and to delineate time-varying commuting patterns (Adams, 1970; Sultana and Weber, 2014). However, their results are limited in explaining the long-term psychological outcome of commuting behaviours. One of the reasons is that urban characteristics related to people's commuting and wellbeing incorporate 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, termed as 'urbanicity' (Vlahov and Galea, 2002; Cyril et al., 2013). Embracing a time-varying and neighbourhood-level composite urbanicity scale can not only identify temporal trends in using different commuting modes within areas of similar levels of urbanicity, but also allow for a comparison of commuting mode choices and associated psychological outcomes 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.

Our study drew upon the China Health and Nutrition Survey (CHNS) dataset (2006–2015) to investigate the associations of changes in commuting mode and mode-specific duration with the outcome of long-term psychological stress. This quasi-longitudinal design contributes to the international research evidence by understanding changes in commuting behaviours over time and the relationship with psychological wellbeing in urbanising China, and equally importantly, by scrutinising the geographic variances in this relationship among different urbanicity areas. Specifically, we started with describing changes in commuting mode and mode-specific duration across urbanicity areas in the studied ten years. Note that the research outcome, long-term psychological stress, was only measured at the last wave of the CHNS in 2015, which limited our ability to use a more stringent longitudinal design. For this consideration, we employed a before-and-after design 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.

## 2. Literature review: Urban commuting and psychological wellbeing

As early as the 1970s, the definition 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 a commuting trip, 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 means of transport, while commuting by public transport and car usually involves higher levels of experienced stress (Legrain et al., 2015; Chatterjee et al., 2020).

Although commuting is considered as a daily episode with higher levels of negative affect than 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 found that certain commuting modes are associated with people's psychological outcomes in both directions. For example, car users tend to regard 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). On the opposite, studies in urban China indicate that car commuting is associated with better life satisfaction and general mental health than long commuting trips by public transport (Zhu et al., 2019; Sun et al., 2021). Regarding the effects of active travel modes, walking or cycling to work is less connected with psychological wellbeing than with physical health. The significant psychological benefit of active mode use is only observed for commuting trips with relatively long duration and in large cities with an accessible natural environment (Legrain et al., 2015; Zijlema et al., 2018; Tao et al., 2023c). In addition, some studies show negligible commuting-wellbeing associations irrespective of travel modes (Hansson et al., 2011; Dickerson et al., 2014; Higgins et al., 2018). Their explanation is that commuters can adapt to the daily hassle of their commuting trips in the long term, 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 (Tao et al., 2023a). Compared with cross-sectional designs, longitudinal designs can not only control for the time-invariant factors confounding the exposure-outcome temporality, but also account for the commuting-induced psychological problems that cumulate over time. To date, however, the evidence drawn from longitudinal studies is weak and focuses exclusively on cities of developed countries. For example, Martin et al. (2014) draw upon the British Household Panel Survey (BHPS) to find that switching from a car to an active commuting mode, including walking, cycling, or public transport, greatly improves general psychological wellbeing in contrast with maintaining car use. After differentiating active mode and public transport, Jacob et al. (2021) show that switching from a car to an active mode enhances general psychological wellbeing, while the switch from an active mode to public transport significantly reduces satisfaction with health. 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 (i.e., public transport and cars) contribute to lower life satisfaction through reduced satisfaction with leisure time. Taken together, reasons for these mixed findings might include differences in survey protocols and research contexts, the inclusion of 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 over time after taking into account the uneven process of urban growth. This is of great concern in urbanizing China, where rapid urban expansion has induced greater job-housing distance and increasing motorised commuting trips over the past two decades (Wang and Chai, 2009; Ta et al., 2017; Tao et al., 2023d). To delineate the spatiotemporal dynamics in commuting patterns, previous research has used 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 also supports that growth in populations and jobs follows each other with time so commuting costs would decrease over a longer timescale (Vale, 2013; Tao, 2023). 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., accessible job locations within walking distance and reliable public transport infrastructure).

When extending to the psychological outcomes of commuting behaviours, research that relies solely on the density indicator does not

sufficiently take into account the contextual exposure to multidimensional urban environments relevant to public health and wellbeing, thereby mis-specifying the 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 choices and psychological outcomes at the same time (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 has the advantages in comparing the psychological effects of commuting modes among areas of different levels of urbanicity, as well as in examining how changes in commuting mode are related to long-term psychological outcomes within areas with similar urbanicity levels.

