The Socioeconomic Characteristics, Urban Built Environment and Household Car Ownership in a Rapidly Growing City: Evidence from Zhongshan, China

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Abstract
Growth in car ownership has significant impacts on the use of urban space and management of urban environments, especially in rapidly developing countries such as China. However, among voluminous literature, few studies have investigated the correlates of household car ownership in the Chinese context, leading to the lack of effective measures to tackle rapid motorization. This study explored the impacts of household-level socioeconomic characteristics and neighborhood-level built environment on household car ownership, with data collected from 25,325 households in Zhongshan, China. The Zero-inflated Poisson regression models detect that, all else being equal, living in a neighborhood with a compact and mixed urban form, better bus service and adjacency to CBD is associated with fewer household cars and higher probability to own zero cars. The models also suggest that household size and income, number of employed or students, and availability of competitive vehicles are significantly related to the number of cars in a household. The findings facilitate our understanding of the effects of socioeconomic characteristics and built environment on household car ownership and provide insights into an effective design of measures to slow down the rapid motorization in China.

Keywords: socioeconomic characteristics; urban built environment; household car ownership; Zero-inflated Poission regression

1. Introduction
Growth in the number of cars has become a prominent feature of contemporary cities, as the accumulation of personal wealth and the demand for transport greatly encourage the ownership and use of cars (Ding et al., 2017a). On one hand, cars provide convenience, but on the other hand, they place unprecedented pressure on energy conservation objectives, transport infrastructure, air quality, and human health (Pucher et al., 2007). Cities have been severely affected by health- and transport-related problems, many of which accompany the growth in the number of cars, such as air pollution, traffic congestion, and shortage of parking space (Clayton et al., 2014).

Taking China as an example, from 2007 to 2016, the annual increment of private cars is 18%. Up to year 2016, the number of household private cars in China was 146 million, which means a quarter of households in China own cars. However, the figure in 2007 is only 20 million. Consequently, the level of motorization and mode split of motorized modes in China is growing rapidly (Zhang et al., 2015). Currently, evidence concerning the correlates that may impact on car ownership is scarce, leading to the lack of practical implications for the design of related interventions.

This study makes an important contribution to the literature. With data collected in Zhongshan, China, the correlates of household car ownership are investigated in an effort to better understand the possible impact of socioeconomic characteristics and built environment attributes. Firstly, the study generated two categories of attributes as independent variables: household-level socioeconomic characteristics and neighborhood-level built environment. Then, Zero-inflated Poisson regression models were used to examine specifically how the number of household cars and the probability of owning zero cars are related to the built environment attributes, together with household socioeconomic attributes. The findings will provide insights for planning agencies, practitioners, and researchers into the effective design of interventions on slowing down motorization and alleviating traffic-related problems.

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2. Literature Review

There have been a number of studies on the influential factors of the growth of car ownership in North America (Potoglou and Kanaroglou, 2008) and the European Union (Kain, 2001). The findings have facilitated our understanding on the socioeconomic characteristics and built environment correlates to car ownership and provided important policy implications for interventions (Ding et al., 2017b). To be specific, the built environment is defined as "the human-made space in which people live, work, and recreate on a day-to-day basis" (Roof and Oleru, 2008) and "encompasses places and spaces created or modified by people including buildings, parks, and transportation systems" (Srinivasan et al., 2003).

The following socioeconomic characteristics and built environment features would impact car ownership, albeit to varied degrees: (1) income, e.g., household total income and average individual income (Dargay et al., 2007; Soltani, 2017); (2) population, e.g., the growth or decline of population (Ritter and Vance, 2013); (3) availability of competitive travel modes, e.g., ownership of e-bikes, motorcycles or taxis (Yang et al., 2017); (4) urban form, e.g., compact urban form or sprawling (Soltani, 2017; Li et al., 2010; Yang et al., 2017); (5) road network design; e.g., road density or intersection density (Yang et al., 2017); (6) access to services, e.g., access to public transportation and recreational facilities (Shen et al., 2016; Pan et al., 2013); (7) walking facilities, e.g., sidewalks and walking trails (Soltani, 2017); (8) safety, e.g., presence of heavy traffic and neighborhood crime-related safety (Sugiyama et al., 2009), and (9) urbanization, e.g., the difference between urban and rural residents (Kemperman and Timmerman, 2009; Lee et al., 2009).

