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1 **INVESTIGATING THE EFFECT OF THE SPATIAL RELATIONSHIP**
2 **BETWEEN HOME, WORKPLACE AND SCHOOL ON PARENTAL**
3 **CHAUFFEURS' DAILY TRAVEL MODE CHOICE**

4

5 **Abstract**

6 Since many parents travel separately for escorting and commuting, certain hidden
7 daily car trips may have been ignored in previous research regarding parental escort
8 behaviors. By defining an escort-space model using the spatial relationships between
9 home, the workplace, and school, this study focuses on the daily modal split among
10 parental chauffeurs using data from Qijing, China, while focusing on the effects of
11 different escort-space models: spatial aggregation, job-housing separation and
12 school-housing separation. The descriptive statistics of parental chauffeurs' travel
13 mode choices under the influences of these three escort-space models are presented.
14 The statistical results demonstrate that the modal splits of parental chauffeurs perform
15 significantly differently under these three escort-space models. Furthermore, the
16 determinants of the daily travel mode of parental chauffeurs, including escort-spaces
17 and other selected variables, are investigated using a multinomial logit model. A
18 model without the escort-space model is also presented for comparison. The results
19 show that the model with the escort-space model has a more significant
20 goodness-of-fit than the model without the escort-space model. Both the job-housing
21 separation and school-housing separation of parental chauffeurs result in the increase
22 of car trips, while the usage amount of car in daily journeys is higher than that in
23 escort trips. Moreover, car ownership, bike ownership, household income, residential
24 location, age, gender, income, and education level all significantly impact the daily
25 travel mode choices of parental chauffeurs. These findings can help policymakers
26 create suitable policies to reduce excessive car trips by parental chauffeurs.

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32 **Keywords:** Parental Chauffeurs; Escort-space; Travel Mode Choice; Child; Nearby
33 Enrollment Policy

34

35

1 1 INTRODUCTION

2 As increasing numbers of parents have begun to drive their children to and from
3 school in the past ten years, parental escort behaviors have become a main focus in
4 many research fields because of their negative effects on urban traffic and the physical
5 and mental health of children (Zhang et al., 2017; Fyhri et al., 2011; Mackett, 2013;
6 Lu et al., 2017). To reduce parental car trips for picking up/dropping off their children,
7 most scholars have focused on promoting children' independent mobility by walking
8 or cycling (Mandic et al., 2017; Wen et al., 2008; Mcdonald, 2008a; Mcdonald, 2008b;
9 Easton and Ferrari, 2015). Transportation scholars and geographers found that
10 individuals' dependence on cars is closely related to their daily activity space, which
11 is formed by the series of individuals' continuous daily activities and travel (Wang
12 and Li, 2015; Yue and Chai, 2013). Because there is a close relationship between
13 travel mode choice and daily activity space, guiding low-carbon travel for parental
14 chauffeurs from the activity space perspective is of great importance.

15 As a major daily activity, the escort can form an activity space for parental
16 chauffeurs through their round trips among the escort-related locations. Different
17 travel mode choices may occur between daily travel and escort trips when parental
18 escort trips are separate from other regular major travel, such as commuting to work
19 (Liu et al., 2017), especially under the influence of related policies.

20 In many developing countries, especially China, school-aged children in the
21 compulsory education stage should follow the nearby enrollment policy by attending
22 the school nearest their home (Zhang et al., 2017; Li and Zhao, 2015). Similar policies
23 can also be found in developed countries. For example, the United States has
24 implemented school zoning policies for public elementary and secondary schools
25 (Wilson et al., 2010). However, the uneven distribution of educational resources often
26 means that many children cannot enroll in a good school within close range. Generally,
27 parents have two possible options to obtain admission to high-quality schools for their
28 children. They can either pay entrance fees for cross-region schools, which are usually
29 far from home, or, as increasing numbers of parents prefer, buy a small, old property
30 in a good school district at a high price (Zhang et al., 2017). The former situation
31 should lead to a longer home-school distance for schooling children, while the latter
32 situation usually leads to a longer home-work distance for commuting parents. Both
33 of these situations may cause a spatial separation between escort-related locations.

34 As a result, many chauffeurs have to use a car as their main transport mode on
35 daily journeys, even though they choose non-motor-transport modes such as walking
36 or cycling for their children's escort trips. This behavior has not only exacerbated
37 urban traffic congestion but also reduced the wellbeing of residents. To understand
38 these hidden car trips, which were easily ignored in escort trips under the nearby
39 enrollment policy, it is necessary to study parental chauffeurs' daily travel mode
40 choice while accounting for the spatial relationship between escort-related locations.

41 This paper attempts to explore the influence of the nearby enrollment and other

1 social-economic attributes on the choice of parental chauffeurs' daily transport modes
2 in China, taking Qijing as a case study. The following section reviews existing
3 relevant literature on the factors that influence the travel mode choice for children's
4 school trips, while the third section introduces the methodology of this study, the
5 fourth section presents empirical evidence using data from Qijing, China, the fifth
6 section summarizes and discusses the research results and the last section proposes
7 further research directions.

8 **2 LITERATURE REVIEW**

9 There is a large body of literature on activity-travel and joint travel of adults.
10 (Gliebe and Koppelman, 2002; Zhang et al., 2005b; Bhat and Pendyala, 2005; Arentze
11 et al., 2013; Liao et al., 2013; Liu et al., 2015). Many Researchers have focused on the
12 travel mode choice behavior in addition to its influencing factors. Empirical evidence
13 indicates that escorting children as a type of joint travel has a significant impact on
14 parental activity-travel patterns (Zhang et al., 2005a; Copperman and Bhat, 2007; He
15 and Giuliano, 2015). Therefore, factors that influence the school commuting mode of
16 children to a large extent also result in the parents' travel mode choice in daily trips.
17 This literature review focuses on the influence factors of school travel mode choice.
18 Several factors have the potential to influence children's school commuting mode,
19 including household characteristics, parental characteristics, children's characteristics
20 and spatial separation characteristics.

21 In school commuting studies, household characteristics usually include
22 household resources (income and vehicle ownership), household structure (numbers
23 of children, employment, the elderly, etc.) and residential location. Household
24 resources are an important factor for individuals' travel mode choice because children
25 from high-income households tend to be driven to and from school more than those
26 from low-income households (Zhang et al., 2017; Liu et al., 2017; Li and Zhao, 2015).
27 Additionally, children in car-owner households are more likely to be escorted by car
28 than those from car-free households (Li and Zhao, 2015). Notably, bikes (including
29 e-bikes) must be considered when investigating vehicle ownership because they are an
30 important travel mode in China (Liu et al., 2017). Household structures may also be
31 another critical factor because employed or unemployed parents, siblings and the
32 elderly in a household can affect the travel mode for a child's school journey
33 (Evenson et al., 2003; Mcdonald, 2008b; Mitra and Buliung, 2014). However, since
34 this research focuses on the travel mode choice of parents who chauffeur their child
35 without others' assistance, we do not consider household structure in this study. In
36 addition, the residential locations of the chauffeurs should be considered, as they are
37 associated with the built environment of the city.

