Exploring the effects of built environment, location and accessibility on travel time of long-distance commuters in Suzhou and Shanghai, China

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Exploring the association of the built environment, accessibility and commute frequency with the travel times of high-speed rail commuters: Evidence from China

Abstract

High-speed rail (HSR) enables time-space shrinkages, thus enlarging the extent of spatial interaction between cities connected by HSR. This opens up new opportunities for the decoupling of workplace and residence for those seeking improved employment options involving long-distance commuting, which did not appear attractive before the arrival of HSR. Although travel distance tends to increase over time, time spent on travel remains relatively stable. This paper attempts to explore door-to-door commuting patterns – the way commuting time is associated with three factors in practice; namely, the built environment, transport modes (from residence and workplace to HSR stations) and commute frequency. Econometric and statistical analyses are employed to examine evidence from China that draws on a survey targeting Suzhou-based HSR commuters who travel to work in Shanghai, a large neighbouring city.

The findings present three major points. First, a dense urban environment around residence and workplace is associated with reduced commuting time to high-density healthcare facilities (Suzhou and Shanghai) and financial institutions (Suzhou only). However, the density of public transport facilities near both residence and workplace has no association with commute time. Second, taking metro systems to and from HSR stations shows significant association with increased commuting time for the first and last miles, while walking from HSR stations to the workplace shows significant reduction of commuting time. Third, daily commuting is associated with reduced commuting time in the first mile, while weekly commuting is reversely related to longer commute time in the last mile, which is coupled with a shorter commuting time for the first mile than the last mile. Essentially, this could be attributed to different urban forms between home and work cities.

These findings lead us to conclude that reducing the total commuting time for a door-to-door journey is a key factor in associated commuting patterns, commuting frequency, and travel mode choice. This reflects the choices commuters make in relation to where they live rather than where they work, which offers fewer options. A longer last mile relates to a weekly commuting pattern rather than a daily commuting. The current public metro systems in both home and work cities appear to be lengthy and inefficient. Transit-oriented and integrated development is required to provide more efficient experiences for commuters.

Keywords: High Speed Rail (HSR), intercity commute, and long-distance travel, Suzhou, Shanghai

Introduction

The development of high-speed rail (HSR) networks significantly reduces train time between cities, which has been found to facilitate economic growth (Chen, 2019) and utilisation for diverse purposes; for instance, business travel, work, tourism, and informal meetings (Chen & Yuan, 2017; Chen et al., 2016). Recent developments in HSR have heightened the opportunity for commuting, especially for people who live in small- and medium-sized cities and travel to work in major metropolitan areas because HSR is more conducive to reducing total travel time compared with cars and conventional rail (Garmendia et al., 2012; Vickerman, 2015). Available evidence has shown that travel time remains relatively stable, and the limit of how far and fast people travel has been extended further with the evolution of transport technology (Lyons & Urry, 2005).

Existing research recognises the critical role played by HSR in long-distance commuting. One conventional notion is that the operation of HSR, to some extent, has mitigated a greater spatial mismatch between home and work. Essentially, this spatial mismatch amplifies the difficulty for residents who commute for better jobs because of greater geographical distance (DeRango, 2001). Long-distance commuting via HSR makes it possible to identify and match prospects of employment for talented and skilled job seekers from other regions as there are more diverse and specialised job opportunities in big metropolitan areas (Fröidh, 2005; Sandow, 2008; Vickerman, 2015). Additionally, HSR has been viewed as an efficient and popular long-distance commute mode, providing benefits including (1) travelling time is shorter; (2) HSR stations are easily accessible using public transport; (3) HSR is relatively more affordable (in some countries) and convenient than other transport modes; (4) HSR is punctual; (5) HSR reduces road congestion and potentially improves air quality as commuters choose to use public transport; and (6) HSR is the most efficient transport mode for intercity trips (Garmendia et al., 2011; Guirao et al., 2018; Lin et al., 2018; Sandow, 2008; Sandow & Westin, 2010).

Although many studies have examined the benefits and effects of HSR, such as efficiency and time saving, insufficient empirical evidence exists to show how HSR commuting may work, how people access HSR stations, time required from home to HSR stations, and whether the built environment attributes, coupled with transport options, affect travel behaviour. Wang et al. (2013) have pioneered research to identify total travel time from the peripheral location of HSR stations to a departing location or destination. Meanwhile, HSR users are well studied in terms of their travel behaviour and their individual socio-economic profiles (Chen et al., 2016). A recent study examines how HSR users choose transport modes in access and egress stages for business and leisure travel in relation to travelers' socioeconomic attributes, built environment of HSR stations and commuting time (Yang et al., 2019). However, few studies have conducted primary research on the travel time optimisation of individual HSR commuters from their commuting spatial patterns of a door-to-door-journey (D2D). In addition, it is worth exploring how the commute times of daily and weekly commuting may vary.

This paper will contribute to the existing literature through a new primary pilot study on HSR commuters and their related D2D commute accessibility to examine spatial commuting patterns and explore how these patterns are expressed in terms of commuting time in relation to the built environment attributes, transport mode choices to and from HSR stations and commute frequency. More specifically, this study will identify whether the built environment attributes coincide with commute time; how transport modes for first-mile travel (home to HSR stations) and last-mile travel (HSR stations to workplace) contribute to total commuting time; and links between daily and weekly commuting in relation to commuting time.

Evidence for this study draws on a survey targeting commuters living in Suzhou and commuting to Shanghai by HSR on a regular basis. As HSR between Suzhou and Shanghai takes about 30 minutes, this can be considered a fixed time. Total commuter time is determined mainly by accessibility of the first and last mile. Although HSR services, intervals and connection with other transport are additional important determinants for assessing travel time, this paper focuses on the potential relationship between built environment and travel mode as major variables in commuting time. OLS econometric models are employed to analyse 223 samples whose built environment attributes (residence and workplace), transport modes, and commuting frequency are obtainable. Findings of this paper aim to provide local and national policy-makers, planners and practitioners with a clear understanding of the spatial patterns of intercity HSR commuting to assist in the formation of sensible transport and land use policy and practice in the era of HSR.

Literature Review

Long-distance high-speed rail commuting

Long-distance commuting can be regarded as a substitute for migration (Green et al., 1999), involving a complex interaction of factors relating to commuting, migration, housing and labour markets (Haas & Osland, 2014). Several studies have considered potentially appropriate levels for the geographical and temporal boundary of commuting. Existing research has shown an average commuting time of 42 minutes in Beijing (Wang & Xu, 2010); 46 minutes in Guangzhou (Zhou & Yang, 2005); and 59.56 minutes in Yangtze River Delta area, which is the largest average commuting time among the three mega-city regions in China (Zhang, 2016).

The general trend shows an increase in commuting distance. Research in England shows a general rise in commuting distance and time (1988-2015) and increased flexibility in work and commuting patterns (DfT, 2006). Commuting time has increased, 4% of UK commuters travelling more than 100 kilometres (Lyons & Chatterjee, 2008). Sweden also has evidence of increased commuting time (Sandow & Westin, 2010). In a recent long-distance commuting survey in California (Mita & Saphores, 2019), about half of commuters travelled between 50 and 75 miles.

