



UNIVERSITY OF LEEDS

This is a repository copy of *Investigating Electric Bicycles as a Travel Mode Choice for Escorting Children to School: A Case Study in Kunming, China*.

White Rose Research Online URL for this paper:
<http://eprints.whiterose.ac.uk/138696/>

Version: Accepted Version

Article:

Liu, Y, Ji, Y, Liu, Q orcid.org/0000-0003-0953-7050 et al. (2 more authors) (2017)
Investigating Electric Bicycles as a Travel Mode Choice for Escorting Children to School: A Case Study in Kunming, China. *Transportation Research Record*, 2634 (1). pp. 8-16. ISSN 0361-1981

<https://doi.org/10.3141/2634-02>

This is an author produced version of a paper published in *Transportation Research Record*. Reprinted by permission of SAGE Publications.

Reuse

Items deposited in White Rose Research Online are protected by copyright, with all rights reserved unless indicated otherwise. They may be downloaded and/or printed for private study, or other acts as permitted by national copyright laws. The publisher or other rights holders may allow further reproduction and re-use of the full text version. This is indicated by the licence information on the White Rose Research Online record for the item.

Takedown

If you consider content in White Rose Research Online to be in breach of UK law, please notify us by emailing eprints@whiterose.ac.uk including the URL of the record and the reason for the withdrawal request.



eprints@whiterose.ac.uk
<https://eprints.whiterose.ac.uk/>

Investigating Electric Bicycles as a Travel Mode Choice for Escorting Children to School: A Case Study in Kunming, China

Yang Liu

Jiangsu Key Laboratory of Urban ITS, Southeast University
Jiangsu Province Collaborative Innovation Center of Modern Urban Traffic Technologies,
School of Transportation, Southeast University
Sipailou 2, Nanjing, 210096, P. R. China
Tel: +86-15261880265
Fax: 86-025-83794102;
Email: kmustliuyang@163.com

Yanjie Ji

School of Transportation, Southeast University
Sipailou 2, Nanjing, 210096, P. R. China
Tel: +86-13813996939
Fax: 86-025-83794102;
Email: jiyanjie@seu.edu.cn

Qiyang Liu

Institute for Transport Studies, University of Leeds
University of Leeds, 36-40 University Rd, Leeds LS2 9JT
Tel: +44-7424740083
Email: tsql@leeds.ac.uk

Min He

Kunming University of Science & Technology
Chenggong Campus, Kunming, Yunnan, CN
Tel: +86-13987193023
Fax: 86-0871-65920131
Email: kmhemin@gmail.com

Xinwei Ma

School of Transportation, Southeast University
Sipailou 2, Nanjing, 210096, P. R. China
Tel: +86-15050547899
Fax: 86-025-83794102;
Email: 230169206@seu.edu.cn

ABSTRACT: Understanding the escorting mode choice in children's school trips is significant to improve urban traffic system by inducing low-carbon travel and reducing car trips. Previous studies mostly focused on walking and bicycling. However, e-bike, as one of the mainstream escorting modes in China has been rarely investigated. This study aims to explore the factors that affect escorting mode choices (including e-bike, car and walking) for children's school trips at the household level using a case study from Kunming, China. Intra-household interactions and parental space-time constraints were represented by comparative working hours of parents and the space-time coordination in parent-child joint trips respectively. A Multinomial Logit Model (MNL) was applied in the mode analysis. The results reveal some interesting phenomena in escorting mode choices. When mothers' working hours are longer than their spouses, children are less likely to be escorted by walking or e-bike. In other words, the car trips acquire more preference in mother-dominated households. The distance deviation between parents and children is a significant factor for determining the mode choice between car and e-bike. Children are more likely to be escorted by e-bikes due to distance deviations, while a long distance from home to school result in a decrease likelihood to choose e-bike or walking. The results of this study could be instrumental for traffic demand management in the way of reducing car usage in school trips. In addition, it is suggested that the development of e-bikes should be taken seriously for the future development of China.

Key Words: school children, parental escort, mode choice, electric bike, space-time constraints

1. INTRODUCTION

The growing popularity of escorted children has already extensively aroused researchers' concern in recent years. A great number of studies verified that escorting children to school worsens the urban traffic, especially causing traffic congestion in peak hours due to the increasing use of cars by chauffeurs (1-4). Meanwhile, the use of cars for children's school commute behavior has also resulted in a series of social, health and environmental issues such as an increasing proportion of overweight children (5). In order to reduce the amount of car trips to school, research should be conducted on the choice of travel mode for escorting trips, which will have significant implications for trip-inducing and transportation demand management (TDM).

In fact, several studies have been carried out to shed light on travel mode choice for school children's trips. While most studies focused on walking and cycling (5-9). Electric bicycles (e-bikes, two-wheelers) have rarely been taken into account due to a relatively low proportion of their ownership. In China, however, the sales of e-bikes in 2012 accounted for 93% of the global sales, and their ownership is nearly twice as much as cars' (10). More importantly, due to the relatively high speed and good loading capacity (11) e-bikes have been widely used and are likely to displace bicycles for escorting children in Chinese cities. Therefore, it is necessary to include e-bikes as an important option of travel mode in children's school trips studies.

To study the travel mode choice for escorting trips, it is crucial to know the factors that affect chauffeurs in decision making. Since escorting children to/from school can be regarded as a group decision within a household (5; 12; 13) attributes of the household and its members as well as intra-household interactions should be considered as essential factors. It should be noted that e-bike is considered as one of the mainstream travel modes with great potential to replace a proportion of car trips in China (10). Hence, study should also emphasize on the similarities/difference between e-bikes and cars. Previous studies have shown that e-bikes allow a greater variety of purposes for longer chained trip making (14). In China, with the growing number of dual-earner households in urban areas, most parents have to escort children to school on their commuting way, which suggests different trip purposes at the same time. In escorting cases, there is a one-to-one correspondence between trip purposes and trip destinations. For this reason, the space and time coordination between chauffeurs and children will have a significant effect on travel mode choice between cars and e-bikes. For instance, chauffeurs may shift from cars to e-bikes if many detours are needed on the road during escorting. Thus, space-time relationship and measures are important for travel mode choice. Nonetheless, this topic has rarely been investigated (15; 16).

