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Public transit, active travel, and the journey to school: a cross-nested logit analysis

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ABSTRACT

Like walking and biking, public transit presents an opportunity to accomplish a portion of the recommended daily physical activity. Much of the previous research has been limited to descriptive analyses quantifying the active component of public transit using advanced econometrics models. This paper overcomes this challenge by applying a two-level cross-nested logit model. We use the school trip information of 3441 middle and high school students in Tehran. We show a 1% increase in home-to-school distance reduces physical activity by 0.91%. Considering public transit a solely non-active mode, this reduction equals 2.21%. Therefore, ignoring the 'quasi-active' role of public transit overestimates the physical activity reduction of students by 142%. We also indicate a 1% decrease in access to transit stations diminishes physical activity by 0.04%. This diminution is 0.02% when we apply the nested logit model. This is the direct consequence of ignoring the active component of public transit trips.

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1. Introduction

The recent epidemic of physical inactivity among children has raised concerns about the potential public health consequences. A study in the USA showed that the prevalence of obesity had increased around 13% among persons aged 6–19 between 1999 and 2004 (Ogden et al. 2006). Physical inactivity enhances the risk of common diseases including obesity, myocardial infarction, stroke, type II diabetes, cancer, hypertension, depression, osteoarthritis, and asthma (Ebbeling, Pawlak, and Ludwig 2002). Studies reveal a significant health gain for children who obtain 60 min of moderate daily physical activity (Salmon and Timperio 2007). In part, these recommended levels of physical activity may be realized by walking or biking to school.

Apart from the active travel modes, public transit is an opportunity to accomplish a portion of the recommended daily physical activity (Bopp, Gayah, and Campbell 2015). Besser and Dannenberg (2005) studied 3312 transit users extracted from the 2001 National Household Travel Survey, and found public transit users spend a median of 19 min daily walking to and from transit. They also showed 29% of transit users achieve more than 30 min of

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physical activity each day by walking to and from transit. Edwards (2008) assessed the net increase in walking associated with taking public transit by applying a Tobit model on a 28,771-person sample of 2001 National Household Transport Survey. The results showed that taking public transit is associated with 8–10 additional minutes of walking per day. In 2009, Lachapelle and Frank (2009) employed a multinomial logit (MNL) model to explore the interdependency of public transit and physical activity in metropolitan Atlanta, Georgia. Controlling for socio-demographics and urban form characteristics, they found a positive correlation between taking public transit, walking, and moderate physical activity. MacDonald et al. (2010) conducted a pre–post analysis to explore the impact of light rail transit (LRT) on body mass index (BMI) and physical activity in North Carolina. The final results demonstrated that the use of LRT is associated with an average BMI reduction of 1.18 points. A more comprehensive review of the literature in regard to the association between public transit and physical activity is available in previous research (De Nazelle et al. 2011; Rissel et al. 2012; Sallis et al. 2012).

The relationship between public transit and physical activity stems from the idea that public transit trips consist of active travel modes for users who walk and bike for the access and egress portions of their trips. Public transit is neither solely active nor solely non-active. Rather, we believe public transit is best described as a 'quasi-active' travel mode that has both characteristics of active and non-active modes.

This is not the first time public transit has been looked at as a combined mode of travel. Studies have considered public transit as a combined travel mode, as walking, biking, park and ride, and kiss and ride trips are typically part of public transit trips. In 2010, for instance, Bekhor and Shiftan (2010) employed a series of models (MNL, nested logit (NL), cross-nested logit (CNL), and kernel logit) to study effective factors on changing individuals' mode from private car to combined alternatives such as park and ride and public transportation in work trips in Tel Aviv. They found that to avoid the model misspecification issue, park and ride, a combined transportation mode, should be investigated in a CNL structure. To the best of the authors' knowledge, this has been the only study where the public transit mode is utilized as a combined mode in a CNL framework.

Previous studies employed descriptive analysis to understand the portion of walking and physical activity in public transit trips. None of the previous studies considered public transit as a 'quasi-active' mode in their model structures. Instead, public transit is typically considered in the category of non-active or motorized travel mode. Understanding the quantitative component of public transit in active and non-active categories reveals information on how active modes of transport can be promoted in routine trips. This paper begins to study this research question by considering public transit in both active and non-active nests in a two-level CNL framework. We use the school trip information of 3272 middle and high school students in Tehran for this analysis. This study extends previous research on school trips of students in Tehran (Samimi and Ermagun 2012; Ermagun, Rashidi, and Samimi 2015a; Ermagun and Samimi 2015).

