Are low-income groups less satisfied with their commute because of transport poverty and poor health conditions?

Abstract: Low-income groups often have limited access to motorized travel modes (i.e., transport poverty) and have poor health conditions. It can therefore be assumed that they may experience low levels of commute satisfaction. However, few previous studies have examined this assumption. Using data derived from 618 face-to-face interviews performed in 2019 in Chengdu, China, we aim to verify whether low-income commuters are less satisfied with commuting than higher-income commuters and how this is related to transport poverty and health conditions. The descriptive results indicate that – compared to higher-income groups – low-income people do report a lower level of commute satisfaction, particularly on the commute from home to work. The negative association between the low-income group and commute satisfaction persists after controlling for socio-demographics, travel mode choice, trip characteristics, and travel attitudes when applying a regression model. After additionally including variables for both transport poverty and health conditions in the model, however, the negative association becomes statistically insignificant. Therefore, it can be concluded that – for the low-income population – dissatisfaction with commuting is largely explained by transport poverty and poor health conditions.
Keywords: Commute satisfaction; low-income groups; transport poverty; health conditions; Chengdu (China)

1 Introduction

As an unavoidable activity for most adults, commuting accounts for a considerable share of daily trips. Therefore, satisfaction with commuting may have important impacts on people's quality of life and life satisfaction (Chatterjee et al., 2020). This commute satisfaction can be affected by the quality and availability of travel options (e.g., Hook et al., 2021). In particular, low-income people – because of financial constraints – tend to suffer from transport poverty, e.g., lower accessibility to transport opportunities and poorer quality of transport services (Lucas et al., 2016; Titheridge et al., 2014; Zhao, 2015). Meanwhile, the low-income population is more likely to have health problems mainly because of limited health services, high-quality food, and physical activities (Khullar & Chokshi, 2018). The poor health conditions may negatively affect the ease of commuting for low-income groups. Consequently, they are expected to have a worse commuting experience, leading to lower commuting satisfaction than higher-income commuters (Ye & Titheridge, 2019). Improving low-income people's satisfaction with commuting is an essential need to achieve inclusive urban transportation development.

Previous studies have fully paid attention to the topic of commute satisfaction and have particularly investigated the determinants of commute satisfaction (e.g., Ettema et al., 2011, 2012, 2013; Friman et al., 2017; Mao et al., 2016; Singleton, 2019; Ye & Titheridge, 2017,

2019; Ye et al., 2020). However, little research focuses on whether and how the satisfaction with commuting varies across income distributions, and particularly between low-income and higher-income groups. Against the above-mentioned background, we aim to verify whether low-income people are less satisfied with commuting and if so, what are the main reasons for these low satisfaction levels. In the present study, the data are derived from 618 valid face-to-face interviews in 2019 in Chengdu, China. The remainder of this paper is organized as follows. In Section 2, related previous studies are described. Data are introduced in Section 3, followed by analyses and results in Section 4. Conclusions and discussion are presented in the final section.

2 Literature review and conceptual analyses

2.1 Literature review

In the past decade, quite a number of studies have conceptually and/or empirically explored the issue of commute satisfaction. Most previous studies focus on the investigation of the factors influencing commute satisfaction. Travel mode choices are found to have important impacts on commute satisfaction. It is widely confirmed that commuting by active modes (e.g., cycling and walking) positively contributes to commute satisfaction, while commuting by public transit has negative impacts on commute satisfaction (e.g., De Vos et al., 2016; Friman et al., 2017; Lades et al., 2020; Morris & Guerra, 2015a; Singleton et al., 2019; St-Louis et al., 2014). Meanwhile, some researchers reveal that the preference for travel modes (i.e., travel attitudes) are also associated with commute satisfaction. For instance, Ye and Titheridge (2017) indicated that commuters with higher preference for walk, transit, and car tend to report higher levels of commute satisfaction. Furthermore, some scholars further investigated the influence of the mismatch between preferred and chosen travel modes on commute satisfaction. A consensus is that people who commute by the preferred modes are more likely to be satisfied with commuting (St-Louis et al., 2014; Ye & Titheridge, 2019; Ye et al., 2020).

Besides travel modes, other trip characteristics are also found to have influence on commute satisfaction. The length of commuting is frequently examined. It is often confirmed that longer commute durations and the increased commute durations after relocations tend to result in a lower level of commute satisfaction (e.g., Ettema et al., 2012, 2013; Gerber et al., 2020; Higgins et al., 2018; Manaugh & El-Geneidy, 2013; Morris & Guerra, 2015b; Singleton et al., 2019; Wang et al., 2020). In addition, some scholars explored the roles of road congestion, in-vehicle crowding, and waiting time for transit. As expected, higher levels of road congestion and in-vehicle crowding, and longer waiting time are often negatively correlated with commute satisfaction (e.g., Ettema et al., 2013; Higgins et al., 2018; Lunke, 2020; Smith, 2017; Ye & Titheridge, 2017).

Additionally, some studies explore the influence of built environment elements on commute satisfaction, however leading to inconsistent findings. For example, Mao et al. (2016) found that people residing in urban areas (compared to suburban areas) tend to be more satisfied with commuting by cycling and metro in Beijing, China. Similarly, Mouratidis et al. (2019) indicated that – in Oslo metropolitan area, Norway – shorter distances from home to the

city center, higher residential density, and compact inner-city areas (compared to sprawled suburban areas) are positively correlated with a higher level of commute satisfaction. Using data collected from Sweden and Xi'an city (China), respectively, however, both Ettema et al. (2012) and Ye and Titheridge (2019) revealed insignificant associations between built environment elements and commute satisfaction. In another study by Ye and Titheridge (2017), they indicated indirect effects of the built environment on commute satisfaction through travel model choices and the characteristics of the trip (e.g., the levels of road congestion and in-vehicle crowding).

Moreover, the physical health is considered as influential factors of commute satisfaction in a few studies. Smith (2013) revealed that higher levels of self-reported health are positively correlated with commute satisfaction in Portland, the United States. Subsequently, using data collected data from Xi'an, China, Ye and colleagues confirmed the positive association between better health conditions and higher commute satisfaction (Ye & Titheridge, 2017, 2019; Ye et al., 2020).

In sum, the determinants of commute satisfaction have been fully explored in existing studies. However, these studies provide "limited understanding of how commute satisfaction varies across the socio-economic status distribution" (Chatterjee et al., 2020, p.24). Meanwhile, low-income groups often suffer from transport poverty (e.g., limited availability of affordable travel modes) (Lucas et al., 2016; Stoke & Lucas, 2011; Titheridge et al., 2014) and poor health conditions (Benzeval & Judge, 2001; Khullar & Chokshi, 2018), thus possibly resulting in low levels of satisfaction with commuting. An in-depth exploration of their (dis)satisfaction with commute is helpful to create policy recommendations. To the best of our knowledge, however, only a study by Ye and Titheridge (2019) specifically revealed the influential factors of commute satisfaction among low-income groups in Xi'an, China. They revealed that low-income commuters have lower levels of commute satisfaction than higher-income commuters. They further found that the influence of travel mode choices on commute satisfaction differ largely between low-income groups and other groups. Their results suggested that commuting by non-transit (e.g., walking, cycling, and car) can significantly increase the levels of satisfaction for higher-income groups. However, travel mode choices have negligible impacts on commute satisfaction among the low-income population. In addition, for both groups, longer commuting durations, higher level of road congestion, and a mismatch between preferred and chosen travel modes are negatively associated with commute satisfaction.