## 3. Data and methods

### 3.1. Data

The China Health and Nutrition Survey (CHNS) was designed for monitoring temporal dynamics in people's health-related behaviours and health outcomes related to 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 and 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 of 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 modes and psychological stress for a decade of urban growth 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 the last wave in 2015 (termed as the follow-up survey year in this study) and at least another survey wave in 2006, 2009 or 2011 (termed as the baseline survey years) constituted the longitudinal samples and were used in the modelling analysis. Table A1 shows the socioeconomic characteristics of the eligible samples, pooled samples and longitudinal samples with the comparison of the socioeconomics of the general working-aged population (20–65 years old) drawn from the latest census data in 2010. Overall, the eligible samples include more well-educated (university or above) and middle-aged (30–49 years old) urban residents compared with the census population. Even so, the characteristics of the eligible samples are similar to those of the pooled samples, while the longitudinal samples were mildly underrepresented for old-aged (50–65 years old) and low-income (0–1,500 RMB/month) populations.

### 3.2. Variables

The outcome variable is psychological stress, one of the affective components of long-term psychological wellbeing. Psychological stress is measured by the well-established 14-item Perceived Stress Scale (PSS14; Katsarou et al., 2012). 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). 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, which determined our study to be quasi-longitudinal in nature.

The primary predictors of interest are changes in commuting modes and the duration of using different travel modes from baseline to follow-up. Specifically, commuting modes were coded as active mode (walking 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 mainly used for their daily commuting trips. This multimodal behaviour takes place when respondents combine different travel modes in their commuting trips (e.g., cycling to transit stations and then taking public transport to work), or they use a certain travel mode (e.g., public transport) on some days of the week and use another mode (e.g., cars) in other days. Given the possibility of misclassifying mode switch behaviours and the time uncertainty for the mode switch between survey waves, 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 other travel modes). Research on maintaining a certain commuting mode also allows for identifying the long-term impact of mode use on psychological health problems which often take time to appear. Additionally, respondents reported the duration of using each commuting mode on a routine workday. In the modelling analysis, we included 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 developed specifically for the CHNS (Jones-Smith and Popkin, 2010). The urbanicity scale employed information on residential neighbourhoods in 12 domains, such as population, economic activities, social services, transportation infrastructure, etcetera (see Table A2). 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; Tao et al., 2023c,d), four subsets of covariates that might confound the commuting-wellbeing relationship were included, namely respondents' socio-economic characteristics, health-related lifestyles, major changes in life, and general health and wellbeing statuses. The time-invariant socio-economics were controlled for at baseline levels, while the time-varying health-related behaviours and general health and wellbeing statuses were adjusted for both at baseline levels and by changes between baseline and follow-up. Besides, the variables of major changes in life are getting married, giving birth to a child, job changes and income changes from baseline to follow-up years. Note that housing-related factors were treated as time-invariant because the CHNS surveys only followed respondents who did not change their residential addresses between survey waves. The city of residence and baseline survey years were also included to take into account the city and time fixed effects. For detailed variable measures and descriptive statistics, see Appendix Table A3.

### 3.3. Methods

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, after controlling for health and wellbeing statuses at baseline. Given the cluster sampling procedure, multilevel linear regression with random intercepts was employed to control for neighbourhood-level variances in psychological stress. 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 baseline covariates, including socio-economic characteristics, the city of residence and baseline survey years. Major changes in life and health-related lifestyles were respectively included in model 2 and model 3 to investigate their mediating effects on the commuting-stress relationship. In model 4, the variables of chronic diseases and life satisfaction were added to examine if the observed commuting-stress relationship was independent from baseline health and wellbeing statuses and their concurrent changes at follow-up. 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 the robustness of the commuting-stress relationship. First, we transformed the reference category of changes in commuting mode to focus on different 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. Second, we examined gender differences in the commuting-stress relationship by separately running the fully adjusted models for men and women.

## 4. Results

### 4.1. Descriptive results

Table 1 shows the descriptive statistics of the pooled samples, focusing on the temporal variations in commuting modes, mode-specific duration and 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 min to 49.5 min in a day. Especially, commuting duration by public transport was as high as around 60 min/day between 2011 and 2015. Regarding long-term psychological wellbeing, commuters generally increased the levels of life satisfaction with time, and the mean score of psychological stress was 22.3 in 2015. 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 modes and duration for areas of different urbanicity levels from 2006 to 2015 (Fig. 1). In low urbanicity areas, the mean duration of a two-way commuting trip stayed constant at around 35 min/day until 2011, and then drastically increased to 50 min/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 use. Medium urbanicity areas had similar trends of changing proportions of car and active commuting trips. However, public transport remained a major part of people's everyday commute given its increasingly long duration and share. In high urbanicity areas, the distribution of commute modes 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 min/day.