38 Parental chauffeurs' characteristics are associated with their sociodemographic
39 variables. The sociodemographic attributes include the age, gender, educational level,
40 driving experience, work status and income of parental chauffeurs. It is widely
41 acknowledged that individuals' age and gender significantly influence their travel

1 mode choices. Elderly people may prefer to take the bus rather than traveling by bike
2 due to physical limitations (Habib, 2015). Mothers tend to make more child-serving
3 stops than do fathers (Schwanen et al., 2008; Elias and Katoshevski-Cavari, 2014) and
4 are less likely to drive their children to/from school, whereas fathers tend to be drivers
5 (Liu et al., 2017). Educational level may also influence transport mode choices. For
6 example, McMillan (2003) found that parents with higher education are less likely to
7 escort their children by walking or cycling. The employment status of parental
8 chauffeurs is also related to their daily travel mode choice. Full-time employed
9 females tend to drive their children to school, whereas full-time employed males are
10 less likely to pick up their children from school by car (Yarlagadda and Srinivasan,
11 2008). In addition, individuals with long driving experience tend to travel by car.
12 However, most Chinese parents who have driving licenses are from one-car
13 households. Consequently, they have to allocate the car on the basis of intrahousehold
14 interactions. Therefore, the income of parental chauffeurs is possibly related to their
15 daily travel mode choice because income determines the allocation of car use to some
16 extent (Habib, 2014).

17 Among the children's characteristics, age and gender are most explored because
18 they exhibit a significant influence on parental travel mode choice. Although the
19 results of different researchers differ, researchers believe that there is a close
20 relationship between age and active mode choice of children (Li and Zhao, 2015;
21 Zhang et al., 2017; Mcdonald, 2012). In addition, escort types (i.e., on the way, out of
22 the way and pure escort) that reflect the space-time relationship between children and
23 their parents in escort trips have been proposed by Liu et al. (2017). Those authors
24 found that children whose departure times differ from those of their parents, namely,
25 pure escorts, tend to be escorted by e-bike modes.

26 The escort spatial characteristics depends largely on the distances from home to
27 the parental workplace and school, and many found that the distance between
28 workplace and school affects children's travel mode choice for school journeys (e.g.,
29 (McMillan, 2007; Mcdonald, 2008a; Li and Zhao, 2015; He, 2013). He and Giuliano
30 (2017) further examined the distances between these three locations and found that
31 the workplace-home-school relationship has a significant impact on the decision
32 making of parental escorts. The results showed that mothers are less likely to
33 chauffeur their children to school with an increasing distance from their workplace to
34 the school. Liu et al. (2017) also found that parents tend to drive their children to
35 school when the distance from home to school is long.

36 Previous studies have provided valuable information on children's schooling
37 activity. However, thus far, these research focus on children's travel mode choices and
38 joint parent-child travel mode choices. Parents' travel mode choice for daily trips is
39 rarely studied in the context of nearby enrollment policy. Little is known regarding
40 whether and why parental chauffeurs' daily travel mode choice is different from that
41 of escorting children under the influence of this specific policy. This paper focuses on
42 the choice of parental chauffeurs' daily transport modes in Qujing, China, which has

1 not been paid much attention given the influence of the nearby enrollment policy. This
2 paper contributes to the current literature in two respects. First, the spatial relationship
3 between the escort-related locations is considered, which contributes to reflect the
4 spatial impact of the nearby enrolling policy. Second, parental travel mode for
5 schooling and other daily trips are considered simultaneously, which represents how
6 children influence their parents' travel mode choice in the context of the nearby
7 enrollment policy.

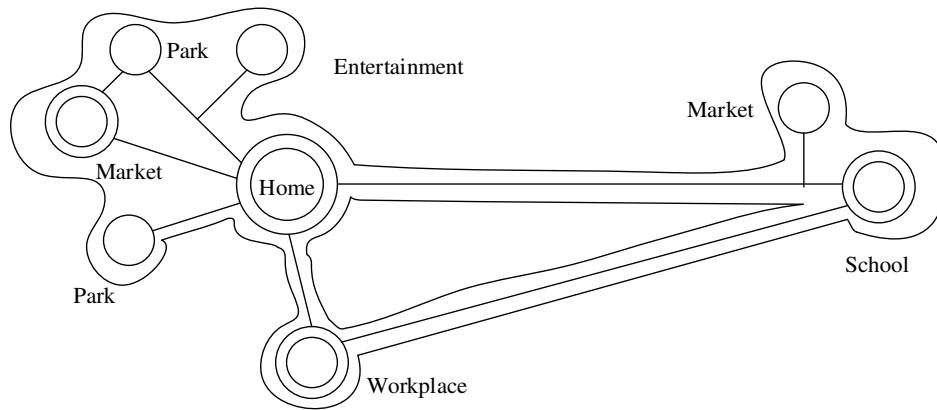
8 **3 METHODOLOGY**

9 In contrast to bringing children with them on the way to work, many parents
10 travel only for the purpose of chauffeuring their children (Vovsha et al., 2004),
11 particularly in China, implying that parental chauffeurs who do not need to travel for
12 their own purposes return home after escorting their children. In this case, the travel
13 mode choice has a higher probability of being affected by spatial constraints than by
14 temporal constraints. We assumed that parental chauffeurs wish to escort their
15 children within an acceptable escort-space and are more likely to use motorized
16 private vehicles when the escort-space is outside their ideal range. Therefore, studies
17 that consider escort-space when examining the daily travel mode choice of parental
18 chauffeurs may help us better understand the potential car trips involved in escort
19 behaviors. Notably, most parents only drop off their children at school but do not pick
20 up them from school. The reason for this behavior is that the time for children to go to
21 school is close to or 1 hour earlier than that for parents to commute to work, whereas
22 the time at which children leave school to travel home is quite different from that at
23 which parents leave work. Therefore, this paper mainly studies parental chauffeurs'
24 travel mode of escorting their children from home to school and their daily travel
25 mode.