2.2 Conceptual analyses

Considering the influential factors of commute satisfaction mentioned above, we assume that the dissatisfaction with commute of low-income groups can be mainly attributed to the following two aspects.

The first aspect refers to transport poverty. According to existing studies, transport poverty can be reflected by three dimensions: low affordability of car ownership, lack of access to transit stations, and lack of access to places of interest (e.g., shopping centers and workplaces) (Lucas et al., 2016; Stoke & Lucas, 2011; Titheridge et al., 2014). The two latter

dimensions are mostly determined by the built environment at home and work locations[1]. Transport poverty is commonly considered as a potential explanation for the low commute satisfaction of the low-income population (e.g., Ye & Titheridge, 2019). Because of financial constraints, low-income commuters can hardly afford to own and run a car. Meanwhile, they may tend to reside in weakly urbanized areas with low accessibility to transit stations and workplaces (Lucas et al., 2016; Zhao, 2015). This means that low-income commuters may be more likely to be in transport poverty and have fewer transport options for commuting, thus leading to lower levels of commute satisfaction (Ye & Titheridge, 2019).

Notably, however, two plausible hypotheses are conflicting with the assumption that low-income people have fewer transport options. The first states that the low-income population may be "forced" to own a car, because they usually live far away from the urban center and must travel long distances in daily life (Currie & Senbergs, 2007; Curl et al., 2018; Zhao, 2015). The second postulates that low-income groups may tend to reside or work in areas with high accessibility to transit, because they have a low level of car ownership (Baum-Snow et al., 2005; Dawkins & Moeckel, 2016; Glaeser et al., 2008). Both hypotheses are reasonable but may depend on local contexts such as the prices of cars, fuel, and housing. For example, in a country or a city with low prices of cars and fuel but a high price of housing, low-income people may choose to own a car rather than to reside in densely urban areas and vice versa. Therefore, in the two situations mentioned above, low-income people may not necessarily suffer more from transport poverty, implying that they may not be less satisfied with commuting than higher-income people.

The second aspect refers to poor health conditions. Compared to trips for other purposes, commutes usually require more physical strength. People with poor health conditions may experience more difficulty when commuting (particularly when traveling by active modes), thus being dissatisfied. Existing studies have confirmed a negative association between poor health conditions and commute satisfaction (Smith, 2013; Ye & Titheridge, 2017, 2019; Ye et al., 2020). This situation may be more likely to occur among the low-income population, because they tend to have poor health conditions for the following reasons (Benzeval & Judge, 2001; Khullar & Chokshi, 2018): (1) They lack access to high-quality health services; (2) They tend to have risk behaviors like smoking and drinking; (3) Their housing conditions are relatively poor (e.g., lack of housing spaces); (4) They are more likely to reside in neighborhoods with a high density of tobacco retailers and fast-food restaurants but with limited open spaces for physical activities. Notably, transport poverty can impose barriers to travel for low-income people to use health care services, get fresh food, and access open spaces for physical activities, which may result in poor health conditions and thus reduce commute satisfaction. Therefore, transport poverty may complement health conditions when affecting commute satisfaction.

In sum, we assume that transport poverty and poor health conditions are the main factors

[1] Some researchers also use the share of transport costs in incomes as an indicator of transport poverty (e.g., Churchill & Smyth, 2019). However, this measurement method has received many critiques, because high-income people are likely to spend a higher share of incomes on transport than low-income people (Stoke & Lucas, 2011; Titheridge et al., 2014). Therefore, the three dimensions mentioned above are adopted in the present study.

resulting in low commute satisfaction for low-income people (see Figure 1). Improving the two issues may narrow and even remove the commute satisfaction gap between low-income and the other groups. Although Ye and Titheridge (2019) contributed valuable knowledge about commute satisfaction among the low-income population, they did not provide direct empirical evidence confirming this assumption. In the present study, the assumption will be empirically examined in the following two sections.

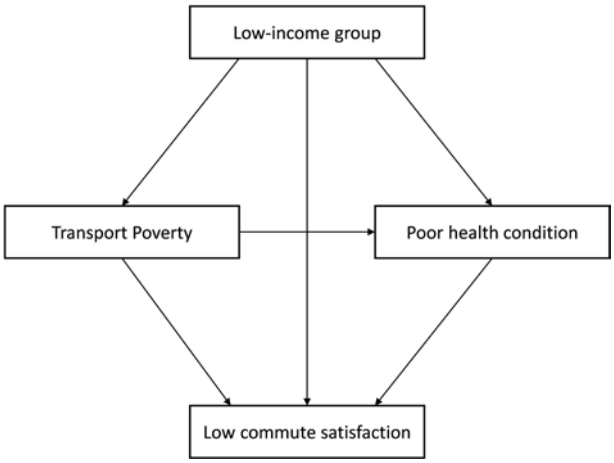


Figure 1 Conceptual framework

3 Data

3.1 Data sources

The data used in the present study are mainly derived from an interview survey between June 30th and August 1st 2019 in Chengdu, China. Chengdu is the capital city of Sichuan Province in China. By the end of 2019, a total of 16.58 million people resided in the city, and 12.34 million (accounting for 74.4%) were urban residents. The interview survey was performed with a two-stage sampling approach. First, the sampled neighborhoods were determined. In Chengdu, the main urban area was divided into five zones by four ring roads. The zones closer to the city center tended to be more strongly urbanized, and vice versa. In this circumstance, 5-7 residential neighborhoods were geographically randomly selected from each zone. In the end, a total of 29 neighborhoods were used as the sampled units (see Figure 2). Second, respondents were recruited by randomly knocking on doors and/or approaching people at public spaces in these neighborhoods. Residents aged 16 or above were considered as the target population. A face-to-face interview was conducted with each respondent. A paper-based questionnaire was used to record their answers. After respondents finished the interviews, a pack of handkerchief papers or a fan was provided as an incentive for their participation. In the end, a total of 1011 residents participated in the survey. After leaving out respondents who were not employed or those missing key information, we obtained 618 valid records for the present study (see Table 1). Commuting behavior is then extracted from the 618 face-to-face interviews.

