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School travel mode choice in Beijing, China

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ABSTRACT

This study explores school travel mode choice behavior of 7–18 year-old students in Beijing, China, based on the data collected in Fifth Travel Survey of Beijing Inhabitants. The integration of tree-based and logit-based models is employed to examine the influence of key variables on school travel mode choice. In particular, the tree-based model is used to preliminarily select the traits which have a statistical effect on mode choice, and the logit-based model is used to provide deeper understanding of the underlying decision processes and the correlation effects of the variables. Results show that car ownership, poor walking/cycling environment, and adults' convenience for escorting students significantly stimulate the use of cars in school commuting. Students are more inclined to choose cars when their departure time is at rush hour compared to the other time. Moreover, the longer distance encourages the use of motorized transport, where the households with local *hukou* (usually related to the car ownership and other welfares) are more willing to drive their children to school. A number of recommendations on car restraint, sustainable travel environment improvement, different working hour implementing, and educational resources layout for the encouragement and promotion of sustainable travel practices are lastly proposed.

1. Introduction

Active modes of travel and independent mobility among children have attracted attention for their benefits to personal growth, communal harmony, and sustainable development of the society (Mitra and Buliung, 2015; Marique et al., 2013). From the personal perspective, the behavior of children now will build their future behavior (Carlos, 2003). The phase in school is the most important period in students' growth, during which the world outlook, philosophy and value view begin to form in their mind. Understanding students' school travel mode choice behavior is significant to reinforce or reshape their travel pattern and awareness of active and independent mobility, and further promote their physical and mental health. For the families, scheduling a child escort becomes increasingly widespread for many parents around the world due to the travel safety concerns and the poor walking/cycling environment. Understanding students' school travel mode choice behavior can help government create a better travel environment for school commuting, and decrease the share of household escort. At the household level, the associated travel demand can be reduced and the travel cost can be saved. From the social perspective, the household escort, especially the auto-based household escort, results in traffic congestion and environment pollution near school. Not only has the road capacity been degraded, but also the access environment of school gate is affected negatively. Thus, it is necessary to analyze students' school travel mode choice behavior to encourage an active and independent lifestyle, and eventually support the sustainable development of the society.

The existing research on students' school travel behavior analysis has paid disproportional attention to Western countries. In view of the situation in China, there are several special aspects need to be mentioned given the different economic and social settings. 1) *Household structure*: Because of the population control effort (i.e., one-child policy) between 1978 and 2015, most Chinese families have no more than one child in recent years. According to the data from United Nations Population Division Department of Economic and Social Affairs, the total fertility rate in China has fallen to nearly 1.5 by the late 1990s from 5.9 births per woman in 1970 and remained at this level since (Zeng and Hesketh, 2016). Specifically, the one-child policy was strictly enforced for urban residents, who accounted for about 20% of the population in 1980, and almost half by 2010. The Beijing Statistical Yearbook (2015) also shows that there are 81.7% of households having three or less people in Beijing. As the result, the only-child is the greatest hope of the whole family and is provided with all the available resources from the emotional aspect to the economical aspect. He/she may be loved and taken good care of, and get the best possible education within the household financial ability. 2) *Public school construction mechanism*: In China, there are more than 95% of students attending the public school constructed and maintained by the local

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government (Lu et al., 2017). In contrast to Western countries, Chinese people have no obligation to pay the property tax and thus have no right to influence the public budgeting of local government. During the rapid spatial expansion of monocentric Beijing city, many citizens move to suburb due to the expensive house price and limited land supply in downtown. However, the government funding cannot afford to build more public schools, especially good-quality public schools in the new neighborhoods. There is a serious spatial separation between public schools of high quality and suburbanites. And many students will face to the longer school travel distance between home and school. 3) *Admissions policy*: In China, especially in a large city like Beijing, *hukou* and house property are the two indispensable requirements for a child to get the access to public school. It should be noted that *hukou* institution is a special population policy used to control the movement of the rural population into the city (Li and Zhao, 2015). Moreover, it directly influences the distribution of the state's welfare, such as education as well as the purchase qualifications of house and vehicle. In this situation, a child without local urban *hukou* can be refused to attend the near public school, while a child with local urban *hukou* can go to a good school although he/she does not actually live in the specified school district. For the later one, his/her parents can buy an old or small house in good school district and live in other place with better living conditions. *Hukou* can provide a child better education, better living conditions, and more travel mode choices, etc. In this context, it is questionable whether the same results concluded in western world can be also found in China.

This paper attempts to conduct an empirical study of China, in order to contribute a deeper understanding of students' school travel mode choice, and further help create a better school commuting environment for students' active and independent mobility in developing countries. To identify and quantify the key influencing factors, a tree-based regression model and a logit-based regression model are employed.

The remainder of this paper is organized as follows: Section 2 reviews recent relevant literature on students' school travel behavior. Section 3 presents an overview of the region selected. Section 4 describes the data set. The methodology is introduced in Section 5, and the modelling results are analyzed in Section 6. This is followed by a discussion of the implications for transport policy and practice in Section 7. Finally, the conclusions of the present paper are provided in Section 8.

2. Literature review

There is a growing literature examining the travel mode choice decision (McDonald, 2008a) or accompaniment decision (Ermagun and Levinson, 2016a) of children in school trips. A few studies (Yarlagadda and Srinivasan, 2008; Ermagun et al., 2015a; Ermagun et al., 2015b) have attempted to model the mode choice and accompaniment choice in a joint framework, as they believe these decisions are made simultaneously. This section discusses the previous studies on travel mode choice of children in school trips, which are in line with the contribution of the current study. Table 1 summarizes the previous studies, which are selected to cover main characteristics of studies including location, year of study, and methodology.

From the methodology side, studies either use descriptive analysis or advanced statistical and machine learning models such as multinomial logit (McDonald, 2008a), nested logit (Ermagun and Samimi, 2015), cross-nested logit (Ermagun and Levinson, 2016b), and random forest (Ermagun et al., 2015b). Descriptive methods are usually used to identify influencing factors based on statistical descriptions only, while analytical methods not only recognize influencing factors but measure the power of these factors such that the final results can be used for forecasting (Ermagun et al., 2015b).

From the influential variable side, research has studied four main categories of variable: children's characteristics, households' characteristics, built environment, and parental concerns.

2.1. Children's characteristics

Age, gender are the most important variables that are explored among children's characteristics. As far as age is concerned, the results of studies are mixed. A few studies reported a positive correlation between age and using active modes of travel (McDonald, 2008a; Ermagun and Samimi, 2015; Li and Zhao, 2015). Some studies found a negative correlation. In a research of Australian students, it is reported that students aged 10–12 years were less likely to travel to school actively compared with their younger counterparts aged 5–6 years when their travel routes to school are well-connected (Timperio et al., 2006). Similarly, the research results of Mitra and Buliung (2015) also indicated the negative effect of age related to senior mobility in active commuting rates. In some studies, no significant correlation is reported (Kerr et al., 2006). This dissimilarity may be rooted in three aspects: 1) different sample selections, especially for the age distribution; 2) different minimum driving ages for different countries; 3) different methodologies (Samimi and Ermagun, 2012).

As far as gender is concerned, the results of studies are also mixed. Fyhri and Hjorthol's (2009) study of Norwegian children's travel modes found that boys were more often independently mobile than girls. A contrary finding was found by Leslie et al. (2010) in Australia. They showed that probability of walking is about 44% among girls and 37% among boys. Samimi and Ermagun (2012) also reported that the propensity of girls choosing to walk to and from school is more than boys in Tehran, Iran.

2.2. Households' characteristics

At a household level, it is generally acknowledged that household characteristics play an important role in students' school travel choice, the hotly debated of which are household wealth (e.g., household income, vehicle ownership etc.), household structure (number of workers,

Table 1
Summary of previous studies on mode choice decision in school trips.

