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Article:
Liu, Y, Ji, Y, Shi, Z et al. (2 more authors) (2018) Investigating the effect of the spatial relationship between home, workplace and school on parental chauffeurs' daily travel mode choice. Transport Policy, 69. pp. 78-87. ISSN 0967-070X

https://doi.org/10.1016/j.tranpol.2018.06.004

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

Abstract

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

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

1 INTRODUCTION

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

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

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

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

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

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

2 LITERATURE REVIEW

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

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

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

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

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

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

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

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

3 METHODOLOGY

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

3.1 The concept of escort-space

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

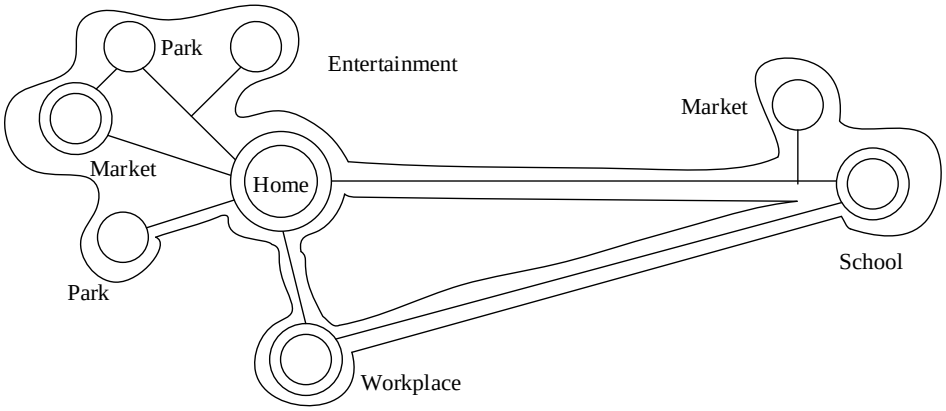


FIGURE 1 The activity space diagram (Golledge et al., 1997)