### 4.2. Modelling results

Drawing from the longitudinal samples, the multilevel linear regression model results for the commuting-stress relationship are shown in Tables 2-3. Specifically, Table 2 reports the associations of changes in commuting mode and duration with psychological stress at follow-up, stratified by baseline commuting mode. Table 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 around one-third of random variances in psychological stress, indicative of a valid multilevel structure (see the results of the fully-adjusted model 5 in Appendix Table A4).

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 1, Model 1). However, active

**Table 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 time[c] | | 32.6 (45.8) | 35.3 (45.3) | 44.2 (55.0) | 49.5 (66.0) | ** |
| Life satisfaction | | 3.6 (1.0) | 3.6 (0.9) | 3.7 (0.8) | 3.8 (0.8) | * |
| (Very) good | | 1224 (53.1) | 1248 (52.0) | 1938 (55.0) | 1935 (63.2) | ** |
| Moderate or (very) bad | | 1080 (46.9) | 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 * $p < 0.05$, ** $p < 0.01$.
c. Commuting time is the duration of a two-way commuting trip between home and workplace in a day.
d. — represents not appliable.

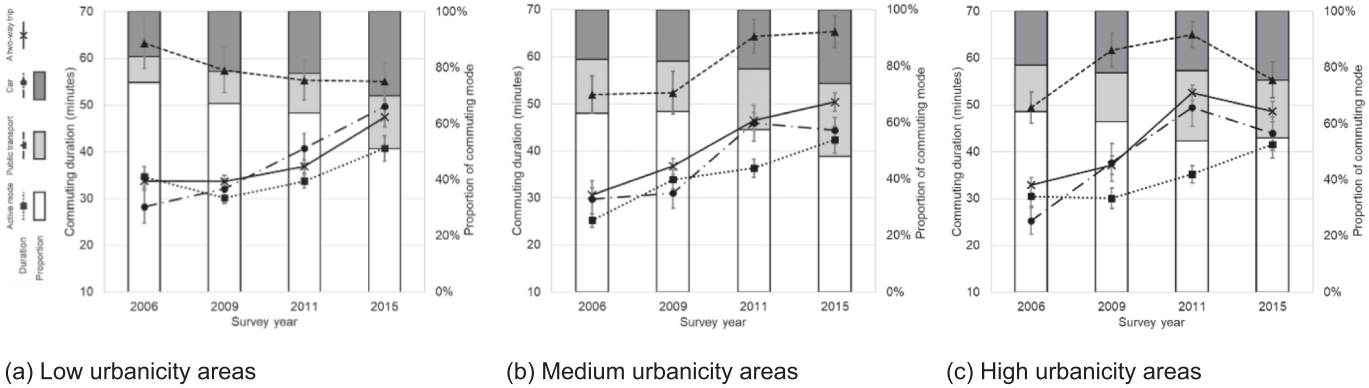



**Fig. 1.** Commuting mode and duration over time for low, medium and high urbanicity areas.

**Table 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 (SE)[e] | β (SE) | β (SE) | β (SE) |
| *Baseline active mode (N = 1053)* | | | | |
| Changes in active commuting | | | | |
| Switching to another mode (N = 336) | Reference | Reference | Reference | Reference |
| Maintaining active mode (N = 717) | 0.32 (0.46) | 0.36 (0.46) | 0.32 (0.45) | 0.32 (0.45) |
| Active commuting duration at baseline | −0.36* (0.16) | −0.34* (0.17) | −0.35* (0.16) | −0.41** (0.15) |
| Changes in active commuting duration | −0.00 (0.01) | −0.00 (0.01) | −0.01 (0.01) | −0.01 (0.01) |
| *Baseline public transport (N = 470)* | | | | |
| Changes in public transport commuting | | | | |
| Switching to another mode (N = 209) | Reference | Reference | Reference | Reference |
| Maintaining public transport (N = 261) | −0.67 (0.56) | −0.76 (0.57) | −0.78 (0.58) | −0.80 (0.58) |
| Commuting duration by public transport at baseline | 0.19 (0.23) | 0.32 (0.43) | 0.24 (0.34) | 0.30 (0.43) |
| Changes in commuting duration by public transport | −0.00 (0.01) | −0.00 (0.01) | −0.00 (0.01) | −0.00 (0.01) |
| *Baseline car (N = 561)* | | | | |
| Changes in car commuting | | | | |
| Switching to another mode (N = 202) | Reference | Reference | Reference | Reference |
| Maintaining car (N = 359) | −1.50** (0.59) | −1.26* (0.59) | −1.22* (0.58) | −1.01 (0.59) |
| Commuting duration by car at baseline | 1.01* (0.39) | 1.05** (0.39) | 0.93 (0.46) | 0.95* (0.44) |
| Changes in commuting duration by car | 0.02* (0.01) | 0.02* (0.01) | 0.02* (0.01) | 0.02* (0.01) |