Study	Location	Age	Method	Travel modes
Ermagun and Levinson (2016b)	Iran	12–17	Cross-nested Logit	Active, auto, public transit, school bus
Ermagun et al. (2015b)	Iran	12–17	Nested Logit & Random Forest	Active, auto, public transit, school bus
Deka (2013)	U.S.	5–15	Heckman Probit	Active, auto, school bus
Nevelsteen et al. (2012)	Belgium	6–12	Logistic Regression	Active, auto, public transit
Alemu and Tsutsumi (2011)	Japan	15–18	Multinomial Logit	Active, auto, public transit
Mitra et al. (2010)	Canada	11–13	Binomial Logit	Active, auto
Lin and Chang (2010)	Taiwan	3–18	Nested Logit	Active, auto, public transit, vanpooling, motorcycle
Nelson et al. (2008)	Ireland	15–17	Logistic Regression	Active, auto, public transit
McDonald (2008a)	U.S.	5–13	Multinomial Logit	Active, auto, public transit
Mota et al. (2007)	Portugal	12–16	Logistic Regression	Active, auto, public transit
Merom et al. (2006)	Australia	5–12	Logistic Regression	Active, auto, public transit
Li and Zhao (2015)	China	13–15	Logistic Regression	Active, auto, public transit

adults and children in the household, etc.), and the interaction between the household members. The work conducted by Ermagun and Samimi (2015) pointed out that both household income and car ownership were recognized in school trip active modes of transportation utilization. Li and Zhao (2015) found that students from low-income households incline to walk rather than use the bicycle, and students from households with private cars are more likely to be driven to school in China. Some recent systematic reviews consider the relationship between school travel mode and household structure. It was identified that students from families with unemployed parents will tend to walk (Kelly and Fu, 2014), and students having siblings were found to be associated with higher rates of walking and biking (McDonald, 2008b). Moreover, Mitra and Buliung (2014) put forward that students were more likely to be driven to school when their mothers were available at home during the school runs, while the absence of an adult caregiver led to the increase of probability of walking, taking transit.

2.3. Built environment

Social and environmental level-factors also have been discussed more generally, including the travel distance between home and school, urban form, transportation infrastructure, social norms. Aiming at the students at primary school in Ireland, Kelly and Fu (2014) concluded that travel distance to school is the most significant determinant of school travel choice, and it is observed that 2 km is a guiding 'splitting line' between the active travel modes and motorized modes. In another study, home distance of 1.5 km from school is identified as the threshold for Canadian students to change from driving to alternative modes of walking or biking (Mammen et al., 2014). Easton and Ferrari (2015) found the small but significant correlations between school commuting distance and urban form, and underscored that students who lived closer to school with high cul-de-sacs (no-through roads) density, were more likely to engage in active commuting when taking account of distance and urban form variable together. Moreover, in the study of Broberg and Sarjala (2015), it is shown that the increases of urban form related variables like the density of major roads, residential density, building use mix decreased the likelihood of engaging in walking or cycling among students in Finland. As far as transportation infrastructure, Kamargianni et al. (2015) stated that transport network characteristics like the availability of bicycle paths, bicycle parking spaces, sidewalks' width significantly affected the school travel mode choice of active transport. Lang et al. (2011) mentioned the role of social norms in students' school travel behavior. When the majority of people act in a certain manner, it may be perceived as a sagacious way to proceed. In order to decrease the share of driving to school, it is suggested to make a social norm that large numbers of students walk/cycle to school. Under the China's context, Li and Zhao (2015) mentioned that students in Beijing of China living near the inner city are more likely to cycle to school due to the more diversity of land use and better jobs-housing balance.

2.4. Parental concerns

Parental concerns on safety, comfort, reliability and convenience have been shown to affect their children's mode choice in school trips. The study conducted by Ermagun et al. (2015a) provided evidence that parents who were concerned about travel safety persisted on escorting their children. And such parents preferred private cars and school bus service for their children's school travel. Ermagun and Levinson (2016b) revealed that parents who were concerned about the comfort of their children preferred to use school bus and private car. Parents who were concerned about the reliability of the travel mode preferred the school bus. Ermagun et al. (2015b) stated that parents who were concerned about their child's convenience preferred to drop their children off themselves or use school bus service. Parents who were anxious about their children's safety were not willing to let their children walk or use public transit.

This study focuses on the school travel mode choice behavior of students in Beijing, China, which has not been paid much attention on an academic and policy level. The contribution of this paper to the current literature lies in two aspects.

First, the traditional methods usually include descriptive methods and parametric regression methods (such as linear regression model, logit-based model, etc.), but these methods have their own disadvantage in data analysis. For example, the descriptive methods can identify influencing factors on the basis of statistical descriptions only, while parametric regression methods are employed to determine the average effect of an independent variable on a dependent variable without considering the special requirements of population subgroups when interventions are developed from model results (Lemon et al., 2003). With regard to the classification for continuous variables, most parametric regression models are usually dependent on intuitions or the results of descriptive statistics, the impacts of influencing factors may be exaggerated or downgraded due to the unreasonable classification. In comparison, decision tree is a nonparametric statistics method, which is usually used to population classification based on the Chi-square significance test. The root node represents the dependent variable, and the parent nodes and child nodes are generated based on their Chi-square significances. The higher the Chi-square significance of the independent variable is, the earlier the classification variable it will be. Given decision tree has the ability to easily segment populations into meaningful subgroups, without the need of a specified functional form and the assumption of additivity of predictors. Therefore, this paper will develop a framework incorporating both tree-based regression method and logit-based regression method to formulate more realistic and richer behavioral representations of the underlying decision processes.

Second, there are many differences of economic and social settings between Western countries and China, such as the level of economic development, urban form, admissions policy, *hukou* institution, and the culture context, etc. There has only been one study in China examining determinants of commuting mode choice among school children (Li and Zhao, 2015), which aims at the school travel of students aged 13–15 in Beijing, on the basis of the data collected in 2005. However, only a few of factors are taken into consideration. In comparison, this study has explored the school travel mode choice of 7–18 year-old students in Beijing from primary school to middle school, and to high school. As we all known, students in these three stages have different school travel patterns. For example, primary school students have a totally different travel behavior due to their high level of dependency compared to older students (McMillan, 2005). The extending of research objective is helpful to capture the characteristics of different age-stage students on school travel mode choice, and further help the society comprehensively understand Chinese students' school travel mode choice in Beijing. Moreover, the data used in this study are from the Fifth Travel Survey of Beijing Inhabitants in 2014, which provides the most recent travel survey data representative of the whole city by far. As a matter of fact, it is universally recognized that China has achieved extraordinary, sustained growth over the past decades in political, economic and cultural fields. With the rapid expansion of Beijing city, as well as the fast-growing population, the stale data can no longer reflect students' school travel behavior under the current urban development pattern. In order to supplement the understanding of students' school commuting behavior in the context of a developing country, especially for China, based on the most recent travel survey data representative of Beijing, more comprehensive and special factors related to student's characteristics, households' characteristics, built environment and parental concerns will be included in this study framework.