3.2 Escort-space measure

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

3.3 Multinomial logit model

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

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

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

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

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

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

4. CASE STUDY

4.1 Study Area and Data

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

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

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

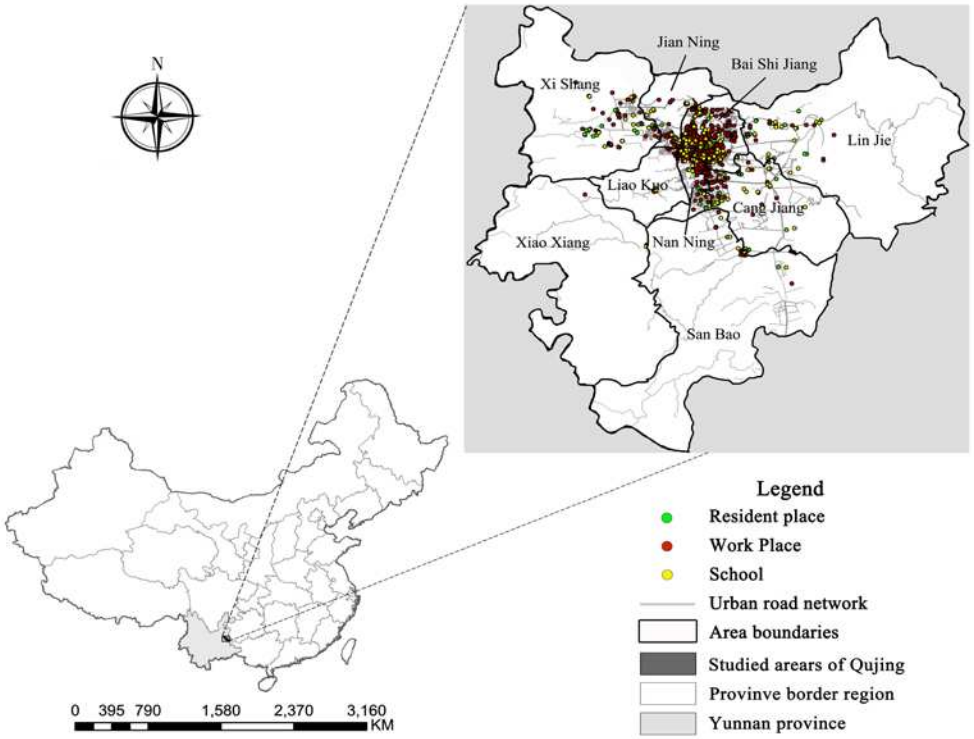


FIGURE 2 Study area of Qujin and sample distribution

4.2 Characteristics of Escort-space Models

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

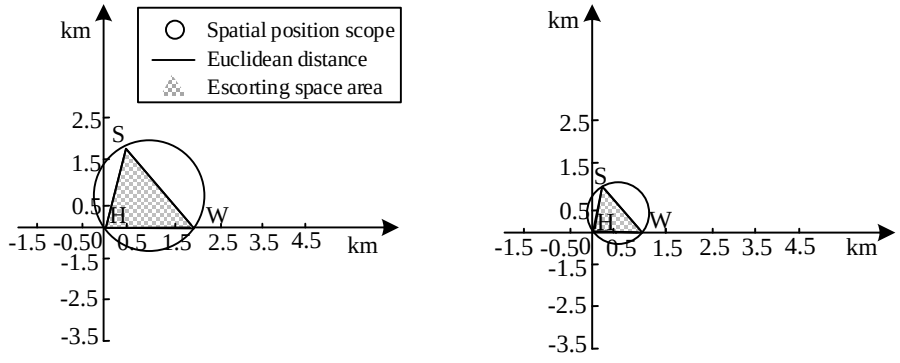
variables. To use the K-means algorithm, the number of clusters must be chosen beforehand. Therefore, we created 2-4 categories according to the distance distribution and possible space combinations of individuals' escort-related locations. Comparing the clustering results of different groups, we finally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

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

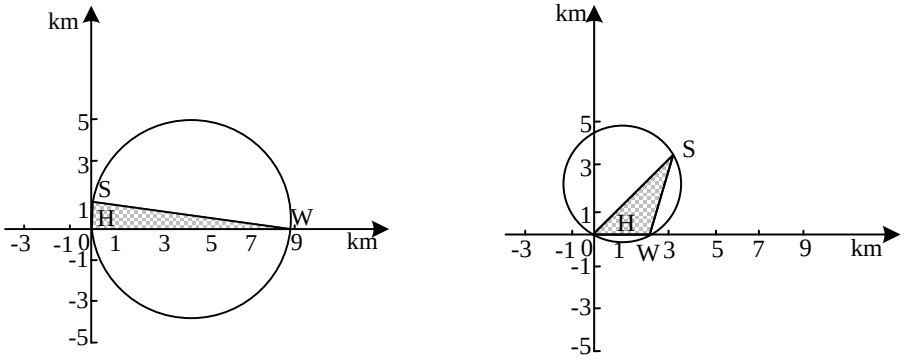
Table 2 The summary statistics of the calculation

Distance (unit: km)	spatial aggregation (Model 1)			job-housing separation (Model 2)			school-housing separation (Model 3)		
	$\overline{\lvert d_{HW} \rvert}$	$\overline{\lvert d_{HS} \rvert}$	$\overline{\lvert d_{SW} \rvert}$	$\overline{\lvert d_{HW} \rvert}$	$\overline{\lvert d_{HS} \rvert}$	$\overline{\lvert d_{SW} \rvert}$	$\overline{\lvert d_{HW} \rvert}$	$\overline{\lvert d_{HS} \rvert}$	$\overline{\lvert d_{SW} \rvert}$
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