Despite the increase in commuting distances, it has been demonstrated that travel time remains stable, extending the limits of how far and fast people can travel (Lyons & Urry, 2005; Urry, 2007; Van Wee et al., 2006). Early studies of HSR anticipated significant impacts on travel behaviour (Blum et al., 1997). Numerous studies have established that one hour has become the threshold for commuting over long distances. Garmendia et al. (2011) show that metropolitan integration has been enhanced in Spain between major cities connected within an hour by HSR, reinforcing existing trends or creating new mobility patterns. Chen and Hall (2011) demonstrate that upgraded high-speed train (HST) services in the UK have made London attractive, both as a workplace and for residence, to people in towns one hour away from London since rail improvements. Another key study has shown that people are willing to spend 30-90 minutes commuting, extending HSR commuting to 2 hours if daily business travel/commuting is included (Ureña et al., 2009).

Commute time and type of commute

Commuting time is closely associated with commuters' socioeconomic attributes, including households' situations and working hours. Commuting time has been shown to be largely influenced by household-related variables, including schooling (Chen et al., 2016). This is because the daily travel pattern depends on the number of destination points and on individual trips. Additionally, two main types of regular commuting are daily and weekly. Daily commuting denotes a daily return travel between home and workplace while weekly commuting refers to commuters who stay in the workplace most of the weekdays and return home once a week. There is a third type of commuting, which is irregular and flexible in commuting and occasionally involving in business trips. Early studies reveal that both daily and weekly trips between home and work increase because of job-housing imbalance (Lyons & Chatterjee, 2008; Sultana & Weber, 2007). Green et al. (1999) examined households choosing to substitute longer-distance commuting for migration. Their findings show that long-distance weekly commuting may produce more substantial financial and career benefits for commuters but most of the costs and household responsibilities are borne by their partners (ibid.). However, intensive working hours of commuters during weekdays impact on their daily travel and activity patterns (Sundo & Fujii, 2005). For instance, a two-hour increase in working time displaces time spent on household activities, such as sleeping, commuting and pre-work preparation, indicating that individual commuters place different values on their commute time (Asensio & Matas, 2008).

Travel mode choices

Travel mode choices for accessing and egressing HSR stations could be key elements in determining total commuting time. Indeed, since commuters use an intermodal system to get to work, 'access time' (first mile: from home to the HSR station of departure) and 'egress time' (last mile: HSR station of arrival to workplace) are considered key segments of intercity trips using HSR services (Zhao & Yu, 2018). All other things being equal, travel time via HSR is fixed for commuters in a specific section of HSR. Several studies have established that accessibility of HSR stations greatly affects total travel time. It is acknowledged that the intermodal transport system connecting different transport modes (airport – other transport modes and HSR – other transport modes) becomes increasingly important for time-efficient travel (Vespermann & Wald, 2011). Several studies have found that HSR stations in many smaller cities are readily accessible to larger metropolitan areas and are well-connected with public transport systems, providing more opportunities for commuters to reduce travel time (Chen et al., 2016; Zhao et al., 2015; Zhao & Yu, 2018). However, several studies have argued that people are more inclined to use cars than public transport when commuting (Van et al., 2014; Zhao, 2013). One study found that more than half the passengers use private cars (28%) and taxis (29.7%), while about 40% use public transport, including bus (27%) and subway (12.1%) (Chen et al., 2016). Moreover, studies show that people are becoming less dependent on active transport such as bikes and e-bikes (Zhao, 2013) whereas this situation depends on the distance between home and workplace in the local contexts and would be likely changed after the COVID-19 crisis due to the fear of infections through using public transport. Wang et al. (2014) argue that people prefer to use HSR if travel time or cost is less than that of other modes and when the journey cannot be made on a single transport mode. Nonetheless, in relation to commuting, little is known about whether HSR influences choice of transport mode.

Built environment

The built environment and land use surrounding the residential location of a commuter could affect travel mode choice and travel time to HSR stations. Numerous studies have examined the effects of built environment and land use patterns on commuting behaviour (Cervero, 1996; Cervero & Kockelman, 1997; Wang and Xu, 2010; Zhao, 2013). High-density development with singular land use type and an inefficient road network could generate congestion, indicating that travel time could increase. Similarly, sprawled urban form leads to expense and time-wasting for commuting because a larger urban area increases the spatial dispersion of jobs and housing, resulting in longer commuting, congestion, and more energy consumption (Lowe, 1998). However, people may choose an affordable location, although they would need to spend more on transport. Thus, HSR commuters may maintain the practice of long-distance commuting if they are willing to stay in smaller cities to save housing costs rather than transport costs. Alternatively, commuters may prefer to minimise the separation and distance between home and job because commuting adversely affects the lives of households (Clark et al., 2003).

Methodology

Study area

This study focuses on long-distance commuters living in Suzhou and working in Shanghai. Following the arrival of HSR services, these long-distance commuters could be native Suzhou residents or new immigrants who voluntarily choose to live in Suzhou for more affordable living costs, a better living environment, and cheaper housing prices.

Suzhou is one of the most important cities in the Yangtze River Delta (YRD), having an area of 453 square miles and a population of 10.46 million in the sixth census of 2010 (MBSS, 2017). It is adjacent to Shanghai, the regional capital in YRD. The centres of the two cities are 100 kilometres apart. They have strong economic and industrial dependences that have long been supported by a railway connection. In fact, many cities in the Yangtze River Delta region should address the issue of long-distance commuting because they share economic connections with Shanghai. According to the 'Yangtze River Delta Cities Inter-City Commute Annual Report 2019', the number of inter-city commuters among Suzhou, Jiaxing, Nantong and Shanghai reached 57,000 in 2019 (Coho, 2019). The first railway arrived in Suzhou at the beginning of the 20th century. Before the railway speed acceleration in the 1990s, a Suzhou-Shanghai railway journey took two hours, which was reduced to 30 minutes following introduction of HSR in 2010. Over the last decade, four stations in Suzhou Urban Districts (namely, Suzhou New District Station, Suzhou Station, Suzhou North Station, SIP Station) have been served by two types of HSR (see Figure 1). Suzhou North Station is located on the Beijing-Shanghai National HSR Trunk line, while Suzhou New District Station, Suzhou Station, and SIP station are located on the Shanghai-Nanjing inter-city HSR line. As illustrated in Figure 1, all four stations are approximately 30 minutes from Shanghai by HSR. Two main HSR stations in Shanghai are Shanghai and Hongqiao HSR stations. The HSR network in the YRD area has been developed mainly along the cities south of Yangtze River with advanced rail networks (Wang, 2018). Shanghai and Suzhou are the most efficient cities in YRD in terms of accessibility (Wang et al., 2013). This implies that Shanghai-Suzhou HSR lines can provide a good testbed for examining commuting behaviour, because it is generally assumed that there is a greater possibility of numbers of HSR commuters increasing as a result of the 'same-city' effects brought about by HSR. Traveling between Suzhou and Shanghai via HSR takes an average of 30 minutes, which is considered a reasonable commuting time.