3. Study region

Beijing covers approximately 16,411 km^2 and is home to a

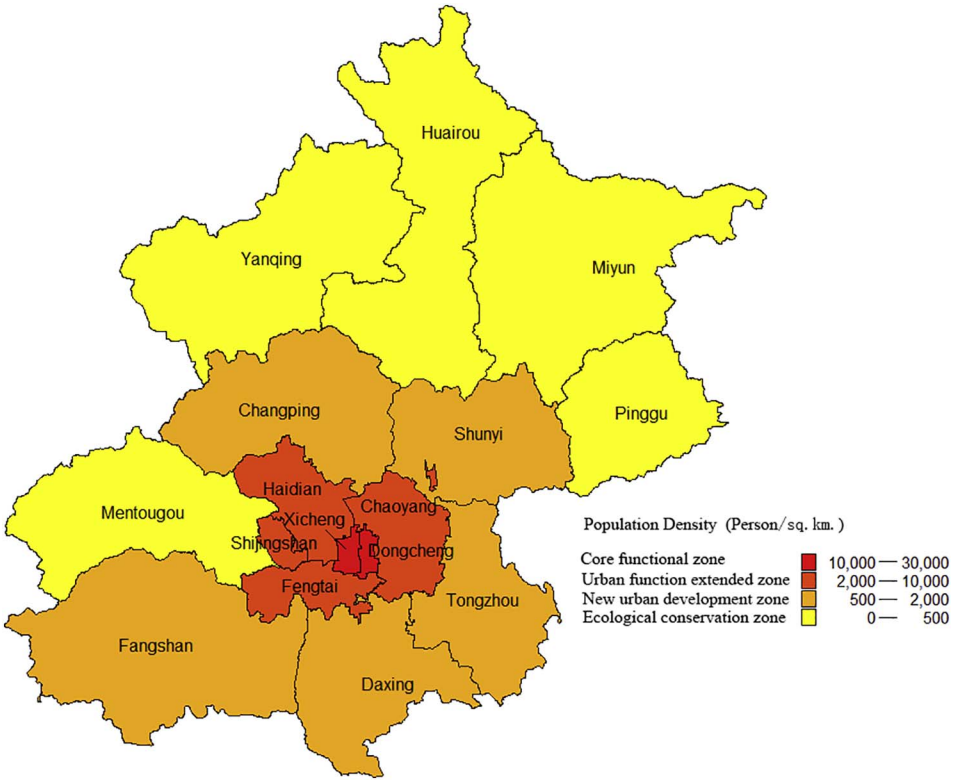

Fig. 1. Location of the study area.

population of nearly 22 million as of 2014 (Peng et al., 2016a). As the capital city and the political and cultural communication center of China, Beijing has experienced the rapid growth of economy and witnessed the fast expansion of urban area in recent years.

Based on the latest administrate divisions, Beijing can be divided into four functional zones: 1) core functional zone, which is characterized by the political and cultural functions of the whole city, including the districts of Dongcheng and Xicheng; 2) urban function extended zone, which is the representative area of high technology industries and educational institutions, including the districts of Chaoyang, Fengtai, Shijingshan and Haidian; 3) new urban development zone, which is the carrier of modern manufacturing or agricultural industries, including the districts of Fangshan, Tongzhou, Shunyi, Changping and Daxing; (4) ecological conservation zone, which is the ecological barrier and plays the key role in sustainable development of Beijing, including the districts of Mentougou, Huairou, Pinggu, Miyun and Yanqing (Peng et al., 2016b). As shown in Fig. 1, the population density (Beijing Statistical Yearbook, 2015) decreases dramatically when the physical distance to the inner city increases. This unique urban expansion spatial pattern makes it interesting to discover how the social and environmental level-factors in Beijing influence students' school commuting mode.

According to the Beijing Statistical Yearbook (2015), the registered students in primary school, middle and high schools of Beijing are 821,000, 474,000 and 178,000 respectively. And the corresponding enrollment rates are 99.8%, 103.5% and 86.5%, indicating that the coverage of elementary and secondary education in Beijing is relatively higher. Given the reality mentioned above, it can be inferred that students' school commuting is an important component of traffic flow during the rush hour (usually is one period of a day: 7:00–9:00 am) in Beijing, and a focus on students' school travel mode choice behavior is of obvious significance where the objective is to create a better travel environment for students' school commuting in developing countries.

4. Data

The data are collected from the 2014 household travel survey in Beijing, the capital of China, which is the perfect reflection of the institutional and cultural dimensions of China (Li and Zhao, 2015). Due to the consideration of unique requirements related to economic and cultural differences in China, this study could provide deeper insights into how school travel mode choice behavior might change with the key influencing factors for students in developing countries, and help the policy-makers put forward the target-oriented proposals to create a better school travel environment for local students there.

The primary data source used in this study comes from the Fifth Travel Survey of Beijing Inhabitants (2014), which is conducted by the Beijing Municipal Committee of Transport, and provides the most recent travel survey data representative of the whole city by far. The dataset includes the activity and travel information of 101,815 members from 40,003 households obtained in Beijing, China during September 1st to November 1st of 2014. The total sample of travel survey is 0.52% of the population in 16 districts of Beijing. The sample distribution is shown in the following table (Table 2). It can be seen that the sampling rate of each district is relatively uniform. Since the travel survey is conducted randomly in each district, thus it can be regarded that the sample from the travel survey is representative of the whole population.

Survey respondents were asked to record their activities for 24 h from 3 am on one day to 3 am the next day. The activity participation was reported with travel purpose, travel origin and destination, travel mode, travel time, departure time, etc. The corresponding background information related household wealth, household structure and personal attributes were also documented.

Considering that the combination of outbound and inbound trips may obscure the characteristics of students' school travel mode choice behavior, this paper focuses on the home to school trips. The return trips are not included in this study for lack of space. Within the context of this study, school commuting trips from home to school by 7–18 year-old students were analyzed (i.e., typically 1th–12th Grades

Table 2
Sample distribution in the 16 districts of Beijing.

District	Population	Population sample	Sampling rate	Household	Household sample	Sampling rate
Dongcheng	919,000	7631	0.83%	314,402	2999	0.95%
Xicheng	1,243,000	7748	0.62%	441,085	3000	0.68%
Chaoyang	3,545,000	14,587	0.41%	1,317,845	6000	0.46%
Fengtai	2,112,000	13,489	0.64%	795,168	5299	0.67%
Shijingshan	616,000	4700	0.76%	219,907	2005	0.91%
Haidian	3,281,000	15,363	0.47%	976,376	6000	0.61%
Fangshan	945,000	4354	0.46%	314,012	1800	0.57%
Tongzhou	1,184,000	7057	0.60%	419,109	3000	0.72%
Shunyi	877,000	3867	0.44%	294,614	1400	0.48%
Changping	1,661,000	5556	0.33%	496,867	2000	0.40%
Daxing	1,365,000	7799	0.57%	425,156	3000	0.71%
Mentougou	290,000	2730	0.94%	107,009	1000	0.93%
Huairou	373,000	1580	0.42%	135,644	600	0.44%
Pinggu	416,000	1749	0.42%	137,695	600	0.44%
Miyun	468,000	2020	0.43%	179,493	700	0.39%
Yanqing	317,000	1585	0.50%	106,170	600	0.57%
Total	19,612,000	101,815	0.52%	6,680,552	40,003	0.60%

from primary school to high school). After error-checking, cleaning and clearing the data, there are 4580 school commuting trips can be used for the case study. The interaction between the household members is also taken into consideration in this paper. Information about the household's accompaniment can be found from the primary data source. School district is an important factor related to built environment. If the addresses of student's school and residence belong to the same district, the student can be thought of living within a school district. To some extent, living within a school district represents a relatively shorter travel distance to school. Distance to the nearest bus/subway station is a measurement of public transit accessibility. The intersection number along the school travel route, which concerns about the travel safety of students, can reflect the environment for active mode. Four school travel modes including walk, bus/subway, cycle, and car are explored in this paper due to the significant proportion of 96.40% of all school trips. The other mode includes school bus, motorcycle and so on. It is worth noting that different from the some Western countries, Chinese citizens are granted the right to driving licenses from the age of 18, compared to the legal driving age of 16 in the US. Therefore, high-school students are allowed to drive to school alone in the US while the Chinese high-school students are not. In this study, the alternative school travel modes for all the students are the same.