The goal of this study is to investigate how space-time constraints between parents and their children affect the mode choice between cars and e-bikes for escorting trips from a household perspective. The findings will provide information for policy makers to design and implement policies that can reduce car use for escorting children. The following sections will provide a review of work on the factors of mode choices among children, describe the study methodology, and use Kunming as a study case to present the research findings. The last section will draw a conclusion and provide recommendations for future research.

2. LITERATURE REVIEW

Many studies have been conducted on the influencing factors of travel mode choices among children's trips. For the research object examined in this study, we focus on the influences at household-level, parents-level and children-level specifically. The research results of empirical findings regarding the factors from these three levels are briefly summarized.

2.1 Household-Level Influences

According to existing studies, household size is an important factor that influences the escorting decision. Evenson et al. (17) stated that the presence of non-workers in the household negatively affects children's walking or biking since he/she may be available to chauffeur children by car. McDonald (5) found that the number of a child's sibling could affect his/her mode of school trips and children with more siblings have a lower probability of traveling by car. Similarly, due to the higher proportion of grandparents living with nuclear households in China, it can be assumed that the presence of grandparents in household may have influence to some extent. Besides, household income and car/e-bike ownership are the main factors influencing the escorting behavior. Many scholars, such as Zwerts and Wets(18), Guo et al. (19), Yarlagaadda and Srinivasan (13), Li and Zhao (20) found that children from households with higher income and car ownership are more likely to be escorted to school by car. Especially, Schwanen and Ettema (21) revealed that a parent who works longer hours has less time for domestic tasks, such as picking up and dropping off children. This suggests that working hours should be considered as a household-level variable which emphasizes on the relative constraints between parents rather than an individual variable.

2.2 Parents-Level Influences

From the perspective of space-time constraints, scheduling and spatial constraints have been considered as the two main factors in a parent-child joint trip, affecting the travel mode choice to/from school(16). Focusing on scheduling, many studies have addressed the effects of parental work schedules on escorting trips to school. An early example on this study is the work of Vovsha and Peterson (22) who indicated that non full-time workers are more likely to escort children to school. Subsequently, Yarlagaadda and Srinivasan (13) further revealed that parental working schedules would influence children's car use, and the effects on fathers and mothers are very different. Recently, He(15) found that flexible working hours can decrease the negative effect of long working hours by offering a higher level of flexibility in scheduling. This suggests that the work status of employed parents in China can be classified into two categories, including full-time workers (FTW) and part-time workers (PTW).

Since parents and their children have to co-exist in space and time, children's escorting trips are less flexible than other types of household activities (23). This suggests that parents' spatial and temporal constraints should be taken into account simultaneously during escorting trips. However, most current studies from McMillan (7), McDonald et al. (24) and He (15) have considered spatial/temporal constraints separately, and have adopted the distance from parents' workplaces to school as a spatial constraint in escorting trips. This indicator may not be appropriate in the case of pure escorting that parents have to arrange special travel for their children, as it neglects route deviation (the school trip from the parent's commuting trip) and the different start/end time. Recognizing the problem of route deviations, He and Giuliano(16) further proposed a spatial coordination variables to investigate the associations between work locations and escort mode choices. They found that parents are less likely to escort their children

when the school is not on the way to their workplace. While such findings are important and worthy, temporal constraints between start time and end time from work to school have not been considered.

2.3 Children-Level Influences

The factors of children-level influences have already been discussed in most studies. It has been shown that children's age or grade in school has a significant influence on the mode choice of children's school trips (6; 13). Many scholars, such as McDonald (20), He (25), Loo and Lam (14) have provided evidences to show that there is a strong association between increased age and decreased escorting behavior. However, there are considerable amount of chauffeurs for older children. It should be noted that older children are more likely to be driven by their parents instead of grandparents. Regarding the other characteristics of children, long distance of commuting to school is a significant barrier to walking to school (26; 27). Similar results have been found in Yarlagadda and Srinivasan (13), Fyhri and Hjorthol (28) etc.

3. METHODOLOGY

Escorting children to school can be considered as a group decision within a household, which refers to a decision-making process and intra-household interaction (29). As traveling patterns are influenced by households when they are organizing their activities in time and space (30), we assume that parents' decision-making is limited by space-time constraints based on the time-geography framework. According to this theory, whether a parent can escort their children to school depends on his/her scheduling and spatial constraints (16). That means household members can allocate escorting tasks to the best fitting member to meet children's travelling needs under time, spatial and resource constraints. Travel mode choice for escorting trips are significantly affected due to a strong association with escort decisions among household members. Hence, it is important to explore what factors could influence escorting mode choice for children's school trips based on space-time constraints from a household perspective.

3.1 Intra-Household Interactions

According to previous findings (21), working hours should be adopted as an indicator of intra-household interaction for domestic tasks. Thus, the comparative work status of parents can be measured by the ratio ρ (ranges from 0 to ∞), which is expressed as:

$$\rho = \frac{\sum_{i=1}^n T_M^i}{\sum_{j=1}^k T_F^j} \quad (1)$$

where ρ represents parental interactions. T_M is the working hours for mother's work-related activity i within a day ($i=0, 1, 2, 3 \dots n$), similarly, T_F stands for the working hours for father's work-related activity j within a day ($j=0, 1, 2, 3 \dots k$). When ρ is close to 1.0, parents are subjected to the same/similar employment constraints, which indicates they can play similar roles in the household. As ρ deviates from 1.0, the difference between parents' employment statuses is manifested. It implies that they may play different roles in the household. For instance, $\rho = 0.2$ represents a busy-father household type. That is to say, mother is more likely to be a

chauffeur in this household. The ratio ρ , by transferring an individual attribute into a relation attribute at the household level, help us to identify the parental interactions.

3.2 Parental Space-Time Constraints

To consider spatial and temporal constraints simultaneously, the space-time prism approach proposed by Scott and He (15) has been introduced in this study. In this approach, the space-time relationship between parents and children can be well reflected through similarity analysis of shapes. As shown in Figure 1(a), space-time paths of the child and his mother have a high coordination to imply the existence of escorting behavior. His father who travels alone is represented by the space-time path without overlapping with other members. Thus, analyzing the degree of similarity among different household members is vital in identifying escorting behaviors.