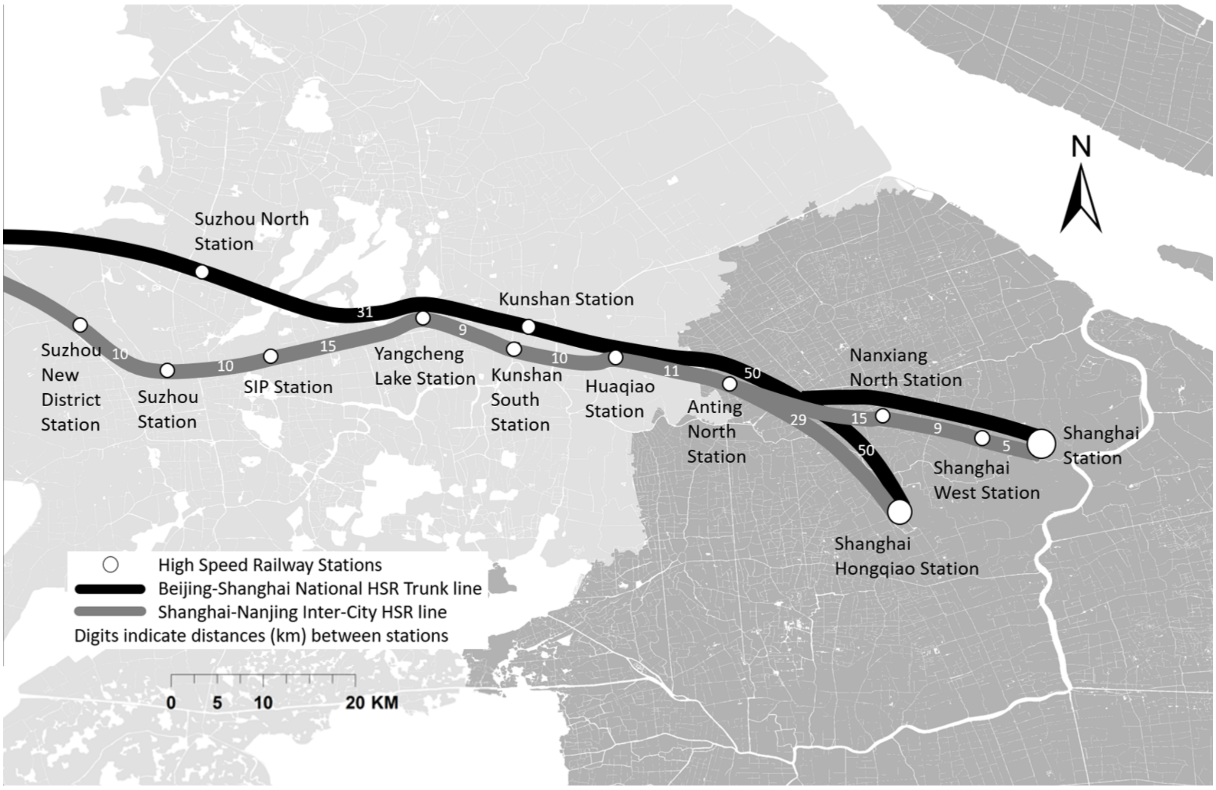


Figure 1: Shanghai-Suzhou High Speed Railway Map
Source: Authors.

Data

This study uses both primary survey and secondary point of interest (POI) data for spatial mapping and measurement. Survey samples were collected in the summer of 2018 for a pilot research project to examine long-distance HSR commuters in China. POI data were collected from the Gaode Map using the API location search function to retrieve commuters' home addresses and POI around their workplaces to measure the built environment configuration around these two locations.

The targeted survey participants are Suzhou-based residents who use Suzhou HSR stations for long-distance commuting. Two survey methods are used: (1) face-to-face (F2F) contact and (2) indirect online questionnaire by circulating QR codes. Since HSR commuting is a relatively new phenomenon and there are no reliable data to estimate the number of HSR commuters, this paper adopts a purposive sampling method (Battaglia, 2008).

In conducting the F2F method, voluntary participants were approached (7-10 am, 10th -18th July, 2018) at four Suzhou stations while waiting for trains. This limited waiting time prohibited them from completing the questionnaires in the station but they were able to take a pamphlet with a QR code to complete the online questionnaire during their journey. An additional survey was conducted at Shanghai station on the evening of July 17th, 2018 with commuters returning home after work. The F2F method proved to be efficient in maximising response rates, since participants could understand the project and questions and were willing to circulate the questionnaire among potential participants using QR codes. This F2F method was successful in reaching HSR commuters who were not members of the two WeChat groups identified.

An indirect online questionnaire was conducted for 11 consecutive days. The social messaging application, ‘WeChat’, was used to circulate the online survey. ‘WeChat’ is similar to

‘WhatsApp’, which is commonly used in western countries. Two WeChat groups were found to have existed for some time, allowing information-sharing among HSR commuters (in total about 500 HSR commuters). Overall, 288 questionnaires were completed and the information stored in the online survey cloud-based platform ‘Wenjuanxing’ (www.WjX.cn), which is widely used in China.

The questionnaire was based on a conceptual framework that primarily includes socioeconomic characteristics of HSR commuters, built environment for origin and destination, travel mode choice of HSR users, HSR commuting time, and distance in three sections (home to HSR station, HSR to HSR, and HSR to destination). Commuting times collected in the questionnaire were divided into three sections according to origin, destination and the two HSR stations used, which were defined and named accordingly. Commuters’ departure from home to work is considered a complete commuting journey (TTT). The travel time from home (origin) to Suzhou HSR stations is defined as TT1; the time taken from Shanghai HSR stations to work (destination) is TT2; and the remaining time, from Suzhou to Shanghai on the high-speed train, is TTR. TTT is the sum of TT1, TT2 and TTR. Unlike the two novel studies that standardise commute time by travel frequency (i.e., total number of trips made in a week) (Shen, 1999, 2000), this study simply uses commuting time for each section of travel and separately utilises dummy variables for commuting frequency for three models of commuting time.

Regarding socio-economic attributes and commuting behaviour, the collected data is described in the following categories (see Table 1), which include commuting time, family structure, working hours, housing cost, built environment, transport mode, and commuting frequency. Built environment attributes include catering, financial, health care, metro stations, bus stations and intersections in both cities. Initially, the model explores the possibility of more variables such as the "lifeservice" and "shopping" variables in the “built environment” category while they are removed due to insignificance of results and correlation issues.

Table 1 Data description

Category	**Variable**	**Description**
Commuting time	TT1 TT2 TTR TTT	TT1 is the respondents' commuting time from home to Suzhou HSR stations. TT2 is the time required from Shanghai HSR stations to workplace. TTR is the time required between boarding HSR in Suzhou and the destination in Shanghai (TTR is not used in the regression model). TTT is the total commuting time from home to workplace, which is the sum of TT1, TT2 and TTR. TT1, TT2 and TTT serve as dependent variables.
Gender	Male Female (ref)	The dummy variable represents the gender of commuters. The dummy variable "Female" is set as a reference variable.