The remainder of the paper unfolds as follows. We provide information on Tehran in the following section. We then discuss the survey method and descriptive analysis. This is followed by the modeling methodology section. We explore the influential parameters on mode choice for school trips in the results section. We also examine the model misspecification resulting from ignoring the active component of public transit trips in the sensitivity analysis section. Finally, we end the paper with concluding remarks and suggestions for future studies.

2. Study region

Tehran, with an area of around 700 km^2 and a population of over 8 million in 22 municipalities, is among the most densely populated cities in the world. The modal split for all daily trips is: 28% private car, 22% bus, 10% subway, 10% mini-bus, 23% taxi, and 7% walking and cycling (Allen 2013). The daily average travel time is 25 min and the daily travel speed is 27.2 km/h. On average, trips by public transit take 15.5 min, and the average travel speed for public transit is 24 km/h (Mohammad-Beigi, Nouri, and Liaghati 2015).

By 2010, 125 km of subway line had been built, serving 70 stations and carrying nearly 3 million passengers daily. The subway consists of 5 main lines, and the headway fluctuates from 3 to 15 min, depending on the line. However, there is not any regular headway for the public bus system. The Bus Rapid Transit system has about 83 km dedicated paths. Approximately 112 km of bike paths had been created by 2011. By 2013, this number had grown to 285 km.

In Tehran, like many other congested cities around the world, policies such as increasing parking cost, increasing fuel cost, odd–even rationing, and cordon pricing are imposed to control and reduce the number of private cars in particular regions of the city. There are two types of limited traffic zones: (1) restricted zones based on odd and even days between 6:30 am and 7 pm and (2) central restricted zones between 6:30 am and 5 pm. These zones are open for public vehicles such as buses, taxis, and ambulances.

Tehran hosts more than 1 million elementary, middle, and high school students (Tehran Census 2006). There are fewer than 1200 middle schools, and more than 1000 high schools, 41% of which are private. Public schools have a standard criterion that students should live within a reasonable walking distance to school. This distance varies from zone to zone and is determined by the Tehran Department of Education. However, private schools are not compelled to abide by this rule. There are 566,331 middle and high school students in the city of Tehran (Ministry of Education 2011). According to Islamic Governmental regulations, schools are gender segregated. Female students make up 43% of the middle school students and 53% of the high school students (Ministry of Education 2011). A staggering 27% of all the 13 million daily trips are educational (Tehran Census 2006).

School busing in Tehran is considered by residents to be an expensive mode of travel and, unlike in many Western countries, is neither state provided nor free. Rather, it is a chartered service using mini-buses, minivans, or private cars that provide door-to-door services. To avoid confusion in the definition, we use 'school service' in reference to school busing in Tehran. Both private and public schools register this school transport service at the request of parents, and parents pay for this service for one school year. The cost of the service depends on the distance to the school.

3. Survey method

A cross-sectional survey was conducted in May 2011 among 4700 middle and high school students in Tehran. To identify problematic questionnaire designs, unclear questions, and to obtain an initial estimate of the response rate, response bias, and survey cost, a pilot survey was conducted in November 2010. For the pilot survey, 500 students from 2 high schools and 2 middle schools were randomly selected in Tehran, from which 341 completed questionnaires were received. Dillman (2000) found this sample size adequate for pilot studies. In accordance with recommendations in former studies (McMillan 2007), parents were asked to fill out the questionnaires and send it back to the school. The pilot survey included 12 questions on socioeconomic and transportation information. Many parents ignored open-ended questions regarding family income, occupation of the family head, and the reasons behind choice of transportation mode. Therefore, such questions were altered with close-ended questions, based on the recommendations of Lazarsfeld (1944).

The final questionnaire had 19 questions divided into 2 sections. The first section contained socioeconomic and demographic questions, such as number of children, level of education, car ownership, number of driver licenses in the household, occupation, and income. The second section included trip information questions such as travel modes to and from school, parents' priorities in choosing a mode, walking time to school, and transportation cost. One hundred cash prizes, ranging from 15 to 50 US dollars, were offered to randomly selected students whose parents completed all the questions. Although financial incentives could distort the response behavior, some studies have argued that money generally works better than other incentives for students of this age group (Kalfs and Van Evert 2003).