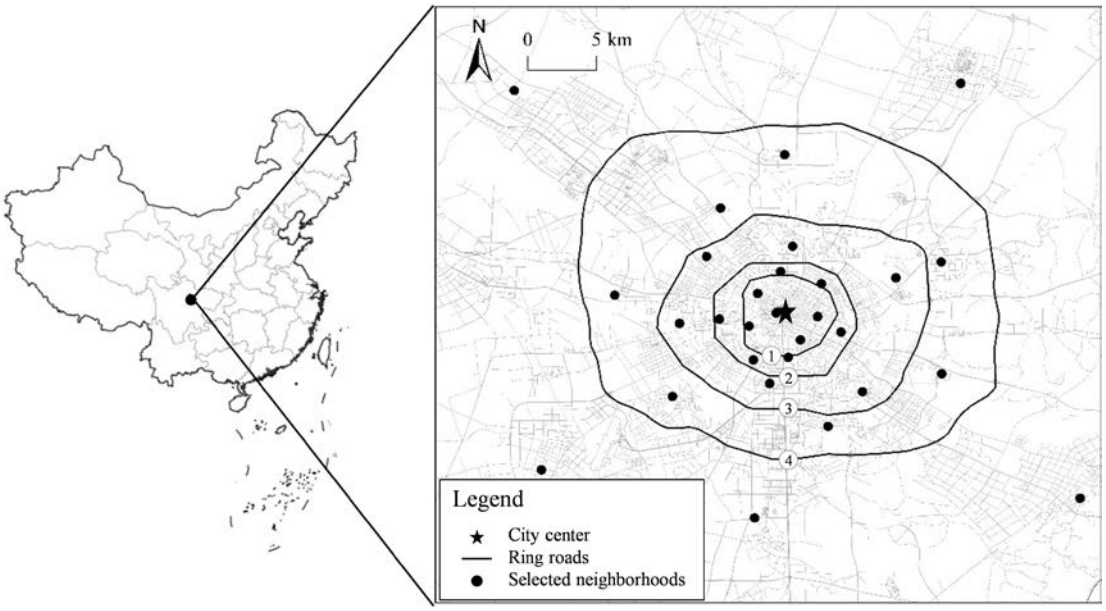


Figure 2 Study area (Chengdu, China) and sampled units

Table 1 Basic characteristics of valid respondents (N=618)

Variables	Categories	N	%
Gender	Male	296	47.9
	Female	322	52.1
Age (years)	20 or younger (Value=1)	42	6.8
	21-30 (Value=2)	368	59.5
	31-40 (Value=3)	153	24.8
	Older than 40 (Value=4)	55	8.9
Education	High school or less (Value=1)	83	13.4
	Colleges/technical school (Value=2)	231	37.4
	Undergraduate school (Value=3)	249	40.3
	Graduate school or more (Value=4)	55	8.9
Household annual income	100 000 or less (Low-income respondents)	223	36.1
(Yuan)	More than 100 000 (higher-income respondents)	395	63.9
Total		618	100.0

In addition to the survey, the points of interest (i.e., POI) from Map.Baidu.com are used as another data source. Map.Baidu.com is one of the most used e-maps in China. On November 16th 2017, we collected the POI data across the Chengdu city regarding bus stations, metro stations, residential points, and office buildings. For each point of interest, we obtained its name and coordinate information. The POI data are then used as the source of built environment elements.

3.2 Criterion for the low-income population

There is no universal criterion for the low-income population, because income levels vary greatly by cities and countries. In the present study, the criterion needs to be determined by the local context of Chengdu city. According to Chengdu Municipal People's Government (2019), residents whose annual household incomes are lower than 100 thousand Yuan

(around 14.5 thousand U.S. dollars) are eligible to apply for a rental subsidy from the government. This criterion is therefore applied to distinguish the low-income respondents from higher-income respondents in the present study. As a result, 223 respondents are categorized in the low-income group, and 395 are in the higher-income group (see Table 1).

3.3 Measurement of commute satisfaction

In previous studies, various methods are used for the measurement of commute satisfaction (Chatterjee et al., 2020). Among them, the satisfaction with travel scale (STS) proposed by Ettema et al. (2011) is widely adopted by researchers. Following Ettema et al. (2011), the STS including nine statements (named S1-S9 in short) was introduced in the survey. This scale asked respondents to what extent they experienced certain affective emotions during their most recent commute and how they evaluated this commute:

1) Time pressed – relaxed (S1);
2) Worried I would not be in time – confident I would be in time (S2);
3) Stressed – calm (S3);
4) Tired – alert (S4);
5) Bored – enthusiastic (S5);
6) Fed up – engaged (S6);
7) Commuting was worst – best (S7);
8) Commuting was low – high standard (S8);
9) Commuting worked poorly – worked well (S9).

All answers were measured on a seven-point scale (from -3, representing negative emotions/evaluations, to +3, representing positive emotions/evaluations). In order to fully depict the process of commuting, the satisfaction with commuting to and from work was measured, separately. The Cronbach's alpha coefficients of the satisfaction with commuting to and from work are respectively 0.94 and 0.95. This means that the nine statements have good internal homogeneity. The average scores of these statements are then calculated to reflect the overall satisfaction with commuting to and from work, respectively.

3.4 Measurement of transport poverty

According to previous studies (Lucas et al., 2016; Stoke & Lucas, 2011; Titheridge et al., 2014), transport poverty can be measured in three aspects: the availability of car use, the accessibility to the places of interest (i.e., workplaces in the present study), and the accessibility to public transit (see Table 2). The availability level of car use is indicated by the household car ownership, which is measured on an ordinal scale. The time spent on the most recent commute to and from work (i.e., commute durations) – which was reported in minutes by respondents – is used as a proxy for the accessibility to workplaces. Accessibility to public transit is reflected by the availability of bus and metro services within 800 m from home and workplaces[2]. Meanwhile, accessibility to transit services is also partly determined by the level of competition for the services. Fiercer competition usually represents lower accessibility. Therefore, the number of residential points within 800 m from home and the

[2]The maximum access distance by walking is around 800 m for most residents in Chinese large cities (Pan et al., 2010), which is the reason why the buffer distance is set to 800 m.

number of office buildings within 800 m from workplaces are used to reflect the level of competition, which can indirectly indicate the accessibility to transit services.

Table 2 Indicators of transport poverty

Indicators	Descriptions	N	%
Household car ownership	No car (Value=1)	224	36.2%
	One car (Value=2)	335	54.2%
	Two or more cars (Value=3)	59	9.5%
		Mean	S.D.
Commuting durations (Min)	Commute to work	29.1	21.3
	Commute from work	30.6	22.0
Built environment at home			
Accessibility to metro stations	Metro stations exist within 800 m from home (0: no; 1: Yes)	0.26	0.44
Accessibility to bus stations	Number of bus stations within 800 m from home	10.8	8.6
Density of residential points	Number of residential points within 800 m from home	34.0	28.0
Built environment at workplaces			
Accessibility to metro stations	Metro stations exist within 800 m from workplaces (0: no; 1: Yes)	0.41	0.49
Accessibility to bus stations	Number of bus stations within 800 m from workplaces	12.6	9.0
Density of office buildings	Number of office buildings within 800 m from workplaces	26.0	27.5

3.5 Measurement of health conditions

According to Hansson et al. (2011), a measurement scale including eight questions is used to measure the self-reported health of respondents:

1) How do you physically feel right now when thinking about your health?
2) How do you psychologically feel right now when thinking about your health?
3) Have you got enough sleep recently?
4) Have you felt stressed recently in your everyday life?
5) Have you felt full of pep recently?
6) Have you had a lot of energy recently?
7) Have you felt worn out recently?
8) Have you felt tired recently?