Age	20-29 30-39 >= 40 (ref)	The dummy variable divides the age of commuters into three groups: 20-29, 30-39, and 40 and over 40.
Family Structure	With children W/out children Single and Other (ref)	The dummy variable indicates commuters in families with or without children. 'Single and Other' is a reference variable that indicates a type of commuters who didn't get married or other situations.
Working Hours	Less than 30 (ref) 30-40 40-50 Over 50	Respondents' weekly working hours are divided into less than 30 hours, 30-40 hours, 40-50 hours and over 50 hours, respectively.
Housing Cost	Less than 3,999 4,000-9,999 Over 10,000 No cost (ref)	The respondents' monthly housing expenses (including mortgage or rent) are divided into 3 groups: less than 3,999 yuan, 4,000-9,999 yuan, and more than 10,000 yuan. "No cost" dummy variable refers to the respondents who do not spend mortgage or rent on housing.
Built Environment	Home in Suzhou Catering 1 financial 1 healthcare 1 Metro station 1 Bus station 1 Intersection 1	The POI variable shows the built environment near the respondents' homes in Suzhou, including the number of catering services, financial institutions, health-care facilities, metro stations, bus stations, and road intersections within the 800-metre buffer zone near their home.
	Workplace in Shanghai Catering 2 Financial 2 Healthcare 2 Metro station 2 Bus station 2 Intersection 2	The POI variable shows the built environment near the respondents' workplace in Shanghai, including the number of catering services, financial institutions, health-care facilities, metro stations, bus stations, and road intersections within the 800-metre buffer zone near their workplace.
Transport Mode	Home to HSR stations -Walking -Biking -Bus -Metro - Car/Taxi (ref)	The dummy variables represent transport modes selected by the respondents from home to Suzhou HSR stations, including walking, biking, bus, metro, and car/taxi.
	HSR stations to workplace -Walking -Biking -Bus -Metro -Car/taxi (ref)	The dummy variables represent the transport modes selected by the respondents from Shanghai HSR stations, including walking, biking, bus, metro, and car/taxi.

Commuting Frequency	Daily Weekly Others (ref)	Frequency variables refer to respondents who commute daily and weekly. "Others" dummy variable is used as a reference variable to indicate other commuting frequencies other than regular weekly and daily commuting.

Source: Authors

Econometric Model

This study employs an econometric model to understand the associations of built environment attributes, transport mode choice and socio-economic attributes with resulting commuting time. The ordinary least square (OLS) regression model is selected as the basic model to estimate the commute time because (1) OLS can intuitively and concisely obtain the marginal effects of categorical variables from the coefficients; (2) OLS can conveniently attain the marginal effect of the model, including interaction variables; (3) the dependent variable commuting time is a continuous variable that can be tested with a quantile regression model; however, the significance of the regression results of OLS is higher than the quantile regression in practice. Following are the conceptual model specifications of the econometric model used in this study.

$$\text{Commuting time}_i = \alpha_i + \beta_0 \cdot \text{Socioeconomic characteristics}_i + \beta_1 \cdot \text{Built environment}_i + \beta_2 \cdot \text{Transport mode}_i + \beta_3 \cdot \text{Commute frequency}_i + \varepsilon_i$$

The variables involved in the OLS model are illustrated in Table 1. Commuting time serves as the only dependent variable. Socioeconomic attributes of these inter-city commuters include family structure, working hours (weekly), housing costs (monthly rent or mortgage). Built environment attributes refer to the condition of surrounding areas of the commuter's home and workplace, expressed by the density of catering services, financial institutions, and healthcare facilities. Transport mode (from residence to HSR stations and from HSR stations to workplace) is classified as walking, cycling, bus or metro.

Three models indicating commuting time are formulated as follows.

(1) residence to HSR stations in Suzhou
$$TT1 = \alpha_i + \beta_0 \cdot \text{Socioeconomic Characteristics}_i + \beta_1 \cdot \text{Built Environment (Suzhou)}_i + \beta_2 \cdot \text{Transport Mode (Suzhou)}_i + \varepsilon_i$$
(2) HSR stations in Shanghai to workplace
$$TT2 = \alpha_i + \beta_0 \cdot \text{Socioeconomic Characteristics}_i + \beta_1 \cdot \text{Built Environment (Shanghai)}_i + \beta_2 \cdot \text{Transport Mode (Shanghai)}_i + \varepsilon_i$$
(3) residence in Suzhou to workplace in Shanghai
$$TTT = \alpha_i + \beta_0 \cdot \text{Socioeconomic Characteristics}_i + \beta_1 \text{ Transport Mode (Suzhou)}_i + \beta_2 \cdot \text{Transport Mode (Shanghai)}_i + \beta_3 \cdot \text{Commute Frequency}_i + \varepsilon_i$$

Table 2 summarises the descriptive statistics of the variables. The most distinctive features of these commutes include a majority of men (78.03%); 30-39 years old as the main age group (60.09%); married with children (61.88%); more than half work 40-50 hours per week (51.12%); more than half access home to HSR stations by car/taxi (54.26%); nearly three-quarters egress HSR stations to workplace by metro (71.75%).

For the age group, it seems reasonable to assume younger commuters would be more likely to tolerate longer commuting time if it is necessary to secure suitable jobs. The variable for 'married with children' is expected to increase commuting time because commuters with children may have to drop off their children at nursery, kindergarten and school. For an acceptable combined work and commuting time, a trade-off between the two is also anticipated. Shorter working hours free up more time for commuting, and vice versa. Housing costs could produce puzzling results but, according to bid rent theory, it can be hypothesised that housing costs decrease commuting time because people tend to prefer residential locations in proximity to their workplace. A correlation test shows no high correlation between socioeconomic characteristics and commute frequency.