The questionnaires were distributed in May 2011 to avoid any conflict with the students' academic breaks and final exams based upon a stratified sampling. The stratified random sampling was based on a gender, level of education, and traffic analysis zone among boys and girls only schools. Survey envelopes were delivered to each school, and a school official was placed in charge of distributing them among students. Parents were asked to complete the questionnaire and send it back to the school. Out of 4700 envelopes that were distributed in 94 schools, 76% were returned. An initial screening excluded 131 envelopes from two schools, because evidence was found that parents did not fill them out. Overall, the response rate of 73% was obtained, which includes 3441 questionnaires. This rate is generally defined as the ratio of the number of completed questionnaires over the total number of eligible participants (Richardson and Meyburg 2003). We also calculated the minimum response rate (RR1) of 64%, in accordance with American Association of Public Opinion Research (2006). This rate of response is deemed satisfactory for this type of study (Schutt 2011).

4. Descriptive analysis

From the survey analysis, approximately 60% of the collected forms were from the public schools, which is fairly compatible with the actual share of 59% for the public middle and high schools in Tehran. All-girls schools have a share of 59.7% and 50.5% in the sample and population, respectively. High schools have a share of 40.5%, of which 58% are from the all-girls schools. This can, arguably, be attributed to a higher level of responsibility among females (Arlow 1991). The lowest rate of response was observed for the occupation question, for which 10% of the parents refused to answer. Only 43 individuals refused the questions about household income, and 24 refused the question about the number of cars in the household.

From the travel behavior analysis, 42.3% of students use walking on their way to school. For the return trips this number rises to 48.9%. As shown in Table 1, 26.8% of girls walk

Table 1. Percentage of each mode of transportation to and from school.

		From school		To school	
Category	Mode of travel	No. boys (%)	No. girls (%)	No. boys (%)	No. girls (%)
Private	Car	107 (*3.1*)	213 (*6.2*)	251 (*7.3*)	349 (*10.2*)
	Carpool	14 (*0.4*)	34 (*1.0*)	14 (*0.4*)	31 (*0.9*)
	Tele taxi	14 (*0.4*)	25 (*0.7*)	21 (*0.6*)	21 (*0.6*)
School service	School service	240 (*7.0*)	526 (*15.3*)	247 (*7.2*)	519 (*15.1*)
Public transit	City bus	264 (*7.7*)	148 (*4.3*)	231 (*6.7*)	152 (*4.4*)
	Subway	11 (*0.3*)	7 (*0.2*)	11 (*0.3*)	7 (*0.2*)
	Taxi	90 (*2.6*)	21 (*0.6*)	73 (*2.1*)	31 (*0.9*)
Active	Bicycle	25 (*0.7*)	0 (*0.0*)	21 (*0.6*)	0 (*0.0*)
	Walk	625 (*18.2*)	1055 (*30.7*)	532 (*15.5*)	923 (*26.8*)
Unknown/missing		11 (*0.3*)	11 (*0.3*)	0 (*0.0*)	7 (*0.2*)
Total		1401 (*40.7*)	2040 (*59.3*)	1401 (*40.7*)	2040 (*59.3*)

Note: Italic numbers in the parentheses stand for percentage (%).

to school and 30.7% of girls walk home from school. This percentage is significantly lower for boys. The imbalance might be explained by cultural and behavioral characteristics of Iranian families, in which girls are more restricted than boys in outdoor activities. As a result, girls find the school trips as an opportunity to socialize with their friends outside of school. Almost one-third of parents drive solely to drop off their children at school, while 35% of parents form a trip chain on their way to work. For return trips, 38% of parents drive just to pick up their children, and 16% of them pick the children up on the way home from work. In Tehran, girl students are not permitted to ride bikes and motorbikes in school trips for religious and ideological reasons. Hence, the share of biking equals zero for girls in school trips. The total share of biking is 1.3% due to the lack of integrated bike lanes when the survey was conducted. We excluded biking from the data for further analysis because of the low share in the travel modes. Public modes of transportation such as bus, subway, or taxi are used by 14.6% of students to school, and 15.7% of students from school.