The answers range from “very poor (1)” to “excellent (5)” for the first two questions and from “not at all (1)” to “always (5)” for the last six questions. A factor analysis with principal axis factoring and Promax rotation is applied to reduce dimensions. The third question is removed from the factor analysis because its loading is too low (its maximum value is 0.276 in the pattern matrix). In the end, three factors are extracted: exhaustion, pep, and self-rated health (see Appendix A). 73.2% of the total variance is explained by the three factors.

3.6 Control variables

According to previous studies on the determinants of commute satisfaction, four categories of control variables are used in the present study. The first category refers to sociodemographic factors including respondents' gender, age, and educational attainments. Both age and educational levels are measured on an ordinal scale (see Table 1). The second category refers to travel mode choices. Respondents were asked to report the mode that was used for the longest duration for their most recent commutes to and from work.

The third category refers to other characteristics of the most recent commute to and from work, including the waiting time, the experience of in-vehicle crowding, and the level of road congestion. Notably, only public transit commuters were asked to report the time used for waiting for transit and the experience of in-vehicle crowding. The waiting time is measured for all respondents on an ordinal scale. A value of 1 is assigned when the respondent was not a public transit user. For public transit users, a value of 2 is assigned when the waiting time was no more than 5 minutes, a value of 3 is assigned when the waiting time was between 6~10 minutes, and a value of 4 is assigned when the waiting time was more than 10 minutes. The experience of in-vehicle crowding relies on the self-reported answers of respondents, which range from "not at all crowded (1)" to "extremely crowded (5)". A value of 1 (i.e., "not at all crowded") is assigned when respondents were not public transit users. In addition, all respondents were asked to report the level of road congestion. The answers range from "not at all congested (1)" to "extremely congested (5)".

The fourth category refers to travel attitudes. In analogy with Cao (2015) and Handy et al. (2005), sixteen statements are used to measure travel attitudes. Respondents could indicate to what extent they agreed on these statements on a five-point scale from "strongly disagree (1)" to "strongly agree (5)". A factor analysis with principal axis factoring and Promax rotation is employed to extract four factors: pro-transit/bicycle/walk, safety of car, pro-car, and status of car, explaining 53.4% of the total variance (see Appendix B).

3.7 Modeling strategy

A regression-based approach with a strategy of statistical control is commonly used to analyze a mediating issue as shown in Figure 1 (Baron & Kenny, 1986; Hayes, 2017). In the field of transportation, this approach is often introduced to address residential self-selection (Cao, 2015; Handy et al., 2005). In the present study, we use this approach to elaborate on the causal paths between low incomes, transport poverty, health conditions, and commute satisfaction. It should be noted that – for simplicity – we do not consider control variables (e.g., sociodemographic factors and travel mode choices) in the following formulation process.

As assumed above, low income (LI), transport poverty (TP), and health conditions (HC) have influence on commute satisfaction (CS). A simplified equation can be written as follows when transport poverty and health conditions are not included:

$$CS = f(LI) + e(TP, HC) \quad (1)$$

In Equation (1), the impacts of transport poverty and health conditions on commute satisfaction are obtained by the error term. Meanwhile, transport poverty and health conditions are influenced by low incomes. This means that the variable of low incomes is correlated with the error term through transport poverty and health conditions, which can be written as:

$$CS = f\,(LI\ (TP, HC)) + e\,(TP, HC) \quad (2)$$

After including transport poverty and health conditions as independent variables, the correlation between low incomes and the error term will be eliminated. Then the equation can be written as follows:

$$CS = f\,(LI, TP, HC) + \varepsilon \quad (3)$$

In the situation expressed in Equation (3), the causal paths between low incomes, transport poverty, health conditions, and commute satisfaction can be inferred as follows. When the magnitude of the coefficient of low incomes becomes smaller than that in Equation (1) but is still statistically significant, it can be concluded that the relationship between low incomes and commute satisfaction is partly mediated by transport poverty and health conditions. When the magnitude of the coefficient of low incomes becomes smaller than that in Equation (1) and is statistically insignificant, it can be concluded that the relationship between low incomes and commute satisfaction is fully mediated by transport poverty and health conditions (Baron & Kenny, 1986; Hayes, 2017).

4 Results

4.1 Transport poverty and health conditions

First, we analyze whether transport poverty is more likely for low-income people. Table 3 reports the comparison of transport poverty between low-income and higher-income groups. As expected, the low-income group has a lower level of car ownership than the higher-income group. Interestingly, the low-income group tends to reside and work in areas with higher accessibility to bus stations. Accessibility to metro stations is also higher for the low-income group than that for the higher-income group, though the difference is not statistically significant (p=0.124). As assumed before, this could be attributed to their lack of access to car use (Baum-Snow et al., 2005; Dawkins & Moeckel, 2016; Glaeser et al., 2008). Meanwhile, there is a higher density of residential points surrounding home locations of low-income people, which means that they are more likely to experience fierce competition for transit services with a lot of other passengers. Therefore, the low-income group may still lack access to transit services.

Table 3 Transport poverty between low-income and higher-income groups

Transport poverty	Low-income group		Higher-income group		Diff.
	Mean	S.D.	Mean	S.D.	(p-values)
Household car ownership	1.54	0.59	1.84	0.62	0.000
Commute durations (Min)					
Commute to work	28.61	21.05	29.33	21.46	0.686
Commute from work	30.21	22.07	30.78	22.00	0.761
Built environment at home locations					
Accessibility to metro stations	0.30	0.46	0.24	0.43	0.124
Accessibility to bus stations	12.01	8.26	10.06	8.68	0.007
Density of residential locations	36.74	27.94	32.41	27.92	0.070
Built environment at work locations					
Accessibility to metro stations	0.40	0.49	0.41	0.49	0.784
Accessibility to bus stations	13.80	8.89	11.93	9.00	0.020
Density of office buildings	25.07	27.62	26.53	27.51	0.554

Note: A Mann-Whitney test is applied for car ownership; T-tests are applied for other variables.

In addition, the comparison of health conditions between low-income and higher-income groups is reported in Table 4. Consistent with expectations, the low-income group tends to have lower levels of health conditions than the higher-income group, and the differences are always statistically significant. This result is in line with previous studies (e.g., Benzeval & Judge, 2001; Khullar & Chokshi, 2018).