Definitions of the selected variables and their descriptive statistics are displayed in Table 3. In the dataset, the average household annual income is nearly the range of 50,000–100,000 CNY; 63% of students are living with the parents who both have jobs; 62% of families have at least one car, showing that the household wealth is relatively higher as for the families have students. 87% of students live within a school district; 56% of students live in the core and extended zones. The average travel distance between students' home and the nearest bus/subway station is 0.71 km, which is an acceptable distance for most of students. And the average intersection number is 5.39. More than half of the students are boys, the average age of the sample is 12.35 years old, and the average school level is 1.66, indicating the distribution of gender and age is relatively uniform. 88% of students have a local *hukou* of Beijing, consisting with the educational resources distribution and admissions policy in Beijing. Moreover, in the dataset, the average travel distance for students' school commuting is 3.89 km, and 87% of students leave for school at rush hour. It should be noted that some trips conducted in rush hour and other time are from the same individual. Due to the traffic condition difference during rush hour and other time, the corresponding travel mode choice results may be different. Given the sample size limitation for trips conducted in other time, we keep both trips and introduce the binary variable “Departure time” to reflect the influence of departure time on travel mode choice. 20% of the students are escorted to school, which is lower than the share in the US (47% of male children are driven to school and 53% of female children, Deka, 2013). More attentions will be given in the following sections to analyze how these factors influence students' school travel mode choice.

Table 4 shows the modal distribution in different distances. It illustrates the mode share of walking decreases with the increase of the travel distance, and that of motorized modes (car and public transit) are the opposite. The mode share of cycling increases with the increase of the travel distance first and then decreases. Also, it indicates that nearly half (47.5%) of the students live within 2 km of the school in Beijing, and their dominating travel mode is walking. For the travel distance of 2–6 km, cycling is the most important travel mode for the students. When the travel distance is greater than 6 km, public transit is preferred by the most students. Overall, it can be concluded from the Table 4 that active modes are used most within the travel distance of 6 km, while motorized modes dominate for the travel distance greater than 6 km.

The travel characteristics of all the school commuting modes are shown in Table 5. It reflects that the average travel distance for Chinese students in Beijing is significantly lower than that for American students in the study of McDonald (2008a). Since over 80% of students live more than 1.5 km from their schools, American students' average travel distance is 6.4 km. For the sample population, the modes of walking and cycling are most suitable for the short-distance school travel, car is appropriate for the middle-distance school travel, and the mode of public transit is more suitable for the long-distance school travel.

5. Methodology: integration of a tree-based and a logit-based regression

In this section, an integration of a tree-based regression model and a logit-based regression model is employed to investigate students' school travel mode choice behavior. Specifically, the tree-based regression model graphically describes some preliminary findings, which can be then used to identify the key influencing factors and classify the target variables for the logistic regression model efficiently. The joint application of these two models can provide more comprehensive and accurate results compared to the previous studies. Logistic regression model has an advantage in parameter estimation and error estimation since the aggregation within the data group has been taken into consideration. However, its outstanding performance relies on the identification and classification of the key influencing factors. Decision tree method can efficiently classify the target audiences into subgroups whose members have the homogeneous characteristics influencing the mode choice. The regression results of the decision tree then can be used to guide the identification of the important independent variables and the classification of the continuous variables in logistic regression model. Specifically, there are several notable algorithms used to create

Table 3
Variables definition and descriptive statistics.

Variables	Definition	Mean	Min	Max	St. Dev.
Household characteristics					
Annual income	1: < 50/2: 50–100/3: 100–150/4: 150–200/5: 200–250/6: 250–300/7: 300–500/8: > 500 thousand CNY household income	2.17	1.00	8.00	1.14
Dual-career	1: if both of the parents are all employed/0: Otherwise	0.63	0.00	1.00	0.48
Car ownership	1: if the family own at least one car/0: Otherwise	0.62	0.00	1.00	0.49
Built environment					
School district	1: if the student lives within a school district/0: Otherwise	0.87	0.00	1.00	0.34
Core zone	1: if the student lives within the core functional zone/0: Otherwise	0.15	0.00	1.00	0.35
Extend zone	1: if the student lives within the urban function extended zone/0: Otherwise	0.41	0.00	1.00	0.49
Development zone	1: if the student lives within the new urban development zone/0: Otherwise	0.28	0.00	1.00	0.45
Ecological zone	1: if the student lives within the ecological conservation zone/0: Otherwise	0.17	0.00	1.00	0.38
Distance to the nearest bus/subway station	Travel distance between students' home and the nearest bus/subway station (km)	0.71	0.01	3.90	0.55
Intersection number	Intersection number along the school travel route	5.39	0.00	38.00	4.88
Demographics					
Sex	1: if the student is a boy/0: Otherwise	0.52	0.00	1.00	0.50
Age	Age of the student (year-old)	12.35	7.00	18.00	3.03
School level	1: primary school/2: middle school/3: high school	1.66	1.00	3.00	0.77
Local *hukou*	1: if the student has a local *hukou* of Beijing/0: Otherwise	0.88	0.00	1.00	0.32
Travel characteristics					
Travel distance	Travel distance between students' home and school (km)	3.89	0.11	50.31	4.71
Departure time	1: if the departure time of the student is during the rush hour/0: Otherwise	0.87	0.00	1.00	0.34
Accompaniment	1: if the student is picked up to school/0: Otherwise	0.20	0.00	1.00	0.40

Sample size = 4580.

Table 4
Travel mode share in different distances.

Travel mode		Travel distance (km)						
		≤ 1	(1,2]	(2,3]	(3,4]	(4,6]	(6,9]	> 9
Walk	Number	684	534	70	14	4	2	0
	Percentage	**67.2**%	**46.0**%	12.2%	4.1%	0.6%	0.5%	0.0%
Car	Number	55	105	98	71	138	100	138
	Percentage	5.4%	9.1%	17.1%	20.6%	21.3%	27.0%	29.7%
Bus or subway	Number	49	113	124	101	217	159	254
	Percentage	4.8%	9.7%	21.6%	29.3%	33.5%	**42.9**%	**54.6**%
Cycle	Number	217	388	251	149	255	83	40
	Percentage	21.3%	33.4%	**43.8**%	**43.2**%	**39.4**%	22.4%	8.6%
Other	Number	13	20	30	10	34	27	33
	Percentage	1.3%	1.7%	5.3%	2.9%	5.2%	7.3%	7.1%
Total	Number	1018	1160	573	345	648	371	465
	Percentage	22.2%	25.3%	12.5%	7.5%	14.1%	8.1%	10.2%

Note: Bold indicates the maximum value of the mode share.

Table 5
Travel characteristics of all the school commuting modes.

Travel mode	Travel distance (km)		Travel time (min)		N
	Mean	Std. deviation	Mean	Std. deviation	
Walk	1.13	0.63	15.95	18.07	1308
Car	5.67	4.83	27.70	26.65	705
Bus or subway	7.04	6.69	50.78	36.24	1017
Cycle	3.00	2.37	20.29	10.47	1383
Other	6.35	6.49	27.23	12.77	167
Total	3.90	4.71	27.21	26.59	4580

a tress-based classification model, such as classification and regression tree (C & RT), Chi-squared automatic interaction detector (CHAID), and quick, unbiased, efficient statistical tree (QUEST). Among these algorithms, QUEST algorithm is chosen for this study due to its advantage on algorithm speed, the size and classification accuracy compared to other algorithms (Loh and Shih, 1999).

6. Modelling results analysis

The effects of selected variables on students' travel mode choice are identified and quantified based on the joint application of tree-based and logit-based regression models. Both models were carried out using the IBM SPSS Statistics 20 Software. First, the key factors are identified and the split thresholds of variables are indicated by the tree-based regression model. Then, the results of the tree-based regression model are used to inspire the variable inputs in the logit-based regression model.