26

27 **3.1 The concept of escort-space**

28 The escort-space presented in this paper is regarded as a special kind of activity
29 space that is formed through the increase in escort activities for children. The concept
30 of activity space originated in behavioral geography, which is an approach to studying
31 individuals' activities and travel behavior in space, place and environment (Golledge
32 and Stimson, 1997; Norton, 2001). The activity space concept can provide a way to
33 understand individual behavior in space by establishing linkages between the activity
34 locations. Since the parents who are mainly responsible for escorting their child are
35 usually employed (O'Fallon et al., 2004), their trips refer to three fixed activity
36 locations, namely, the residence, workplace and school (called escort-related locations
37 in this paper), which create a space in the shape of a triangle. This paper treats the
38 triangle connected by home, workplace and school and the routes between the three
39 points as the escort-space. A diagram of activity space including the escort-space is
40 shown in Figure 1.



1
2 **FIGURE 1 The activity space diagram (Golledge et al., 1997)**

3
4 **3.2 Escort-space measure**

5 Methods such as the confidence ellipse, kernel density estimation and the
6 minimum spanning tree that primarily aim to measure a range of space have been
7 widely used in previous studies (Li and Tong, 2016). However, these methods are not
8 suitable for measuring escort-space because most escort behavior has a fixed route. As
9 escort trips require the chauffeurs and their children to coexist in the same space-time
10 path, they are less flexible than other activities (He, 2013). Thus, the shape of the
11 spatial triangle of the chauffeurs is likely to have an impact on their choice of travel
12 mode. Based on the existing literature reviewed above, we acknowledge that the
13 relationship among the locations of home, workplace and school may influence
14 chauffeurs' travel mode choice. In fact, the spatial changes caused by school choice
15 and house purchasing in a school district are different from each other. Therefore, the
16 Euclidean distance between home, workplace and school is accepted as a measure of
17 spatial relationships for activity locations in the escort-space.

18
19 **3.3 Multinomial logit model**

20 The main object of this study is to investigate the effect of the escort-space
21 model on parental chauffeurs' mode choice in daily travel. However, the travel mode
22 choice is also the result of a number of factors, including household and individual
23 characteristics, in addition to the spatial model. To generalize logistic regression to
24 multiclass discrete outcomes, the multinomial logit model (MNL model) was
25 employed in this study.

26 We assume that there are K travel modes, the utility of which is known only by
27 the chauffeur and is denoted $U_{nj}, j=1, L, K$. The expression of the utility is given
28 as $U_{nj} = \sum_{m=0}^M \theta_{jm} X_{nm} + \varepsilon_{nj}$, where ε_{nj} is a random error term that follows a double
29 exponential distribution. Then, the probability that the i th chauffeur will choose the
30 j th travel mode can be calculated as follows:

31

$$P_{ij} = \frac{e^{U_{ij}}}{\sum_{k=1}^K e^{U_{ik}}}$$

1 When using the MNL model, one category of the dependent variable is chosen as the
 2 reference category. In general, a selected travel mode is taken as the reference group,
 3 the utility coefficients of which can be given as $(\theta_{r0}, \theta_{i1}, \kappa, \theta_{iM}) = (0, 0, \kappa, 0)$. According
 4 to the above formula, the probability of the i th chauffeur choosing other travel
 5 modes can be calculated using the following log odds ratio (OR):

$$6 \quad \ln\left(\frac{P_{ij}}{P_{ir}}\right) = \ln\left(\frac{\exp(e^{U_{ij}})}{1}\right) = \theta_{j0} + \theta_{j1}X_{i1} + \kappa + \theta_{jM}X_{iM}$$

7 In the model, the parental chauffeur was assumed to select the alternative with the
 8 maximum utility from four travel modes, and a maximum likelihood estimation was
 9 performed (McFadden, 1972). By verifying the estimated coefficients of MNL models,
 10 we statistically test the suitability of the assumed models for the research. Focusing on
 11 the differences between walking, biking, and taking the bus and car, we take the car as
 12 the reference group in the model and regard the household characteristics, individual
 13 characteristics and escort-space models as explanatory variables.

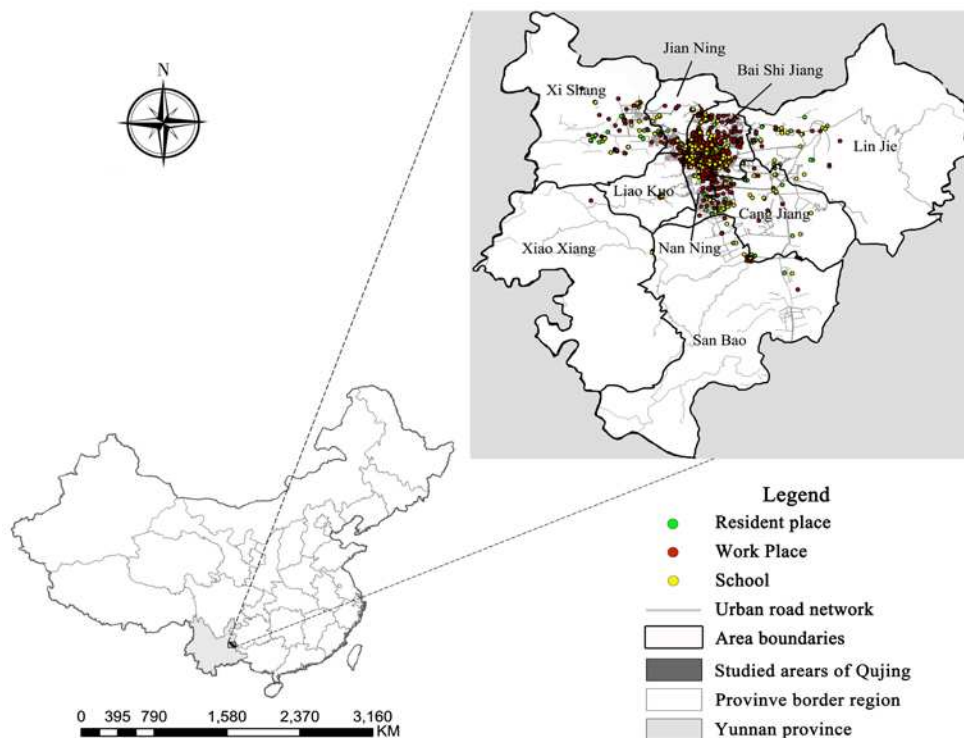
14 4. CASE STUDY

15 4.1 Study Area and Data

16 Qujing, the second-largest city of Yunnan Province in southwestern China, is
 17 adopted as a case study for this research. At the end of 2014, Qujing's permanent
 18 resident population was 6.01 million. Qujing is a typical large Chinese city according
 19 to the Standards for Categorizing City Sizes (The Chinese Government, 2015). Qilin
 20 district is the main urban area of Qujing, with a built-up area of approximately 70
 21 square kilometers and an estimated urbanization rate of 67.7%. The district is in the
 22 early stage of rapid urbanization. Approximately 710 thousand urban individuals live
 23 in this district, and the per capita gross domestic product was 27,045 CNY/year
 24 (nearly 4,342 US dollars/year) in 2014 (Qujing Statistics Bureau, 2015). Along with
 25 the accelerating urbanization process and economic growth, the expansion of urban
 26 spatial structures could lead to significant changes in individual activity spaces and
 27 consequently influence individuals' daily travel mode.