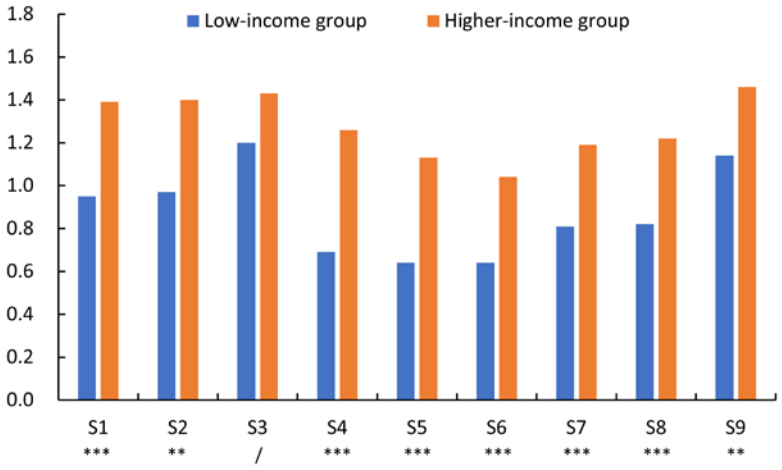
Table 4 Health conditions between low-income and higher-income groups

Health conditions	Low-income group		Higher-income group		Diff.
	Mean	S.D.	Mean	S.D.	(p-values)
Exhaustion	0.16	0.94	-0.09	0.95	0.003
Pep	-0.16	0.96	0.09	0.95	0.002
Self-rated health	-0.16	1.00	0.09	0.90	0.003

Note: T-tests are applied for the differences.

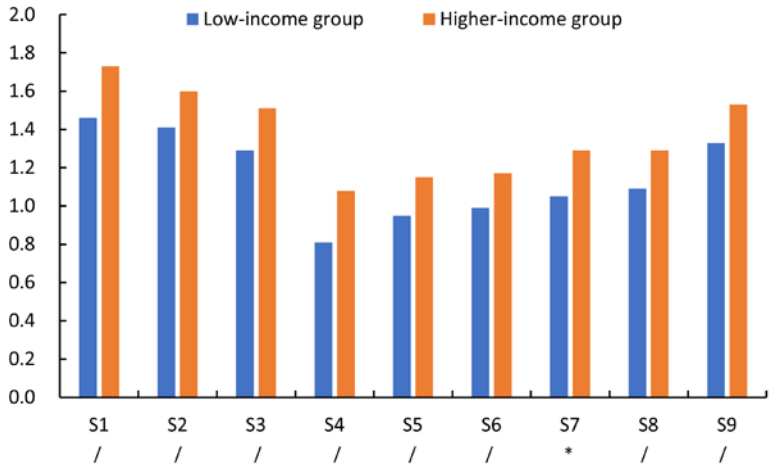
4.2 Commute satisfaction

In this section, the difference in commute satisfaction between low-income and higher-income groups is preliminarily explored. The average STS scores for commuting to and from work are reported in Figures 3 and 4, respectively. On average, the low-income group always reported lower satisfaction with both commutes to and from work than the other group. Given the ordinal nature of scores, Mann-Whitney tests – a nonparametric approach – are used to further examine the satisfaction differences between two groups. The results suggest that – when commuting to work – the differences in scores on S1-S2 and S4-S9 are statistically significant. When commuting after work, only the score on S7 is significantly different.



Note: ** p<0.05; *** p<0.01; / p≥0.10.

Figure 3 The average satisfaction with commuting to work



Note: * p<0.10; / p≥0.10.

Figure 4 The average satisfaction with commuting from work

We then compare the average difference in overall satisfaction with commuting (see Figure 5). Similarly, on average, the overall satisfaction with both commuting to and from work for the low-income group is always lower than that for the higher-income group. T-tests show that the differences in satisfaction with commuting to and from work between the two groups are at the significance level of p<0.01 and p<0.10, respectively.

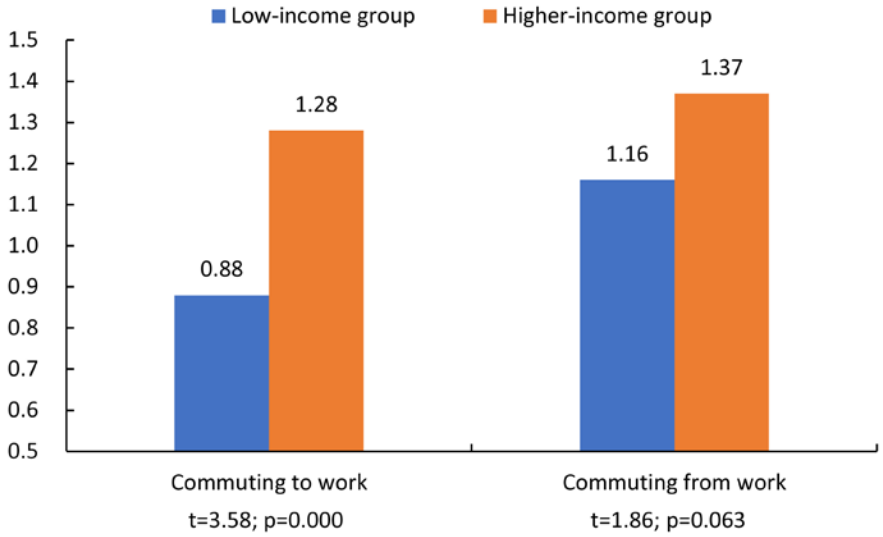


Figure 5 The average overall satisfaction with commuting to and from work

In sum, two things can be preliminarily learned from the above analyses. First, low-income people are less satisfied with commuting than higher-income people. This finding is consistent with our expectations and previous studies (Ye & Titheridge, 2019). As reasoned in Section 2.2, the satisfaction gap between the two groups may be explained by their differences in transport poverty and health conditions. In the following section, we will empirically examine this assumption.

Second, the commute satisfaction gap between the two groups is smaller when commuting from work than when commuting to work. This is an interesting finding that researchers have almost not been aware of before. A possible explanation is as follows. Commuters are usually required to start working at a certain point of time, which means that the arrival time is less flexible when commuting to work than when commuting from work (Ansari Esfeh et al., 2021). The fixed arrival time – to a larger extent – increases the level of competition for travel opportunities among low-income commuters who suffer more from transport poverty (i.e., lack of transport options). Consequently, they feel more stressed and less satisfied when commuting to work.

4.3 Regression analyses

In this section, an Ordinary Least Squares (OLS) regression method is applied to elaborate on why low-income people feel dissatisfied with commuting, particularly from the perspectives of transport poverty and poor health conditions. Pooled regression models are performed with consideration of both commuting to and from work, so that the number of observations can be extended to increase the robustness of outcomes. Because most respondents are counted twice in these pooled models, the cluster-robust Standard Error (S.E.) of independent variables are estimated. Using the overall commute satisfaction as the dependent variable, a total of four regression models are developed (see Table 5). In Model 1, only control variables mentioned in Section 3.6 are taken into account to verify again whether low-income people are less satisfied with commuting than higher-income people.