As it is complicated to analyze the similarity of space-time paths in three-dimensional environments, the space-time path of each household member can be transformed into a two-dimensional path in a time-distance plane coordinate system (31). In particular, the first tour in children's school journey is home-based. Therefore, all the household members start from the vertical line of the time-distance coordinate system. As shown in Figure 1(b), this transformed paths not only reserve the significant features of household members' space-time paths such as trip (to school/work), start/end time and work duration, but also reflect the relative positions among household members based on the shape of path. According to the two-dimensional paths, parents' space-time constraints during escorting trips can be measured by determining the coincidence of activity start/end time and overlapping/turnover paths between parents' and their child's. This method could also be applied to analyze the space-time relationship between parents and their child, and cluster the typical escorting types in this research.

3.3 Measure of Factors' Influence

As an important type of discrete choice model, the Multinomial Logit Model (MNL) can predict the probability of an individual's choice of different travel modes according to the utility function. In this study, the MNL model is used to estimate the travel mode choice of escorting in the household scale due to its good interpretation and simple specification. In the model, a household is assumed to choose the alternative mode with the maximum utility from different travel modes. The estimation is performed by the maximum likelihood method (32). How various explanatory variables influence the travel mode choice for escorting trips can be quantitatively analyzed with the use of the estimated regression parameters.

4. CASE STUDY

4.1 The City Background

Kunming, the capital city of Yunnan, is one of the regional central cities in Western China. It is also the gateway for trade and transnational cooperation with south and southeast Asia. According to data from the sixth nationwide population census, the resident population is 6.5 million in metropolitan area, and 4.3 million in urban area. The per capita gross domestic product of urban residents (38831 RMB/year) in 2011 was below the national average. (China Data Online, 2011)

Although there was no subway system in 2011, public transportation was well developed

in downtown Kunming where the first pilot Bus Rapid Transit System in China was launched. It has been selected as a representative case for this study for two reasons. First of all, Kunming has an illustrative structure of travel mode choice. As shown in Figure 2(a), the e-bike mode has become as an important travel mode as cars. Secondly, Kunming shares the same characteristic with other Chinese cities—with a high proportion of car used to escort children to school. Thus, the burden of urban road traffic would be aggravated during peak hours, especially rush hours in the morning. (As shown in Figure 2(b), the overlapping trips are represented by the below one).

4.2 Study Area and Data

The data source was drawn from the Resident Trip Survey of Kunming City conducted by the Transport Institute of Kunming in 2011. In this survey, respondents were asked to record their activity and travel information for 24h at the household level, and their social-economic characteristics were also collected. In this research, the sample is selected based on following principles: (a) Each household should include two heads (male-female) and their school-age child who was escorted (it was found that the under condition of escorting, at least one of the household heads and the child share the same departure time, same travel mode and same destination). (b) Those who own more than one car were excluded as they cannot represent the majority (91.7% car-owner households have only one automobile). Moreover, in order to study household automobile allocation, both male and female household heads need to have a driving license in this study. (c) Escorting children to/from school can be completed by one chauffeur with one travel mode. Finally, 497 households were been selected for this study, including 239 car-owner households and 258 car-free households. The chosen households were evenly distributed in four main urban areas of Kunming (Wuhua, Panlong, Guandu, and Xishan District). Studied areas and urban roads employed in this study are shown in Figure 3(a). According to the approach of space-time prism, an ArcGIS 10.0 based C-Sharp secondary development software was adopted for 3D visualization of these traveling paths (as shown in Figure 3(b)).

4.3 Influencing Factors

In order to thoroughly investigate the mechanism of travel mode choice for escorting, it is necessary to choose appropriate and comprehensive influencing factors. As mentioned above, escorting mode choices can be seen a group decision under household resource limited and individual space-time constraints. Thus, the influencing factors can be classified into three categories: household characteristics, parental characteristics and characteristics of children.

4.3.1 Household Characteristics

Household characteristics mainly include household income, resource and structures. Among these factors, car ownership and household structure refer to escorting decisions among household members, which led to complicated effects on escorting mode choices. Thus, they should be discussed in detail. Regarding resource status (car ownership), we categorize households into two types: car-owner households and car-free households. In addition, household structures can be classified into nuclear households (including mother, father and their children) and stem households (with elderly in nuclear household) based on the Chinese situation. Since there are extra household members in stem families, the responsibility for escorting children may be, to some extent, shared by grandparents. The analysis result will be given in Figure 4 and Table 1.

Figure 4 displays a compared travel mode choice between car-owner and car-free households. It is shown that e-bike has become an essential travel mode in car-free household, and has been widely used in school escorts (40.94%). Since 82.3% of chauffeurs escort their children by automobile, e-bike or on foot, we only considers the combination of these three types of travel mode in this study. Further analysis is shown in Table 1. For both car-owner and car-free households, mothers are more frequent to escort children with e-bikes than fathers, especially in car-owner households (15.24% vs. 6.45%, 30.47% vs. 19.87%). The similar result can be found in walking escorts. The results reveal that mothers prefer to use other travel modes than car to escort children than fathers. It indicates that a significant difference between fathers and mothers in escort-mode choices exists. In addition, compared with car-free households, the elderly are less likely to assist parents to escort children in car-owner households (6.50% vs 14.72%).

Table 1 also shows that mothers (51.11%) carry prime responsibility for escorting their children, followed by fathers (38.00%) and the elderly (10.89%). Overall, parents have a high percentage of escorting tasks, which results in a strong link between parental constraints and escorting mode choices, especially in nuclear households. In our case, around 44.73% of parents in nuclear households escort children by cars, while only 10.31% were showed in stem households. It indicates that parents tend to use cars to alleviate the conflict between work and escorting tasks, when assistance cannot be obtained from other people (such as the elderly).

Thus, the statistical results suggested that parental interactions can affect the escorting mode choice due to their different levels of the work-family conflict. According to the ratio ρ proposed before, three typical household types can be obtained by the K-means clustering method. When $\rho \in [0, 0.8]$, the father works longer hours than the mother, unbalanced work constraints exist between parents (busy father); it accounts for 46.8 % of all types. If ρ is close to 1 (0.8~1.2), it seems work constraints are equal between parents (balanced). As ρ increases, the mother is busier in the household (busy mother), which accounts for 24.63%.