a. Adjusted for baseline covariates, including demographics, housing, baseline income, the city of residence and baseline survey years.
b. As model 1, plus major changes in life.
c. As model 2, plus health-related lifestyles.
d. As mode 3, plus life satisfaction and physical diseases.
e. Results are shown in the unstandardised coefficients (β) and standard errors (SE). * $p < 0.05$, ** $p < 0.01$.

**Table 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 (N = 1053) | Public transport (N = 470) | Car (N = 561) |
| | β (SE)[b] | β (SE) | β (SE) |
| Changes in commuting mode | | | |
| Switching to another mode | Reference | Reference | Reference |
| Maintaining baseline mode | 0.53 (0.64) | −0.23 (0.48) | −0.51* (0.28) |
| Commuting duration at baseline | −0.14 (0.11) | 0.20 (0.38) | 0.31 (0.37) |
| Changes in commuting duration | −0.01 (0.01) | −0.03 (0.02) | 0.01 (0.01) |
| Urbanicity at baseline | | | |
| Low urbanicity | Reference | Reference | Reference |
| Medium urbanicity | 2.17* (0.89) | 1.56 (0.94) | 1.05 (0.67) |
| High urbanicity | −1.03* (0.52) | −1.18* (0.56) | −1.14 (0.74) |
| Urbanicity * Commuting mode | | | |
| Low urbanicity * Maintaining baseline mode | Reference | Reference | Reference |
| Medium urbanicity * Maintaining baseline mode | −0.39 (0.48) | 0.87 (0.64) | −0.49 (0.38) |
| High urbanicity * Maintaining baseline mode | −0.28 (0.37) | −0.67 (0.45) | −0.78* (0.42) |
| Urbanicity* Commuting duration at baseline | | | |
| Low urbanicity * Baseline commuting duration | Reference | Reference | Reference |
| Medium urbanicity * Baseline commuting duration | −0.36* (0.17) | 1.36** (0.50) | 1.42** (0.37) |
| High urbanicity * Baseline commuting duration | −0.57** (0.20) | −0.81 (0.93) | 0.12 (0.29) |
| Urbanicity* Changes in commuting duration | | | |
| Low urbanicity * Commuting duration change | Reference | Reference | Reference |
| Medium urbanicity * Commuting duration change | −0.01 (0.01) | 0.06* (0.02) | 0.03* (0.01) |
| High urbanicity * Commuting duration change | −0.02* (0.01) | 0.01 (0.03) | 0.01 (0.02) |

a. Covariates as model 4.
b. Results are shown in the unstandardised coefficients (β) and standard errors (SE). * $p < 0.05$, ** $p < 0.01$.

commuting with a longer duration was associated with lower levels of psychological stress (Model 1). After adjusting for general health and wellbeing statuses at baseline and their concurrent changes till follow-up, the effect size of active commuting duration was even larger and baseline life satisfaction was predictive of follow-up psychological stress (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 indicative of marginally lower levels of psychological stress

(see Table 3).

For baseline public transport commuters, neither maintaining public transport nor commuting duration by public transport was associated with follow-up psychological stress (Model 4). It is intriguing that public transport commuters had significantly higher levels of psychological stress in medium urbanicity areas (Model 5), where the absolute commuting duration by public transport was the highest among urbanicity areas (Fig. 1). 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. Moreover, a prolonged 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 effect on lowering follow-up psychological stress (Model 1), and this effect to some extent attenuated but stayed significant after adjusting for major changes in life (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 stress effect of baseline commuting duration was only marginally significant at $p < 0.10$ after controlling 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 prolonged commuting duration by car led to even higher stress levels in medium urbanicity areas (Model 5). In high urbanicity areas, maintaining car commuting was marginally predictive of lower levels of psychological stress at follow-up.