28 We use the activity-travel survey of residents of Qujing, conducted by the local
 29 statistics bureau in July 2015, as a data source. The questionnaire included household
 30 and individual characteristics and daily escort situations as well as a one-day activity
 31 diary designed to capture information on a personal digital assistant (PDA). Although
 32 the survey was conducted during summer vacation, when most children did not go to
 33 school, the timing had no influence on the study because it asked about their daily
 34 situations. Respondents would not have answered the question about escort behavior
 35 if they never escorted in daily travel. The survey covered different residential
 36 communities evenly distributed throughout Qujing. Nine of these communities in
 37 Qilin district were selected as our study areas, of which Jiang Ning, Liao Kuo, Nan
 38 Ning and Xiao Xiang are in the central area of the city in an area of mixed land use

1 with high densities of jobs and schools near public transport facilities. The other five
 2 residential communities are in the peripheral area. Compared to those in the central
 3 area, these communities are in an area of single-function land use and have a low
 4 population density and poor public transport facilities. To explore the transport mode
 5 choice of parental chauffeurs in daily travel under the influence of the escort-space
 6 model, the data were filtered according to the following principles: (a) one escorted
 7 school-aged child should be included in the household; (b) one parent should mainly
 8 pick up/drop off their child; and (c) the chauffeur should also be a worker. Finally,
 9 752 households with one main parental chauffeur were selected for study. The sample
 10 covered the majority of primary and high schools in Qilin district, and its distribution
 11 is shown in Figure 2.



12
 13 **FIGURE 2 Study area of Qijun and sample distribution**

14 15 **4.2 Characteristics of Escort-space Models**

16 According to the measure of escort-space mentioned before, the Euclidean
 17 distance between home and school, home and workplace and school and workplace
 18 was calculated by the latitude and longitude of the locations. Their escort-spaces can
 19 be built with these three kinds of distances. Although individual escort-spaces differed
 20 from each other, they exhibited similar spatial position relationships. To calculate the
 21 transformation of an individual's escort-space to a spatial relationship, cluster analysis
 22 is adopted in this paper. Because of its good performance in partitioning datasets into
 23 a number of clusters, the K-means algorithm has been widely applied in various fields
 24 (Jiang et al., 2017). Therefore, we use it to cluster the escort-space of 752 individuals
 25 and use the relative distances between home, workplace and school as the clustering

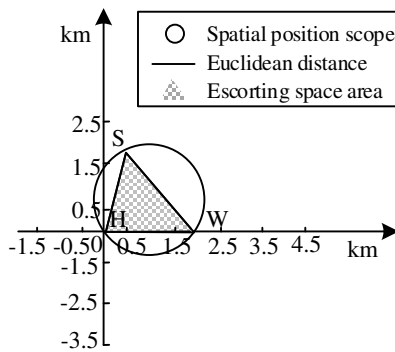
1 variables. To use the K-means algorithm, the number of clusters must be chosen
 2 beforehand. Therefore, we created 2-4 categories according to the distance
 3 distribution and possible space combinations of individuals' escort-related locations.
 4 Comparing the clustering results of different groups, we finally determined three
 5 types of escort-space models.

6 In Model 1, the escort-related locations of parental chauffeurs were within a
 7 relatively short average distance. This model, defined as spatial aggregation, accounts
 8 for 70.6% of all models. In Model 2, the distance from home to school is far shorter
 9 than the distance from home to workplace and from workplace to school. Thus, the
 10 model is defined as job-housing separation (12.8%). In contrast, the parental
 11 chauffeurs in Model 3 travel a long distance from home to school and a relatively
 12 short distance from home to workplace, and the model is defined as school-housing
 13 separation (16.6%). Table 2 presents the summary statistics of the calculations for
 14 these three models. The variance of the distances in Model 2 is greater than that in the
 15 other two models, suggesting that the job-housing separation differs among the
 16 individual parental chauffeurs.

17 **Table 2 The summary statistics of the calculation**

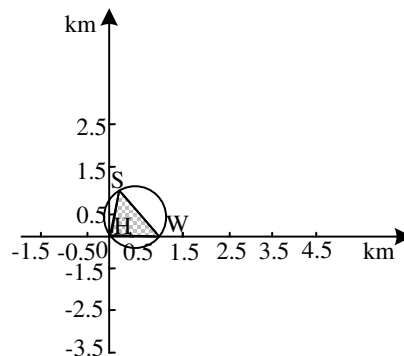
Distance (unit: km)	spatial aggregation (Model 1)			job-housing separation (Model 2)			school-housing separation (Model 3)		
	$ d_{HW} $	$ d_{HS} $	$ d_{SW} $	$ d_{HW} $	$ d_{HS} $	$ d_{SW} $	$ d_{HW} $	$ d_{HS} $	$ d_{SW} $
Mean	1.1	1.1	1.4	8.8	1.3	8.8	2.2	4.6	3.4
Variance	1.6	0.4	1.2	5.3	1.1	3.0	4.5	1.5	9.8
Maximum	5.7	2.8	5.4	16.0	4.9	14.4	9.8	10.2	9.9
Minimum	0.0	0.0	0.0	4.7	0.1	4.7	0.0	2.7	0.0

18 The spatial distribution of these three models is shown in Figure 3 (b), (c) and (d).
 19 (a) is the reference group of the spatial distribution before the classification, where H
 20 stands for home, S stands for school and W stands for workplace, and the Euclidean
 21 distance is represented by the mean distance between the escort-related locations. The
 22 figure reflects not only the average travel distance of the parental chauffeurs between
 23 the escort-related locations but also the spatial relationships between home, workplace
 24 and school. A further analysis of the models is conducted as follows.