4.3.2 Parental Characteristics

Parental characteristics mainly include space-time constraints, work arrangement, gender, age, and education background. By analyzing the coordination in space and time between parents and children, parental space-time constraints can be reflected considerably. In this study, this space-time relationship was defined as the escorting type. Based on the two-dimensional path provided above, three types of escorts can be summarized by using path similarity analysis (Shown in Figure 5). Figure 5(a) shows that when the father escorts child on his commuting way, the distance deviation is inconspicuous. Figure 5(b) is similar to Figure 5(a), however, a large distance deviation exists in it. Unlike these two types, Figure 5(c) shows that chauffeur has to travel additionally for her child due to the different departure time.

According to the above features, the escort types can be reflected by distance deviations and the departure time. The method for measuring distance deviation was proposed by He and Giuliano(16). Based on the result of our survey, parents' travel distance deviation from school to work should be less than 20%. Thus, we defined on-the-way escorts, and out-of-way escorts to represent these different situations. In on-the-way escorts, the parent's distance deviations should satisfy the formula below:

$$\frac{(D_{HS} + D_{SW} - D_{HW})}{D_{HW}} \times 100\% \leq 20\% \quad (2)$$

In out-of-way escorts, it should satisfy the formula below:

$$\frac{(D_{HS} + D_{SW} - D_{HW})}{D_{HW}} \times 100\% > 20\% \quad (3)$$

where D_{HS} represents the distance between home and school, and D_{SW} refers to the distance between school and workplace. In addition, pure escorts was defined based on the different departure time between parents and children. The three types of escort account for 28.00%, 39.75% and 32.25% respectively.

4.3.3 Characteristics of Children

The child's age, school grade, sex and commuting distance to school are included in characteristics of children. Primary school students account for 57.32% of escorted children, followed by junior high school children (23.90%) and high school students (18.78%). For the escorting mode choice, various travel modes are used to escort primary school students, while most junior high school students are escorted by car or e-bike and high school students are mostly escorted by car. Besides, children who are escorted by cars have a longer average distance from home to school than other escorted children (7.6 vs 6.1 kilometers).

A summary of the above-mentioned potential characteristic variables of escorting travel mode choice is shown in Table 2.

5. MODELLING AND RESULTS

As described in Section 3, the characteristic variables (in Table 2) were examined and measured by the MNL model. For our research objective, car, e-bike and walking were selected to be alternative modes, and car was chosen as the reference group compared with other modes. Table 3 shows the regression results for the influence of factors on e-bike and walking, respectively. The explanatory variables which were not significant at the 0.05 level were excluded in model results. As expected, attributes of individual and factors at the household level significantly influence the travel mode choice for escorts. Particularly for the main variables in this study, the variable that measures the space-time relationship between parents and children has a significant impact on the mode choice between car and e-bike for escorting trips. Furthermore, the results also reflect the different impacts on escorting mode choice between fathers and mothers.

As shown in the Table 3, there is a significant modal split across the different household types. In the household where the mother works less hours than the father (busy father), the child is more likely to use e-bikes or walk to school. The probable reason is that cars are more likely to be used by employed fathers in car-deficient households (ie, both parents with a driver license but just one car)(33), and childcare has been regarded as mothers' responsibilities in previous research (34). Thus, most mothers escort their children by walking or e-bikes. However, the increase of mother's working hours will negatively affect the option. It shows that for every doubling of the "balanced" household and "busy-mother" household, the probability of choosing e-bikes will reduce by 1.3 and 1.8 times, respectively. The result also reflects that car availability increases the likelihood of car use for school trips. Besides, having elderly people in a household makes children more likely to be escorted by walking and e-bikes. This effect confirms that, to some extent, the elderly would share escorting tasks for working parents.

The parental attributes for the variable that gives the strongest impact is the escorting type. This confirms the hypothesis that a strong link exists in space-time constrains and escorting

behavior. Fathers' distance deviation on their commuting way (out-of-way escorts) for school trips contributes to a higher rate of e-bike use and walking, while correlations in the same situation of mothers are not significant at the 0.05 level. Nonetheless, different departure times between parents and children (pure escorts) are positively associated with e-bikes usage for both fathers and mothers. This suggests that using e-bikes could overcome individual spatial-temporal constraints, which is one of the important reasons for chauffeurs to consider. In terms of work status variables, if the father is full-time employed, his child will tend to be escorted by e-bikes or walking, whereas the flexible-time work for mothers does not seem to have significant impact on escorting mode choices. This result is contrary to the previous research (15).

The impact of children's attributes can be mainly shown in age and school trip distance. With the increase of age and school trip distance, walking and e-bikes have become less likely for escorting children. It reveals that the distance from home to school plays a crucial role in decision-making of car use. In addition, the effect of children's gender is not strong.

6. CONCLUSIONS

This paper is intended to investigate the factors that would affect the escorting mode choice of e-bike, car and walking for children's school trips at the household level. The closely correlated attributes are identified to reflect the escorting mode choice under intra-household interactions and individual space-time constraints. Furthermore, a space-time path in two-dimensional environments has been proposed to determine individual's space coordination for route deviations and time synchronization for departure time. The 2011 Kunming resident travel diary survey data are used in the model estimation. According to the findings, household types, the distance from home to school and escorting types have great influence on whether children are chauffeured by cars or e-bikes.

These results have important policy implications, particularly the policies to reduce car trips to school. For example, since females are mainly responsible for escorting children, the travel mode choice for escorting children to school largely depends on females' travel mode. Although cars are usually allocated to males in car-deficient households, they could be transferred to the females who have longer hours than their spouses. Thus, policies should guide female employees to balance their work and family, for instance, decreasing females' working hours. It could reduce the car trips to school, and the likelihood of owning a second car in the household. On the other hand, parents tend to escort their children by car due to a long distance from home to school, it suggests that the enrollment in a nearby school policy needs to be effectively implemented. The uneven distribution of educational resource is a major barrier to this policy, which can be reflected in widespread school district houses. Thus, the government should exert more efforts to promote the equality of educational resources distribution, and make the nearby enrollment policy more attractive. Besides, many chauffeurs who have distance deviations of the school in their commuting trip would like to choose e-bikes rather than cars. However, in consideration of the safety issues, e-bikes have been banned in a large number of Chinese cities (10; 11). If all of e-bike riders become car users, there will be a great challenge for urban transportation system. Therefore, it is necessary to rethink of the positioning of e-bikes. For example, all e-bikes are operated like regular bikes in China currently, which should be re-classified reasonably according to their speed, weight and categories. Although relative laws and regulations are still under debate and revision, practical policies should be implemented.