Results for the relationships between covariates and psychological stress are shown in Table A4. Regarding the results for baseline socio-economic characteristics, urban residents, people older than 50 years, high-income people (>3000 RMB/month) and housing owners had lower stress levels than rural-to-urban migrants, young people (18–30 years old), low-income people (<1500 RMB/month) 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. Besides these baseline socio-economics, life transitions between baseline and follow-up years were also significant indicators of psychological stress at follow-up. Specifically, giving birth to a child and the increase in income were predictive of lower stress levels. These major changes in family and personal lives might confound the effects of maintaining car use on alleviating psychological stress (as shown in model 2). Regarding the results for health-related lifestyles, (changes in) sleep time did not show a systematic relationship with follow-up psychological stress, while frequent exercisers had lower levels of psychological stress and the transition from less frequent to more frequent exercises marginally decreased the stress levels. Regarding the effects of life satisfaction and physical diseases, not only the baseline status but also changes in value from baseline to follow-up were strongly and significantly associated with follow-up psychological stress. This entails our quasi-longitudinal study to control for (changes in) general health and wellbeing statuses. Finally, there were no systematic associations of psychological stress with baseline survey years and city-level factors after taking into account the two-level data structure (e.g., individual respondents nested in the residential neighbourhoods).

### 4.3. Sensitivity analysis results

The results of several sensitivity analyses are shown in Tables A5 and A6. First, we corroborated the psychological benefit of car commuting, because 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 A5). This is particularly the case for baseline public transport commuters in medium urbanicity areas. In high urbanicity areas, however, switching from car to active commuting was marginally associated with lower levels of psychological stress. Second, men and women showed little difference in the commuting-stress relationship, except that women were psychologically more stressed with longer commuting duration by motorised means of transport while men were less stressed with longer active commuting duration (Table A6).

## 5. Discussion and conclusions

### 5.1. Interpretation of main findings

Our study investigated changes in commuting patterns for a decade of urbanising China, and further, analysed how these changes in commuting mode and mode-specific duration were associated with long-term psychological stress among different urbanicity areas. The main findings are that rapid urban growth in China had contributed to increasingly motorised commuting patterns, especially greater car use for commuting, along with longer commuting duration from 2006 to 2015. In contrast, cycling or walking to work had been losing its appeal in the ten-year study period, even though it still constituted around half of the commuters' mode choice in 2015. Regarding the impact of commuting modes on psychological stress, the car was the means of transport that imposed the least stress burden. Even so, longer-duration commuting trips by motorised travel mode (i.e., car and public transport) were predictive of higher levels of psychological stress, while active commuting for a longer duration was associated with lower stress levels. 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 motorised commuting trips that contributed to lower levels of psychological stress. By contrast, 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 switched to other travel modes. Second, switching from public transport or active modes to cars was associated with lower stress levels compared with maintaining public transport or active modes. This finding is consistent with recent cross-sectional evidence in urban China (Zhu et al., 2019; Sun et al., 2021), but is discordant with some longitudinal evidence in cities of developed countries (Roberts et al., 2011; Martin et al., 2014). Their longitudinal 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 modes to exclude the active parts (e.g., cycling to transit stations) of a commuting trip undertaken mainly by public transport and corroborated the psychological benefits of car use as the cross-sectional findings in China. The impact of switching from active modes to cars on alleviating psychological stress could relate to the fact that rapid urban growth in China has led to an increasing job-housing mismatch. Under this circumstance, previous active commuters would be psychologically more relieved if they could switch to car use to cover longer commuting journeys. Besides, major changes in life, such as giving birth to a child and gaining more disposable income, could increase the demand for car use and mitigate psychological problems at the same time (Tao, 2023). Our model results also support that after taking into account these life transitions, the effect of maintaining car commuting on lowering stress levels was attenuated to some extent. For these considerations, possible pathways accounting for the psychological benefits of car commuting, such as contextual (e.g., job-housing mismatch and less exposure to environmental hazards) and socio-psychological factors (e.g., great controls over daily life and a visible sign of affluence) still warrant further examination in urban China.