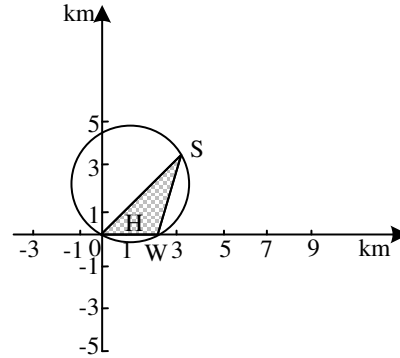
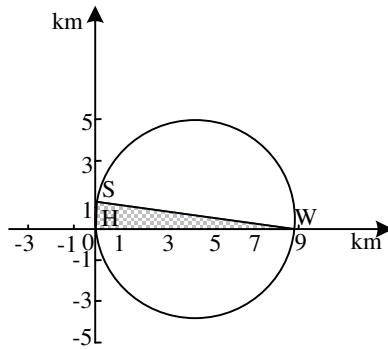


25

26 (a) Total sample



(b) Spatial aggregation model



1

2 (c) Job-housing separation model

3 (d) School-housing separation model

4 **FIGURE 3 Escort-space models**

5 Figure 3 (a) shows that the average travel distances between the escort-related
 6 locations of parental chauffeurs were within 1.5 km and formed an acute triangle for
 7 the shape of the escort-space model. This shape suggested that the chauffeurs
 8 preferred to pick up/drop off their children at school within an aggregated
 9 escort-space. Figure 3 (b) shows that the distances between the home, workplace, and
 10 school were shorter than those of the reference group with a relatively equal
 11 distribution. This finding reflected the fact that most children in Qijing are escorted to
 12 school within a reasonable range under the guidance of the nearby enrollment policy.

13 Figure 3 (c) shows that the distance from home to the workplace was much
 14 longer than that from home to school and was longer than that of the total samples.
 15 One major reason for this result is that parents buy a house in a good school district
 16 that can provide a better education for their child under long-distance commuting
 17 conditions. Compared to the distance in the other models, although the distance from
 18 home to school (1.3 km) decreases, the distance from home to workplace (8.8 km) and
 19 from workplace to school (8.8 km) increases significantly. As a result, parental
 20 chauffeurs who pick up/drop off their children at school by walking or cycling have a
 21 higher possibility of using private cars in work commutes and work-related trips or
 22 other daily activities trips. Since escort travel is only one component of daily travel
 23 for commuter parents, the use of cars in daily travel is more than that in escort trips
 24 for a given traffic network.

25 In contrast, Figure 3 (d) shows that the distance from home to school is longer
 26 than that from home to workplace (4.6 km vs. 2.2 km). Thus, although the parental
 27 chauffeurs have relatively short commuting distances, they must travel a long distance
 28 to escort their children. Such a spatial separation model, which may be caused by
 29 parents choosing good educational resources far from home for their children, may
 30 also result in an increase in the chauffeurs' car trips. In addition, by comparing these
 31 two escort-space models, we found that the spatial separation of home and workplace
 32 is more obvious than that of home and school, suggesting that the behavior of buying
 33 houses in good school districts may lead to increased urban traffic problems.

4.3 Escort-space Models and Travel Mode Choice

To investigate the relationship between travel mode choice and escort-space models among parental chauffeurs, this study analyzes the travel mode distribution in different models. As mentioned above, the parental travel mode for escorting children is likely to differ from that of daily travel; thus, this paper performs a statistical analysis of these two groups of travel mode choices, and the results are shown in Figure 4.

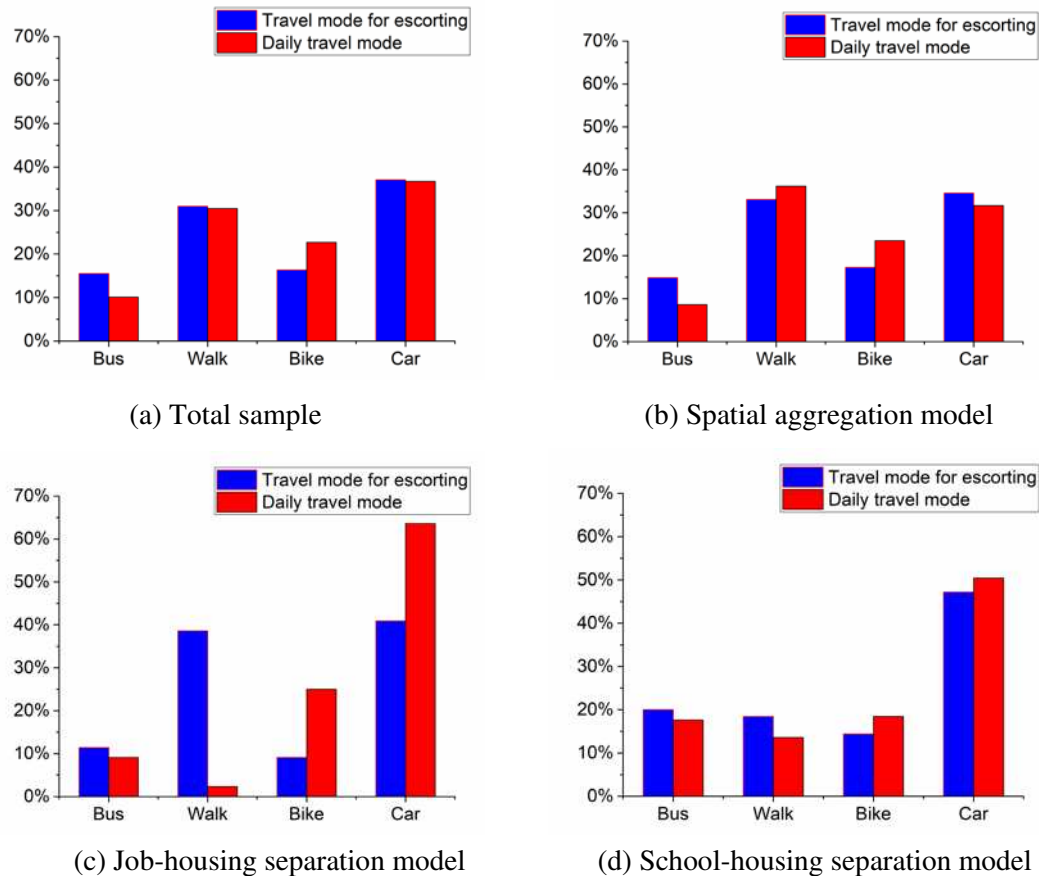


FIGURE 4 Travel mode choice by escort-space models

Figure 4 (a) shows that the car is the most important travel mode of parental chauffeurs among all of the samples. There seems to be no significant difference in the mode share of car use, as well as walking, between escort trips and daily trips. We found that parents prefer to escort their children by bus, while the percentage of those traveling daily by bike (24.6%) is greater than that traveling daily by bus (16.5%). It is possible that 66.1% of children in the sample are older than 13 and cannot be chauffeured using a bike. To better understand the reasons for the distribution of the travel modes of parental chauffeurs in detail, this paper further analyzes the modal split characteristics under each escort-space model. Figure 4 (b) shows that the modal splits in the spatial aggregation model are similar to those of the total sample expect for car and walking. The percentage of parents who drive their children to school is greater than that who use a car daily, and the situation for walking is the opposite. This finding confirms the results of previous studies that showed that escorting children increases the proportion of car trips (Yoon et al., 2011; He et al., 2013).