Table 2. Descriptive statistics of socio-economic characteristics, transport mode, built environment, and commuting frequency

Category	Variable	# of Samples	Percentage	Mean
Commuting time	TT1	223	-	23.00
	TT2	223	-	35.49
	TTR	223	-	31.06
	TTT	223	-	89.56
Gender	Male	174	78.03%	0.78
	Female (Ref)	49	21.97%	0.22
Age	20-29	57	25.56%	0.26
	30-39	134	60.09%	0.60
	>40 (ref)	32	14.35%	0.12
Family Structure	Family_children	29	13.01%	0.13
	Family_nochild	138	61.88%	0.62
	Single and other (Ref)	56	25.11%	0.25
Working Hour	30-40	59	26.46%	0.22
	40-50	114	51.12%	0.57
	>50	39	17.49%	0.18
	<30 (Ref)	11	4.93%	0.03
Housing Cost	Cost(<3,999)	77	34.53%	0.31
	Cost(4000-9999)	71	31.84%	0.32
	Cost(>10000)	29	13.00%	0.13
	No Cost (Ref)	46	20.63%	0.24
Built Environment	catering1	223	-	113.21
	financial1	223	-	16.22
	healthcare1	223	-	13.45
	Metrostation1	223	-	0.39
	Busstation1	223	-	8.05
	Intersection1	223	-	292.25
	catering2	223	-	516.78
	financial2	223	-	127.17
	healthcare2	223	-	53.12
	Metrostation2	223	-	192.78
	Busstation2	223	-	14.17
	Intersection2	223	-	730.88

Transport Mode	Home to HSR stations			
	Walk	13	5.83%	0.06
	Bike	12	5.38%	0.05
	Bus	28	12.56%	0.13
	Metro	49	21.97%	0.22
	Car/Taxi (Ref)	121	54.26%	0.54
	HSR stations to workplace			
	Walk	14	6.28%	0.06
	Bike	3	1.35%	0.01
	Bus	19	8.52%	0.09
	Metro	160	71.75%	0.72
	Car/Taxi (Ref)	27	12.11%	0.12
Commuting Frequency	Daily commuting	79	35.43%	0.35
	Weekly commuting	64	28.70%	0.29
	Others (ref)	80	35.87%	0.24

Source: authors

Results and Findings

The results of the regression analysis are summarised in Table 3. In general, the direction of the estimated parameters is similar across the three models although the statistical significance of the models varies. The results show several possible associations of built environment and transport mode choice to and from HSR stations with HSR commuting time.

Built Environment

Regarding the density of three types of land use, the regression results show a statistical significance of healthcare facilities (-0.211**) around residence while significance of financial institutions (-0.0409**) and healthcare facilities (-0.116*) around workplace. A high density of financial institutions can be places close to city centres and regarded as a place for jobs whereas healthcare facilities are more associated with residential locations. This finding reflects the reality of a general residential area of living in Suzhou and more mixed-use workplaces in Shanghai. However, an unanticipated finding is that density of metro and bus station around both residence and workplace does not show significant associations with commuting time. The only statistical significance is the road intersection density is associated with increased commuting time near workplace. The finding implies that the public transport accessibility around either residence or workplace does not significantly associate with commuting time.

Transport mode

The regression results show that among four modes, the two public transport modes in the TT1 section are statistically significant increasing average times while in the TT2 section walking reduces average time whilst metro increases average time. The results indicate that the access trip in Suzhou by public transport would take longer than driving. The egress trip by metro in Shanghai is similarly taking more time than by car while the commuting time is much shorter by walking. Interestingly, the figures show that the increased time by metro in a smaller city, Suzhou is larger than that a much larger city, Shanghai. These regression findings support explanations of the picture presented by descriptive statistics. Avoiding long access time by metro, the car/taxi modes are the major mode in the access trip while, in spite of long commuting time, the metro is the primary form of transport in the egress trip in Shanghai. This will be discussed in more detail in the discussion section.

Table 3: Regression results of three commuting models

Independent Variables	Dependent Variables		
	TT1	TT2	TTT
Male	-0.871	2.234	2.349
	(2.275)	(2.938)	(3.956)
Age 20-29	-4.254	-2.316	-4.515
	(3.227)	(4.190)	(5.640)
Age 30-39	-1.227	-3.077	-2.970
	(2.683)	(3.496)	(4.708)
Family_children	0.504	4.901	3.918
	(2.530)	(3.133)	(4.411)
Family_nochild	3.947	15.3138***	18.207***
	(3.617)	(4.399)	(5.864)
Workinghour3040	-1.896	-17.399**	-44.300***
	(5.932)	(7.635)	(10.248)
Workinghour4050	1.950	-15.835**	-37.913***
	(5.789)	(7.353)	(9.903)
Workinghour50	2.802	-16.691***	-35.623***
	(5.958)	(7.634)	(10.317)
Cost3999	-2.603	-2.582	1.057
	(2.480)	(3.368)	(4.500)
Cost40009999	-3.657	-10.801***	-12.687***
	(2.588)	(3.239)	(4.392)
Cost10000	-1.866	-8.606**	-8.559
	(3.226)	(4.147)	(5.722)
catering1	0.002		
	(0.014)		
financial1	-0.014		
	(0.056)		
healthcare1	-0.211**		
	(0.094)		
Metrostation1	0.846		
	(1.694)		
Busstation1	0.310		
	(0.280)		
Intersection1	0.004		
	(0.008)		
hometoHSR_Walk	-0.037		4.210
	(4.253)		(7.653)
hometoHSR_Bike	-6.063		-8.922
	(4.117)		(7.014)
hometoHSR_Bus	15.556***		19.860***
	(2.945)		(5.060)

hometoHSR_Metro	11.993***		12.632***
	(2.334)		(4.142)
catering2		0.010	
		(0.008)	
financial2		-0.0409**	
		(0.016)	
healthcare2		-0.116*	
		(0.060)	
Metrostation2		0.035	
		(0.029)	
Busstation2		-0.365	
		(0.290)	
Intersection2		0.006**	
		(0.002)	
HSRtoworkplace_Walk		-16.010***	-15.697**
		(5.913)	(7.922)
HSRtoworkplace_Bike		-9.718	-0.931
		(10.722)	(14.545)
HSRtoworkplace_Bus		-3.224	11.485
		(5.520)	(7.633)
HSRtoworkplace_Metro		10.746***	12.802**
		(3.713)	(5.203)
Dailycommuting	-5.434**	0.564	-7.237*
	(2.269)	(2.940)	(3.954)
Weeklycommuting	-0.401	6.095*	5.090
	(2.584)	(3.295)	(4.432)
Constant	22.588***	44.950***	115.915***
	(6.740)	(8.226)	(11.084)
Samples	223	223	223
Adjusted R square	19.93%	22.88%	30.29%

Standard errors in parentheses
*p < 0.1; **p < 0.05; ***p < 0.01.