This section discusses the results of the modelling. We attempt not only to present the school travel behavior in China, but also to compare this behavior with other countries.

6.1. Tree-based regression model

A tree-based regression model is built to offer a clear interpretation of the results despite only six most important independent variables are used: travel distance, intersection number, car ownership, school level, accompaniment, and extended zone. In order to include more independent variables in the tree construction, the minimum number of

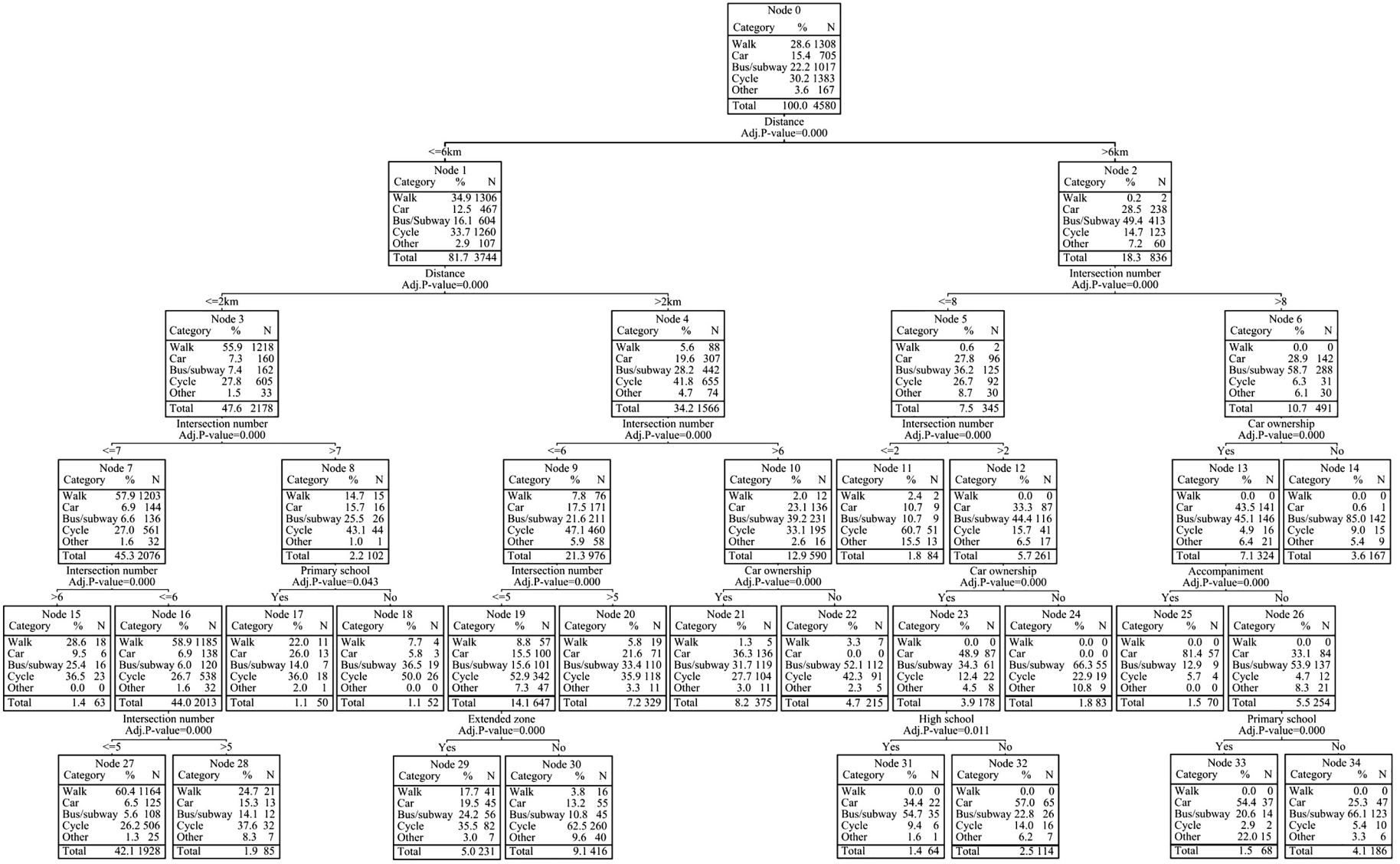

Fig. 2. Tree-based regression model classifying school travel mode.

cases for parent nodes and child nodes are set with the default values as 100, 50 respectively in the tree-based model, the significance values for splitting nodes and merging categories are set as 0.05. Since the larger the tree depth is, the more independent variables will be included, and more detailed information will be provided, the tree depth is set as 5 levels, which is the largest tree depth for the QUEST algorithm.

As shown in Fig. 2, the first optimum split in node 0 is according to travel distance, which classifies student travel mode into two subgroups. For travel distance ≤ 6 km, the shares of walk, cycle, bus or subway, and car are 34.9%, 33.7%, 16.1% and 12.5% respectively. For travel distance > 6 km, the shares of bus or subway, car, cycle and walk are 49.4%, 28.5%, 14.7% and 0.2% respectively. Obviously, the active travel modes will turn to motorized modes as the travel distance increases. Further, the variable of *Travel Distance* divides the population into some specific intervals, i.e., ≤ 2 km; 2–6 km; > 6 km. *Intersection Number* divides the population into five subgroups, i.e., ≤ 5; 5–6; 6–7; 7–8; > 8. And *School Level* distinguishes the population of students in primary school and that in high school respectively. Since the high correlation between school level and age, the results of the tree-based model indicates that the variable of *School Level* plays more significant effect on school travel mode choice than the variable of *Age*.

Fig. 2 shows the percentage of walk decreases rapidly with the increasing of travel distance; the percentage of motorized modes increases with the increasing of travel distance; the mode choice of cycle changes in a nonlinear form. The percentage share of walk is highest (60.4%) among the students for travel distance ≤ 2 km, and the intersection number is ≤ 5. The percentage share of cycle is highest (62.5%) among the students living in the extended zone for travel distance of 2–6 km, without available household vehicles, and intersection number is ≤ 5. The percentage share of public transit is highest (85.0%) among the students without available household vehicles for travel distance > 6 km, and intersection number is > 8. The percentage share of car is highest (81.4%) among the students who are dropped off for travel distance > 6 km, and intersection number is > 8.

Apparently, the tree-based regression model provides an intuitionistic exhibition of students' school travel mode, and gives implications related to classification of key factors. Given few variables are taken into consideration within the tree construction, as well as the direction and the effect of key factors are uncertain, it is necessary to investigate the influencing factors based on a logit-based regression model in the next step.

6.2. Logit-based regression model

The tree-based regression model shows that travel distance with the threshold of 6 km is the most important classification factor for students' school travel mode choice. Thus the students are divided into two subgroups: students living within 6 km and out of 6 km. The corresponding regression results are described in Tables 6 and 7 according by the categories mentioned above, respectively, where the referent group for dependent variable is car. The problem of multicollinearity also has been tested through the measurement of Variance Inflation Factor (VIF).

6.2.1. Children's characteristics factors

For students living within 6 km from school, the coefficients on sex are highly significant for cycle, public transit and walk. The positive sign suggests that active modes and public transit are most favored by boys. For students living longer than 6 km from school, it shows that sex is uncorrelated with students' school travel choice. This finding reveals that there are male-female differences in school travel mode only for the short travel distance in Beijing. Similar and dissimilar findings can be found in previous studies conducted in other countries. For example, Ermagun et al. (2015a) proposed that the propensity of male students to choose public transit or walk is greater than that of female students in Iran. Nelson et al. (2008) found that there are approximately one third

Table 6
Regression results for travel distances within 6 km (reference group: car).