The built environment attributes employed in car ownership-related studies were typically derived (Siu et al., 2012) by: (1) surveying individuals' perceptions of the social or built environment (Rodriguez et al., 2009; Shigematsu et al., 2009); (2) aggregating neighborhood measures from secondary data, such as Census or Traffic Analysis Zone (Zhang et al., 2013; Riva et al., 2009; Ding et al., 2015); (3) measuring these characteristics within a certain distance of the individuals' residences (Frank et al., 2007; Cerin et al., 2013), e.g., by buffer radii (ranging from 100 m to 1 km); or (4) quantifying the built environment attributes objectively at high resolution or used cluster analysis to identify different urban forms (Ewing and Cervero, 2010; King et al., 2005; Riva et al., 2009). In Ewing and Cervero's research (2010), the built environment variables that influenced travel behavior were named with words beginning with D as "five Ds" from five aspects: density, design, distance to transit, destination accessibility, and diversity.

Worth mentioning is that the majority of car ownership-related studies were predominantly conducted in Western contexts and their findings are not necessarily translatable to Asian contexts. In recent years, scholars began to examine the effects of built environment on car ownership and related travel behavior in Asian countries, which are experiencing fast growth in car numbers along with dramatic economic growth and urban expansion (Yang et al., 2017; Zhang et al., 2014b; Lee et al., 2016; Tana et al., 2016; Soltani, 2017; Shen et al., 2016; Li et al., 2010). However, rare studies have examined the association between the socioeconomic and environment attributes and car ownership on the household-level in a rapidly developing Chinese city, as the present paper does. Since household car ownership is an indispensable starting point to facilitate the understanding and design effective interventions on slowing down motorization and alleviating traffic-related problems, the present paper will serve as an extended body of literature.

3. Data and Methods

3.1 Study Area

As stated in previous studies (Zhang et al., 2013; Zhang et al., 2014a), the Zhongshan Metropolitan Area was chosen to examine the household car ownership of a rapidly growing city in the Chinese context. Zhongshan is a prefecture-level city in Guangdong Province of southern China (Fig.1.). In the three largest coastal urban agglomerations with the most competitive economies in China, there are about 20 cities with similar urban population, urbanization and motorization level, as well as urban transport characteristics to Zhongshan (Zhang et al., 2016). Thus, the research findings in Zhongshan might be typical and informative to the type of cities. In Zhongshan, the average household car ownership was 0.21 (as of 2010, the year of the data collected).

The CBD area in Zhongshan is located in the Shiqi District, which is marked blue in the district No. 2 in Fig.1. The distance from the CBD area to other neighborhoods ranges from 0.41 to 42.88 km.

3.2 Data Collection

Household car ownership was derived from the Zhongshan Household Travel Survey (ZHTS) in 2010 (Zhongshan Municipal Bureau of Urban Planning, 2010). Selected by stratified random sampling covering the whole of Zhongshan City, the sample size of the households was 25,325 from all 279 neighborhoods, with a sample rate of 2.0%. The ZHTS also provided household socioeconomic data.

The following data for the characterization of built environment attributes come from Zhongshan Municipal Bureau of Urban Planning (Zhang et al., 2013; Zhang et al., 2014a): (1) traffic analysis zones' boundaries—proxy for neighborhood boundaries; (2) land use in 2010 with five major types of land use (residential land, commercial and service facilities, industrial and manufacturing, green space, and other types); (3) neighborhood population in 2010; (4) road networks; (5) bus stops; and (6) political boundaries.
such as city and zone boundaries. All the data were then integrated into ArcGIS for further analysis.

3.3 Built Environment Attributes

Ewing and Cervero suggested (2010) that each D variable of “five Ds” built environment contains a number of attributes that are commonly used in travel behavior-built environment research (Table 1.). In this study, considering the best available data, the authors identified five neighborhood-level built environment attributes in response to the five Ds: population density (density), intersection density (design), land-use mixture (diversity), distance to CBD (destination accessibility), and distance from home to the nearest bus-stop (distance to transit).

The population density, intersection density, distance to CBD, and distance from home to the nearest bus-stop are self-explanatory. The land-use diversity was calculated with respect to the context of Zhongshan, as applicable. The land-use diversity represents the degree to which different land uses in a neighborhood are mixed. The authors calculated the land-use diversity by the Entropy Index (EI) (Kockelman, 1997), wherein 0 indicates single-use environments and 1 stands for the equalization of different land uses in area coverage. EI is defined by:

$$ EI = \sum_{i=1}^{n} P_i \log(1 / P_i) $$

(1)

where $n$ = number of unique land uses, $n \geq 1$; $P_i$ = percentage of land use $i$’s coverage over total land use coverage (Zhang et al., 2013).