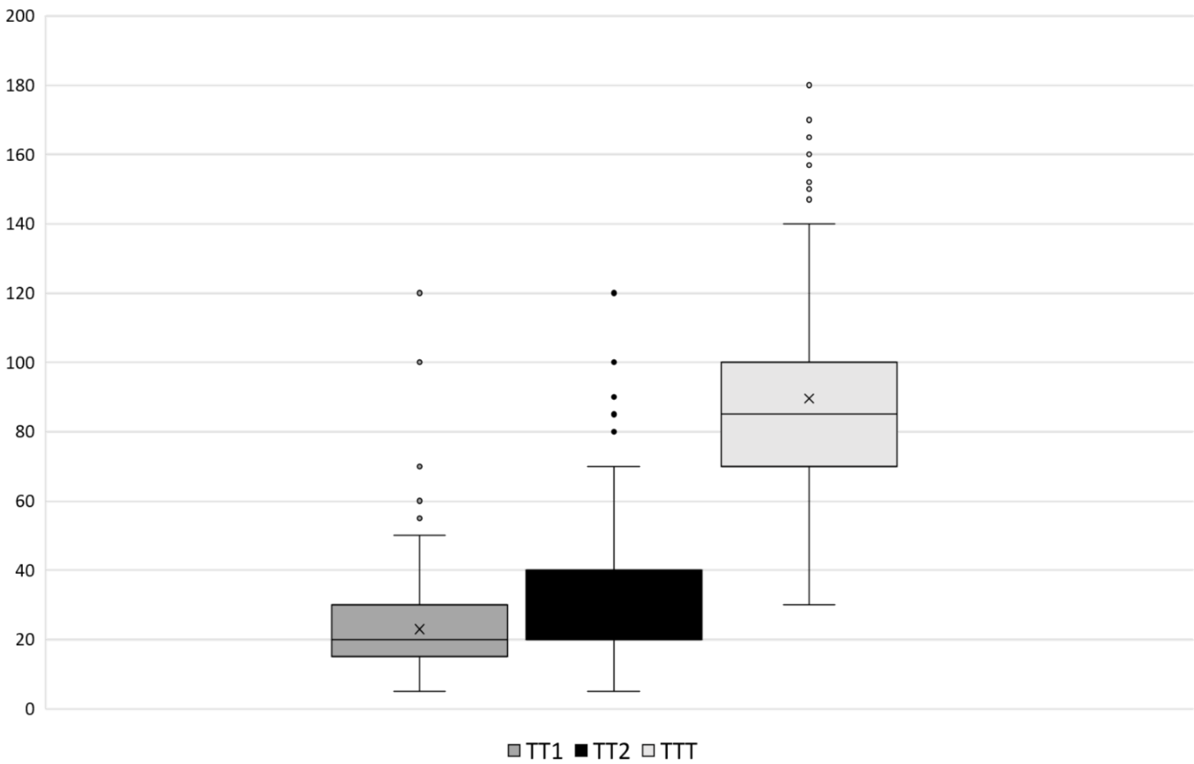
The five types of control variables, such as gender, age, family structure, and working hours show mixed results. Both gender and age variables are not statistically significant, which means that they are not important determinants in HSR commuting. However, variables of the family structure, costs and working hours are statistically significant, which could possibly characterize long-distance commuters. Concerning the family structure variable, unlike the original assumption, having children in a family does not show association with increased commuting time while families without children spend longer commuting time, which suggests those without children are less constrained by family responsibilities and can afford more time commuting. Regarding housing expenses, the results suggest that there is a general inverse relationship between the level of housing costs and commuting time.

In terms of weekly working hours, the TT1 model shows inconsistencies compared with the other two models. The coefficients for TTI are both negative and positive, while the coefficients for TT2 and TTT are all negative for three groups of working hours. This suggests that commuters tend to reduce commuting time in TT2 rather than in TT1. The most significant results lie in the inverse relationship between the TTT model and the working hours. The results indicate people working more than 50 hours would spend more time commuting than other groups ('working hours 40-50' and 'working hours 30-40'). This suggests that commuters working for a routine pattern (30-40 hours) are associated with the most of reduced commuting time, which could be related to a more constrained arrangement between work and life balance.

Regarding commuting frequency, daily commuters generally show a statistical significance of reduced commuting time in the access trip while weekly commuters show a statistical significance of increased commuting time in the egress trip. For a total door-to-door journey, statistical significance in reduced commuting time is also found for daily commuters. The modelling result clearly reflects that daily commuters tend to be associated with reduced commuting time in their first mile, while weekly commuters show increased commuting time in the last mile. This can be explained that daily commuters must travel at a specific time of day while weekly commuters can be more flexible. This flexibility suggests that weekly commuters' workplace is distant from HSR stations, which may be a factor for deciding to live in Shanghai near their workplace to avoid travelling between HSR stations and workplace.

To supplement interpretation of the regression results, this study further highlights the varied commuting time of access and egress trips to and from HSR section from three aspects, namely the average of commuting time, transport mode, and commuting frequency. According to the box plot of commuting time in three sections of time (see Figure 2), the access time (TT1) is smaller than the egress time (TT2). These results reflect a fundamental difference of urban form and spatial scale between Suzhou and Shanghai. As Shanghai covers a much greater urban area and has a larger population than Suzhou, travel times in the two cities also differ.

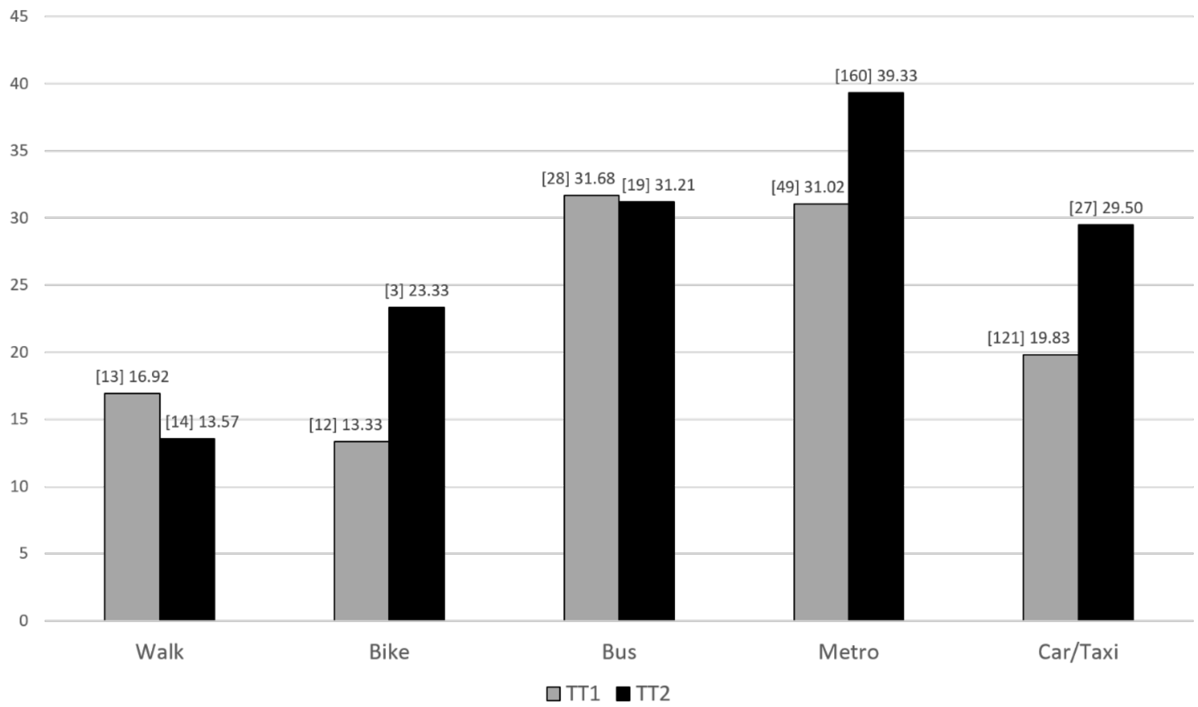
Figure 2. Commuting time in three models



Source: Authors
Note: Average commuting time

In relation to transport mode, Figure 3 reveals that time spent in TT1 is mostly less than TT2, which could be in principle justified through the difference of spatial scale between Suzhou and Shanghai. However, walking and bus are the exception, which reflects the walking and taking bus from home to HSR stations took more time than walking and taking bus from HSR stations to workplace. In TT1, biking spends the least time while in TT2 walking is the quickest mode. In general, commuters spend most time on public transport, such as metro and bus in both TT1 and TT2.