Further work will focus on the following aspects. Firstly, the impact of different household structures, different children ages and different school types could be considered in

analyzing school escorting behaviors with larger sample sizes. Secondly, we only studied the situation that one household head uses the same travel mode to escort children. The combination of different escorts and travel modes has not been studied yet. Therefore, the approach proposed in this paper should be extended in that scenario. Furthermore, the universal two-child policy was implemented nationwide in 2015, ending the one-child policy which had lasted for more than three decades. It is indubitable that the two-child policy will influence school escorting behavior in the near future.

ACKNOWLEDGEMENTS

The financial support from the key project of National Natural Science Foundation of China (No.51338003), the International Cooperation and Exchange of the National Natural Science Foundation of China (No. 5151101143), and the Jiangsu Students' Program of Innovation and Entrepreneurship Training (201612086126X) is gratefully acknowledged.

REFERENCES

- [1] Chu, Y.-L. Work departure time analysis using dogit ordered generalized extreme value model. *Transportation Research Record: Journal of the Transportation Research Board*, No. 2132, 2009, pp. 42-49.
- [2] Beck, L. F., and A. I. Greenspan. Why don't more children walk to school? *Journal of safety research*, Vol. 39, No. 5, 2008, pp. 449-452.
- [3] Wen, L. M., D. Fry, C. Rissel, H. Dirkis, A. Balafas, and D. Merom. Factors associated with children being driven to school: implications for walk to school programs. *Health education research*, Vol. 23, No. 2, 2008, pp. 325-334.
- [4] Daisy, N. S., and M. A. Habib. Investigation of Mode Choice Behavior for School Trips in Dhaka City, Bangladesh: A Random Parameter Logit Model Application. In *Transportation Research Board 93rd Annual Meeting*, 2014.
- [5] Mcdonald, N. C. Household interactions and children's school travel: the effect of parental work patterns on walking and biking to school. *Journal of Transport Geography*, Vol. 16, No. 5, 2008, pp. 324-331.
- [6] Ewing, R., W. Schroeer, and W. Greene. School location and student travel analysis of factors affecting mode choice. *Transportation Research Record: Journal of the Transportation Research Board*, No. 1895, 2004, pp. 55-63.
- [7] Mcmillan, T. E. The relative influence of urban form on a child's travel mode to school. *Transportation Research Part A Policy & Practice*, Vol. 41, No. 1, 2007, pp. 69-79.
- [8] Lang, D., D. Collins, and R. Kearns. Understanding modal choice for the trip to school. *Journal of Transport Geography*, Vol. 19, No. 4, 2011, pp. 509-514.
- [9] Black, C., A. Collins, and M. Snell. Encouraging walking: the case of journey-to-school trips in compact urban areas. *Urban studies*, Vol. 38, No. 7, 2001, pp. 1121-1141.
- [10] Fishman, E., and C. Cherry. E-bikes in the Mainstream: Reviewing a Decade of Research. *Transport Reviews*, Vol. 36, No. 1, 2016, pp. 72-91.
- [11] Cherry, C., and R. Cervero. Use characteristics and mode choice behavior of electric bike users in China. *Transport Policy*, Vol. 14, No. 3, 2007, pp. 247-257.
- [12] Yoon, S., M. Doudnikoff, and K. Goulias. Spatial analysis of propensity to escort children to school in southern California. *Transportation Research Record: Journal of the Transportation Research Board*, No. 2230, 2011, pp. 132-142.
- [13] Yarlagadda, A. K., and S. Srinivasan. Modeling children's school travel mode and parental escort decisions. *Transportation*, Vol. 35, No. 2, 2008, pp. 201-218.
- [14] Langford, B., C. Cherry, T. Yoon, S. Worley, and D. Smith. North America's First E-Bikeshare: A Year of Experience. *Transportation Research Record: Journal of the Transportation Research Board*, No. 2387, 2013, pp. 120-128.
- [15] He, S. Y. Will you escort your child to school? The effect of spatial and temporal constraints of parental employment. *Applied Geography*, Vol. 42, 2013, pp. 116-123.
- [16] He, S. Y., and G. Giuliano. Factors affecting children's journeys to school: a joint escort-mode choice model. *Transportation*, 2015, pp. 1-26.

- [17] Evenson, K. R., B. J. Huston SLMcMillen, P. Bors, and D. S. Ward. Statewide prevalence and correlates of walking and bicycling to school. *Archives of Pediatrics & Adolescent Medicine*, Vol. 157, No. 157, 2003, pp. 887-892.
- [18] Wets, G., and E. Zwerts. Children's Travel Behavior: World of Difference. In *Transportation Research Board 85th Annual Meeting*, 2006.
- [19] Guo, J., S. Srinivasan, N. Eluru, A. Pinjari, R. Copperman, and C. Bhat. Activity-Based Travel-Demand Modeling for metropolitan areas In Texas: Cemselts model estimations and prediction procedures, 4874 zone system cemdap model estimations and procedures, and the SPG software details. In, Research report 4080–7 for Research project 0–4080 “Activity-based travel-demand modeling for metropolitan areas in Texas, 2005.
- [20] Li, S., and P. Zhao. The determinants of commuting mode choice among school children in Beijing. *Journal of Transport Geography*, Vol. 46, 2015, pp. 112-121.
- [21] Schwanen, T., D. Ettema, and H. Timmermans. If you pick up the children, I'll do the groceries: spatial differences in between-partner interactions in out-of-home household activities. *Environment and Planning A*, Vol. 39, No. 11, 2007, pp. 2754-2773.
- [22] Vovsha, P., and E. Petersen. Escorting children to school: statistical analysis and applied modeling approach. *Transportation Research Record: Journal of the Transportation Research Board*, No. 1921, 2005, pp. 131-140.
- [23] Misra, R., and C. Bhat. Activity-travel patterns of nonworkers in the San Francisco Bay area: exploratory analysis. *Transportation Research Record: Journal of the Transportation Research Board*, No. 1718, 2000, pp. 43-51.
- [24] McDonald, N. C., E. Deakin, and A. E. Aalborg. Influence of the social environment on children's school travel. *Preventive medicine*, Vol. 50, 2010, pp. S65-S68.
- [25] He, S. Effect of School Quality and Residential Environment on Mode Choice of School Trips. *Transportation Research Record Journal of the Transportation Research Board*, Vol. 2213, No. -1, 2011, pp. 96-104.
- [26] McDonald, N. C. Active transportation to school: trends among US schoolchildren, 1969–2001. *American journal of preventive medicine*, Vol. 32, No. 6, 2007, pp. 509-516.
- [27] Mcdonald, N. C. Children's mode choice for the school trip: the role of distance and school location in walking to school. *Transportation*, Vol. 35, No. 1, 2008, pp. 23-35.
- [28] Fyhri, A., and R. Hjorthol. Children's independent mobility to school, friends and leisure activities. *Journal of Transport Geography*, Vol. 17, No. 5, 2009, pp. 377-384.
- [29] Zhang, J., H. J. Timmermans, and A. Borgers. A model of household task allocation and time use. *Transportation Research Part B: Methodological*, Vol. 39, No. 1, 2005, pp. 81-95.
- [30] Ho, C., and C. Mulley. Intra-household interactions in transport research: a review. *Transport Reviews*, Vol. 35, No. 1, 2015, pp. 33-55.
- [31] Chen, J., S.-L. Shaw, H. Yu, F. Lu, Y. Chai, and Q. Jia. Exploratory data analysis of activity diary data: a space–time GIS approach. *Journal of Transport Geography*, Vol. 19, No. 3, 2011, pp. 394-404.
- [32] Zarembka, P. *Frontiers in econometrics*. Academic Press, 1974.
- [33] Habib, K. N. Household-level commuting mode choices, car allocation and car ownership level choices of two-worker households: the case of the city of Toronto. *Transportation*, Vol. 41, No. 3, 2014, pp. 651-672.