Despite the psychological benefits of maintaining car commuting, we found that longer commuting duration by car was predictive of higher levels of psychological stress. Aside from the attention fatigue and congestion experiences of long-duration car commuting trips, it is likely that long commuting duration restricts the disposable time for health-related activities, such as leisure and sleep. Consistent with the findings from American and European cities (Künn-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 health-related behaviours, and a lower stress level was associated with more frequent recreational exercises (but not with sleep time). Simply put, 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 stress levels at follow-up. The reason is explained by another study that walking or cycling to work for a longer time involves higher intensity of physical activity with positive moods and is more likely to meet the required dose of generating long-term psychological benefits (Martin et al., 2014). A recent natural experiment during the COVID-19 pandemic also indicates pre-pandemic active commuters miss their commuting experiences when they are mandated to working from home, thereby showing more affective symptoms (e.g., feeling upset, depressed and nervous; Tao et al., 2023c). 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 was 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 often lags behind the urban land expansion. As shown in Fig. 1, public transport commuters in medium urbanicity areas had to endure more than 1 h for daily commuting trips. This not only causes great opportunity costs for participating in health-related activities, but also implies the inflexibility of and loss of control for commuting trips due to unpredictable delays and multiple transfers (Hansson et al., 2011; Chatterjee et al., 2020), jointly contributing to long-term psychological stress. In this case, public transport commuters are likely to switch to car use for commuting and thus relieve from commuting-induced psychological stress. Generally, our 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.

### 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-related psychological wellbeing. Using the neighbourhood-level urbanicity scale, our study extended Adams' growth waves and the commuting transition hypothesis to examine a finer-grained geographic pattern of commuting behaviours over time. We found that the later stage of urban growth with high urbanicity levels made for the reduced motorised commuting duration and increased active commuting trips, which contributes to lowering psychological stress in the long term. Therefore, urban growth is 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 and decentralizing employment opportunities. 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 (Sultana and Weber, 2014; Yin et al., 2023).

In the context of urbanizing China, however, rapid urban growth might not spontaneously create high urbanicity areas conducive to people's commuting experiences 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, 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. Then, the newly-developed land was leased to commercial and residential markets to earn the differential rural–urban land rent. One remarkable downside of 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 (Wang and Wang, 2016; Ta et al., 2017). As a result, an increasing number of commuters turn to motorised means of transport, especially private cars, to commute long to work. Notably, this trend is expected to be intensified in urbanizing China, given the absolutely low share of car commuters and the psychological benefits of maintaining or switching to car commuting as shown in our study.

## 6. Limitations

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 modes from baseline to follow-up and long-term psychological stress at follow-up. We also carefully separated the time-varying and time-invariant covariates, as well as adjusting for baseline and changes in general health and wellbeing statuses. Even so, we are still cautious to conclude the causal commuting-stress relationship. 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 urban societies (Tao et al., 2023c). Besides, the under-representation of low-income and old-aged commuters in the longitudinal samples might underestimate the long-term stress effect resulting from longer commuting duration or/and less car use in these groups. Third, our study did not investigate the event of residential relocation as another major change in life because the on-site CHNS survey lost to follow those households who relocated their houses between survey waves. Residential relocation is an interesting event for longitudinal research because it could involve a self-selection process where people regard relocation as a way to temper their stressful commuting journeys (Tao, 2023; Tao et al., 2023b). Fourth, our study did not expound on the pathways linking commuting mode and psychological stress. We recommend future studies to examine more

detailed contextual and socio-psychological mediators in explaining the commuting-stress relationship.

## 7. Concluding remarks

Given the worrying trend of longer commuting journeys and greater car use in urbanising China, our study represents one of the first quasi-longitudinal analyses on the relationship between commuting modes and psychological wellbeing. 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 by car or public transport. We further identified that commuting-related stress risks were prominent the most in rapidly urbanizing areas with medium urbanicity levels. High-urbanicity areas, however, 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 urban China, we urge researchers and policymakers to refocus the urban growth path from urban space expansion to urbanicity and urban lives.

## CRediT authorship contribution statement

**Yinhua Tao:** Conceptualization, Methodology, Formal analysis, Writing – original draft. **Maarten van Ham:** Supervision, Writing – review & editing. **Ana Petrović:** Supervision, Writing – review & editing.

## Declaration of Competing Interest

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

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tbs.2023.100667.

## References


Adams, J.S., 1970. Residential structure of Midwestern cities. Ann. Assoc. Am. Geogr. 60 (1), 37–62.

Chatterjee, K., Chng, S., Clark, B., Davis, A., De Vos, J., Ettema, D., Handy, S., Martin, A., Reardon, L., 2020. Commuting and wellbeing: a critical overview of the literature with implications for policy and future research. Transport Rev. 40 (1), 5–34.