3.4 Model Specification

The percentage of households owning 0, 1 or 2+ cars is 81.5%, 16.6% and 1.9%, respectively. Thus the count of household car ownership has more zero observations than predicted by a Poisson process, which assumes that the conditional variance of the distribution of cars is equal to the expected value (Long, 1997; Long and Freese, 2006). The Vuong model selection test indicates insignificant over-dispersion, strongly favoring a zero-inflated poisson (ZIP) regression approach to analyzing the data. Compared to a standard Poisson regression model, a ZIP model can capture both the excess zero group and the non-zero group by estimating two separate models and connecting them (Khattak et al., 2010). First, a binary logit model is estimated for the certain-zero cases, predicting whether or not a household would own cars. Then, a poisson model is estimated for households that own one or more cars.

This study chose a ZIP model to analyze the relationship between the socioeconomic characteristics, built environment and household car ownership. The authors have checked for multicollinearity of all the

| Five Ds | Meaning | Commonly used attributes |
|---------|---------|--------------------------|
| Density | The variable of interest per unit of area | Population density, dwelling units density, employment density |
| Design  | Street network characteristics within an area | Average block size, number of intersections per square mile, average building setbacks, numbers of pedestrian crossings |
| Diversity | The number of different land uses in a given area and the degree to which they are represented | Entropy measures of diversity, jobs-to-housing ratios, jobs-to-population ratios |
| Destination accessibility | Ease of access to trip attractions | Distance to CBD, number of jobs or other attractions within a given travel time, distance from home to the closest store |
| Distance to transit | The level of transit service at the residences or workplaces | Distance from home to the nearest rail station or bus stop, number of stations per unit area, bus service coverage rate |
independent variables by calculating the variance inflation factor (VIF). All the VIFs are smaller than 10, indicating a low degree of multicollinearity. The ZIP model assumes that the dependent variable (in this case, the household car ownership for sample size $k$, $N = (n_1, n_2, ..., n_k)$, is independent. The model is (Anastasopoulos et al. 2009):

$$
\begin{align*}
\text{Pr}(n=0 | z) &= \frac{p}{1 + \lambda + \lambda p} \\
\text{Pr}(n=n | z) &= \frac{\lambda^n p^n}{\text{S. D.}} \\
\end{align*}
$$

where $p_i$ is the probability of being a household owning zero car and $n$ is the number of household cars.

To calibrate the coefficient of a ZIP model with Stata 12.0, the authors rewrote the ZIP model with natural log transform in both a poisson and binary logit model. The authors employed the same independent variable sets in both the poisson and binary logit model as those variables were assumed to be significantly associated with household car ownership. The ZIP model specifications were expressed as follows in the order of poisson model and binary logit model:

$$
N_{cars} = \beta_0 + \beta_1 \cdot \text{HHFSIZE} + \beta_2 \cdot \text{EMPLOYED} + \beta_3 \cdot \text{STUDENT} + \beta_4 \cdot \text{HIGNINC} + \beta_5 \cdot \text{MEDINC} + \beta_6 \cdot \text{BIKES} + \beta_7 \cdot \text{EBIKES} + \beta_8 \cdot \text{MOTORS}
$$

where $N_{cars}$ in the poisson model is the household car ownership; $Pr_{cars}$ in the binary logit model is the probability of owning zero car; HHSIZE is the number of people aged over 5 in the household; EMPLOYED stands for the number of people employed full/part-time; STUDENT means the number of people in primary school or middle school; HIGNINC and MEDINC are dummies for the household total annual income ranges of above 60000 Renminbi (RMB, 6.6 Renminbi ≈ 1 US Dollar) and 20000-60000 RMB (with a reference category of 0-20000 RMB); BIKES, EBIKES and MOTORS represent the number of bicycles, electric bikes and motorcycles in a household, respectively.

Along with the basic model presented above, regression of the dependent variables proceeded in an expanded model. The expanded model adds five neighborhood-level built environment measures as independent variables, where POPDEN, INTERDEN, MIX, CBDDIST, and BUSDIST demonstrate the population density, intersection density, land-use mixture, average distance to Zhongshan’s CBD, and average distance from home to the nearest bus-stop.