[34] Presser, H. B. Employment schedules among dual-earner spouses and the division of household labor by gender. *American sociological review*, 1994, pp. 348-364.

LIST OF ALL FIGURE CAPTIONS AND TABLE TITLES

FIGURE CAPTIONS:

FIGURE 1 Space-time paths of household members

FIGURE 2 Travel mode shares and peak hours in Kunming

FIGURE 3 Study area

FIGURE 4 Choice summary of escort mode (N = 497)

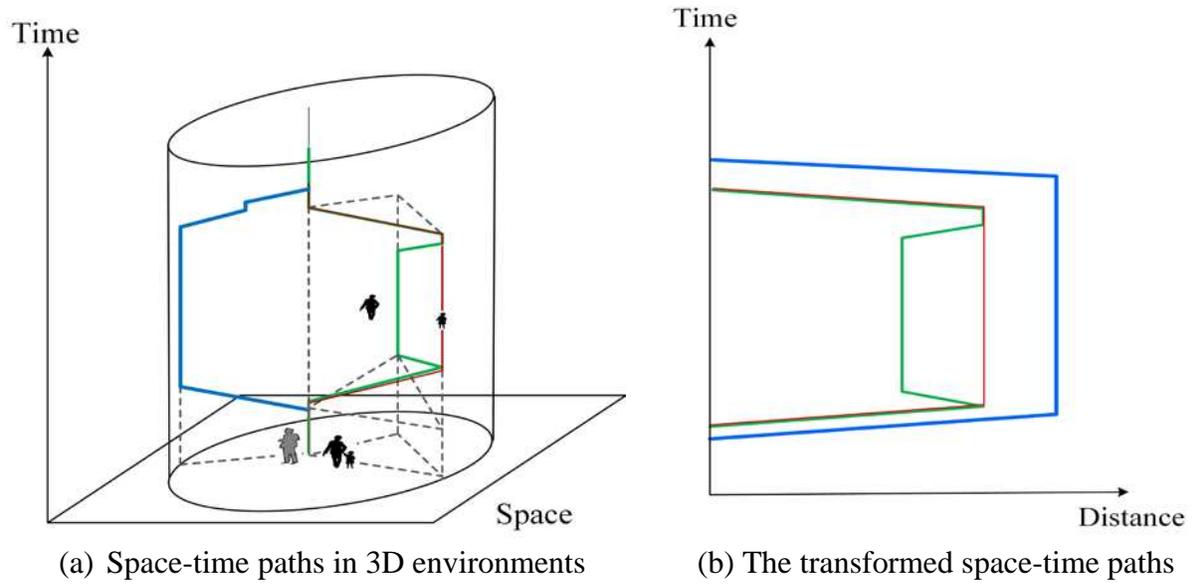
FIGURE 5 Examples in three escort types

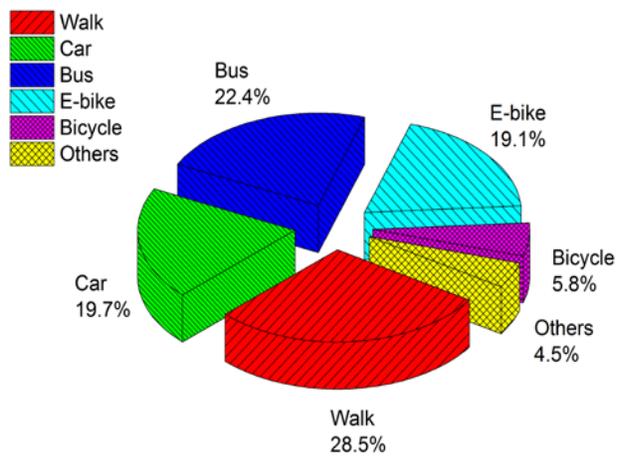
TABLE TITLES:

TABLE 1 Escort Patterns by Household Types and Structure (N=409)

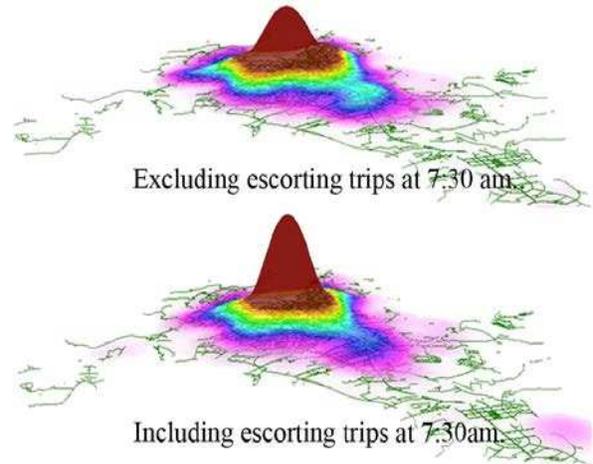
TABLE 2 Characteristic Variables of Escorting Travel Mode Choice