1 For the travel mode distribution in the job-housing separation model (shown in
2 Figure 4 (c)), parental chauffeurs perform significantly differently between escort
3 trips and daily travel; although 38.6% escort their children by walking, only 2.3%
4 travel daily on foot. Moreover, car is the most important mode of daily travel, with a
5 high proportion of 63.6%. In fact, the percentage of car use for escort trips does not
6 decrease but rather increases (35.2% vs 41.5%), and the mode shares of cycling and
7 bus decrease. These findings indicate that the reduction in distance from home to
8 school alone does not reduce the number of car trips. In contrast, it significantly
9 increases car use by decreasing the home-school distance at the cost of increasing the
10 home-workplace distance (e.g., because of purchasing houses in good school districts).
11 The results are consistent with the above analysis. In contrast to the job-housing
12 separation model, Figure 4 (d) shows that there is no significant difference between
13 escort trips and other daily trips in the travel distribution in the school-housing
14 separation model. However, the proportion of car use in the two groups is much
15 higher than that of other travel modes; that is, the distance from home to school has a
16 great impact on car use. When children choose schools far from home, their parents
17 prefer to use a car.

18 We can conclude from Figure 4 that the modal split shows significant differences
19 in the different escort-space models, indicating that the spatial relationships between
20 home, school and the workplace have a significant effect on parental chauffeurs'
21 travel mode choice. Job-housing separation and school-housing separation in
22 particular increase the proportion of car use during travel. Because parental chauffeurs
23 in the spatial aggregation mode account for a great proportion in this study (70.6%),
24 the mode share of car use in escort trips is comparable to that in daily travel. However,
25 with the continual progress of urbanization in Qijing city, the proportions of the
26 job-housing separation model and the school-housing separation model will continue
27 to increase, which may lead more parental chauffeurs to use cars or more families to
28 buy cars. Therefore, the mode share for car use in daily travel is greater than that in
29 escort trips

30 **4.4 MODELING AND RESULTS**

31 In this study, the escort-space model is considered the main factor that influences
32 parental chauffeurs' travel mode choice. Therefore, it is important to test the joint
33 significance of the variables capturing the impact of the spatial models on mode
34 choice (Model I) by comparing the model against a simplified model without these
35 spatial models (Model II). Other factors that may influence the parental chauffeurs'
36 daily travel mode choice based on previous studies are considered in both of these two
37 models. All the explanatory variables were checked for multicollinearity before being
38 entered into the models. These variables and the corresponding definitions are listed
39 in Table 3. Notably, the children's characteristics, including age and gender, have been
40 excluded from the explanatory variables because they are not significantly associated
41 with the outcome variables.

42

1 **Table 3 Explanation of observation variables**

Variables	Classification and definitions	Sample
Household		
Annual household income	Less than 50,000=1	32.5%
	50,000-100,000=2	47.9%
	More than 100,000=3	19.7%
Car ownership	No car=0	33.6%
	One or more than one car=1	66.4%
E-bike ownership	No bike=0	31.4%
	One or more than one bike=1	68.64%
Household location	Not core area=0	67.7%
	Core area=1	32.3%
Parental chauffeur		
Age	Less than 40 years old=0	34.9%
	40 or more than 40 years old=1	65.1%
Gender	Female=0	50.8%
	Male=1	49.2%
Income	Less than 2,000=1	42.0%
	2,000-5,000=2	27.8%
	More than 5,000=3	30.2%
Education level	High school or less=0	54.4%
	College or more=1	47.6%
Driving experience	No driving experience=0	32.7%
	1-3 years=1	27.4%
	3-10 years=2	14.1%
	More than 10 years=3	17.8%
Escort-space model	Spatial aggregation=1	70.6%
	Job-housing separation=2,	12.8%
	School-housing separation=3	16.6%
Escort type	On-the-way escorts=1	18.5%
	Out-of-way escorts=2	21.4%
	Pure escorting=3	60.1%
Spatial relationship		
Escort-space model	Spatial aggregation=1	70.6%
	Job-housing separation=2,	12.8%
	School-housing separation=3	16.6%

2 Note: Bold font represents the reference group.

3 The estimation and evaluation results of Model I and Model II (shown in
4 parentheses) are reported in Table 4. As the selected variables that were not significant
5 at the 0.10 level were excluded, escort type is not included in Table 4. One possible
6 reason that this exceptional factor is not significant is that the space-time relationship
7 between parents and their children during escort trips has little impact on the

1 chauffeurs' daily travel. As the p-value of the model is 0.0 (<0.05), both Model I and
 2 Model II have regression results superior to those of their null models.

3 **Table 4 Regression results for parental chauffeurs' daily travel mode choice**