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



(a) Total sample (b) Spatial aggregation model



(c) Job-housing separation model (d) School-housing separation model

FIGURE 3 Escort-space models

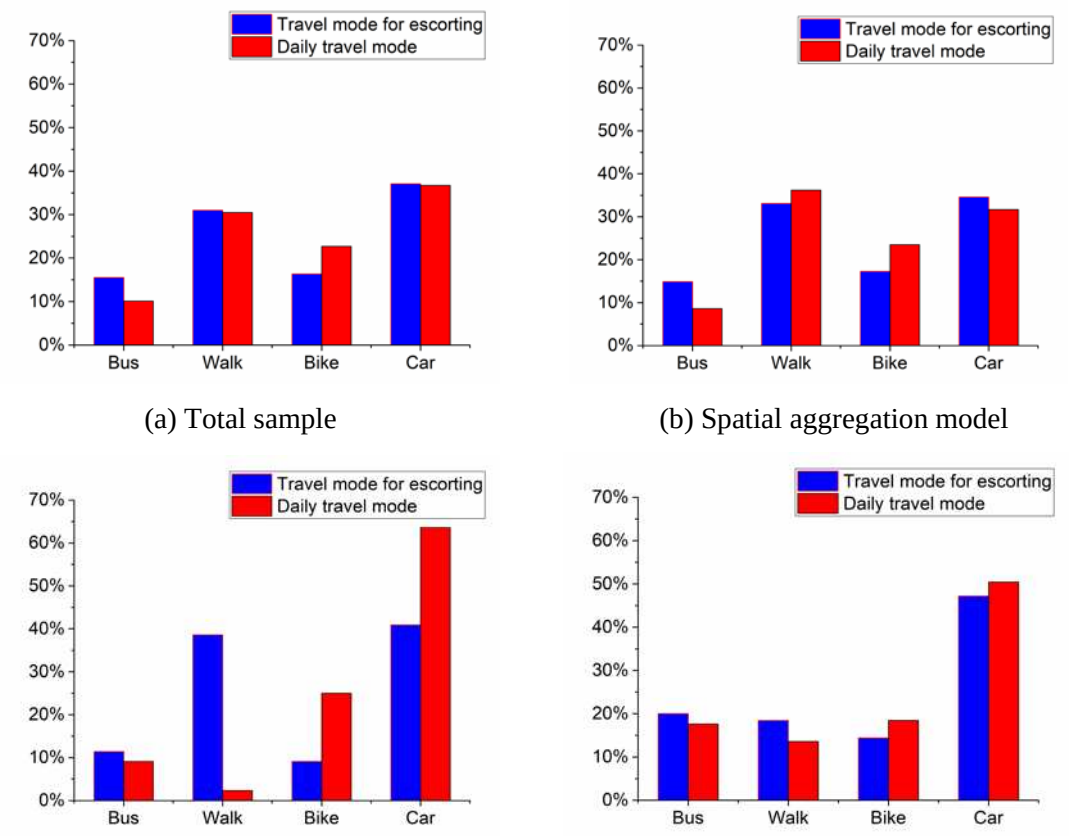
Figure 3 (a) shows that the average travel distances between the escort-related locations of parental chauffeurs were within 1.5 km and formed an acute triangle for the shape of the escort-space model. This shape suggested that the chauffeurs preferred to pick up/drop off their children at school within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

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

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



(a) Total sample (b) Spatial aggregation model

(c) Job-housing separation model (d) School-housing separation model

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).

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

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

4.4 MODELING AND RESULTS

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

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%

Note: Bold font represents the reference group.