TABLE 3 Parametric Regression Results





(a) Travel mode shares



(b) Peaking hours

FIGURE 2 Travel mode shares and peak hours in Kunming

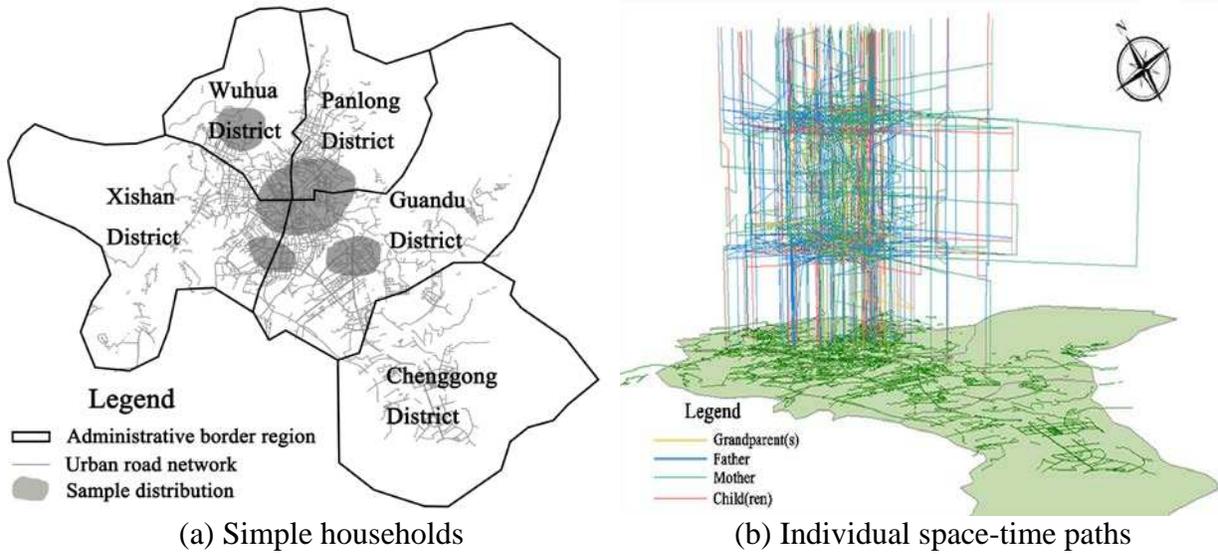


Figure 3 Study area.

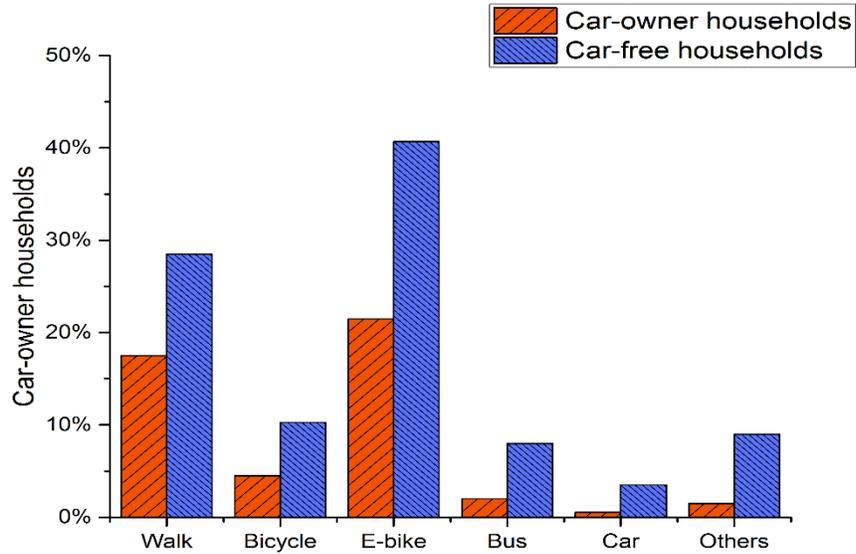
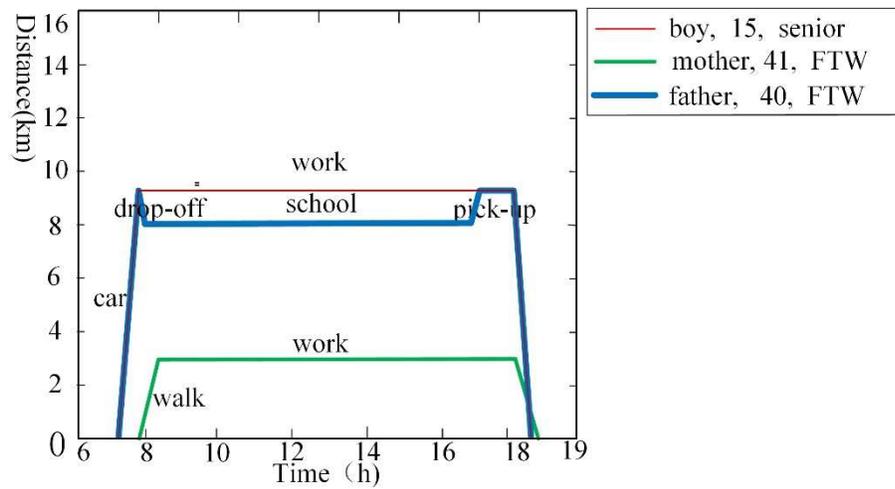


Figure 4 Choice summary of escort mode (N = 497).