Mode	Walk			Bus			Bike		
	Coef.	S.E.	P> z	Coef	S.E	P> z	Coef.	S.E.	P> z
<i>Constant</i>	4.59 (4.69)	0.95 (0.86)	0.00* (0.00*)	6.95 (6.03)	0.84 (0.77)	0.00* (0.00*)	3.56 (2.97)	1.10 (1.05)	0.00* (0.01*)
<i>Household</i>									
Household income2	0.25 (0.27)	0.41 (0.40)	0.54 (0.50)	-0.63 (-0.50)	0.30 (0.29)	0.04* (0.09*)	-0.38 (-0.29)	0.34 (0.34)	0.27 (0.39)
Household income3	-0.31 (-0.21)	0.54 (0.53)	0.57 (0.62)	-1.14 (-1.08)	0.40 (0.39)	0.00* (0.01*)	-0.77 (-0.73)	0.48 (0.47)	0.10 (0.12)
Car-owning	-3.78 (-3.43)	0.55 (0.51)	0.00* (0.00*)	-3.18 (-2.92)	0.50 (0.45)	0.00* (0.00*)	-3.51 (-3.27)	0.50 (0.47)	0.00* (0.00*)
Bike-owning	-0.21 (-0.30)	0.34 (0.33)	0.53 (0.37)	-0.31 (-0.29)	0.25 (0.24)	0.22 (0.23)	3.32 (3.32)	0.75 (0.75)	0.00* (0.00*)
Center area	0.30 (0.05)	0.38 (0.35)	0.42 (0.89)	0.92 (1.23)	0.31 (0.28)	0.00* (0.00*)	0.05 (0.16)	0.32 (0.30)	0.87 (0.60)
<i>Parental chauffeurs</i>									
>40 years old	0.51 (0.34)	0.37 (0.36)	0.16 (0.34)	-0.67 (-0.58)	0.25 (0.24)	0.00* (0.01*)	-0.09 (-0.01)	0.29 (0.28)	0.76 (0.96)
Father	-0.92 (-0.98)	0.37 (0.37)	0.01* (0.00*)	-0.40 (-0.42)	0.27 (0.26)	0.13 (0.11)	0.04 (0.03)	0.31 (0.31)	0.89 (0.92)
Income 2	-0.01 (-0.09)	0.40 (0.39)	0.97 (0.81)	-0.91 (-0.89)	0.33 (0.30)	0.01* (0.00*)	-0.09 (-0.07)	0.35 (0.34)	0.78 (0.82)
Income 3	-0.96 (-1.07)	0.46 (0.45)	0.03* (0.02*)	-0.88 (-0.95)	0.42 (0.32)	0.85 (0.00*)	-0.77 (-0.85)	0.41 (0.40)	0.06* (0.03*)
College or more	0.59 (0.64)	0.35 (0.35)	0.09* (0.07*)	-0.07 (-0.13)	0.26 (0.26)	0.78 (0.62)	-0.60 (-0.66)	0.31 (0.30)	0.05* (0.03*)
Driving experience 1	-3.30 (-3.16)	0.63 (0.62)	0.00* (0.00*)	-2.97 (-2.90)	0.58 (0.57)	0.00* (0.00*)	-3.19 (-3.09)	0.60 (0.59)	0.00* (0.00*)
Driving experience 2	-3.20 (-3.08)	0.66 (0.65)	0.00* (0.00*)	-3.69 (-3.29)	0.61 (0.59)	0.00* (0.00*)	-3.81 (-3.75)	0.64 (0.63)	0.00* (0.00*)
Driving experience 3	-5.33 (-5.11)	0.95 (0.94)	0.00* (0.00*)	-3.48 (-3.34)	0.62 (0.60)	0.00* (0.00*)	-5.10 (-4.97)	0.71 (0.69)	0.00* (0.00*)
<i>Escort-space</i>									
Spatial model 2	-1.42	0.79	0.07*	-4.36	1.19	0.00*	-1.51	0.69	0.03*
Spatial model 3	0.85	0.41	0.03*	-0.95	0.36	0.01*	-0.33	0.38	0.38
N=752 LR chi ² =671.52 (622.390)									
Log likelihood:									
L(0)=-862.28 (-830.59)									
L(β)=-526.53 (-519.39)									
McFadden Pseudo R ² 0.344 (0.319)									

7 Note: * significance at the 10% level

8 As indicated in Table 4, the R² value (i.e., likelihood ratio index) of Model I is

1 equal to 0.344, which is more than the R^2 value (0.319) of Model II. R^2 is one of the
 2 most important indexes for evaluating the total performance of various models. When
 3 the R^2 value is approximately 0.4, it may indicate an excellent fit for the daily travel
 4 mode choices of parental chauffeurs (Ortuzar and Willumsen, 2011). Thus, it shows
 5 that the model with the escort-space models has a more significant goodness-of-fit
 6 than the model without the escort-space models. This finding confirms that the main
 7 variable in this study, the escort-space, which reflects the spatial relationship between
 8 home, workplace, and school, displays a significant impact on the daily travel mode
 9 choice of parental chauffeurs. Moreover, individual socioeconomic attributes and
 10 household characteristics also significantly impact the daily travel mode choice of
 11 parental chauffeurs

12 The negative coefficients of the job-housing separation model, compared to those
 13 of the reference group, are highly significant for walk, bus, and bike. This finding
 14 suggests that parental chauffeurs under the influence of spatial separation between job
 15 locations and residential locations are more likely to travel daily by car. For instance,
 16 the spatial model 2 coefficient for bus is -4.36, which implies that, *ceteris paribus*, the
 17 OR (P_{Car}/P_{Bus}) for parental chauffeurs belonging to the spatial model 2 is $OR = \exp$
 18 $(4.36) = 78.26$ times larger than that for parental chauffeurs belonging to spatial model
 19 1. In other words, the parental chauffeurs who live in job-housing separation model
 20 are more likely to use car in their daily trips relative to bus than the parental
 21 chauffeurs who live living in spatial aggregation model. Similar trends could also be
 22 found in travel mode choice of walk and bike. However, compared with those in
 23 spatial model 2, parental chauffeurs in the spatial model 3 show different preferences
 24 for travel model. The spatial model 3 coefficients for walk and bike are 0.85 and -0.95,
 25 respectively, which implies that the ORs for parental chauffeurs belong to the spatial
 26 model 3 are $OR = \exp(0.85) = 2.34$ and 0.39 times, respectively, larger than those for
 27 the reference group. Thus, parental chauffeurs under the influence of spatial
 28 separation between school locations and residential locations prefer to walk in their
 29 daily trips rather than use a car, whereas they are less likely to use a bus than a car.
 30 There is not a statistically significant difference between using a bike and a car. These
 31 findings demonstrate that the spatial separation is a major barrier that prevents
 32 parental chauffeurs from using a bus on their daily trips and that job-housing
 33 separation has a significant impact on their car use.

34 Regarding household characteristics, household annual income significantly
 35 influences parental chauffeurs' travel mode choice for daily trips. Since the
 36 coefficients are negative, compared to those whose annual household income is less
 37 than 50000 CNY, *ceteris paribus*, other chauffeurs are more likely to choose car than
 38 bus. Chauffeurs from households with cars are most likely to choose the car as their
 39 daily travel mode, as shown by highly significant and negative coefficients. This
 40 result implies that parents who are responsible for escorting their children are more
 41 likely to use a car, which agrees with the findings of previous studies. Furthermore, it
 42 can be concluded that parental chauffeurs often drive to other destinations on their
 43 daily journeys, even when they escort their child by walking or cycling. Similarly,

1 chauffeurs from households with bikes tend to use bikes as their daily travel mode;
2 the coefficient of 3.3 was large and highly significant. These findings reveal that the
3 allocation of the household vehicle to some extent depends on the parents' will to
4 escort their child. Moreover, the residential location has a significant impact on the
5 daily mode choice. Parental chauffeurs living within the center core present positive
6 coefficients for both walking and bus. This result is probably caused by intensive land
7 use and relatively perfect public transport facilities in the center core.