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

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

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|
Constant	4.59	0.95	0.00*	6.95	0.84	0.00*	3.56	1.10	0.00*
	(4.69)	(0.86)	(0.00*)	(6.03)	(0.77)	(0.00*)	(2.97)	(1.05)	(0.01*)
Household									
Household income2	0.25	0.41	0.54	-0.63	0.30	0.04*	-0.38	0.34	0.27
	(0.27)	(0.40)	(0.50)	(-0.50)	(0.29)	(0.09*)	(-0.29)	(0.34)	(0.39)
Household income3	-0.31	0.54	0.57	-1.14	0.40	0.00*	-0.77	0.48	0.10
	(-0.21)	(0.53)	(0.62)	(-1.08)	(0.39)	(0.01*)	(-0.73)	(0.47)	(0.12)
Car-owning	-3.78	0.55	0.00*	-3.18	0.50	0.00*	-3.51	0.50	0.00*
	(-3.43)	(0.51)	(0.00*)	(-2.92)	(0.45)	(0.00*)	(-3.27)	(0.47)	(0.00*)
Bike-owning	-0.21	0.34	0.53	-0.31	0.25	0.22	3.32	0.75	0.00*
	(-0.30)	(0.33)	(0.37)	(-0.29)	(0.24)	(0.23)	(3.32)	(0.75)	(0.00*)
Center area	0.30	0.38	0.42	0.92	0.31	0.00*	0.05	0.32	0.87
	(0.05)	(0.35)	(0.89)	(1.23)	(0.28)	(0.00*)	(0.16)	(0.30)	(0.60)
Parental chauffeurs									
＞40 years old	0.51	0.37	0.16	-0.67	0.25	0.00*	-0.09	0.29	0.76
	(0.34)	(0.36)	(0.34)	(-0.58)	(0.24)	(0.01*)	(-0.01)	(0.28)	(0.96)
Father	-0.92	0.37	0.01*	-0.40	0.27	0.13	0.04	0.31	0.89
	(-0.98)	(0.37)	(0.00*)	(-0.42)	(0.26)	(0.11)	(0.03)	(0.31)	(0.92)
Income 2	-0.01	0.40	0.97	-0.91	0.33	0.01*	-0.09	0.35	0.78
	(-0.09)	(0.39)	(0.81)	(-0.89)	(0.30)	(0.00*)	(-0.07)	(0.34)	(0.82)
Income 3	-0.96	0.46	0.03*	-0.88	0.42	0.85	-0.77	0.41	0.06*
	(-1.07)	(0.45)	(0.02*)	(-0.95)	(0.32)	(0.00*)	(-0.85)	(0.40)	(0.03*)
College or more	0.59	0.35	0.09*	-0.07	0.26	0.78	-0.60	0.31	0.05*
	(0.64)	(0.35)	(0.07*)	(-0.13)	(0.26)	(0.62)	(-0.66)	(0.30)	(0.03*)
Driving experience 1	-3.30	0.63	0.00*	-2.97	0.58	0.00*	-3.19	0.60	0.00*
	(-3.16)	(0.62)	(0.00*)	(-2.90)	(0.57)	(0.00*)	(-3.09)	(0.59)	(0.00*)
Driving experience 2	-3.20	0.66	0.00*	-3.69	0.61	0.00*	-3.81	0.64	0.00*
	(-3.08)	(0.65)	(0.00*)	(-3.29)	(0.59)	(0.00*)	(-3.75)	(0.63)	(0.00*)
Driving experience 3	-5.33	0.95	0.00*	-3.48	0.62	0.00*	-5.10	0.71	0.00*
	(-5.11)	(0.94)	(0.00*)	(-3.34)	(0.60)	(0.00*)	(-4.97)	(0.69)	(0.00*)
Escort-space									
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)								

Note: * significance at the 10% level

As indicated in Table 4, the R^2 value (i.e., likelihood ratio index) of Model I is

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

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

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

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

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

5 DISCUSSION AND POLICY IMPLICATIONS

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

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

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

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

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

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

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

6. CONCLUSION

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

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

ACKNOWLEDGMENTS

The financial support from the Projects of International Cooperation and Exchange of the National Natural Science Foundation of China (No. 51561135003), the Key Project of National Natural Science Foundation of China (No. 51338003), the

Fundamental Research Funds for the Central Universities (No. KYLX16_0270) and the Project of National Natural Science Foundation of China (No. 51668029) are gratefully acknowledged.

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