Clark, B., Chatterjee, K., Martin, A., Davis, A., 2020. How commuting affects subjective wellbeing. Transportation 47 (6), 2777–2805.

Commuting monitoring report of 36 cities of China, 2022. https://huiyan.baidu.com/cms/report/2022tongqin/.

Cyril, S., Oldroyd, J.C., Renzaho, A., 2013. Urbanisation, urbanicity, and health: A systematic review of the reliability and validity of urbanicity scales. BMC Public Health 13 (1), 1–11.

Dickerson, A., Hole, A.R., Munford, L.A., 2014. The relationship between well-being and commuting revisited: does the choice of methodology matter? Reg. Sci. Urban Econ. 49, 321–329.

Fan, Y., Allen, R., Sun, T., 2014. Spatial mismatch in Beijing, China: implications of job accessibility for Chinese low-wage workers. Habitat Int. 44, 202–210.

Feng, Z., Boyle, P., 2014. Do long journeys to work have adverse effects on mental health? Environment and Behavior 46 (5), 609–625.

Flint, E., Webb, E., Cummins, S., 2016. Change in commute mode and body-mass index: prospective, longitudinal evidence from UK Biobank. Lancet Public Health 1 (2), e46–e55.

Hansson, E., Mattisson, K., Björk, J., Östergren, P.O., Jakobsson, K., 2011. Relationship between commuting and health outcomes in a cross-sectional population survey in southern Sweden. BMC Public Health 11 (1), 834.

Higgins, C.D., Sweet, M.N., Kanaroglou, P.S., 2018. All minutes are not equal: Travel time and the effects of congestion on commute satisfaction in Canadian cities. Transportation 45 (5), 1249–1268.

Ingenfeld, J., Wolbring, T., Bless, H., 2019. Commuting and life satisfaction revisited: Evidence on a non-linear relationship. J. Happiness Stud. 20 (8), 2677–2709.

Jacob, N., Munford, L., Rice, N., Roberts, J., 2021. Does commuting mode choice impact health? Health Econ. 30 (2), 207–230.

Jones-Smith, J.C., Popkin, B.M., 2010. Understanding community context and adult health changes in China: Development of an urbanicity scale. Soc. Sci. Med. 71 (8), 1436–1446.

Kahneman, D., Krueger, A.B., Schkade, D.A., Schwarz, N., Stone, A.A., 2004. A survey method for characterizing daily life experience: The day reconstruction method. Science 306 (5702), 1776–1780.

Katsarou, A., Panagiotakos, D., Zafeiropoulou, A., Vryonis, M., Skoularigis, I., Tryposkiadis, F., Papageorgiou, C., 2012. Validation of a Greek version of PSS-14: A global measure of perceived stress. Cent. Eur. J. Publ. Heal. 20 (2), 104–109.

Künn-Nelen, A., 2016. Does commuting affect health? Health economics 25 (8), 984–1004.

Legrain, A., Eluru, N., El-Geneidy, A.M., 2015. Am stressed, must travel: The relationship between mode choice and commuting stress. Transport. Res. F-Traf. 34, 141–151.

Lorenz, O., 2018. Does commuting matter to subjective well-being? J. Transp. Geogr. 66, 180–199.

Martin, A., Goryakin, Y., Suhrcke, M., 2014. Does active commuting improve psychological wellbeing? Longitudinal evidence from eighteen waves of the British Household Panel Survey. Prev. Med. 69, 296–303.

Morris, E.A., Zhou, Y., 2018. Are long commutes short on benefits? Commute duration and various manifestations of well-being. Travel Behav. Soc. 11, 101–110.

Novaco, R. W., Gonzalez, O. I., 2009. Commuting and well-being. Technology and Well-being 3, 174–4.

Novaco, R.W., Stokols, D., Campbell, J., Stokols, J., 1979. Transportation, stress, and community psychology. Am. J. Commun. Psychol. 7 (4), 361–380.

Patterson, R., Panter, J., Vamos, E.P., Cummins, S., Millett, C., Laverty, A.A., 2020. Associations between commute mode and cardiovascular disease, cancer, and all-cause mortality, and cancer incidence, using linked Census data over 25 years in England and Wales: A cohort study. Lancet Planet. Health 4 (5), e186–e194.

Popkin, B.M., Du, S., Zhai, F., Zhang, B., 2010. Cohort Profile: The China Health and Nutrition Survey—monitoring and understanding socio-economic and health change in China, 1989–2011. Int. J. Epidemiol. 39 (6), 1435–1440.