4. Results

4.1 Descriptive Statistics

Descriptive statistics provide a general view of the dependent and independent variables (Table 2.), broken down by whether or not there is car ownership. For households that own cars, the average ownership is 1.12 cars. The households owning zero cars have smaller household size, fewer employed or students, lower income, more bikes and e-bikes, compared to their counterparts. The standard deviation values of population density, intersection density and the average distance from home to the nearest bus-stop were larger than or close to their mean values, implying substantial variations of built environment features among neighborhoods in Zhongshan (Table 2.).

| Variable                              | Description                                                                 | Households owning zero cars (sample = 20,641) | Households owning at least one car (sample = 4,684) |
|---------------------------------------|-----------------------------------------------------------------------------|-----------------------------------------------|-----------------------------------------------------|
|                                      |                                                                             | Mean   | S. D. | Min. | Max. | Mean   | S. D. | Min. | Max. |
| Dependent Variables (household car ownership) |                                                                             |        |      |      |      |        |      |      |      |
| CARS                                  | Number of cars in a household, count                                        | 0      | 0     | 0    | 0    | 1.12   | 0.41  | 1    | 5    |
| Socioeconomic Attributes (Independent Variables) |                                                                             |        |      |      |      |        |      |      |      |
| HHSIZE                                | Household size, count                                                       | 2.44   | 1.14  | 1    | 10   | 2.83   | 1.19  | 1    | 10   |
| EMPLOYED                              | Number of persons employed full/part-time, count                           | 1.59   | 0.94  | 0    | 5    | 1.79   | 0.87  | 0    | 5    |
| ST affiliate                         | Number of people in primary school or middle school, count                 | 0.21   | 0.47  | 0    | 3    | 0.28   | 0.52  | 0    | 4    |
| HIGNINC                               | High household income (>60000 RMB/yr), binary, 1 = yes                     | 0.10   | 0.30  | 0    | 1    | 0.54   | 0.50  | 0    | 1    |
| MEDINC                                | Medium household income (20000-60000 RMB/yr), binary, 1 = yes              | 0.64   | 0.48  | 0    | 1    | 0.43   | 0.50  | 0    | 1    |
| LOWINC                                | Low household income (<20000 RMB/yr), binary, 1 = yes                      | 0.26   | 0.44  | 0    | 1    | 0.03   | 0.18  | 0    | 1    |
| BIKES                                 | Number of bikes in a household, count                                      | 0.54   | 0.68  | 0    | 5    | 0.33   | 0.61  | 0    | 5    |
| E-BIKES                               | Number of electric bikes in a household, count                            | 0.31   | 0.52  | 0    | 4    | 0.10   | 0.33  | 0    | 5    |
| MOTORS                                | Number of motorcycles in a household, count                               | 1.06   | 0.85  | 0    | 5    | 0.98   | 0.78  | 0    | 5    |
| Built Environment Attributes (Independent Variables) |                                                                             |        |      |      |      |        |      |      |      |
| POPDEN                                | Population density, 1000 persons/km², continuous                           | 5.38   | 7.62  | 0    | 44   | 6.04   | 7.45  | 0    | 44   |
| INTERDEN                              | Intersection density, number of 5 intersections per km², continuous       | 2.01   | 2.60  | 0    | 13.26| 2.38   | 2.56  | 0    | 13.26|
| MIXTURE                               | Land-use mixture, Entropy Index, continuous                               | 0.71   | 0.18  | 0    | 1    | 0.72   | 0.17  | 0    | 1    |
| CBDDIST                               | Distance from home to the CBD, continuous                                  | 19.21  | 9.76  | 0.41 | 42.88| 20.45  | 10.21 | 0.41 | 42.88|
| BUSDIST                               | Distance from home to the nearest bus-stop (km), continuous               | 0.53   | 0.37  | 0.1  | 1.2  | 0.45   | 0.34  | 0.1  | 1.2  |

Note: S. D. = Standard Deviation; Min. = minimum; Max. = maximum.
4.2 Poisson Regression Analysis of Household Car Ownership

All of the household socioeconomic attributes displayed significant associations with driving trips in the poisson regression, except for the number of students and those having a medium income (Table 3.). The results implied that, for households already owning cars, household socioeconomic characteristics played important roles in the number of cars. All else being equal, additional household members or those in employment were associated with a 26.7% (= exp (0.237) -1) or 11.9% (= exp (0.113) -1) increase in cars (basic model). Affluent households had a higher propensity to own more cars as high-income households owned 2.35 times more, compared to the low-income ones. Owning other vehicles would significantly reduce the number of household cars as additional bike, e-bike or motorcycle related to a 32.4%, 61.9% or 47.7% decrease in car ownership.