Variables	Coefficients (std. err.)		
	Walk	Bus or subway	Cycle
Household characteristics			
Annual household income (CNY, > 200,000 = ref.)			
< 100,000	NS	0.814**(0.349)	0.575**(0.283)
100,000–200,000	NS	0.630*(0.355)	NS
Car ownership	− 4.757***(0.589)	− 5.054***(0.590)	− 4.838***(0.586)
Dual-career	0.242*(0.145)	0.319**(0.156)	0.233*(0.136)
Built environment			
School district	0.435*(0.352)	0.546**(0.238)	0.429*(0.229)
Living location (ecological zone = ref.)			
Core zone	2.083***(0.270)	1.657***(0.304)	1.534***(0.256)
Extended zone	0.794***(0.202)	1.444***(0.233)	NS
Development zone	0.928***(0.195)	0.666***(0.238)	0.622***(0.184)
Public transportation accessibility (km, > 2 = ref.)			
0–1	NS	14.934***(0.188)	NS
1–2	NS	NS	NS
Intersection number (> 7 = ref.)			
0–5	2.446***(0.282)	NS	0.881***(0.172)
5–7	0.808**(0.334)	NS	NS
Demographics			
Sex	0.242*(0.132)	0.267*(0.140)	0.346***(0.123)
Local *hukou*	− 0.330*(0.199)	− 0.400*(0.217)	NS
School level (high school = ref.)			
Primary school	NS	− 1.272***(0.223)	− 1.294***(0.209)
Middle school	NS	NS	-0.410*(0.223)
Travel characteristics			
Departure time	− 1.036***(0.243)	− 0.081*(0.308)	− 1.046***(0.233)
Accompaniment	− 1.069***(0.159)	− 1.791***(0.210)	− 0.577***(0.145)
Travel distance (km, > 4 = ref.)			
0–1	5.366***(0.542)	− 0.571**(0.266)	0.572***(0.222)
1–2	4.634***(0.531)	NS	0.524***(0.187)
2–3	2.867***(0.543)	NS	NS
3–4	1.717***(0.598)	NS	NS
Constant	15.147***(1.996)	14.780***(0.907)	3.348***(0.982)
No. observations	3637		
Chi-square	2906.658		
Log likelihood at zero	− 4452.083		
Log likelihood at convergence	− 3209.952		
McFadden pseudo R^2	0.279		

NS: Non-significant.
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.

of students actively commute to school in Ireland, and the more male students commute actively (more travel by bicycle) than females, while the others (Leslie et al., 2010) in Australia found the opposite. The reasons behind gender difference in mode choice have not been well illustrated (Ermagun and Samimi, 2015). Under the Chinese context, this gender difference can be attributed to parental concern and limited travel world of female students.

Regarding the effect of local *hukou*, for students living within 6 km from school, the coefficients on local *hukou* are highly significant for the choice of public transit and walk. The negative sign suggests that school trips with local *hukou* can reduce the propensity of public transit and walk for the short travel distance. For students living longer than 6 km from school, local *hukou* is significant between the public transit and car. The negative sign shows that students with local *hukou* are more willing to be driven to school (compared to public transit) for the long travel distance. As introduced before, *hukou* institution is a Chinese unique population policy used to control the movement of the rural population into the city (Li and Zhao, 2015), especially in Beijing. It is related to the distribution of state's welfare, such as education as well as the purchase qualifications of house and vehicle. In generally, a student

Table 7
Regression results for travel distances greater than 6 km (reference group: car).

Variables	Coefficients (Std. err.)		
	Walk	Bus or subway	Cycle
Household characteristics			
Annual household income (CNY, > 200,000 = ref.)			
< 100,000	NS	0.981*(0.542)	NS
100,000–200,000	NS	NS	NS
Car ownership	NS	−6.080***(1.044)	−6.042***(1.060)
Dual-career	NS	NS	NS
Built environment			
School district	NS	0.494**(0.233)	0.834**(0.348)
Living location (ecological zone = ref.)			
Core zone	NS	NS	NS
Extended zone	NS	NS	NS
Development zone	NS	NS	NS
Public transportation accessibility (km, > 2 = ref.)			
0–1	NS	NS	NS
1–2	NS	NS	NS
Intersection number (> 8 = ref.)			
0–2	NS	NS	2.473***(0.547)
2–8	NS	−0.579**(0.237)	NS
Demographics			
Sex	NS	NS	NS
Local *hukou*	NS	−1.049**(0.472)	NS
School level (high school = ref.)			
Primary school	NS	−1.857***(0.300)	−1.416***(0.409)
Middle school	NS	−1.143***(0.267)	NS
Travel characteristics			
Departure time	NS	−2.880***(0.794)	−3.227***(0.828)
Accompaniment	NS	−2.119***(0.326)	NS
Travel distance (km, > 10 = ref.)			
6–10 km	NS	NS	0.817**(0.330)
No. observations	776		
Chi-Square	753.708		
Log likelihood at zero	−592.535		
Log likelihood at convergence	−368.557		
McFadden pseudo R^2	0.378		

NS: Non-significant.
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.

with a local *hukou* has the priority to access private car, and therefore has higher possibility to be driven to school.

As for the school level, for students living within 6 km from school, school level acts significantly on travel alternatives of public transit and cycle. For students at primary school, they don't prefer the modes of public transit and cycle, while the students at middle school dislike cycling compared with high-school students. For students living longer than 6 km from school, the coefficient of primary school is negative for public transit and cycle, indicating car is most preferred by primary-school students for the long-distance travel. The negative coefficient of middle school for public transit implies that middle-school students are more willing to use cars compared with public transit. The study conducted by Yarlagadda and Srinivasan (2008) stated that children aged 6–12 years in the US are more likely to use the motorized travel modes, while children aged 13–17 years have the highest utility for biking or walking independently to school. In Beijing, when the travel distance is greater than 6 km, the likelihood of travelling by car is relatively higher among the primary-school students, which is similar to what is found in the US. And for the short-distance school travel, due to the parental concern to their young children, public transit or cycle is not allowed for primary-school students. Moreover, in accordance with some previous studies (Nevelsteen et al., 2012; Ermagun and Samimi, 2015; Ermagun and Levinson, 2016a), older children are more likely to travel autonomously and less willing to be accompanied by either parents or siblings, to seek a more independent lifestyle. Therefore, compared with middle school students, high-school students prefer cycling under the short-distance school travel, and most likely to use public transit for the long-distance school travel in Beijing.

6.2.2. Households' characteristics factors

Household income is found to be an important factor influencing students' school travel mode choice. For students living within 6 km from school, low-income families are found to be more likely to choose public transit mode to school. Moreover, low-income variable also has a significant effect on the mode choice of cycle. For students living longer than 6 km from school, low-income families are fond of public transit compared with car. Many studies have addressed a positive correlation between the propensity of driving students to school and household income (Ermagun et al., 2015a; Ermagun and Levinson, 2016b). Ermagun and Samimi (2015) reveal that increased household income reduces the likelihood of public transit use while increases the chance of driving and walking in Iran. Similar to these countries, students in Beijing from low-income families are most likely to use the non-car modes, due to the high relationship between household income and car ownership. In this study, household income has no effect on walking under short-distance travel, indicating that the mode choice of walking has no correlation to household income. In Beijing, there is no difference between students from high-income households and that from low-income households when they walk to school. Similar conclusion is also obtained from the study of Deka (2013) in the US. For the low-income families, students walk to school because of the travel cost, while for the high-income families, students walk to school maybe due to their parents' awareness about their health benefits or the better neighborhood quality.