Rissel, C., Petrunoff, N., Wen, L.M., Crane, M., 2014. Travel to work and self-reported stress: Findings from a workplace survey in south west Sydney, Australia. J. Transp. Health 1 (1), 50–53.

Roberts, J., Hodgson, R., Dolan, P., 2011. "It's driving her mad": Gender differences in the effects of commuting on psychological health. J. Health Econ. 30 (5), 1064–1076.

Sposato, R.G., Röderer, K., Cervinka, R., 2012. The influence of control and related variables on commuting stress. Transport. Res. F-Traf. 15 (5), 581–587.

Sultana, S., Weber, J., 2014. The nature of urban growth and the commuting transition: Endless sprawl or a growth wave? Urban Stud. 51 (3), 544–576.

Sun, B., Lin, J., Yin, C., 2021. How does commute duration affect subjective well-being? A case study of Chinese cities. Transportation 48 (2), 885–908.

Ta, N., Chai, Y., Zhang, Y., Sun, D., 2017. Understanding job-housing relationship and commuting pattern in Chinese cities: Past, present and future. Transport. Res. D-Tr. E. 52, 562–573.

Tajalli, M., Hajbabaie, A., 2017. On the relationships between commuting mode choice and public health. J. Transp. Health 4, 267–277.

Tao, Y., 2023. 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. Urban Stud. 1–21.

Tao, Y., Petrović, A., van Ham, M., 2023c. Working from home and subjective wellbeing during the COVID-19 pandemic: The role of pre-pandemic commuting distance and mode choices. Journal of Transport Geography. https://doi.org/10.1016/j.jtrangeo.2023.103690.

Tao, Y., Petrović, A., van Ham, M., 2023a. Commuting behaviours and subjective wellbeing: A critical review of longitudinal research. Transp. Rev. 43 (4), 599–621.

Tao, Y., Petrović, A., van Ham, M., Fu, X., 2023b. Residential relocation as a key event in commuting mode shift. Transp. Res. D Transp. Environ. 119, 103772.

Tao, Y., van Ham, M., Petrović, A., Ta, N., 2023d. 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, 103640. https://doi.org/10.1016/j.tra.2023.103640.

Treff, C., Benseñor, I.M., Lotufo, P.A., 2017. Leisure-time and commuting physical activity and high blood pressure: The Brazilian Longitudinal Study of Adult Health (ELSA-Brasil). J. Hum. Hypertens. 31 (4), 278–283.

Vale, D.S., 2013. Does commuting time tolerance impede sustainable urban mobility? Analysing the impacts on commuting behaviour as a result of workplace relocation to a mixed-use centre in Lisbon. J. Transp. Geogr. 32, 38–48.

Van Ham, M., Manley, D., Bailey, N., Simpson, L., Maclennan, D., 2012. Neighbourhood effects research: new perspectives. In: Neighbourhood Effects Research: New Perspectives. Springer, Dordrecht, pp. 1–21.

Vlahov, D., Galea, S., 2002. Urbanization, urbanicity, and health. J. Urban Health 79 (1), S1–S12.

Wang, D., Chai, Y., 2009. The jobs–housing relationship and commuting in Beijing, China: The legacy of Danwei. J. Transp. Geogr. 17 (1), 30–38.

Wang, F., Wang, D., 2016. Geography of urban life satisfaction: An empirical study of Beijing. Travel Behav. Soc. 5, 14–22.

Wener, R.E., Evans, G.W., 2011. Comparing stress of car and train commuters. Transport. Res. F-Traf. 14 (2), 111–116.

Wu, F., 2015. Planning for growth: Urban and regional planning in China. Routledge, New York.

Yin, C., Peng, N., Li, Y., Shi, Y., Yang, S., Jia, P., 2023. A review on street view observations in support of the sustainable development goals. International Journal of Applied Earth Observation and Geoinformation 117, 103205.
Zhu, Z., Li, Z., Chen, H., Liu, Y., Zeng, J., 2019. Subjective well-being in China: How much does commuting matter? Transportation 46 (4), 1505–1524.
Zijlema, W.L., Avila-Palencia, I., Triguero-Mas, M., Gidlow, C., Maas, J., Kruize, H., Andrusaityte, S., Grazuleviciene, R., Nieuwenhuijsen, M.J., 2018. Active commuting through natural environments is associated with better mental health: Results from the PHENOTYPE project. Environ. Int. 121, 721–727.