8 In terms of parental chauffeurs' characteristics, age has negative effects on the
9 travel mode choice of the bus. The OR for parental chauffeurs older than 40 is
10 $OR = \exp(-0.67) = 0.51$ times larger than that for the reference group. This result
11 suggests that parental chauffeurs older than 40 prefer to use cars in their daily trips
12 rather than busses. The negative coefficients for the father regarding the choice to
13 walk indicate that father chauffeurs are more likely to use a car as their daily travel
14 mode than are mother chauffeurs. Similarly, a significant difference between bus
15 choice and reference group was found in terms of income 2, indicating that parental
16 chauffeurs with an income between 2,000 and 5,000 CNY prefer to use a car on their
17 daily journeys rather than a bus. However, chauffeurs with income greater than 5,000
18 CNY have an opposite preference of daily travel mode choice. One possible reason is
19 that household cars are usually allocated to males because they are primarily in charge
20 of earning money to support the family, according to traditional Chinese concepts.
21 Another possible reason is that biking is the main daily travel mode for the chauffeurs
22 who cannot afford to buy a car. However, chauffeurs in car-owner households are
23 more willing to use cars than bikes, even if they have bikes. In contrast to the findings
24 of McMillan (2007), the positive coefficient for college or higher education for the
25 choice of the bus indicates that parental chauffeurs with a high education are more
26 likely to adopt public transport as their main travel mode. Moreover, as driving
27 experience increases, parental chauffeurs have a higher possibility of using the car and
28 are less likely to use the bike on daily trips.

29 **5 DISCUSSION AND POLICY IMPLICATIONS**

30 Like many of the Western countries, to guarantee the implementation of the
31 nine-year compulsory education system, the Chinese government requires that
32 school-age children enter schools close to the place of household registration. The
33 purpose of the nearby enrollment policy is to avoid inequalities in educational
34 resources and to provide a nonmobilized travel environment for children. However, it
35 directly causes 60.1% parents travel separately for escorting and commuting in Qijing.
36 Thus, research regarding parental chauffeurs' daily travel mode choice that takes into
37 account the spatial relationship between escort-related locations is needed. In addition,
38 this research can help better understand the daily use of cars by parental chauffeurs
39 and guide them low-carbon travel choices through the implementation of relevant
40 policies.

41 This study reveals that although both types of spatial separation contribute to the

1 increase in daily car trips, they result in different chauffeurs' travel mode choices.
2 When the escort-space pertains to school-housing separation, many parental
3 chauffeurs are willing to choose public transport as their daily travel mode under the
4 condition of a short job-housing distance. However, when the escort-space pertains to
5 job-housing separation, the choice of the car is far more popular than other travel
6 modes, even though the distance between home and school is short. The main reason
7 may be that the daily travel mode choice of parental commuters depends largely upon
8 their home-workplace distance. Parents usually need to live farther from their
9 workplaces, which considerably increases their car use. Consequently, decreasing the
10 distance between home and school at the expense of an increased distance between
11 home and workplace leads to increased daily car trips. We confirm that the nearby
12 enrollment policy, which encourages higher-income parents to buy properties near
13 high-quality schools for their children, actually increases their car use for daily trips.
14 Therefore, in addition to shortening the distance between home and school by
15 improving the distribution of high-quality schools (Zhang et al., 2017), attention
16 should be paid to public transport and educational resources in areas near workplaces.
17 Moreover, the government should encourage and support the free sharing of resources
18 between high-quality schools and ordinary schools to reduce the purchases of houses
19 in particular school districts.

20 There are at least three methods to reduce the use of cars by parents in the
21 cultural and institutional contexts of Qijing. First, we find that car ownership is an
22 important factor that influences parental chauffeurs' daily car trips. Currently,
23 approximately 67.3% of the people in Qijing have driving licenses, but only 36.7%
24 choose the car as their main travel mode due to insufficient car availability in
25 households. Bikes, especially e-bikes, are likely to be the main mode of transport for
26 car-free households. The findings of Liu et al. (2017) also show that mothers in
27 car-free households tend to use e-bikes to escort their children to/from school.
28 However, with the development of the social economy and urban sprawl, increasing
29 numbers of parents currently tend to buy a second car, especially those from
30 high-income households. Thus, travel demand policies based on the modeling results
31 should be implemented to avoid the excessive use of cars. Since high-income
32 households contribute to the increasing purchase and use of cars, the government
33 should raise the purchase tax on private cars when a household plans to buy a second
34 car and increase parking fees in the central area, where both educational resources and
35 public transport are relatively good.

36 Second, bike-sharing schemes have been sweeping across China since 2016. The
37 bike-sharing boom is a good opportunity to encourage parental chauffeurs to commute
38 via bike because the presence of bikes has a strong positive impact on the choice of
39 cycling. Since the spatial separation between workplaces and home is the leading
40 cause of parent chauffeurs' car use for daily trips based on our research findings,
41 bike-sharing systems alone can hardly change those chauffeurs travel modes.
42 Therefore, a marriage between bike-sharing and rail transit is essential. Ji et al. (2016)

1 found that young commuters and high-income commuters are willing to use the public
2 bike as a feeder mode to rail transit. Therefore, bike-sharing companies and the
3 government should pay more attention to optimal resource configuration for an
4 integrated bike-sharing and rail transit system, e.g., increasing the supply of bikes
5 near the metro stations in the peripheral area.

6 Finally, because parental chauffeurs play a key role in household vehicle
7 allocation, as analyzed previously, policymakers should consider their characteristics.
8 For parents older than 40, the bus company and the government should encourage and
9 support work units to offer public transportation allowances for them if possible, in
10 addition to improving the service quality of the public transit system in Qujing. In
11 addition, it is important to enhance parental public awareness of low-carbon travel
12 (Zhang et al., 2017). For example, schoolteachers should encourage environmental
13 consciousness in children so that they can pass it on to their parents.

14 **6. CONCLUSION**

15 This study investigates the daily modal split among parental chauffeurs while
16 focusing on the effects of different escort-space models: spatial aggregation,
17 job-housing separation, and school-housing separation. The findings showed that
18 spatial separation is a major barrier that prevents parental chauffeurs from using the
19 bus on their daily trips and that job-housing separation is associated with their car use.
20 Decreasing the distance between home and school at the expense of an increased
21 distance between home and the workplace leads to increased daily car trips. Therefore,
22 policies focusing on an activity space perspective are helpful for developing and
23 creating a sustainable transportation system.

24 This research contributes to understanding parental chauffeurs' daily travel mode
25 choice under the effects of the nearby enrollment policy. Parental chauffeurs' car use
26 for daily trips should not be overlooked under the influence of the uneven distribution
27 of educational resources, particularly in regard to the spatial separation caused by
28 urban sprawl. Moreover, we discuss implications for policy and practice from travel
29 demand management, urban planning and individual behavior level. Because different
30 spatial models result in different travel mode choices, additional studies should
31 explore the factors that can influence parental chauffeurs' mode choice for each
32 spatial model. Moreover, the built environment, urban structure and school
33 distribution should be considered as factors (Lin et al., 2010; Broberg et al., 2015;
34 Easton et al., 2015). Furthermore, long-term activity-based survey diary data for both
35 children and their parents are needed, which also should be the focus of important
36 question of future studies.

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