Car ownership is another major predictor of school travel choice with highly significant and large coefficients. For students living within 6 km from school, the students are more likely to be driven to school when their families have cars, while the students from households with dual-career parents prefer non-car travel modes. For students living longer than 6 km from school, the highly significant and negative coefficients on car ownership for other travel modes also suggest the propensity of car for households with cars. Dual-career displays no significant effect on the school travel trips. Consistent with foreign studies (Ermagun et al., 2015a; Ermagun et al., 2015b; Ermagun and Levinson, 2016a), the students in Beijing from households with cars have a higher likelihood of being driven to school since they have access to private cars. Yarlagadda and Srinivasan (2008) have found the strong impacts of parental employment and work flexibility on children's mode choice decisions in the US. Specifically, mothers who go to work on the school day (and do not have full flexibility in their work schedules) are more willing to drive their children to school, while the fathers who have full flexibility in their work schedules are more likely to drive their children to school. Contradictory results are found in this study, dual-career parents choose non-car travel modes for their children in Beijing, maybe because of their great greater time constraints.

6.2.3. Built environment factors

Regarding the effect of school district, for students living within 6 km from school, households living within school district show their preference to public transit, cycle and walk, this means shorter travel distance is helpful for encourage students' active and independent mobility. For students living longer than 6 km from school, school district displays a significant effect on all the travel modes except for walk (the sample size of walk is small when the school travel distance is more than 6 km). The results show living within the school district increases the propensity of these modes. In conclusion, the likelihood of being driven to school is relatively lower for students living within the school district in Beijing. Since the variable *School District* represents a relatively shorter travel distance to school to some extent, we will discuss the effect of distance on students' mode choice afterwards.

With respect to geographic distribution, for students living within

6 km from school, the significant effects on all travel modes confirm that students living within core and development zones are more willing to walk, following by are public transit and cycle, while students living within extended zone are most likely to use public transit followed by walk. Specifically, the positive coefficients for core zone are the largest. This implies that different functional zones have their own school travel pattern, and the students living within core zone have the maximum probability to choose active modes and public transit. The coefficient on public transportation accessibility only works on the mode of public transit, and the result indicates that the likelihood of using public transit is particularly large when the travel distance between students' home and the nearest bus/subway station is within 1 km for the short-distance school travel. For students living longer than 6 km from school, no significant difference among different school travel modes has been found in term of living location and public transportation accessibility, indicating these two factors are not the determinants in regards to students' school travel mode choice for students living far from school. The study conducted by Merom et al. (2006) in Australia has discussed the effect of geographic distribution on students' school travel mode choice. It found that students in rural areas are most dependent on bus travel while students in urban communities use cars more frequently. Another study conducted by Deka (2013) in the US found that students in large metropolitan areas are most likely to walk or cycle to school compared to rural, non-metropolitan, and small metropolitan areas. In Beijing, core zone is regarded as the inner city of Beijing, thus the neighbor quality and travel environment are better for students' independent mobility. The extended zone is the representative area of high technology industries and educational institutions, therefore the population density is also at a high level. Similar to the results of Ermagun and Levinson (2016b), the use of walking and public transit increases in school trips with the increase of population density. For development zone, bicycle is also used most among the students, mainly because of the imperfect public transit system. In addition, a negative relationship between the public transit usage and distance to the nearest public transit station is widely recognized although the effect magnitudes are different. Ermagun et al. (2015b) described that the tendency to use public transit will increase for school travel when the home-public transit station distance is less than 600 m. While Alemu and Tsutsumi (2011) thought 1.5 km distance to public transit station is available to take the public transit. These findings are all similar to what is found in Beijing with regard to the effect of public transportation accessibility.

As for intersection number, for students living within 6 km from school, intersection number has significant effects on the choice of walk and cycle. It indicates that less intersection number encourages children to walk or cycle to school. For students living longer than 6 km from school, it is found that intersection number has significant effects on the choice of cycle when intersection number is ≤ 2, and works on the choice of public transit when intersection number of 2–8, indicating that less intersection number increases the propensity of using cycle while decreases the propensity of using public transit for the long-distance school travel. Some researchers have reported the positive relationship between walking to school and intersection density (Schlossberg et al., 2006). And some have found that the choice of walking is uncorrelated with the street intersections density (Mitra et al., 2010). Contradictory results are found in the study of Lin and Chang (2010) that increased intersection numbers discourage children from walking to school independently in Taiwan. Similar to the later study, the reduced intersection number correlates with increase in the use of active modes in Beijing. For long-distance school travel, the increased intersection number reduces the propensity of using the public transit for students due to the travel comfort.

6.2.4. Travel characteristics factors

The coefficients on departure time are highly significant across all travel modes for students living both within 6 km and greater than 6 km from school. And the negative signs suggest that leaving for school at rush hour reduces the propensities of using these alternative modes. That is, students in Beijing are most likely to be driven to school when they are leaving for school at rush hour. In Beijing, the traffic volume will significantly increase during the rush hour. Considering their children's travel safety, parents will be more willing to escort their children to school. Moreover, it is convenient for parents to drive their children to school in the morning on their way to work since the start times of schools for students are usually before or approximate the same time that parents depart for work in Beijing. Similar findings can also be found in the study of Lin and Chang (2010), although which is conducted in Taiwan, China.

With regard to the effect of accompaniment, for students living within 6 km from school, car is most likely to be used for school trips with adults' accompaniment. For students living longer than 6 km from school, the coefficients on accompaniment are highly significant for the choice of public transit. The negative sign suggests that school trips with adults' accompaniment can reduce the likelihood of using public transit. Therefore, in Beijing, when students are escorted by their families, the likelihood of being driven to school is relatively higher. The finding from Ermagun et al. (2015b) also shows that younger students had more probability to choose escorted modes of transportation, including school buses and private cars. However, school bus service isn't common in China since it is neither state provided nor free like in many Western countries (Ermagun and Levinson, 2016a), thus it is reasonable for most parents in Beijing to drive their children to school.

Consistent with many studies worldwide (Yarlagadda and Srinivasan, 2008; Deka, 2013; Kelly and Fu, 2014), the likelihood of using non-motorized modes decreases with the increased distance to school. In this study, distance is also found as a significant reason for a decline in shares of active school transport and an increase in shares of motorized modes. For students living within 6 km from school, increased travel distance reduces the active modes utilization. For students living longer than 6 km from school, compared to school travel longer than 10 km, the school trips made within 6–10 km are more likely to use bicycle. Thus increased travel distance can reduces the utility of using the bicycle.

7. Discussions

In Western countries, many efforts have been devoted into the policy research and investment evaluation related to the improvement of active and independent mobility for students. For example in the US, the Safe Routes to School (SRTS) programs have been implemented since 2005, and the major focus of these programs is the investments toward infrastructure improvement (NCSRS, 2010). In Canada, school travel plans (STPs) have been proposed to help the families choose green travel modes. In addition to the engineering projects, these strategies emphasize the education and encouragement on sustainable travel, and the law enforcement about parking and driving near schools (ARTA, 2007). Although there are some differences on fundamental realities between the Western countries and China, their practices still suggest a systematic research that would improve our current understanding of students' school travel mode choice and further inform development of future interventions to create a better travel environment for students in Beijing, China.

The results from this study reveal that the planning and layout of infrastructures, as well as the travel demand management policies may play potentially important roles in enabling the active and independent mobility among the students. The specific lessons from this are discussed in the following subsections.

7.1. Planning and layout of infrastructures

First, different from the Western countries, the urban form in Beijing is divided into four different functional zones. The modelling results

indicate the use of active modes and public transit increases in school trips with the increase of population density in Beijing. Therefore, in addition to continuing improving the travel environment for active modes in high-population density zones, attention on transport and education should also be paid to the low-population density zones, like ecological conservation zone in Beijing. Since the likelihood of being driven to school decreases for students living within the school district in Beijing, it is necessary to arrange the schools scientifically according to the land use, population structure and distribution. Meanwhile, the educational resources of high quality should be distributed evenly to lead the students choose the school near their home.