5. Modeling methodology

5.1. CNL model

The logit family (MNL, NL, CNL, and mixed) has the merit of a closed-form formulation, which eases the estimation process (Train 2009). The MNL model is usually criticized for the Independence of Irrelevant Alternatives (IIA) property of unobserved random error terms, which triggers constraints in some choice situations (Train 2009). As per the IIA property, if a private vehicle user is unable to drive for any reason, the probability of choosing other available travel modes will increase evenly. While in reality, the reasons that persuade this person to drive, say distance to destination, may increase the probability of choosing public transit more than walking or biking. Applying an MNL model in this situation causes model misspecification.

To remedy the IIA assumptions, NL and CNL models were developed, which remove the IIA property from alternatives to nests. In the NL models, alternatives with correlated error terms are embedded in a nest. A CNL model allows for alternatives located at more than one nest when it shares its correlation with alternatives of various nests. This model was employed for the first time by Small (1987) to investigate the departure time of travel. Then, Vovsha (1997) named the model CNL and utilized it to scrutinize the park and ride mode of travel as both public and private modes.

The probability of choosing alternative *i* from nest *n* is derived by multiplying the probability of selecting the nest (P_n) by conditional probability of choosing alternative *i* ($P_{i|n}$) as per Equation (1). In this equation, (V_i) is the utility that perceives from travel mode *i*, μ represents the inverse logsum parameter or inclusive value (IV), α_{in} stands for the portion of alternative *i*, which is assigned to the sub-nest *n*, and τ_n is given by Equation (2).

$$P_i = P_n \times P_{i|n} = \frac{\exp\left(\frac{1}{\mu_n}\tau_n\right)}{\sum_{n' \in N} \exp\left(\frac{1}{\mu_{n'}}\tau_{n'}\right)} \times \frac{\propto_{in}^{\mu_n} \exp(\mu_n V_i)}{\sum_{i' \in n} \exp(\mu_n V_{i'})} \tag{1}$$

$$\tau_n = \ln\left(\sum_{i' \in N_j} \propto_{\text{in}}^{\mu_n} \exp(\mu_n V_{i'})\right). \tag{2}$$

5.2. Model structure and estimation

To quantify the role of public transit as a 'quasi-active' travel mode, we use a two-level CNL model. We consider four modes of travel, including private car, school service, public transit, and walking. Figure 1 shows the proposed tree structure, which has the better fit among other possible structures. As shown, the upper level has two limbs that split into active and non-active limbs. To quantify the active portion of the public transit mode, this mode is considered in both the active and non-active nests. The IV parameters are determined in the estimation procedure. In a two-level CNL, the IV parameters should be positive and less than one (Wen and Koppelman 2001).

We depicted the definition of explanatory variables used in the models in Table 2. We also outlined the estimation results for MNL, NL, and CNL models in Table 3. The IV parameters of the non-active and active limbs in the CNL model are 0.76 and 0.62, respectively. Both the IV parameters are statistically positive and less than one, according to a Wald and student's *t*-test. As the model specification shows, public transit needs to be considered as a 'quasi-active' mode of travel in the modeling framework for two reasons. First, the IV parameters of the active and non-active limbs are statistically between 0 and 1. It indicates that the

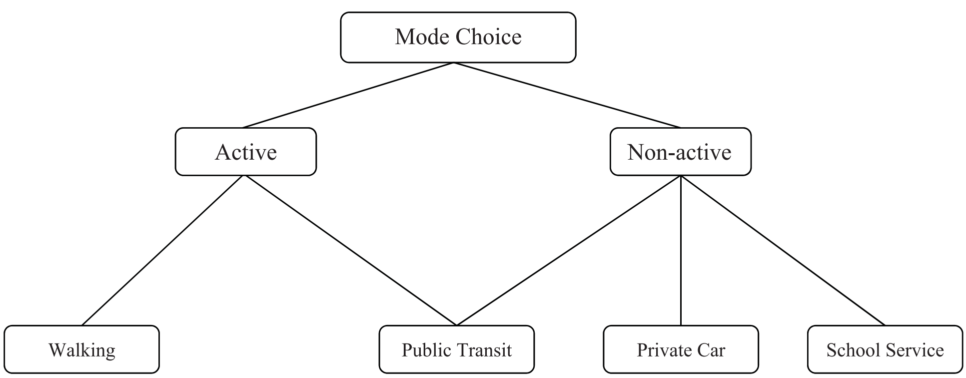

Figure 1. Tree decision for a two-level CNL model.