Table 3. Zero-inflated Poisson Regressions of Household Car Ownership in Zhongshan

| Variables | Basic model | Expanded model |
|-----------|-------------|----------------|
| Poisson   | Logit       | Poisson        | Logit |
| Socioeconomic Attributes (LOWINC is a reference category) | Coef. | Coef. | Coef. | Coef. |
| CONSTANT  | -1.601      | -1.519         | 4.035  |
| HH SIZE   | 0.237       | -0.548         | 0.228  | -0.591 |
| EMPLOYED  | 0.113       | 0.061          | 0.102  | -0.028 |
| STUDENT   | -0.005      | -0.795         | -0.014 | -0.735 |
| HIGHINC   | 1.209       | -21.058        | 1.173  | -20.344 |
| MEDICC    | 0.073       | -3.332         | 0.109  | -3.013 |
| BIKES     | -0.391      | 0.651          | -0.375 | 0.696 |
| E-BIKES   | -0.965      | 0.784          | -0.803 | 1.032 |
| MOTORS    | -0.649      | -0.460         | -0.638 | -0.154 |

Built Environment Attributes

| Variables | Coef. | Coef. | Coef. | Coef. |
|-----------|-------|-------|-------|-------|
| POPDEN    | -0.009| 0.024 |
| INTERDEN  | 0.026 | -0.019|
| MIXTURE   | 0.010 | 0.638 |
| CBDIST    | 0.001 | -0.027|
| BUSDIST   | 0.106 | -0.642|

Note: Denotes significance at p < 0.01, * denotes significance at p < 0.05, and ** denotes significance at p < 0.1. Blank cells mean a variable was not included in that model. Obs = observations; LR = likelihood ratio; chi2 = chi-square; prob = probability.

In the expanded model, population density, intersection density and distance from home to the nearest bus-stop are statistically significant at 90% confidence. Given the range of 44 of population density (Table 2.) and an incident rate ratio (IRR) of -0.9% (= exp (10.009) -1), households located in the most populated neighborhoods owned 40.8% fewer cars than in the least populated ones. Similarly, households in the neighborhood with the highest intersection density were likely to own 34.6% more cars than in the neighborhoods with the lowest. Accessibility to bus stops also showed modest significance with 11.2% rise of car ownership if the distance to the nearest bus-stop increases by one kilometer.

4.3 Logit Regression Analysis of the Probability of Owning Zero Cars

Six out of eight household socioeconomic attributes displayed significant associations with the probability of owning a car in the logit regression (Table 3.). With one more member or student in the household, the probability of owning zero cars will decrease by 42.2% or 54.9%. An additional bike or e-bike related to a substantial rise in the probability of owning zero cars, indicating the competition between car and the two modes.

Three built environment attributes displayed significant associations at 99% confidence (Table 3.). A one unit increase of land-use mixture or the distance to the nearest bus-stop was associated with an 89.3% increase or 47.4% decrease of the probability of owning zero cars. With an additional one-kilometer farther from the CBD, the probability of a household owning zero cars will increase by 2.6%.

The significance and signs for the household socioeconomic attributes persisted across all models and the relative risk ratios (RRRs) showed only slight variation. The increase of LR chi2 and Log likelihood (Table 3.) in the expanded model compared to the basic one demonstrated the improvement of goodness of fit. This implied that the built environment contributed to strengthening the explanatory power.

5. Discussion and Policy Implications

For households owning at least one car, the household socioeconomic attributes show a significant association with car ownership. To be specific, bigger and richer households with more persons employed and fewer other vehicles (bike, e-bike or motor) tend to own more cars, conforming to previous literature (Li et al., 2010). While for households owning zero cars, smaller household size, fewer students, or more other vehicles is related to an increase in the probability of owning zero cars, consistent with previous findings (14).