Second, the findings from this study reveal that each alternative travel mode has its own competitive scope, which is also unlike the Western countries. For example, the criterion distance for Irish students to walk and cycle to school is less than 2.4 km and less than 4.0 km, respectively. For the distance of 4.0–4.8 km, government needs to subsidize transport to school for post-primary pupils in Ireland. In Denmark, it is required that secondary school students must live a distance greater than 8 km from school to avail of free transport (Nelson et al., 2008). In Canada, it is regarded that a distance more than 5 km will restrict the school travel mode to motorized transport only (Mitra et al., 2010). In China, 3 km is deemed as the cut-off value between active modes and motorized modes in 2005 (Li and Zhao, 2015). Compared with students in Western countries, Chinese students walk shorter but cycle farther. And compared with Chinese students in Beijing a decade ago, students now both walk and cycle farther, indicating the school commuting distance continues to grow in recent years.

In comparison, the corresponding service supporting facilities should be designed appropriately to maximize the function of each travel mode in Beijing according to the descriptive and modelling results from this study. As shown in Table 4, the majority of the students choose to walk for the distances of 0–2 km. Therefore, the urban planners should concentrate on the construction of pedestrian-friendly environment to enhance the walkability, and the connection with the public transportation. Regarding the safety issue on the young students, it is advisable to introduce the travel mode of walking school bus (WSB), which is widely practiced in England, New Zealand, and US. The WSB programs, i.e., a group of children picked up throughout the neighborhood walk to/from school with the accompaniment of parents or other adults, have been proved to be a potential option to improve children's pedestrian safety (Mendoza et al., 2012). The statistical results also show that the optimal scope for cycling is the distance of 2–6 km. Thus, the construction of a cycling-friendly road networks should be focused on. In Beijing, the characteristics of urban mixed traffic make the motorized vehicle and non-motorized vehicle interfere each other seriously. As a result, efforts should be devoted to the separate bicycle lanes, bicycle parking/storage facilities, and so on. Given the efficiencies of travel modes, it is reasonable for the students using public transit when the travel distance is above 6 km. Within the optimal service radius near the school for public transit, the bus or subway stations should be set reasonably to ensure a high accessibility for the public transit. As the modelling results suggest in this study, the likelihood of using public transit is particularly large when the travel distance between students' home and the nearest bus/subway station is within 1 km.

Third, similar to the foreign countries, students in Beijing from households with cars are more willing to be driven to school. For the families which are accustomed to drive their children to school, it isn't easy to force them change their habits in the short term. Therefore, it is important for the urban planners to reserve the parking facilities within some distance of the school according to the school scale, students' structure and land use.

7.2. Implementing of related policies

It has been reported in recent studies that the integration of infrastructure construction and policy formulation has an excellent impact on active school travel rates (Mitra and Buliung, 2015). Based on the findings from this study, three travel demand management policies are proposed according to the institutional and cultural context in Beijing.

First, the modelling results in this study reveal that students in Beijing are most likely to be driven to school when they are leaving for school at rush hour. The reason behind this phenomenon may lie in two aspects. On the one hand, given large travel demand at peak hours deteriorates the travel environment and increases the risk of accidents, many parents drive their children to school to ensure a comfortable and safe school trip. On the other hand, it is convenient for the parents to drive their children to school on their way to work within the time constraint. Therefore, it is crucial to implement different working hour in Beijing to reduce the travel demand at rush hour, and further increase parents' perception about their children's travel safety to school, as well as cause the inconvenience of driving students to school.

Second, it should be noted that this study cannot analyze students' school travel mode choice behavior escorted by friends or relatives due to the unavailability of the related data. The modelling results in this study explore that when students are escorted to school, the likelihood of using cars is relatively higher in Beijing. Therefore, it is important to shed light on the education about the sustainable travel modes and cultivate an awareness of independent mobility for both students and their parents. As for the students requiring the accompaniment of adults due to some specific reasons, it is advised to walk or use bicycle to escort the students for the short distance, while for the longer distance, it is advocated to use school bus or public transit. Although car is more convenient, the awareness of sustainable travel should root in every citizen's mind with the improvement of public transit network and school bus service. The finding of Ermagun et al. (2015b) shows that younger students in Tehran are more willing to choose escorted travel modes, including school buses and private cars. It should be noted that there are some school strips using school bus in the sample data (2.6% of the sample population), the average travel distance of school bus (7.04 km) is the same as the public transit's, and the school bus can reduce the average travel time up to 42.54% compared with public transit (the average travel time of school bus is 28.67 min). However, school bus service isn't common in China since it is neither state provided nor free like in many Western countries (Ermagun and Levinson, 2016a), thus it is urgent for the government to take measures to promote the development of school bus service in Beijing, and the focus should be concentrated on the problems such as school bus route planning and the school bus stop station layout.

Third, the modelling results in this study indicate that school trips with local *hukou* of Beijing reduce the propensity of public transit and active modes, while increase the likelihood of being driven to school. Different from the Western countries, *hukou* institution is a unique Chinese policy in Beijing to control the rural population and the related welfare distribution. It is also one of the premises of vehicle purchase in Beijing. Similar to the students from households with cars, students with local *hukou* also have the priority to access private car, and then have higher possibility to be driven to school. Thus, it is necessary to keep on implementing the quota control policy for car ownership, and further promote and encourage students' active and independent mobility. In addition to the existing quota control for Beijing *hukou* which can impose restrictions on the car ownership in total to some extent, efforts can be made from the following aspects in light of the successful experience of foreign countries. 1) Increase the vehicle purchase cost, such like the car ownership system in Singapore. It is managed via both the requirement to bid for a Certificate of Entitlement (COE) and the payment of an Additional Registration Fee (ARF), which typically account for more than half the purchase cost of a vehicle. The COE entitles the usage of local roads and the ARF is refundable to incentivize the

vehicle deregistration (Chu, 2015). 2) Raise the standards for vehicle purchase, such like the vehicle registration law in Japan. Its vehicle registration is conditional upon demonstrating access to a long-standing parking space near the residence. And the practice proves that this policy can effectively slow the growth of car ownership, especially in the places with high property prices (Barter, 2011).

8. Conclusions

This study is an effort to develop a framework incorporating tree-based regression method and logit-based regression method to explain the behavioral aspects of students' school travel mode choice. Understanding the motives behind such behaviors is significant for urban planners to create a better travel environment for students' active and independent mobility, which is widely recognized as an opportunity to solve the health issues related to individuals, cost issues related to households, negative externalities issues related to the transportation system.

Specifically, the tree-based regression model is introduced to offer a clear interpretation of the results through identifying the key factors and indicating the split thresholds of the variables. The logit-based regression model is used to enrich and broaden the preliminary findings based on the results of decision tree. Both of the two methods provide different insights into the behavioral representations of the underlying decision processes. In this study, some significant factors that influence school travel mode choice were examined. Especially, the results show that car ownership, poor walking/cycling environment and adults' convenience for escorting students significantly stimulate the use of cars in school commuting. The students are more inclined to be driven to school when their departure time is at rush hour compared to the other time. Moreover, the longer distance encourages the use of motorized transport, where the households with local *hukou* (usually related to the car ownership and other welfares) are more willing to drive their children to school. Further, it is found that living within school district can reduce the probability of using the car.

According to the findings from this study, recommendations for policymakers and advocates on school travel environment planning and management are proposed to improve the transportation services for students in Beijing from primary to high schools. The strategies about layout of educational resources, development of alternative school travel options within the optimal distance scope, planning of parking facilities near school are introduced specifically. In addition, the literature suggests that travel demand management-related policies on implementing different working hour, education and propaganda about the sustainable travel modes, as well as the quota control for car ownership are also should be paid attention to. These findings improve current knowledge on the correlation of school travel choice and provide local evidence that may inform school transportation planning practice in Beijing, China. The study also advances school travel behavior research by addressing the integration of parametric and non-parametric statistics methods.

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