Table 2. Description of explanatory variables used in the study.

Variable	Description	Average	Std. Dev.
GENDER	1: Male/0: Female	0.40	0.47
AGE	Age of children between 12–17 years old	14.10	1.61
INCOME	1: less than 5/2: 5–10/3: 10–15/4: 15–20/5: 20–25/6: more than 25 million Iranian Rials[a] household income	2.09	1.21
PARTTIME	1: If one parent works part time /0: Otherwise	0.333	0.47
EDUCATION	Educational level of parents 1: less than a high school diploma/2: high school diploma/3: bachelor of science/4: master of science or equivalent/5: higher degrees	NA	NA
SS_N_COST	Out-of-pocket school service travel cost (10 Rials) divide by INCOME	2074.84	1068.43
AUT_N_COST	Out-of-pocket automobile travel cost (10 Rials) divided by INCOME	212.04	118.86
WALKTRNT	Distance between home and the nearest bus station (meter)	571.21	449.72
POPDENS	Population density in each zone (person per m^2)	0.02	0.01
WALKSCH	1: less than 10/2: 10–20/3: 20–30/4: 30–40/5: 40–50/6: more than 50 min walking time to school	2.63	1.54
DURATION	1: If parents are primarily concerned about their child travel time/0: Otherwise	0.23	0.42
SAFETY	1: If parents are primarily concerned about their child travel safety/0: Otherwise	0.31	0.46
RELIABLE	1: If parents are primarily concerned about their child travel reliability/0: Otherwise	0.18	0.38
TRF_LIMIT	1: Students that live or study in a limited traffic zone/0: Otherwise	0.11	0.31
COMFORT	1: If parents are primarily concerned about their child travel comfort/0: Otherwise	0.30	0.46

Note: NA, not applicable.
[a] 11,800 Iranian Rails was equivalent to 1 USD in May 2011.

CNL model, which encompasses public transit mode in both active and non-active nests, is a stable structure. Second, the overall fit of the CNL model is better than both MNL and NL models by about 26% and 15%, respectively. It implies that the proposed CNL model captures more realistic characteristics of the system. All the variables are significant at a more than 90% confidence interval, and have the expected sign. Allocation coefficients of public transit for the non-active and active nests equal 0.47 and 0.53, respectively. In other words, 53% of the public transit utility plays a role in the active nest, while 47% is allocated in the non-active nest. The following section represents the discussion on impact of parameters on mode choice.

6. Results

We analyze influential parameters on travel modes, particularly, walking and public transit in school trips. The variables are divided into three main categories: (1) household characteristics, (2) urban and transportation system characteristics, and (3) parental concerns. The results are based on the final CNL model.

6.1. Household characteristics

Age and gender of the students, household income, parental employment status, and educational level of parents are found significant in the final model. In accordance with previous studies (Leslie et al. 2010; Ermagun, Rashidi, and Lari 2015b), girls are more likely to walk than boys in school trips in Tehran. Boys are more likely to take public transit rather than take the school service or private car. The results also show the positive correlation between

Table 3. Summary of MNL, NL, and CNL models.