The correlations of the built environment attributes on the household car ownership in Zhongshan yield some interesting findings. All five built environment attributes showed a significant correlation to the number of household cars or the probability of owning zero cars, albeit to varied degrees. In more populated and mixed developed neighborhoods, households tend to own fewer or even zero cars. This may be because the compact and mixed urban form, closely related to high population density and land-use mixture, increases the possibility of having short-to-medium distance trips instead of long distance ones.
As expected, connective transportation linkages are substantially positively related to household car ownership. This may be due to the fact that in neighborhoods with better road network design, the car mobility is higher and driving is easier.

In areas with a convenient access to bus service, the household car ownership is low and the probability of owning zero cars is high. This proves that in Zhongshan, the bus is a competitive mode to cars (Wu et al., 2016a) and improving bus service may encourage people to shift from cars to public transport.

The farther the CBD is, the lower the probability of owning zero cars is. The CBD is the biggest attraction for working and leisure trips, therefore households located farther from CBD tend to own cars to increase mobility and reduce travel time. The second possible reason is that households living inside or near the CBD tend to have shorter trips for working and leisure, which lower their needs to use or own cars. The third possible reason is that in neighborhoods within or near the CBD the bus service is better, which increases the probability to choose the bus instead of a car in medium-to-long distance trips.

From the discussions above, the authors could find out that policies involving the built environment may be potentially effective in slowing down the increase in household car ownership. The findings in the paper provide insights for planning agencies, practitioners, and researchers into four possible policies as: 1) maintaining a compact and mixed urban form related to high density and mixed-use development; 2) providing more accessible and convenient bus service (Wu et al., 2016a; Wu et al., 2017); 3) improving the layout of job and commercial attractions, and 4) developing from a monocentric urban structure to a polycentric one.

According to the latest national standard for urban scale division, Zhongshan is a Type II Big City in China. There are more than 50 cities categorized as Type II Big City in China. Those cities are featured by similar urban population scale, urbanization level, motorization level, income per capita and transport characteristics to Zhongshan. In the past decade, the car ownership in those cities has been growing rapidly, leading to a significant increase in car usage and mode split. The high dependence on cars for daily trips in big Chinese cities has caused severe social problems, e.g. frequent congestion, traffic emissions, and traffic accidents (Sun et al., 2017; Wu et al., 2015; Zhang et al., 2015).

However, few of those big cities have introduced effective policies to slow down car ownership, which will continue to increase along with household income. Therefore, it is imperative to investigate potential policies from the perspective of urban built and social environment in the context of big cities of China. The research methodology in the present study could apply to other big cities in China for similar case studies. The research findings will help to facilitate understanding and the policy-making process in other cities.

6. Strengths and Limitations

Previous literature mainly focused on developed countries or cities with a high dependency on cars. Therefore, the interventions sometimes may not be effective in the context of extensive car ownership and usage. This study has a number of strengths and limitations, compared to previous literature. In terms of the strengths, firstly, the study focused on car ownership and provided informative policy implications for the rapidly-motorizing society. Secondly, the study revealed the household socioeconomic and built environment correlates of household car ownership in a developing country with rapid urbanization and motorization, which might further promote comparative research between different contexts. In terms of the limitations, cross sectional data were used in this study. The full evaluation of causal inferences concerning the effects of household socioeconomic and the built environment on household car ownership will require longitudinal and multilevel analyses over time.

7. Conclusions

This study makes an important contribution to the literature. The correlates of the household car ownership in Zhongshan, China, are investigated in an effort to better understand the possible impact of socioeconomic characteristics and built environment attributes. Firstly, the study generated two categories of attributes as independent variables: household socioeconomic and neighborhood-level built environment. Then, Zero-inflated Poisson regression models were used to examine specifically how the number of household cars and the probability of owning zero cars are related to the built environment attributes, together with household socioeconomic attributes.

The research findings suggest that household size and income, number of employed, students and other vehicles are strongly related to the household car ownership in Zhongshan. With respect to the built environment, all else being equal, living in a neighborhood with a compact and mixed urban form, better bus service and adjacency to CBD is associated with fewer household cars and higher probability to own zero cars.

The findings provide insights for planning agencies, practitioners, and researchers into the effective design of interventions from household socioeconomics and the built environment to slow down the rapid increase in car ownership. Among the possible interventions, the authors suggested to (1) encouraging the ownership of non-motorized vehicles including bikes and e-bikes; (2) maintaining a compact and mixed urban form related to high density and mixed-use development; (3) providing more accessible and convenient bus service; (4) improving the layout of job and commercial attractions, and (5) developing from a monocentric urban structure to a polycentric one.
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