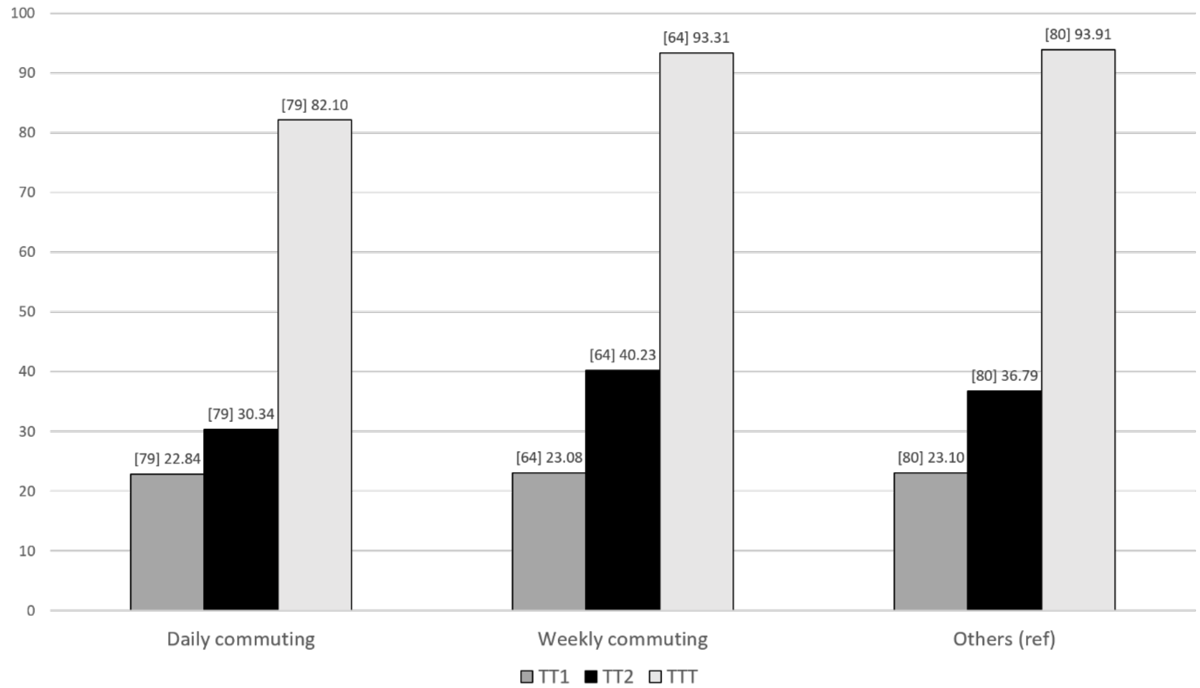
Figure 3. Characteristics of Commuting Time of Transport Modes in TT1 and TT2



Source: Authors
Note: [sample size] average commuting time

About commuting frequency, daily commuters are more time-cautious than weekly commuters. The regression results show statistical significance in reduced access time for daily commuting and increased egress time in weekly commuting, which could be further supported by Figure 4 which clearly shows daily commuters spend less time commuting than weekly commuters in three sections (TT1, TT2 and TTT). The survey results show that HSR commuters spend an average of 90 minutes on such daily or weekly commuting. This obviously exceeds the maximum commuting time regardless of transport modes of 59.56 minutes identified in the YRD area (Zhang, 2016).

Figure 4. Commute time in two groups of commuting frequency



Source: Authors
Note: [sample size] average commuting time

Discussion, Policy Implications and Conclusion

This study investigates the association of built environment, travel mode and commuting frequency with travel times through a survey of HSR commuters living in Suzhou and working in Shanghai. The empirical findings in this study provide a new understanding of HSR commuters in Chinese contexts. Prior to this study it was difficult to make predictions about how commute time of HSR commuters is determined, particularly from the perspective of the combination of built environment, travel mode choice, and commuting frequency. Instead of looking purely at the travel from home to transit stations, this paper, having looked at the door-to-door journey of commuting, confirms that travel mode choice is more important than built environment in determining total commuting time. In addition, for such a door-to-door journey, this study also establishes that weekly commuters spent longer time than daily commuters. This finding is rarely discussed in earlier studies. This study also offers an additional contribution, having discovered that access time is generally less than egress time. However, what determines such a geographical distribution of home and workplace is barely discussed. This will be further discussed in future research.

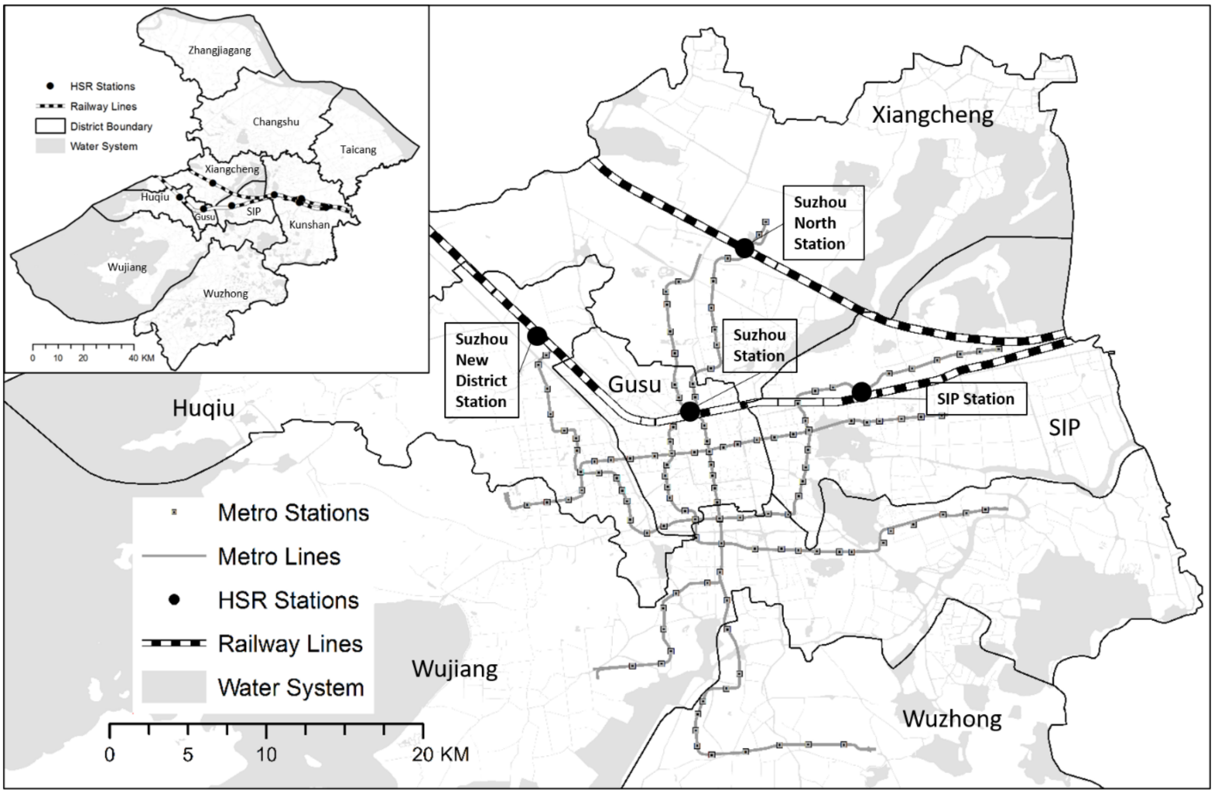
With respect to the mixed results found in the relationship between built environment and commuting time, the high density of urban environment close to home decreases commuting time. High-density healthcare facilities reduce commuting time in residence places in Suzhou and density of financial institutes and healthcare facilities decrease commute time in workplace in Shanghai. These results corroborate the findings of much previous work in the relationship between urban form and commuting (Cervero, 1996; Zhao, 2013; Guo et al., 2007). However, the density of public transport facilities and other types of urban service facilities near a residence has no impact on commuting time, which does not encourage the benefit for active travel (Sallis et al., 2016). A possible explanation is that accessibility of public transport systems in both Suzhou and Shanghai are not well-distributed for reducing commuting time, although Shanghai HSR station might have good connections with other public transport, including extensive metro networks. In the case of Suzhou, only two (Suzhou North and Suzhou) of four HSR stations interchange with metro services.