		MNL		NL		CNL	
Variables	Alternatives	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic
Constant	Automobile	−2.96	−4.93	−2.95	−4.93	−2.70	−4.78
WALKSCH		−0.34	−6.02	−0.32	−4.69	−0.25	−4.02
PARTTIME		0.25	2.45	0.24	2.35	0.20	2.22
TRF_LIMIT		−1.26	−6.07	−1.20	−4.90	−0.97	−4.40
INCOME		0.21	2.59	0.22	2.77	0.22	3.05
DURATION		0.98	8.59	0.94	6.64	0.82	5.97
AUT_N_COST		−0.002	−2.68	−0.002	−2.44	−0.001	−2.48
COMFORT		0.66	4.56	0.63	4.31	0.59	4.40
SAFETY		−0.75	−6.08	−0.72	−4.63	−0.58	−4.19
Constant	School service	−2.72	−4.03	−2.73	−3.90	−2.50	−3.86
COMFORT		0.77	4.97	0.74	4.80	0.71	5.06
RELIABLE		0.64	5.00	0.61	4.26	0.52	4.00
INCOME		0.31	3.42	0.31	3.44	0.30	3.65
AGE		−0.11	−3.00	−0.10	−2.75	−0.08	−2.64
SS_N_COST		−0.0003	−3.63	−0.0003	−2.96	−0.0003	−2.97
Constant	Public transit	−4.40	−6.52	−4.31	−6.02	−3.01	−4.25
AGE		0.13	3.07	0.13	2.87	0.10	2.95
WALKTRNT		−0.0005	−3.55	−0.0005	−3.16	−0.0004	−3.49
EDUCATION		−0.57	−6.44	−0.54	−4.65	−0.47	−5.42
GENDER		1.06	7.84	1.01	5.56	0.82	5.91
SAFETY		−0.74	−5.05	−0.72	−3.99	−0.79	−4.31
POPDENS		12.18	2.82	12.19	2.82	10.78	2.76
WALKSCH		−0.31	−4.98	−0.29	−3.65	−0.35	−3.70
EDUCATION	Walk	−0.32	−4.95	−0.31	−4.89	−0.32	−5.23
WALKSCH		−1.46	−16.48	−1.43	−12.85	−1.29	−11.78
AGE		0.07	2.13	0.07	2.12	0.08	2.45
SAFETY		−2.25	−15.45	−2.22	−13.67	−2.02	−12.24
POPDENS		12.18	2.82	12.19	2.82	10.78	2.76
GENDER		−1.18	−4.13	−1.16	−4.01	−0.93	−3.43
IV parameters:							
Non-active		–	–	0.94	7.15	0.76	5.33
Active		–	–	1	Fixed	0.62	1.92
Allocation parameters:							
Public transit as non -active		–	–	–	–	–	0.47
Public transit as active		–	–	–	–	–	0.53
Log-likelihood at zero:		−3750.01		−3750.01		−3750.01	
Log-likelihood at convergence:		−2615.27		−2512.50		−2325.01	
McFadden pseudo R^2:		0.30		0.33		0.38	
Sample size:		3272		3272		3272	

age of students and both walking and taking public transit. Families with higher incomes are more likely to use private car and school service. Educational level of parents has a negative correlation with using public transit and walking modes. To wit, parents with higher level of education are less likely to select public transportation and walking for their children. The relationship between income and household level of education is a reason behind this preference, as educated parents are more able to either afford the cost of a school service or use private car.

6.2. *Transport system and urban characteristics*

We found distance from home to school, access to public transport stations, population density, and student's school location in limited traffic zones significant in the final model.

An increase in the home-to-school distance reduces the probability of walking, which is in line with Western observations (Woldeamanuel 2016). The results also show the probability of choosing public transit mode is reduced by decreasing access to transit stations. Hence, long-term urban policies, such as school siting and public transit station locations, affect mode choice.

We found that with increasing population density, use of walking and public transit increases in school trips. This is rooted in three main reasons. First, the increased population density means increased residential units in the area, and increased eyes on the street, which reduces parental concerns for safety of their children. Second, high population density is a feature of areas with small residential units, and in Tehran such a structure generally indicates low-income residents. Third, dense places are usually more walkable because of the diversity of land uses and favorable street network characteristics (Saelens and Handy 2008). Restricted Traffic Zones have a negative correlation with private car use. In Tehran, the share of low-income household regions in Restricted Traffic Zones is significantly more than high-income households because of the urban structure. Therefore, the low use of private cars in these regions is not surprising.

6.3. Parental concerns

We assessed the influence of parental attitudes toward safety, comfort, travel reliability, and travel duration of various modes of travel on mode choice decision. Confirming with previous studies (Deka and Von Hagen 2015; Ermagun and Samimi 2016), our results indicate parents who are concerned about the safety of their children are less likely to allow their children to use public transport or walking to school. Therefore, implementing programs like ‘safe routes to school’ and the ‘walking school bus’ may promote active and public modes of travel in Tehran. As expected, the results indicate that parents who prefer to use school service and private car are considering the comfort of their children. Also, parents who are concerned about the reliability of the mode of transport prefer to use the school service. Considering this, it could be said that the lack of regular schedule for public transport in Tehran, particularly buses, discourages its use for school trips.