In Models 2 and 3, the variables indicating transport poverty and health conditions are respectively added to examine whether and how the negative association between the low-income group and commute satisfaction is mediated by them. In Model 4, the variables indicating transport poverty and health conditions are included together to analyze the total mediating power of both aspects for the association between the low-income group and commute satisfaction.

As reported in Model 1, the low-income group is negatively associated with commute satisfaction at a significance level of $p<0.05$ even when considering sociodemographics, travel mode choice, trip characteristics, and travel attitudes. This confirms the preliminary finding that – compared to higher-income people – low-income people are more likely to feel dissatisfied with commuting.

In Model 2, the low-income group is still negatively correlated with commute satisfaction at a significance level of $p<0.10$. However, the magnitude of the coefficient decreases from -0.25 in Model 1 to -0.20, suggesting that the negative correlation between the low-income group and commute satisfaction is partly mediated by transport poverty. In particular, longer commuting durations, lower accessibility to bus stations, and higher density of residential points at home locations are negatively associated with commute satisfaction. It seems that high levels of transport poverty have adverse impacts on commute satisfaction. However, higher accessibility to metro stations is negatively correlated with commute satisfaction, which is somewhat counterintuitive. This finding may be attributed to the early stage of the metro system in Chengdu. Normally, people who have higher accessibility to metro stations make metro trips frequently for commuting. In Chengdu, the metro system just started operating in 2010. Metro services are still unavailable in many areas. According to Table 2, only 26% of respondents in the present study can access metro stations within 800 m from home. Therefore, many metro users may need to make transfers when commuting to and from work, possibly leading to lower satisfaction levels. It should be noted that – although low-income people have higher accessibility to metro stations in Chengdu (see Table 3) – they may suffer from the low quality of metro services.

In Model 3, the negative association between the low-income group and commute satisfaction still exists at a significance level of $p<0.05$. Meanwhile, the magnitude of the coefficient decreases from -0.25 in Model 1 to -0.22. Consistent with expectations, poor self-rated health conditions are negatively associated with commute satisfaction at a significance level of $p<0.05$. This implies that the negative contribution of the low-income group to commute satisfaction is partly explained by their poor health conditions.

The outcomes in Model 4 suggest that the association between the low-income group and commute satisfaction becomes statistically insignificant ($p=0.150$). The magnitude of the coefficient decreases from -0.25 in Model 1 to -0.17. Meanwhile, the estimated coefficients of variables indicating transport poverty and health conditions are quite robust among Models 2-4. According to Hayes (2017) – in such a situation – it can be concluded that the negative influence of low incomes is fully mediated by transport poverty and health conditions, confirming the assumptions raised in Section 2.2.

Table 5 OLS regression results

Independent variables	Model 1			Model 2			Model 3			Model 4		
	B	S.E.	p	B	S.E.	p	B	S.E.	p	B	S.E.	p
Low-income group (No=ref.)												
Yes	-0.25**	0.11	0.017	-0.20*	0.11	0.079	-0.22**	0.11	0.040	-0.17	0.12	0.150
Control variables												
Socio-demographics												
Gender (Female=ref.)	-0.04	0.09	0.706	-0.10	0.10	0.321	-0.08	0.09	0.408	-0.12	0.10	0.214
Age	0.14**	0.07	0.041	0.12	0.07	0.104	0.15**	0.07	0.031	0.13*	0.07	0.075
Education	0.13**	0.06	0.041	0.10	0.06	0.108	0.12*	0.06	0.054	0.09	0.06	0.163
Travel modes (Walking=ref.)												
Car/taxi	-0.40***	0.15	0.007	-0.26	0.16	0.105	-0.45***	0.15	0.002	-0.31**	0.16	0.049
Bus	0.06	0.21	0.772	0.14	0.23	0.538	0.05	0.21	0.798	0.12	0.23	0.593
Metro	-0.04	0.23	0.853	0.04	0.25	0.882	-0.02	0.23	0.922	0.03	0.25	0.908
Cycling	-0.40***	0.15	0.006	-0.39**	0.16	0.014	-0.42***	0.15	0.004	-0.39**	0.16	0.012
Trip characteristics												
Waiting	-0.21**	0.09	0.024	-0.17*	0.09	0.071	-0.20**	0.09	0.026	-0.17*	0.10	0.074
Crowding	-0.17***	0.06	0.003	-0.14**	0.07	0.038	-0.18***	0.06	0.002	-0.14**	0.07	0.033
Congestion	-0.21***	0.05	0.000	-0.14***	0.05	0.009	-0.21***	0.05	0.000	-0.15***	0.05	0.005
Travel attitudes												
Pro-transit/bicycle/walk	0.06	0.06	0.304	0.10	0.06	0.138	0.04	0.06	0.496	0.08	0.07	0.213
Safety of car	0.09	0.06	0.161	0.11*	0.07	0.096	0.08	0.06	0.199	0.11*	0.07	0.095
Pro-car	0.06	0.06	0.356	0.08	0.06	0.242	0.03	0.06	0.661	0.04	0.07	0.537
Status of car	0.12*	0.07	0.068	0.10	0.07	0.183	0.13**	0.07	0.046	0.10	0.07	0.158

Transport poverty												
Household car ownership				-0.02	0.08	0.813				0.01	0.08	0.948
Commuting durations				-0.01***	0.00	0.003				-0.01***	0.00	0.007
Built environment at home locations												
Accessibility to metro stations				-0.26**	0.13	0.046				-0.22*	0.13	0.094
Accessibility to bus stations				0.02**	0.01	0.016				0.02**	0.01	0.011
Density of residential points				-0.00*	0.00	0.062				-0.00**	0.00	0.048
Built environment at work locations												
Accessibility to metro stations				0.18	0.12	0.142				0.16	0.12	0.206
Accessibility to bus stations				-0.01	0.01	0.241				-0.01	0.01	0.194
Density of office buildings				0.00	0.00	0.618				0.00	0.00	0.488
Health conditions												
Exhaustion							0.04	0.06	0.469	0.07	0.06	0.252
Pep							0.10	0.06	0.125	0.11*	0.07	0.098
Self-rated health							0.14**	0.06	0.027	0.11*	0.07	0.093
Constant	1.94***	0.29	0.000	2.11***	0.32	0.000	1.97***	0.28	0.000	2.09***	0.32	0.000
R^2	0.18			0.20			0.20			0.22		
Observations	1182			1018			1175			1013		

Note: * P<0.10, ** p<0.05, *** p<0.01.

5 Conclusions and discussion

Satisfaction with commuting has considerable spillover effects on commuters' daily life because commutes account for a high share of daily trips. However, because of financial constraints, low-income population groups usually suffer from transport poverty and poor health conditions when commuting to and from work. Consequently, they may feel less satisfied with commuting than those with high incomes. However, little empirical evidence from previous studies is presented to fully explore this issue. In the present study, we use data collected from 618 face-to-face interviews performed in Chengdu, China to particularly investigate how commute satisfaction varies between low-income and higher-income groups. The findings can contribute valuable insights to the understanding of the mechanism behind the low commute satisfaction of the low-income population. Accordingly, policymakers can benefit from the present study to develop an inclusive transportation system.