Another important finding is that public transport modes (bus and metro) have increased commuting times in the TT1 section of Suzhou. In Shanghai, a similar finding is also established for the metro mode but not the bus mode. Surprisingly, walking reduces commuting time. Two reasons for this are suggested. Firstly, a less congested city with wide roads in Suzhou enables shorter commuting times when travelling to HSR stations by car, whereas driving on narrow, congested roads in Shanghai takes longer than the metro. Secondly, there are extensive metro networks connecting with the HSR station in Shanghai while, in Suzhou, the metro network is smaller. That could be the reason why longer commuting time can be justified in Shanghai Metro. Taking even longer commute time in the smaller metro network in Suzhou indicated the metro system is not sufficient and efficient. Also, as shown in the TT2 section, walking could be associated significantly with reduced commuting time, while high coefficient values of metro increase commuting time significantly. This suggests two major types of workplaces. One tends to be located closer to HSR stations in Shanghai such as Hongqiao station and Shanghai station while the other supposes to exploit the accessibility of workplaces through the extensive metro network.

In relation to differences in the impacts of daily and weekly commuting on total commuting time, this study focuses on two regular commuting patterns, confirming that weekly commuters spend more time commuting than daily commuters. This may indicate that, in comparison with weekly commuters, daily commuters must limit their commuting time through choosing either a time-saving mode or living close to HSR stations as they must be punctual, whereas weekly commuters return to home only once a week between Suzhou and Shanghai. The third type of commuting frequency which is used as a reference variable in this paper depends on occupations and positions while, in light of COVID-19, it might be implemented more in the future because of the work-from-home practice. Another associated finding is that travel time for the first mile (home to Suzhou stations) is shorter than the journey for the last mile. This implies that commuters tend to reduce access times from home to HSR stations, whereas they may be prepared to travel to good jobs regardless of the location in a large city. For workplaces with a longer last mile, it is reasonable to argue that daily commuters may become weekly commuters, thus limiting daily travel to weekdays within Shanghai.

This finding has important implications for policies concerning development of HSR stations and connected infrastructure. For future urban and transport planning, the role of transport mode choice and accessible HSR stations coupled with built environments, requires attention from policy makers to reduce commute time for intercity travel. Long-distance HSR travel is driven by the desire to travel quickly between two cities, while the entire journey (including the first mile and the last mile) is largely unaddressed. It takes an average of 30 minutes to travel one-way between Suzhou and Shanghai on HSR, while the travel mode for the first and last mile of the commute greatly increases the total journey time. Railway stations are situated in different parts of Suzhou (see Figure 5), thus accessibility to HSR stations differs. For instance, Suzhou railway station is located in the northern part of Gusu (old district). As the road systems in the central city area are less efficient than those in other districts, commute time to Suzhou railway station naturally increases. In addition, when the transport system is congested, the situation worsens. However, Suzhou Industrial Park railway station, located in the northern part of the district, has relatively better transport accessibility by taxi and bus, but the public metro system is not connected to it.

Figure 5. Urban Districts, Transportation Network and High-Speed Railway Stations in Suzhou



Source: authors

To address such issues, comprehensive land-use transport coordination policy should be encouraged, depending on varying urban contexts. First, careful reconsideration is required by policy makers for restructuring of the transport network system such as new expression metro transit systems which could be developed to strategically reduce commute time of current extensive metro systems in Shanghai. This problem is stark because there are some cases where long distance commuters might take longer door-to-door journeys by metro within Shanghai than that by inter-city HSR commute. In Suzhou, instead, a denser and seamless metro network will be desirable. Second, integration of public transport with proficient connectivity to HSR stations would enable intercity commuters to experience reduced journey times. Third, possible answers would also rely on businesses who can encourage flexible working hours, allowing commuters more control over their journey times. This study raises the issue that government should improve residential and commercial development around HSR stations including their walkability to and from HSR stations for daily commuters who prefer to live close to HSR stations. This could potentially attract young people and professionals who would work in big cities like Shanghai but live in smaller cities because of housing affordability and better living environments. In Suzhou, it is recommended that land-use plans should focus on encouraging higher density by providing good connections between public transport and HSR stations to improve accessibility for commuters. In newly-developed areas of Suzhou, consideration should be given to allocating a proportion of residential districts, based on demand, for buyers or renters wishing to commute to Shanghai.

Although this study provides important findings, several research questions remain to be answered. First, it is difficult to generalise the findings of this study as the survey samples mainly focus on commuters travelling between Suzhou and Shanghai. Using a similar framework, the study should be repeated in other big cities in China, such as the Pearl-River

Delta Region, and Beijing metropolitan area, where a higher population is concentrated. Second, as discussed, the first-mile and last-mile issue has importance for long-distance commuters. Built environment and transport mode would be determined based on the location of commuters' homes. Little is known about how HSR commuters choose their home location. HSR commuters' satisfaction with current environment and living conditions should be investigated, as well as the location choice of commuters living close to HSR stations. Third, as this study identifies transport modes as important elements in commuting via HSR, it is important to understand how HSR commuters choose their mode of transport. Fourth, due to the nature of data collection, sample sizes are restricted. It is important not only to increase sample size, but also to compare HSR commuters with long-distance commuters using other transport modes.

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