7. Sensitivity analysis

Table 4 shows the elasticity of continuous variables for the MNL, NL, and CNL models. The results of the CNL model suggest that for people who choose walking, an increase of 1% in home-to-school distance reduces the probability of walking by 3.51%. This reduction was found to be significantly lower in the MNL and NL models, which is a direct consequence of the model misspecification that misrepresents the effect of distance. A 1% increase in the home-to-school distance diminishes the probability of taking public transit by 1.04% among public transit users, while it increases the probability of shifting to public transit from walking by 1.39%. The elasticity results of the CNL model indicate that with a 1% increase in the household income level of school service and private car users, the probability of choosing public transit diminishes by 0.23% and 0.14%, respectively. Further, a 1% increase in the residential population density increases the probability of walking by 0.17%, followed by 0.17% reduction in using public transit. Access to transit stations is another pivotal variable that has a positive correlation with public transit use, and consequently increases the level

Table 4. Results of the elasticities for MNL, NL, and CNL models.

Attribute	Primary alternative	Automobile			School service			Public transit			Walk		
		MNL	NL	CNL	MNL	NL	CNL	MNL	NL	CNL	MNL	NL	CNL
WALKSCH	Automobile	−0.71	−0.57	−0.66	0.2	0.3	0.23	0.2	0.3	0.19	0.2	0.15	0.15
	Public transit	0.12	0.18	0.18	0.12	0.18	0.18	−0.71	−0.59	−1.04	0.12	0.08	0.42
	Walk	1.08	1.56	0.96	1.08	1.56	0.96	1.08	1.56	1.39	−2.82	−2.27	−3.51
WALKTRNT	Public transit	0.03	0.07	0.04	0.03	0.07	0.04	−0.27	−0.22	−0.29	0.03	0.02	0.07
AGE	School service	0.38	0.5	0.43	−1.24	−1.03	−1.2	0.38	0.5	0.36	0.38	0.32	0.29
	Public transit	−0.24	−0.5	−0.28	−0.24	−0.5	−0.28	1.7	1.37	1.78	−0.24	−0.15	−0.47
	Walk	−0.49	−0.66	−0.52	−0.49	−0.66	−0.52	−0.49	−0.66	−0.7	0.63	0.45	0.89
INCOME	Automobile	0.35	0.28	0.45	−0.1	−0.18	−0.17	−0.1	−0.18	−0.14	−0.1	−0.07	−0.1
	School service	−0.2	−0.26	−0.28	0.45	0.39	0.55	−0.2	−0.26	−0.23	−0.2	−0.19	−0.2
EDU	Public transit	0.12	0.23	0.14	0.12	0.23	0.14	−1.05	−0.88	−1.13	0.12	0.08	0.29
	Walk	0.24	0.33	0.25	0.24	0.33	0.25	0.24	0.33	0.35	−0.41	−0.31	−0.55
POPDENS	Public transit	−0.14	−0.19	−0.13	−0.14	−0.19	−0.13	−0.14	−0.19	−0.17	0.15	0.1	0.17
	Walk	−0.14	−0.19	−0.13	−0.14	−0.19	−0.13	−0.14	−0.19	−0.17	0.15	0.1	0.17
AUT_N_COST	Automobile	−0.4	−0.29	−0.4	0.09	0.17	0.13	0.09	0.17	0.11	0.09	0.06	0.08
SS_N_COST	School service	0.17	0.21	0.2	−0.59	−0.49	−0.59	0.17	0.21	0.16	0.17	0.14	0.13

of physical activity among children. Although access to transit has been studied in previous research, little is known about how much accessibility to transit may affect the utility of public transit in school trips. The elasticity of WALKTRNT variable shows the probability of taking public transit is reduced by 0.29% when access to transit is diminished by 1%. As a result, the probability of private car and school service increases equally by 0.04%. The NL model misrepresents this growth twice as much as the CNL model.

Among the travel mode specific characteristics, the cost of private car and school service are found significant in the final model. Studies emphasize that taste variations of people affects their decision-making behavior (Train 2009). For instance, people with different income levels behave in a different way toward the changes in cost of transportation modes. As a result, considering the same responses for all of them may lead to inappropriate policies. To accommodate the alternative taste variations, the cost of private cars and school service use is normalized by the household income level. A 1% increase in the cost of private car travel reduces the probability of choosing private car by 0.40%, and thereby people shift to public transit and walking by a probability of 0.11% and 0.08%, respectively. However, this reduction varies considerably, depending on level of income. While the rate of reduction is 0.40% among low-income families, the probability of selecting private car diminishes by only 0.20% among high-income families.