The analyses confirm that – compared to higher-income people – low-income people do have a lower level of commute satisfaction, particularly during commutes to work. In addition, it seems that low-income people are more likely to be in transport poverty, even though they tend to reside or work in areas with higher accessibility to transit stations. Meanwhile, consistent with expectations, they have worse health conditions. Regression models with the strategy of statistical control indicate that the low level of commute satisfaction of low-income people can be largely attributed to their transport poverty and poor health conditions.

To our best knowledge, only one study (Ye & Titheridge, 2019) has focused on the commute satisfaction of the low-income population before. In our study, we provide an important finding that is different from the study of Ye and Titheridge (2019). As assumed before, low-income people may take two measures to reduce transport poverty: (1) to buy a car, and (2) to change their residential or job locations to areas with higher public transit accessibility. The study by Ye and Titheridge (2019) revealed that – in Xi'an, China – low-income people do not take many actions to alleviate their transport poverty, because they own fewer cars and reside and work in areas with fewer transit opportunities than higher-income people. In contrast, we find that – in Chengdu, China – low-income commuters tend to reside and work in areas with more transit opportunities. This means that they are taking the latter measure to reduce transport poverty. As assumed before, the difference between the two cities may be attributed to some local contexts such as the prices of housing and the level of average incomes. By the end of 2019, the housing prices per square meter were respectively 10.1 thousand Yuan (around 1.6 thousand U.S. dollars) and 11.0 thousand Yuan (around 1.7 thousand U.S. dollars) in Xi'an and Chengdu, which are roughly equivalent to each other (Fang.com, 2020). Meanwhile, the annual incomes per capita in 2019 were 34.1 thousand Yuan (around 5.2 thousand U.S. dollars) and 45.9 thousand Yuan (around 7.1 thousand U.S. dollars) in Xi'an and Chengdu, respectively (CEIC, 2020). Apparently, the housing is more affordable for residents in Chengdu, which may be the main reason for the different choices of the low-income population between the two cities.

For an inclusive urban transportation system, it is important to improve the commute

satisfaction of the low-income population in planning practice. According to findings in the present study, some possible policy strategies can be recommended. First, as shown before, low-income commuters are more likely dissatisfied with commuting to work than with commuting from work. Therefore, policymakers and urban planners may need to give a higher priority to improve the inclusivity of transportation systems in morning peak hours (e.g., by increasing the frequency, punctuality, and coverage area of public transport services, thereby improving travel time reliability). Second, only improving the access to public transit facilities may not be effective to increase the commute satisfaction of low-income people. We reveal that the low-income group tends to live in neighborhoods with higher residential densities. This may involve them in strong competition for transport services with other passengers, thus leading lower satisfaction levels. Therefore, reducing residential density in low-income communities would help them decrease the competition and eliminate transport poverty, thus increasing commute satisfaction. Third, we find that low-income people are less satisfied with commuting because of their poor health conditions. Therefore, improving health conditions may make positive contributions to commuting satisfaction for the low-income population. Some specific planning strategies like increasing public/open spaces and sport facilities, and improving access to healthy food, can be implemented in low-income communities to help them better manage their health conditions.

Appendix A Pattern matrix of factor analysis for health conditions

Factors	Questions	Loadings
Exhaustion	Have you felt tired recently?	0.91
	Have you felt worn out recently?	0.89
	Have you felt stressed recently in your everyday life?	0.48
Pep	Have you felt full of pep recently?	0.92
	Have you had a lot of energy recently?	0.92
Self-rated health	How do you psychologically feel right now when thinking about your health?	0.91
	How do you physically feel right now when thinking about your health?	0.87

Appendix B Pattern matrix of factor analysis for travel attitudes

Factors	Statements	Loadings
Pro-transit/bicycle/walk	I prefer to walk rather than drive whenever possible	0.73
	I prefer to take transit rather than drive whenever possible	0.73
	I prefer to ride a bicycle rather than drive whenever possible	0.70
	To me, walking is sometimes easier than driving	0.64
	To me, cycling is sometimes easier than driving	0.62
	To me, taking transit is sometimes easier than driving	0.59
	I like taking transit	0.54
	I like walking	0.44
Safety of car	Overall, driving is safer than walking	0.90
	Overall, driving is safer than taking transit	0.86
	Overall, driving is safer than cycling	0.75
Pro-car	I like driving	0.86
	I feel free and independent when I drive	0.83
	I like driving just for fun	0.79
Status of car	To me, driving is only a convenient way to get around	0.75
	To me, it does not matter which type of car I drive	0.65

References

Ansari Esfeh, M., Wirasinghe, S. C., Saidi, S., & Kattan, L. (2021). Waiting time and headway modelling for urban transit systems–a critical review and proposed approach. Transport Reviews, 41(2), 141-163.

Baron, R. M., & Kenny, D. A. (1986). The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. Journal of Personality and Social Psychology, 51(6), 1173.

Baum-Snow, N., Kahn, M. E., & Voith, R. (2005). Effects of urban rail transit expansions: Evidence from sixteen cities, 1970-2000. Brookings-Wharton Papers on Urban Affairs, 147-206.

Benzeval, M., & Judge, K. (2001). Income and health: The time dimension. Social Science & Medicine, 52(9), 1371-1390.

Cao, X. (2015). Examining the impacts of neighborhood design and residential self-selection on active travel: a methodological assessment. Urban Geography, 36(2), 236-255.

CEIC (2020). China Disposable Income per Capita. Available at: https://www.ceicdata.com/en/china/disposable-income-per-capita-prefecture-level-city-urban/disposable-income-per-capita-urban-sichuan-chengdu, and https://www.ceicdata.com/en/china/disposable-income-per-capita-prefecture-level-city/disposable-income-per-capita-shaanxi-xian (Accessed on March 17, 2021).

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

Chengdu Municipal People's Government (2019). Guidelines of applications for a rental subsidy. Available at: http://cdzj.chengdu.gov.cn/cdzj/bzzn/2020-03/10/content_16055285665841f799dcba99b3026434.shtml (Accessed on March 15, 2021).

Churchill, S. A., & Smyth, R. (2019). Transport poverty and subjective wellbeing. Transportation Research Part A: Policy and Practice, 124, 40-54.

Curl, A., Clark, J., & Kearns, A. (2018). Household car adoption and financial distress in deprived urban communities: A case of forced car ownership? Transport Policy, 65, 61-71.

Currie, G., & Senbergs, Z. (2007). Exploring forced car ownership in metropolitan Melbourne, Australasian Transport Research Forum 2007.

Dawkins, C., & Moeckel, R. (2016). Transit-induced gentrification: Who will stay, and who will go? Housing Policy Debate, 26(4-5), 801-818.