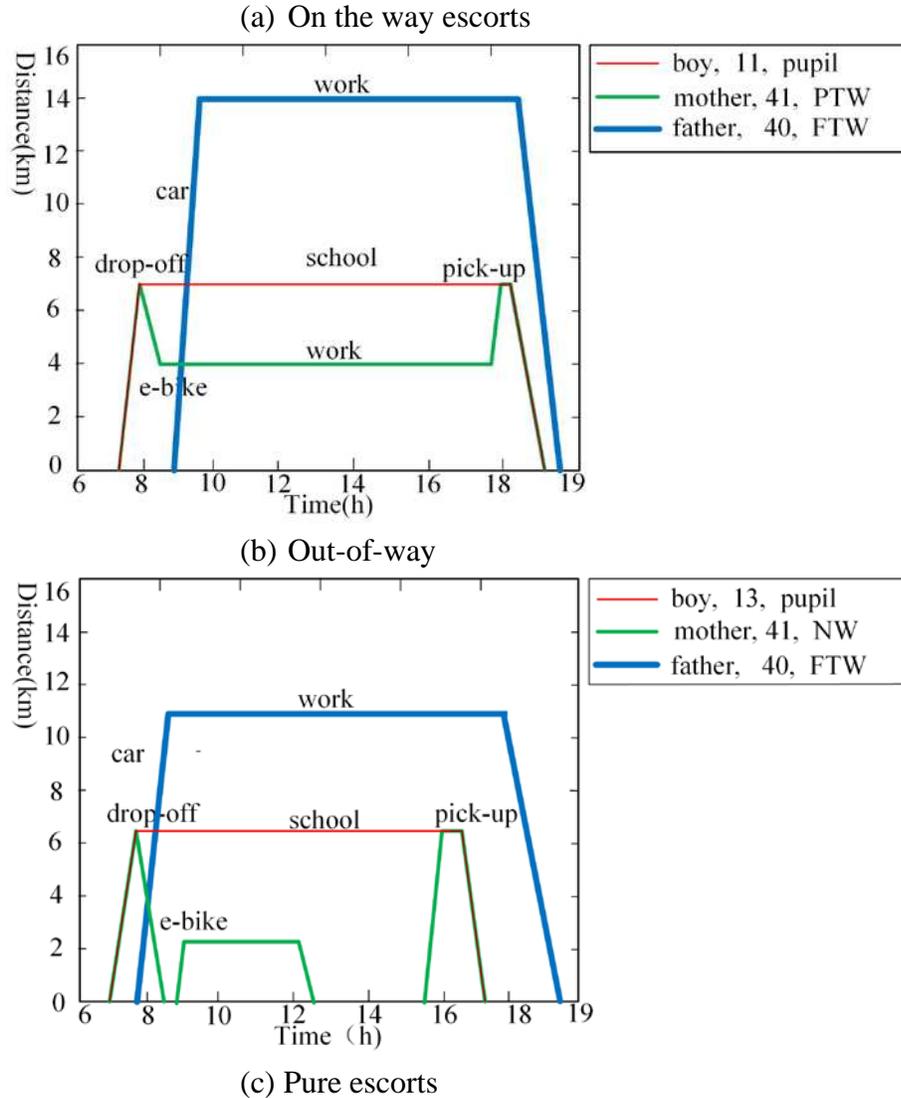


FIGURE 5 Examples in three escort types.

TABLE 1 Escort Patterns by Household Types and Structure (N=409)

Escort patterns		Household resources		Household structures	
		Car-owner households	Car-free households	Nuclear households	Stem households
		Nt1=228	Nt2=181	Ns1=251	Ns2=158
Mother 51.11%	Car	22.47%	0%	18.26%	4.21%
	E-bicycle	15.24%	30.47%	21.85%	23.86%
	Walk	8.34%	20.23%	13.50%	15.07%
Father 38.00%	Car	32.56%	0%	26.46%	6.10%
	E-bicycle	6.45%	19.87%	12.28%	14.04%
	Walk	3.88%	6.94%	5.21%	5.61%

Elderly 10.89%	Walk	6.50%	14.72%	0%	21.22%
Percentage		95.44%	92.23%	97.57%	90.11%

* A few children are escorted by car in car-free households. (Car-sharing etc.)

* A few elderly escort children by e-bikes.

TABLE 2 Characteristic Variables of Escorting Travel Mode Choice

Cluster of variables	Characteristic variables	Explanation
Household attributes	Household income	<30 thousand RMB=0, 30-50 thousand RMB=1, 50-100 thousand RMB=2, 100-200 thousand RMB=3, >200 thousand RMB=4
	Household structure	nuclear household=0, stem household=1
	Car ownership	yes=1, no=0
	E-bike ownership	0-3
	Household type	busy father=0, balanced=1, busy mother=2

Parental attributes	Educational background	Father	junior high school and lower education=0, high school/ secondary vocational school=1, graduates and higher education=2	
		Mother		
	Work status	Father		flexible-time work=0, full-time work=1
		Mother		
	Escorting type	Father		on-the-way=0, out-of-way=1, pure=2
		Mother		
Children attributes	Gender		boy=1, girl=0	
	School-grade		primary school=0, junior high school =1, high school=2	
	Commuting distance to school		<0.5m=0, 0.5-1km=1, 1-3km=2, 3-5km=3, 5-10km=4, >10km=5	
Independent variables	Escorting mode choice		car=0 (reference group) e-bike = 1, walking = 2	

TABLE 3 Parametric Regression Results

Escorting travel mode	E-bike (M2)			Walking (M3)		
	Coef.	S.E	P>z	Coef.	S.E	P>z
Constant	-7.51	0.91	0.00*	-6.97	0.87	0.01*
School grade	-0.73	0.27	0.00*	-1.96	0.22	0.00*
School trip distance	-0.68	0.14	0.02*	-1.06	0.64	0.00*
Household structure	0.26	0.21	0.02*	0.19	0.21	0.00*
Household income	-0.41	0.13	0.01*	-0.23	0.25	0.29
Car ownership	-0.62	0.87	0.00*	-0.57	0.15	0.07
E-bike ownership	0.33	0.37	0.02*	0.43	0.34	0.33
Household type=0 (busy-father)	0.45	0.16	0.01*	0.32	0.22	0.02*

Household type=1 (balance)	-0.28	0.32	0.21	-0.16	0.16	0.02*
Household type=2 (busy-mother)	-0.59	0.07	0.00*	-0.39	0.17	0.00*
Mother escorting type=2(pure escorts)	0.12	0.18	0.09	0.31	0.28	0.03*
Father escorting type=0 (on-the-way)	-0.16	0.13	0.01*	-0.27	0.32	0.00*
Father escorting type=1 (out-of-way)	0.37	0.16	0.01*	0.26	0.32	0.03*
Father escorting type=2 (pure escorts)	0.11	0.24	0.03*	0.09	0.12	0.18
Father work status	0.16	0.12	0.03*	0.18	0.61	0.24

N=409

Log likelihood:

L(0)=723.13

L(β)= 511.97

Pseudo R² 0.29

Note: * significance at the 5% level

S.E. stands for Standard Error of Mean