One of the main aims of this study is to indicate how much the consideration of public transit as a 'quasi-active' mode affects describing active modes of travel. Table 5 illustrates the elasticity of choosing active and non-active nests in the NL and CNL models for policy sensitive variables. Without considering public transit as a 'quasi-active' mode, the probability of choosing an active nest decreases by 2.2% following a 1% increase in home-to-school distance. With considering public transit as a 'quasi-active' mode this reduction is about 0.91%. This is due to the shifting of a significant proportion of walkers to public transit by increasing the home-to-school distance. A 1% increase of the distance to public transit decreases the probability of students' physical activity by approximately 0.04%. The CNL model, by considering public transit mode as a 'quasi-active' mode, expresses that the

Table 5. Elasticity analysis of upper level of the NL and CNL models.

	NL		CNL	
Attributes	Active	Non-active	Active	Non-active
WALKSCH	−2.211	0.758	−0.918	0.716
WALKTRNT	0.026	−0.027	−0.042	−0.007
POPDENS	0.142	−0.126	0.069	−0.112
AUT_N_COST	0.073	−0.063	0.045	−0.046
SS_N_COST	0.139	−0.048	0.122	−0.059
AGE	0.654	−0.282	0.774	−0.484

probability of a student being active increases about 0.02%. This difference in not only magnitude but in sign is a direct consequence of model misspecification. Ignoring the active side of public transit can easily result in wrong policies to be presented by those who are seeking to promote walking mode of travel. According to the CNL model, the elasticity results of AUT_N_COST and SS_N_COST variables show that a 1% increase in the ratio of private car and school service cost to household's income increases the probability of being active for students by 0.04% and 0.12%, respectively. Such results not only give more awareness to politicians in order to reduce the use of private car, but they also are effective in improving physical activity and public health.

8. Conclusion

This study quantified the active travel component of the public transit mode for journeys to school by applying a two-level CNL model in Tehran. Much of the previous research has been limited to descriptive analysis for quantifying the active component of public transit by the complexity associated with advanced econometrics models. This paper overcomes this challenge by applying a two-level CNL model. To the best of the authors' knowledge, this study is the first attempt to develop such a tree decision structure and scrutinize the public transit mode as both active and non-active mode of travel in a simultaneous framework.

From a substantive viewpoint, the model structure embodies the philosophy that public transit is a 'quasi-active' mode of travel and, as evidenced by the findings of this research, should be modeled in a cross-nest structure for mode choice decisions. Model estimation results highlight the need to deem public transit as a 'quasi-active' mode of travel for two main reasons: (1) the better fit than both MNL and NL models and (2) the stability of tree structure as per the IV parameters. Developing such a model structure constitutes an important step forward in understanding the active side of mode choice decisions.

We found public transit provides an opportunity to accomplish part of the daily recommended physical activity for children. It is typically known that increasing home-to-school distance reduces the likelihood of children to walk, and thereby decreases the physical activity of children. However, a portion of this reduction shifts to public transit. Acknowledging the 'quasi-active' role of public transit, this shift helps to alleviate the assumed reduction in the physical activity of children. Concretely speaking, we showed 1% increase in home-to-school distance reduces physical activity by 0.91%. Building on the traditional models, which consider public transit a solely non-active mode, this reduction equals 2.21%. Therefore, ignoring the 'quasi-active' role of public transit overestimates the physical activity reduction of students by 142%. The model explicitly incorporates a number of influential parameters that affect active modes of travel for a physically active lifestyle. These include household characteristics, transport system and urban characteristics, and parental concerns. To measure the amount of physical activity in a transportation network accurately, it is essential to develop a framework that allows seeing both active and non-active sides of travel modes. The findings of the model suggest that the home-to-school distance, cost of travel, access distance to transit stations, and safety are more sensitive variables in choosing walking and taking public transit. While this research offers some insights into the role of public transit in active travel, it yet has room to improve with further research:

- We overlooked the effects of built environment and transit system information in our model, as they were not publicly available for Tehran.
- We studied the school travel behavior of children older than 12, due to the lack of data. We recommend comparing the travel behavior of children younger than 12 with older than 12 using the proposed modeling framework.
- As we discussed, 'school bus' in Tehran is a door-to-door service, unlike the school bus in Western countries that typically includes walking for the access. We hence recommend testing school bus as a quasi-active mode of travel akin to public transit in a CNL framework.

Disclosure statement

No potential conflict of interest was reported by the authors.

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