De Vos, J., Mokhtarian, P.L., Schwanen, T., Van Acker, V., & Witlox, F. (2016). Travel mode choice and travel satisfaction: bridging the gap between decision utility and experienced utility. Transportation 43 (5), 771-796.

Ettema, D., Friman, M., Gärling, T., Olsson, L. E., & Fujii, S. (2012). How in-vehicle activities affect work commuters' satisfaction with public transport. Journal of Transport Geography, 24, 215-222.

Ettema, D., Gärling, T., Eriksson, L., Friman, M., Olsson, L. E., & Fujii, S. (2011). Satisfaction with travel and subjective well-being: Development and test of a measurement tool. Transportation Research Part F: Traffic Psychology and Behaviour, 14(3), 167-175.

Ettema, D., Gärling, T., Olsson, L. E., Friman, M., & Moerdijk, S. (2013). The road to happiness: Measuring Dutch car drivers' satisfaction with travel. Transport Policy, 27, 171-178.

Fang.com (2020). The report on housing prices of 100 Chinese cities (December 2019). Available at:

https://fdc.fang.com/report/12720.html (Accessed on March 17, 2021).

Flint, E., & Cummins, S. (2016). Active commuting and obesity in mid-life: cross-sectional, observational evidence from UK Biobank. The Lancet Diabetes & Endocrinology, 4(5), 420-435.

Friman, M., Gärling, T., Ettema, D., & Olsson, L. E. (2017). How does travel affect emotional well-being and life satisfaction? Transportation Research Part A: Policy and Practice, 106, 170-180.

Gerber, P., El-Geneidy, A., Manaugh, K., & Lord, S. (2020). From workplace attachment to commuter satisfaction before and after a workplace relocation. Transportation Research Part F: Traffic Psychology and Behaviour, 71, 168-181.

Glaeser, E. L., Kahn, M. E., & Rappaport, J. (2008). Why do the poor live in cities? The role of public transportation. Journal of Urban Economics, 63(1), 1-24.

Handy, S., Cao, X., & Mokhtarian, P. (2005). Correlation or causality between the built environment and travel behavior? Evidence from Northern California. Transportation Research Part D: Transport and Environment, 10(6), 427-444.

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), 1-14.

Hayes, A. F. (2017). Introduction to mediation, moderation, and conditional process analysis: A regression-based approach. Guilford publications.

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.

Khullar, D., & Chokshi, D. A. (2018). Health, income, & poverty: Where we are & what could help. Health affairs, Doi: 10.1377/hpb20180817.901935.

Lades, L. K., Kelly, A., & Kelleher, L. (2020). Why is active travel more satisfying than motorized travel? Evidence from Dublin. Transportation Research Part A: Policy and Practice, 136, 318-333.

Lucas, K., Mattioli, G., Verlinghieri, E., & Guzman, A. (2016). Transport poverty and its adverse social consequences. In Proceedings of the Institution of Civil Engineers-Transport, 169(6), 353-365.

Lunke, E. B. (2020). Commuters' satisfaction with public transport. Journal of Transport & Health, https://doi.org/10.1016/j.jth.2020.100842.

Manaugh, K., & El-Geneidy, A. M. (2013). Does distance matter? Exploring the links among values, motivations, home location, and satisfaction in walking trips. Transportation Research Part A: Policy and Practice, 50, 198-208.

Mao, Z., Ettema, D., & Dijst, M. (2016). Commuting trip satisfaction in Beijing: Exploring the influence of multimodal behavior and modal flexibility. Transportation Research Part A: Policy and Practice, 94, 592-603.

Martin, A., Panter, J., Suhrcke, M., & Ogilvie, D. (2015). Impact of changes in mode of travel to work on changes in body mass index: Evidence from the British Household Panel Survey. Journal of Epidemiology & Community Health, 69(8), 753-761.

Morris, E. A., & Guerra, E. (2015a). Mood and mode: Does how we travel affect how we feel? Transportation, 42(1), 25-43.

Morris, E. A., & Guerra, E. (2015b). Are we there yet? Trip duration and mood during travel. Transportation Rresearch Part F: Traffic Psychology and Behaviour, 33, 38-47.

Mouratidis, K., Ettema, D., & Næss, P. (2019). Urban form, travel behavior, and travel satisfaction. Transportation Research Part A: Policy and Practice, 129, 306-320.

Pan, H., Shen, Q., & Xue, S. (2010). Intermodal transfer between bicycles and rail transit in Shanghai,

China. Transportation Research Record, 2144(1), 181-188.

Singleton, P. A. (2019). Walking (and cycling) to well-being: Modal and other determinants of subjective well-being during the commute. Travel Behaviour and Society, 16, 249-261.

Smith, O. (2017). Commute well-being differences by mode: Evidence from Portland, Oregon, USA. Journal of Transport & Health, 4, 246-254.

Smith, O.B. (2013). Peak of the Day or the Daily Grind: Commuting and Subjective Well-Being. Portland State University Ph.D. thesis.

St-Louis, E., Manaugh, K., van Lierop, D., & El-Geneidy, A. (2014). The happy commuter: A comparison of commuter satisfaction across modes. Transportation Research Part F: Traffic Psychology and Behaviour, 26, 160-170.

Stokes, G., & and Lucas, K. (2011) National Travel Survey Analysis. TSU Working Paper Series, Ref. 1053, School of Geography and the Environment, Oxford.

The United Nations. (2020). World Cities Report 2020: The Value of Sustainable Urbanization. https://unhabitat.org/sites/default/files/2020/10/wcr_2020_report.pdf (Accessed on March 12, 2021).

Titheridge, H., Mackett, R. L., Christie, N., Oviedo Hernández, D., & Ye, R. (2014). Transport and Poverty: A Review of the Evidence. University College London, London.

Walsleben, J. A., Norman, R. G., Novak, R. D., O'Malley, E. B., Rapoport, D. M., & Strohl, K. P. (1999). Sleep habits of Long Island rail road commuters. Sleep, 22(6), 728-734.

Wang, F., Mao, Z., & Wang, D. (2020). Residential relocation and travel satisfaction change: An empirical study in Beijing, China. Transportation Research Part A: Policy and Practice, 135, 341-353.

Ye, R., & Titheridge, H. (2017). Satisfaction with the commute: The role of travel mode choice, built environment and attitudes. Transportation Research Part D: Transport and Environment, 52, 535-547.

Ye, R., & Titheridge, H. (2019). The determinants of commuting satisfaction in low-income population: A case study of Xi'an, China. Travel Behaviour and Society, 16, 272-283.

Ye, R., De Vos, J., & Ma, L. (2020). Analysing the association of dissonance between actual and ideal commute time and commute satisfaction. Transportation Research Part A: Policy and Practice, 132, 47-60.

Zhao, P. (2015). The determinants of the commuting burden of low-income workers: Evidence from Beijing. Environment and Planning A: Economy and Space, 47(8), 1736-1755.